Thirty-Second Report of the International Whaling Commission

Covering the thirty-second financial year 1980–1981
Approved by the Commission at its thirty-third meeting in Brighton, June 1981
Authorised to be printed together with the Chairman's Report of the thirty-third meeting.

Cambridge
1982

The International Whaling Commission
was constituted under the International Convention for the
Regulation of Whaling signed at Washington on 2 December 1946.

The International Whaling Commission

The Red House, Station Road, Histon,
Cambridge CB4 4NP

Preface

This year's Annual Report contains materials from the following meetings:
the 33rd Annual Commission and Scientific Committee Meetings;
the Workshop on the Design of Sightings Surveys;
the Workshop on the Identity, Structure and Vital Rates of Killer Whale Populations: and
the Special Meeting on Southern Hemisphere Minke Whales.

In addition to the Reports of these meetings, eighty-seven scientific papers are included, all of which have been revised to some extent since their presentation to the Scientific Committee. Copies of papers presented to the Scientific Committee but not published here can be obtained from the Office of the Commission at cost price.

GREG DONOVAN
Scientific Editor

Contents

Progress reports submitted to the Scientific Committee:

Papers submitted to the Scientific Committee:

Sperm whales

Minke whales

Other Baleen Whales

Other Protected Species and Aboriginal Whaling

Small Cetaceans

Other

SIGHTINGS SECTION

KILLER WHALE SECTION

MINKE WHALE SECTION

List of Members of the Commission

Contracting Government	*Commissioner*
Argentina	Mr E. H. Iglesias (*Chairman*)
Australia	Prof. J. D. Ovington
Brazil	Mr J. P. do Rio Branco
Canada	Mr M. C. Mercer
Chile	Prof. M. C. Schweitzer
People's Republic of China	Mr Zhou Youzhan
Costa Rica	Not notified
Denmark	Mr E. Lemche (*Vice-Chairman*)
Dominica	Mr A. Shillingford
France	Prof. C. Roux
Iceland	Not notified
India	Mr S. Singh
Jamaica	Not notified
Japan	Mr K. Yonezawa
Republic of Korea	Mr K. H. Kim
Mexico	Mr J. J. de Olloqui
Netherlands	Mr F. H. J. von der Assen
New Zealand	Mr I. L. G. Stewart
Norway	Mr P. Tresselt
Oman	Mr M. A. Al-Barwani
Peru	Dr J. E. Valdivia
Philippines	Not notified
Saint Lucia	Mr P. Josie
Saint Vincent and the Grenadines	Not notified
Seychelles	Mr M. J. Delcy
South Africa	Dr L. Botha
Spain	Mr J. Prat
Sweden	Mr B. Hägerhäll
Switzerland	Federal Veterinary Office
USSR	Dr I. V. Nikonorov
UK	Mr R. J. Packer
USA	Not notified
Uruguay	Not notified

Dr R. Gambell
Secretary to the Commission
31 August, 1981

International Whaling Commission Report 1980–81

This report sets out the events which have taken place in the year following the 32nd Annual Meeting of the Commission held in Brighton, UK, 21–26 July 1980 under the Chairmanship of Mr T. Asgeirsson (Iceland). The Chairman's Report of that meeting was published in the thirty-first Annual Report of the Commission (*Rep. int. Whal. Commn* 31: 17–40).

REVIEW OF MANAGEMENT PROCEDURES

At its 32nd Annual Meeting the Commission agreed to establish a Technical Committee Working Group, including representatives of the Scientific Committee, the Special Working Group on Management Procedures and the group concerned with the Legal Revision of the Schedule, to consider revised management procedures for commercial whaling and to prepare specific proposals for consideration at the 1981 Annual Meeting.

The Government of Japan invited the Working Group to meet in Tokyo, 23 February–3 March 1981 and a further session was held in FAO, Rome, 12–15 May 1981.

The Commission also decided that it would be helpful to develop appropriate principles and guidelines for subsistence catches, parallel to those reflected in the management procedures for commercial whaling. It therefore established an *ad hoc* Working Group on Subsistence Whaling.

A Steering Committee met in Seattle, Washington, 18–19 February 1981 to develop the arrangements and activities of this *ad hoc* Working Group, which met in Brighton, UK, July 1981.

STOCK CLASSIFICATIONS AND CATCH LIMITS

The classifications of the whale stocks and the catch limits adopted by the Commission for the 1980/81 Antarctic season and the 1981 seasons elsewhere are shown in Tables 1, 2 and 3.

A 5% flexibility allowance in quotas between Areas was agreed for minke whales in the Southern Hemisphere instead of the 10% allowance which had been adopted in earlier years.

The designation of the sperm whale stocks in Divisions 1–8 of the Southern Hemisphere as Unclassified, with zero catch limits, was adopted by a postal vote of the Commission on the proposal of the USA when it was realised that the Annual Meeting had not made a positive decision on these stocks.

CATCHES, 1980/81 AND 1980 SEASONS

The catches taken by IWC member nations in the 1980/81 and 1980 seasons in the Southern Hemisphere are shown in Table 4.

The catches taken by IWC member nations in the 1980 seasons in the North Atlantic and North Pacific are shown in Table 5.

INTERNATIONAL OBSERVER SCHEME

Observers were appointed by the Commission for the 1980/81 and 1981 seasons as follows:

Southern Hemisphere	— pelagic: 2
North Pacific	— coastal: 1
North Atlantic	— coastal: 1

Reports by the Observers appointed for the immediately preceding seasons were examined at the 32nd Annual Meeting. The Commission noted that the Observers' reports received corresponded with infractions reports from Contracting Governments, thus validating these records. The Commission was also pleased to note that all the Observers commented on the full co-operation and assistance received from the hosting member government.

INFRACTIONS

Reports on the infractions of the Commission's regulations provided by Contracting Governments for the 1980/81 Antarctic season and the 1980 seasons elsewhere are summarised in Table 6.

The Commission examined the reports from the immediately preceding seasons at its 32nd Annual Meeting. In response to a recommendation that the Government of the Republic of Korea be encouraged to assign additional national inspectors to monitor whaling activity, an additional inspector was appointed by that government.

SCIENTIFIC COMMITTEE

Arising out of the IWC/IDCR Southern Hemisphere minke whale assessment cruise in 1978/79, the Scientific Committee recognised the need for a Workshop on the Design of Sightings Surveys. This Workshop was held in Seattle, Washington, 11–16 September 1980.

At its meeting in 1980 the Scientific Committee noted that all stocks of minke whales in the Southern Hemisphere are in a robust state. However, it encountered many problems in carrying out assessments and, in particular, agreeing on a procedure to be used in certain Areas. It was therefore decided to hold a Special Meeting on Southern Hemisphere Minke Whale Assessments immediately prior to the next meeting of the Scientific Committee in 1981.

After extensive discussion in the 32nd Annual Meeting on the Commission's responsibilities for small cetaceans, the Commission adopted a Resolution which in part recommended that the Scientific Committee continues to

Table 1

Baleen whale stock classifications and catch limits (excluding Bryde's whales)

		Sei		Minke		Fin		Blue	Hump-back	Right, Bowhead, Pygmy Right	Gray	
Area	Longitudes	Classi-fication	Catch limit	Classi-fication	Catch limit	Classi-fication	Catch limit	Classification			Classi-fication	Catch limit
SOUTHERN HEMISPHERE—1980/81 pelagic season and 1981 coastal season												
I	120°W–60°W	PS	0	—	910	PS	0	PS	PS	PS	—	—
II	60°W–0°	PS	0	—	1,176	PS	0	PS	PS	PS	—	—
III	0°–70°E	PS	0	—	1,237	PS	0	PS	PS	PS	—	—
IV	70°E–130°E	PS	0	—	2,386	PS	0	PS	PS	PS	—	—
V	130°E–170°W	PS	0	—	1,250	PS	0	PS	PS	PS	—	—
VI	170°W–120°W	PS	0	—	467	PS	0	PS	PS	PS	—	—
Total catch not to exceed:			0		7,072		0	0	0	0		
NORTHERN HEMISPHERE—1981 season												
ARCTIC		—	—	—	—	—	—	—	—	PS	—	—
NORTH PACIFIC												
Whole region		PS	0	—	—	PS	0	PS	PS	PS	—	—
Okhotsk Sea-West Pacific Stock		—	—	SMS	421[1]	—	—	—	—	—	—	—
Sea of Japan–Yellow Sea–East China Sea Stock		—	—	SMS[2]	940[3]	—	—	—	—	—	—	—
Remainder		—	—	IMS	0[4]	—	—	—	—	—	—	—
Eastern Stock		—	—	—	—	—	—	—	—	—	SMS	179[5]
Western Stock		—	—	—	—	—	—	—	—	—	PS	0
NORTH ATLANTIC												
Whole region		—	—	—	—	—	—	PS	PS	PS	—	—
West Greenland Stock		—	—	SMS	444[6]	SMS[2]	6	—	—	—	—	—
Newfoundland-Labrador Stock		—	—	—	—	IMS	90	—	—	—	—	—
Canadian East Coast Stock		—	—	—	0[7]	—	—	—	—	—	—	—
Nova Scotia Stock		PS	0	—	—	PS	0	—	—	—	—	—
Central Stock		—	—	SMS	320	—	—	—	—	—	—	—
East Greenland-Iceland Stock		—	—	—	—	SMS	304[8]	—	—	—	—	—
Iceland-Denmark Strait Stock		SMS	100[9]	—	—	—	—	—	—	—	—	—
Spain-Portugal-British Isles Stock		—	—	—	—	SMS	240[10]	—	—	—	—	—
Northeastern Stock		—	—	SMS	1,790	—	—	—	—	—	—	—
West Norway-Faroe Islands Stock		—	—	—	—	PS	0	—	—	—	—	—
North Norway Stock		—	—	—	—	SMS	61	—	—	—	—	—
Eastern Stock		—	0	—	—	—	—	—	—	—	—	—
NORTHERN INDIAN OCEAN		—	—	—	—	—	—	PS	PS	PS	—	—

[1] The total catch of minke whales shall not exceed 1,678 in the five years 1980 to 1984 inclusive.
[2] Provisionally listed as SMS for 1981.
[3] The total catch of minke whales shall not exceed 3,634 in the five years 1980 to 1984 inclusive.
[4] Pending a satisfactory estimate of stock size.
[5] Available to be taken by aborigines or a Contracting Government on behalf of aborigines pursuant to paragraph 13b.
[6] The total catch of minke whales shall not exceed 1,778 in the five years 1981 to 1985 inclusive.
[7] Pending submission of data leading to an adequate assessment.
[8] The total catch of fin whales shall not exceed 1,524 in the six years 1977 to 1982 inclusive.
[9] The total catch of sei whales shall not exceed 504 in the six years 1980 to 1985 inclusive.
[10] The total catch of fin whales shall not exceed 440 in the two years 1980 and 1981.

consider the status of small cetaceans and to make scientific advice available to Contracting Governments, coastal states and other interested governments and inter-governmental organisations. The Scientific Committee therefore held a Killer Whale Workshop immediately before its meeting in 1981.

SCIENTIFIC RESEARCH

The series of minke whale marking and sighting cruises carried out in Antarctic Area IV in 1978/79 and Area III in 1979/80 was continued by a third programme conducted in Area V from 17 December 1980 to 13 February 1981. This activity is a major item under the International Decade of Cetacean Research, and was supported by the IWC Research Fund, the provision of two vessels from Japan and one from the USSR, and participating scientists from Australia, Japan, New Zealand, South Africa, the USSR and the USA. A total of 474 minke whales was marked. Both the Japanese and Soviet whaling fleets assisted in the programme by agreeing to stop their activities in the marking area while the research vessels were operating.

The Commission has also given financial support towards the completion of a report on sperm whales of the Southeast Pacific; gray whale research in the breeding lagoons of Baja California; an analysis of whale diving times; a sightings cruise off the west coast of the British

Table 2

Bryde's whale stock classifications and catch limits

	Classification	Catch limit
SOUTHERN HEMISPHERE AND NORTHERN INDIAN OCEAN 1980/81 pelagic season and 1981 coastal season		
South Atlantic Stock	IMS	0
Indian Ocean Stock	IMS	197
Solomon Islands Stock	IMS	0
Western South Pacific Stock	IMS	237
Peruvian Stock	SMS	264
Eastern South Pacific Stock	IMS	188
NORTH PACIFIC–1981 season		
Eastern Stock	IMS	0[1]
Western Stock	SMS	510
East China Sea Stock	SMS[2]	19
NORTH ATLANTIC–1981 season	IMS	0[1]

[1] Pending a satisfactory estimate of stock size.
[2] Provisionally listed as SMS for 1981.

Isles; a workshop on the identification of cephalopod beaks; research programmes on sperm whales around the Azores, including their food; and studies on the humpback whale population off Greenland.

HUMANE KILLING

The Republic of Korea lodged an objection within the prescribed time to the Schedule amendment adopted at the 32nd Annual Meeting for a ban on the use of the cold grenade harpoon in the commercial killing of whales other than minke whales from the start of the 1980/81 pelagic and 1981 coastal seasons. However, it withdrew its objection in April 1981.

A workshop meeting of invited experts on the humane killing of whales was held from 10–14 November 1980, in Cambridge, UK. This had the aim of improving existing techniques and suggesting alternative, more humane methods, as recommended by the 31st Annual Meeting of the Commission.

MEASURES AGAINST NON-IWC WHALING

Because of legal problems, a proposal at the 32nd Annual Meeting for the inclusion in the Schedule of prohibitions on the importation of whales and whale products from, and the transfer of vessels, equipment, expertise and any kind of assistance to non-member nations and a requirement for Contracting Governments to institute enforcement measures and punish infractions, was replaced by a Resolution with the same intent.

The Commission established a Working Group of the Technical Committee to examine all aspects of the problem of non-IWC whaling and to submit recommendations for action to the next Annual Meeting. This Working Group held a Preliminary Meeting in London on 19 March 1981, and then met in Brighton, UK in the week prior to the 33rd Annual Meeting.

REVISION OF THE INTERNATIONAL CONVENTION FOR THE REGULATION OF WHALING, 1946

Informal discussions between the interested parties during 1980 indicated that while there was some support for the writing of a completely new Convention, others favoured a

Table 3

Toothed whale stock classifications and catch limits

		Sperm		Bottlenose
Divisions	Longitudes	Classification	Catch limit	Classification
SOUTHERN HEMISPHERE 1980/81 pelagic season and 1981 coastal season				
1	60°W–30°W	*	0	—
2	30°W–20°E	*	0	—
3	20°E–60°E	*	0	—
4	60°E–90°E	*	0	—
5	90°E–130°E	*	0	—
6	130°E–160°E	*	0	—
7	160°E–170°W	*	0	—
8	170°W–100°W	*	0	—
9	100°W–60°W	—	300[1]	—
NORTHERN HEMISPHERE–1981 season				
NORTH PACIFIC				
Western Division	males	—	890[2,3]	—
	females	—	0	—
Eastern Division	males	—	0	—
	females	—	0	—
NORTH ATLANTIC	males	—	130	PS[4]
	females	—	—	
NORTHERN INDIAN OCEAN		—	0	—

[1] The catch in 1982 shall be zero.
[2] Included within this figure there may be a by-catch of females not to exceed 11.5% and all whaling operations for this species are to cease when the by-catch is reached.
[3] It is forbidden to take or kill any sperm whale from this stock over 45 feet (13.7 metres) in length in the 1981 season.
[4] Provisionally listed as PS for 1981 pending the accumulation of sufficient information for classification.

Table 4

Catches by IWC member nations in the Southern Hemisphere, 1980 and 1980/81 seasons (previous season in parentheses)

Country	Bryde's	Minke	Sperm	Other	Operations	Catchers
Brazil		902 (739)	30 (27)		1[1] (1[1])	1 (1)
Chile			94 (34)	— (65[3])	1[1] (1[1])	1 (3)
Japan		3,120 (3,279)			1[2] (1[2])	6 (7)
Peru	215 (300)		450 (742)		1[1] (1[1])	3 (3)
USSR		3,120 (3,897)		— (916[4])	1[2] (2[2])	4 (10)
Total	215 (300)	7,142 (7,897)	574 (803)	— (981)	5 (6)	15 (24)

[1] Shore station. [2] Factory ship. [3] Sei whales. [4] Killer whales.

Table 5

Catches by IWC member nations in the Northern Hemisphere in the 1980 season (1979 in parentheses). No pelagic catches were allowed in 1980. Pelagic catches in the North Pacific in 1979 (not included in the table) were: Japan, 51 sperm and 175 Bryde's whales; USSR, 1,948 sperm and 227 Bryde's whales

Country	Fin	Sei	Bryde's	Minke	Sperm	Aboriginal	Land stations	Catchers
North Atlantic								
Denmark								
Greenland	13 (7)			141[1] (204[1])		13[2] (11[2])		
Faroes	— (11)	— (1)					1 (1)	1 (1)
Iceland	236 (260)	100 (84)		201[1] (199[1])	101 (96)		1 (1)	4 (4)
Norway				2,002[1] (1,980[1])				89[1]
Spain	219 (465)	2 (—)			13 (82)		2 (2)	3 (4)
Total	468 (743)	102 (85)		2,344 (2,383)	114 (178)	13 (11)	4 (4)	8 (9)
North Pacific								
Japan			307 (52)	379[1] (407[1])	1,192 (1,269)		4 (4)	10 (10)
Korea	7 (—)		— (18)	925 (906)			3 (3)	21 incl.[1]
USSR						179[3] (178[3])		1 (1)
USA						34[4] (31[5])		
Total	7 (—)		307 (70)	1,304 (1,313)	1,192 (1,269)	213 (209)	7 (7)	

[1] Small-type whaling. [2] Humpback whales. [3] Gray whales. [4] Bowhead whales, incl. 18 struck and lost.
[5] Bowhead whales, incl. 15 struck and lost, and 4 gray whales.

Table 6

Summary of infractions, Antarctic season 1980/81 and outside the Antarctic 1980

Species of whale	Total catch	Undersized whales		Oversized whales		Lactating whales		Other		Total infractions	
		No.	%	No.	%	No.	%	No.	%	No.	%
Antarctic											
Minke	6,240	N/A	N/A	N/A	N/A	0	0	1[1]	0.02	1	0.02
Protected	0	—	—	—	—	—	—	—	—	—	—
Total	6,240	N/A	N/A	N/A	N/A	0	0	0	0	1	0.02
Outside Antarctic											
Fin	236	1	0.42	N/A	N/A	2	0.85	0	0	3	1.27
Sei	100	1	1.00	N/A	N/A	1	1.00	2[1]	2.00	4	4.00
Bryde's	307			N/A	N/A	0	0	0	0	0	0
Minke	4,030	N/A	N/A	N/A	N/A	0	0	17[2]	0.42	17	0.42
Sperm	1,323	0	0	0	0	3	0.23	0	0	3	0.23
Protected	0	—	—	—		—	—	—	—	—	—
Total	5,996	2	0.03	0	0	6	0.10	19	0.31	27	0.45

[1] Lost whales.
[2] Quota excess.

more limited amendment of the present Convention. In response to the Commission's request for a Contracting Government to convene another preparatory meeting to improve and update the present Convention, the Government of Iceland extended an invitation to hold such a meeting in Reykjavik, 6–9 May 1981.

CO-OPERATION WITH OTHER ORGANISATIONS

Observers represented the Commission at meetings of the International Council for the Exploration of the Sea, October 1980; the Inter-American Tropical Tuna Commission, October 1980 and April 1981; the International Council for the Conservation of Atlantic Tuna, November 1980; the International Commission for Southeast Atlantic Fisheries, December 1980; the Third Meeting of the Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora, March 1981, and the FAO Committee on Fisheries, May 1981.

FINANCE

The Commission approved the statement of estimated income and expenditure for the financial period ending 31 August 1980 at its 32nd Annual Meeting. The audited statement appears on pages 8–9 of the 31st Annual Report (*Rep. int. Whal. Commn* 31).

The measures adopted over the last few years and an improvement in timely payment of national contributions has greatly strengthened the Commission's financial position, so that in approving a budget of £300,972 for 1980/81, the contribution from members (£235,822) were about 15% lower than in the previous year.

Because of concern expressed at previous meetings on the present system of calculating national contributions, the Commission agreed that new proposals should be examined with the intention of taking a decision at the 33rd Annual Meeting.

The Commission amended its Financial Regulations at the 32nd Annual Meeting to provide for the withholding of services by the Commission from a member nation which falls into arrears of more than two years on payment of its financial contributions and the charging of interest on those contributions.

MEMBERSHIP

Notifications of adherence to the International Convention for the Regulation of Whaling 1946 were deposited by the Governments of the People's Republic of China on 24 September 1980, India on 9 March 1981, St Lucia on 29 June 1981, Dominica on 9 July 1981, Jamaica on 15 July 1981, Uruguay on 15 July 1981, St Vincent and the Grenadines on 22 July 1981, and Costa Rica on 24 July 1981.

Notice of withdrawal from the Convention was deposited by the Government of Canada on 24 June 1981. This will become effective on 30 June 1982.

Income and Expenditure Account for the year ended 31 August 1981

	Note		1981		*1980*
INCOME					
Contributions			266,933		*285,597*
Interest receivable			31,728		*32,884*
Sales of publications			9,122		*5,509*
Voluntary contributions to research			19,755		*25,391*
Value added tax recoverable			13,639		*10,828*
Staff assessments			14,748		*11,615*
Surplus on exchange translation			260		—
			356,185		*371,824*
EXPENDITURE					
Secretariat costs	4	143,259		*112,169*	
Publications	4	70,243		*50,559*	
Annual meetings	4	51,730		*40,172*	
Special meetings	4	6,175		*9,651*	
Research	5	67,625		*22,218*	
			339,032		*234,769*
EXCESS OF INCOME OVER EXPENDITURE			17,153		*137,055*
NET TRANSFER TO RESEARCH FUND (note 2)			4,079		*35,397*
SURPLUS FOR THE YEAR			£13,074		*£101,658*

NOTES TO THE INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 AUGUST 1981

	1981	*1980*
1. Secretariat Costs		
Salaries and national insurance	79,498	*54,906*
Pension contributions	2,143	*4,845*
Severance pay provision	5,000	*5,000*
Additional assistance	219	*1,358*
Travelling expenses	4,077	*2,001*
Office rent, heating and maintenance	7,700	*5,534*
Insurance	1,200	*999*
Stationery	1,637	*1,113*
Postages	2,840	*1,944*
Telephone and telex	3,479	*3,334*
Computer facility (including staff costs)	22,679	*16,467*
Office furniture and equipment		
Purchases	1,612	*1,224*
Leasing	7,733	*7,211*
Maintenance	423	*417*
Professional fees	1,903	*1,409*
General expenses	1,116	*215*
Provision against unpaid contribution	—	*4,192*
	£143,259	*£112,169*

2. Publications		
30th Annual Report	—	*29,810*
31st Annual Report	48,728	—
Additional reports	15,312	*12,930*
Other printing and copying	6,203	*7,819*
	£70,243	*£50,559*

	1981	*1980*
3. Annual Meetings		
31st Meeting	—	*361*
32nd Meeting	1,707	*39,811*
33rd Meeting	50,023	—
	£51,730	*£40,172*
4. Special Meetings		
Whale sightings	2,870	*3,159*
Revised management procedures	3,305	*1,267*
Cetacean behaviour and intelligence	—	*5,000*
BIOMASS	—	*225*
	£6,175	*£9,651*
5. Research Expenditure		
Tongan humpback survey	445	*1,805*
Whale marking	17,011	*19,413*
Whale/Seabird cruise	—	*1,000*
1980/81 S. Hemisphere minke whale cruise	23,758	—
Humane killing workshop	1,208	—
Indian Ocean Sanctuary meeting	5,000	—
Discretionary support	3,600	—
Gray whales project	2,067	—
Azores sperm whales project	2,000	—
S.E. Pacific sperm whales project	3,284	—
Greenland humpback whales project	4,212	—
Minke whales/vessels reponse project	1,645	—
Other	3,395	—
	£67,625	*£22,218*

Balance Sheet 31 August 1981

	Note	1981	*1980*
CURRENT ASSETS			
Cash at banks			
Deposit accounts		76,843	*147,738*
Deposit accounts (Research Fund)		59,028	*55,967*
Deposit account (severance pay)		23,432	*12,329*
Current account		54,988	*4,725*
Cash in hand		38	*69*
Outstanding contributions from members		57,878	*40,396*
Other debtors and prepayments		36,717	*27,365*
		308,924	*288,589*
CURRENT LIABILITIES			
Creditors		22,346	*27,302*
NET CURRENT ASSETS		286,578	*261,287*
SEVERANCE PAY PROVISION	1 & 3	21,419	*13,281*
		£265,159	*£248,006*
FINANCED BY			
FUNDS	2		
Research		62,071	*57,992*
General		203,088	*190,014*
		£265,159	*£248,006*

RAY GAMBELL
Secretary

NOTES TO THE ACCOUNTS 31 AUGUST 1981

1. **Accounting Policies**

These accounts have been prepared under the historical cost convention. The accounting policies adopted by the Commission in the preparation of these accounts are as set out below.

FIXED ASSETS
The full cost of office furniture and equipment is written off in the income and expenditure account in the year in which it is incurred.

ANNUAL REPORTS
The full cost of printing the Annual Report is written off in the year. No account is taken of stocks of the report which remain unsold at the balance sheet date.

SEVERANCE PAY PROVISION
In accordance with the practice of other international organisations, the Commission provides for an indemnity to specified members of staff in the event of their appointment being terminated on the abolition of their posts. The indemnity varies according to length of service and therefore an annual provision is made for the amount of the maximum liability.

TRANSLATION OF FOREIGN CURRENCY
Deposits with the Bank of New Zealand have been translated at the rate of $2.2305 to the £.

2. Funds	Research	General	Total
Transfers (to) from income and expenditure account			
Surplus on exchange translation	260	—	260
Voluntary contributions to research	19,755	—	19,755
Allocation for research	42,801	—	42,801
Interest on investments	8,742	—	8,742
Sales	146	—	146
Research expenditure	(67,625)	—	(67,625)
	4,079	—	4,079
Surplus for the year	—	13,074	13,074
Balances at 1st September 1980	57,992	190,014	248,006
Balances at 31st August 1981	£62,071	203,088	£265,159

3. Severance pay provision	1981	*1980*
Balance at 1st September 1980	12,381	*6,683*
Transfer from income and expenditure account	5,000	*5,000*
Interest receivable	3,138	*1,598*
Balance at 31st August 1981	£21,419	*£13,281*

REPORT OF THE AUDITORS TO THE COMMISSION

We have audited the financial statements set out above in accordance with approved Auditing Standards. In our opinion the financial statements which have been prepared under the historical cost convention, give a true and fair view of the state of affairs of the Commission at 31 August 1981 and of its surplus for the year ended on that date.

Leda House, Station Road, Cambridge
16 November 1981

SPICER AND PEGLER
Chartered Accountants

33rd Annual Meeting
July 1981—Brighton
List of Delegates and Observers Attending

Argentina

Mr E. H. Iglesias	Commissioner
Captain A. Casellas	Adviser

Australia

Prof. J. D. Ovington	Commissioner
Dr K. R. Allen	Adviser
Mr G. R. V. Anderson	Adviser
Mr J. L. Bannister	Adviser
Mr W. De la Mare	Adviser
Dr D. F. de Stoop	Alternate Commissioner

Brazil

Mr F. Fontoura	Commissioner

Canada

Mr R. B. Fadden	Adviser
Mr D. Goodman	Adviser
Dr I. McTaggart-Cowan	Adviser

Chile

Prof. L. Goycolea	Commissioner
Dr R. Maturana	Adviser
Prof. C. Conley	Adviser

China, People's Republic of

Mr Y. Zhou	Commissioner
Ms R. Zhang	Adviser
Mr R. Liu	Adviser
Mr R. Li	Adviser
Mr Zhou Hong-am	Adviser

Denmark

Mr E. Lemche	Commissioner
Dr P. Agger	Adviser
Mr F. Erskov	Adviser
Dr F. O. Kapel	Adviser
Dr V. Koester	Adviser
Mr A. Olafsson	Adviser
Mr M. B. Thomsen	Adviser
Mrs K. Trolle	Adviser

France

Prof. C. Roux	Commissioner
Mr D. Hery Mr G. Marchand	Alternate Commissioners
Dr M. Pascal	Adviser
Mrs J. Mackintosh	Adviser

Iceland

Mr T. Asgeirsson	Commissioner
Mr A. Einarsson	Adviser
Mr J. Jónsson	Adviser
Mr K. Loftsson	Adviser

India

Mr S. Singh	Commissioner

Jamaica

Mr A. Isaacs	Commissioner
Ms A. Haynes	Adviser

Japan

Mr K. Yonezawa	Commissioner
Mr T. Atoda	Adviser
Mr M. Endo	Adviser
Mr S. Hasui	Adviser
Dr I. Ikeda	Adviser
Mr T. Isogai	Adviser
Mr S. Kadota	Adviser
Mr M. Kakibaya	Adviser
Mr F. Kasamatsu	Adviser
Mr R. Kiyomiya	Adviser
Mr M. Miyahara	Adviser
Mr K. Nagao	Adviser
Mr T. Nakamura	Adviser
Mr M. Nakamura	Adviser
Mr T. Nishitani	Adviser
Mr C. Ohmura	Adviser
Dr S. Ohsumi	Adviser
Mr K. Ohtsuru	Adviser
Mr T. Saito	Adviser
Mr M. Tanaka	Adviser
Mr Y. Takase	Adviser
Mr T. Takayama	Adviser
Mr H. Yagita	Adviser
Mr K. Yamamura	Adviser
Mr N. Yanagihara	Adviser
Mr R. Yoshimura	Adviser
Mr Y. Yoshinari	Adviser

Republic of Korea

Mr K. H. Kim	Commissioner
Mr N. C. Choi	Adviser
Mr Y. Gong	Adviser
Mr H. S. Park	Adviser
Mr J. W. Choi	Adviser

Mexico

Dr E. Polanco-Jaime	Commissioner
Mr L. Fleischer	Alternate Commissioner
Mr J. Terres	Adviser
Mr S. Monroy	Adviser

Netherlands

Mr F. H. J. von der Assen	Commissioner
Mrs Y. Goedkoop-van Opijnen	Adviser
Dr W. van Reenen	Adviser
Mr J. H. L. van Lissa	Adviser
Dr J. G. van Beek	Adviser

New Zealand

Mr I. L. G. Stewart	Commissioner
Mr F. Wong	Alternate Commissioner
Mr M. Donaghue	Adviser

Norway

Mr P. Tresselt	Commissioner
Mr K. Hauge	Adviser
Mr M. Norderhaug	Adviser
Mr K. Raasok	Adviser
Mr T. Foss	Adviser
Mr T. Øritsland	Adviser
Mr I. Christensen	Adviser
Mr J. Valderhaug	Adviser
Mr J. W. Hegg	Adviser
Mr J. A. Bolle	Adviser

Oman

Mr M. A. Al Barwani	Commissioner
Mr J. Carr	Adviser

Peru

Dr J. Valdivia	Commissioner
Dr J. Leon	Adviser
Dr R. Leon Seminario	Adviser

St Lucia

Hon. P. Josie	Commissioner
Dr F. Palacio	Alternate Commissioner
Mr H. L. Haynes	Adviser

St Vincent and the Grenadines

Dr C. Davey	Commissioner

Seychelles

Dr L. Watson	Alternate Commissioner
Dr S. Holt	Adviser
Ms C. Durrant	Adviser
Mr R. Delpech	Adviser

South Africa

Dr L. Botha	Commissioner
Dr P. Best	Adviser
Mr A. L. Manley	Adviser
Mr D. van Schoor	Adviser
Mr R. Sherwood	Adviser

Spain

Mr J. Prat	Commissioner
Mr E. de Salas	Alternate Commissioner
Mr A. Aguilar	Adviser
Mr A. Munoz Seca	Adviser
Mr J. Pintos	Adviser
Ms C. Brennan-Maza	Adviser

Sweden

Mr B. Hägerhäll	Commissioner
Mr L. Alvin	Alternate Commissioner
Prof. H. Ackefors	Alternate Commissioner

Switzerland

Mr J. Doswald	Commissioner

USSR

Dr I. V. Nikonorov	Commissioner
Dr M. V. Ivashin	Adviser
Dr R. G. Borodin	Adviser
Dr E. Sabourenkov	Adviser
Mr Y. Riazantsev	Adviser

UK

Mr R. J. Packer	Commissioner
Mr G. Belchamber	Alternate Commissioner
Mr A. Church	Alternate Commissioner
Mr S. G. Brown	Adviser
Mr J. W. Horwood	Adviser
Mr D. J. Garrod	Adviser
Sir Peter Scott	Adviser
Ms J. Gordon-Clark	Adviser
Mr W. Jordan	Adviser

USA

Mr T. Garrett	Commissioner
Mr R. Tucker Scully	Alternate Commissioner
Mr D. Bonker	Adviser
Mr P. N. McCloskey	Adviser
Dr R. Brownell	Adviser
Prof. D. Chapman	Adviser
Ms A. Crichton	Adviser
Mr R. Eisenbud	Adviser
Ms C. Kendrew	Adviser
Mr P. Pilkauskas	Adviser
Ms J. Mackenzie	Adviser
Mr R. Roe	Adviser
Dr D. Swanson	Adviser
Dr M. F. Tillman	Adviser

Ms M. Adams	Adviser
Mr R. Ellis	Adviser
Ms M. McCloskey	Adviser
Ms P. Wray	Adviser
Ms C. A. Grunberg	Adviser
Ms C. Fronville	Adviser
Miss C. E. Carlson	Adviser

Uruguay

Mr M. Magarinos de Mello	Commissioner

Non-member Government Observers

Belgium	Dr W. De Smet
Colombia	Dr F. Palacio Mr J. P. Fortom-Gouin Ms J. Gutierrez Mrs A. Smith
Costa Rica	Dr C. Davey Ms J. Gutierrez Dr E. Lahmann
Egypt	Dr A. R. Bayoumi
Finland	Mrs K. Lintonen
Federal Republic of Germany	Mr D. Eberle
Republic of Ireland	Mr E. O'Connor Dr F. O'Gorman
Kenya	Mr N. Odero Mr H. Ochieng
Portugal	Capt. J. G. Boavida Dr A. Pinheiro-Gonzalves Comm. J. Oliveira-Costa Dr D. Carvalho

Inter-Governmental Organisation Observers

Commission of the European Communities (CEC)	Dr M. Leigh Mr W. Wijnstekers
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	Mr O. Menghi Ms P. Deimer
Food and Agriculture Organisation of the United Nations (FAO)	Dr M. Savini
Inter-American Tropical Tuna Commission (IATTC)	Dr P. S. Hammond
International Council for the Exploration of the Sea (ICES)	Dr F. O. Kapel
International Commission for the Southeast Atlantic Fisheries (ICSEAF)	Dr L. Botha
United Nations Environment Programme (UNEP)	Mr A. Renlund
International Union for the Conservation of Nature and Natural Resources (IUCN)	Prof. G. Hempel

International Non-Governmental Organisations

(Alternate Observers in brackets)

African Wildlife Leadership Foundation	Ms F. Lipscomb
The American Cetacean Society	Ms K. Slap
Animal Protection Institute of America	Ms J. Risk (Ms P. Feltz)
Antarctic and Southern Ocean Coalition	Mr R. M'Gonigle
Assembly of Rabbis	Mr L. A. Carter
Campaign Whale	Mr M. Glover
Centre for Action on Endangered Species	Ms B. Britten
Centre for Environmental Education	Mr W. Kardash
Commission of the Churches on International Affairs of the World Council of Churches	Mr E. Brower (Mr R. Silook)
Connecticut Cetacean Society	Dr R. Barstow (Ms M. Hall)
European Environmental Bureau	Ms S. Owen
Fauna and Flora Preservation Society	Mr R. Fitter (Mr S. Lyster)
Friends of the Earth Limited	Mr C. Secrett
Greenpeace International	Mr D. McTaggart
Innuit Circumpolar Conference	Mr H. J. Helms
The Institute for the Study of Animal Problems	Ms P. Forkan
International Environmental Advisors Inc.	Mr J. Frizell
International Federation of Institutes for Advance Study	Mr A. V. Kuder
International Fund for Animal Welfare	Mr I. S. MacPhail
International Institute for Environment and Development	Ms T. Borge
International League for Animal Rights	Mr R. Parmentier (Mr P. Hyde)
International League for the Protection of Cetaceans	Dr P. Spong
International Ocean Institute	Ms L. Busby
International Primate Protection League	Mrs A. Doncaster
International Transport Workers' Federation	Mr S. Kondo
International Youth Federation for Environmental Studies and Conservation	Mr R. Hunter (Mr M. Schultz)
Leviathan International	Ms D. Shephard
League Against Cruel Sports	Mr J. Alexander-Sinclair
Marine Action Centre	Mr M. Kennedy
Monitor International	Ms K. Harper
Monitor	Mr C. Van Note
Natur og Ungdom	Mr G. Sørensen (Mr B. Hoff Johannssen)
Prevention of Cruelty to Animals and Plants International	Mr J. May (Mrs S. Kilvington)
People's Trust for Endangered Species	Mr W. Jordan
Royal Society for the Prevention of Cruelty to Animals	Mr P. Vodden

Save the Whales—Hawaii	Mr H. Da Cruz
Sea Shepherd Conservation	Mr D. McColl (Mr A. Jones)
Sierra Club	Mrs P. Birnie
Threshold Foundation Bureau	Mrs C. Brennan
Whale Centers International	Mr W. Clayton
The Whale Coalition	Mr D. Phillips (Mr D. Lafen)
The Whale Project	Mr A. Thornton (Mr M. Roberts)
World Association of World Federalists	Mr S. L. Sutcliffe (Ms D. Gottheil)
World Council of Indigenous Peoples	Mr E. Brower
World Society for the Protection of Animals	Mr V. S. Watkins
World Wildlife Fund	Ms J. Barber
Werkgroep Zeehond	Dr P. Lagendijk

Agenda of the Thirty-Third Annual Meeting

1. Address of Welcome

2. Opening Statements (Paper IWC/33/OS–)

3. Adoption of Agenda

4. Arrangements for the Meeting

5. Appointment of Committees
(Rules of Procedure, Rule J.1.)

6. Implementation of a World-wide Ban on Whaling

A. Proposals for Banning Commercial Whaling
(Proposals may be implemented by amendment of the Schedule, paragraph 10(a) and Tables 1, 2 and 3 or other paragraphs, or the addition of new paragraphs)
  A.1 Indefinite ban/moratorium on all commercial whaling
  (Chairman's Report of the 32nd Meeting, paragraph 8)
  A.2 Indefinite ban on commercial whaling in the North Atlantic
  A.3 Commercial moratorium for the pelagic catch of minke whales after the 1983/84 season (Paper IWC/33/21)
  A.4 Commercial catching of sperm whales
  (Chairman's Report of the 32nd Meeting, paragraph 9)
   A.4.1 Conditional prohibition/indefinite ban/moratorium
   A.4.2 Moratorium for five years (Paper IWC/33/21)

B. Revision of Present Management Procedure
(Chairman's Report of the 32nd Meeting, paragraph 10)
  B.1 Report of Working Group on Revised Management Procedures (Paper IWC/33/13)
  B.2 Report of Scientific Committee
  B.3 Consideration of proposed amendments to the Schedule
  B.4 Action arising
  (Changes in criteria, stock categories, or procedures will require amendment of the Schedule, including paragraph 10 or the addition of new paragraphs)

9. Consideration of Protected Species
  9.1 Review of status
  9.2 Possible amendments to the Schedule

10. Whale Sanctuaries
(Chairman's Report of the 32nd Meeting, paragraph 12)
  10.1 Scientific research in the Indian Ocean Sanctuary
   10.1.1 Report on the Seychelles planning meeting
   10.1.2 Report of Scientific Committee
   10.1.3 Action arising
  10.2 Examination of the general concept and characteristics of whale sanctuaries
   10.2.1 Report of Scientific Committee
   10.2.2 Action arising

11. Whale Stocks and Catch Limits
(Chairman's Report of the 32nd Meeting, paragraph 13 and Circular Communications from the Secretary dated 27 August 1980 and 26 November 1980, refs: RG/CAB/3540 and RG/EE/3693)
   11.1.1 Geographical boundaries of Bryde's whale stocks in the Southern Hemisphere
   11.1.2 Geographical boundaries of minke whale stocks in the North Pacific
  11.2 Action arising, 1981/82 Southern Hemisphere pelagic season and 1982 coastal seasons elsewhere
  (Changes of catch limits, of effort limitations, or areas or sub-areas, or of size limits will require amendment of the Schedule including paragraphs 2, 4, 5, 9, 11, 12, 13, 15, 16, 17, 19 and Tables 1, 2 and 3)
   11.2.1 Southern Hemisphere
   11.2.2 North Pacific
   11.2.3 North Atlantic
   11.2.4 Arctic
   11.2.5 Northern Indian Ocean

12. Aboriginal/Subsistence Whaling
(Chairman's Report of the 32nd Meeting, paragraph 6 and Appendix 3)
  12.1 Management principles and guidelines for subsistence catches of cetaceans by indigenous peoples
   12.1.1 Report of *ad hoc* Working Group on Subsistence Whaling (Paper IWC/33/14)
   12.1.2 Action arising
  12.2 Documentation of the utilisation of the meat and products of any whales taken for aborignal/subsistence purposes
  12.3 Bering Sea stock of bowhead whales
   12.3.1 Report of the Scientific Committee, including results of research by the USA
   12.3.2 Documentation of aboriginal needs by the USA
   12.3.3 Review of Resolution on the Bering Sea bowhead whales adopted at the 31st Annual Meeting concerning the whaling regime, scientific analysis and status of the stock
   (Chairman's Report of the 31st Meeting, Appendix 4)
  12.4 Eastern Pacific stock of gray whales
  12.5 West Greenland stock of humpback whales
  12.6 Action arising
  (Changes of catch limits will require amendment of the Schedule, paragraphs 12, 13 or Table 1)

13. Small Cetaceans
    (*Chairman's Report of the 32nd Meeting, paragraph 15 and Appendix 8*)
    13.1 Consideration of the Commission's responsibilities for small cetaceans
    13.2 Report of Scientific Committee
    13.3 Action arising

14. Measures to Discourage Whaling Operations Outside IWC Regulations
    (*Chairman's Report of the 32nd Meeting, paragraph 14 and Appendices 6 and 7*)
    14.1 Report of Working Group on Non-IWC Whaling (Paper IWC/33/16)
    14.2 Prohibition on importation of whale products from and export of whaling vessels, equipment and expertise to non-member countries
    (Proposal to be implemented by amendment of the Schedule)
    14.3 Register of whaling vessels (Paper IWC/33/17)
    14.4 Action arising

15. Computing Requirements
    15.1 Report of Scientific Committee
        15.1.1 Review of Commission's computing capability
        15.1.2 Consideration of future requirements
    15.2 Action arising

16. International Decade of Cetacean Research
    (*Chairman's Report of the 32nd Meeting, paragraph 16 and Appendices 9 and 10*)
    16.1 Report of Scientific Committee
    16.2 Whale habitats, including reports from Governments on degradation of the marine environment
    16.3 Action arising

17. Collation and Distribution of Annual Summary of National Research on Cetaceans by the Commission

18. Humane Killing
    (*Chairman's Report of the 32nd Meeting, paragraph 19 and Appendix 11*)
    18.1 Report of Workshop Meeting of invited experts (Paper IWC/33/15)
        18.1.1 Report of Scientific Committee
        18.1.2 Action arising
    18.2 Collection of data required
    (*Chairman's Report of the 31st Meeting, Appendix 6*)
    18.3 Reports by Contracting Governments concerning the implementation of Schedule paragraph 6
    18.4 Prohibition on the use of the cold grenade harpoon for killing minke whales
    (An amendment to the Schedule will be submitted)

19. Consideration of Cetacean Behaviour and Intelligence and the Ethics of Killing Cetaceans
    19.1 Report by the Secretary on actions taken in response to the recommendations of the *ad hoc* Steering Committee of the Meeting on Cetacean Behaviour and Intelligence and the Ethics of Killing Cetaceans, 28 April – 1 May 1980 in Washington, D.C.
    19.2 Action arising

20. Adoption of Report of the Scientific Committee (to be circulated as Paper IWC/33/4)

21. Revision of the Schedule
    (*Chairman's Report of the 32nd Meeting, paragraph 22 and comments by the Secretary in Circular Communication dated 27 August 1980, ref: RG/CAB/3540*)
    21.1 Report of Technical Committee
        21.1.1 Paragraphs dealing with Factory Ship Whaling in Section II, Seasons
        21.1.2 Style used to designate limits of the Indian Ocean Sanctuary (paragraph 7)
        21.1.3 Use of terms 'excluding' and 'except' in paragraphs 10(d), 2(a), 3 and 4(b)
        21.1.4 Policy on treatment of Protected whales taken by accident
        21.1.5 Review of description of whale processing in paragraph 20(b)
        21.1.6 Definition of 'local consumption'
    21.2 Action arising
    (Any changes will require amendment of the Schedule)

22. Infractions and Reports from International Observers, 1980 and 1980/81 Seasons
    (*Chairman's Report of the 32nd Meeting, paragraph 23 and Appendix 13*)
    22.1 Report of Technical Committee
        22.1.1 Infractions reports from Contracting Governments (Paper IWC/33/6)
        22.1.2 Checklist of information required under the terms of Section VI of the Schedule
        22.1.3 Reports from Observers (Paper IWC/33/7)
    22.2 Action Arising

23. International Observer Scheme
    (*Chairman's Report of the 32nd Meeting, paragraph 24 and Appendix 13*)
    23.1 Report of Technical Committee
        23.1.1 Expansion and extension of existing schemes and consideration of means by which to facilitate communication and the development of new schemes among Contracting Governments
        23.1.2 New schemes for whaling operations by Brazil, Chile, Peru and Spain
        23.1.3 Inclusion of other functions in duties of observers, including scientific
    23.2 Action arising
    (Changes to observer schemes may require amendment of the Schedule, paragraph 22)

24. Adoption of Report of the Technical Committee (to be circulated as Paper IWC/33/5)

25. Finance and Administration
    (*Chairman's Report of the 32nd Meeting, paragraph 26*)
    25.1 Review of provisional financial statement, 1980/81 (Paper IWC/33/9)
    25.2 Consideration of estimated basic budget 1981/82 (Paper IWC/33/9)
    25.3 Consideration of supplementary budget
        25.3.1 Computing
        25.3.2 Research
        25.3.3 Meetings
        25.3.4 Other
    25.4 Methods of calculating contributions from Contracting Governments (Paper IWC/33/18)
    25.5 Proposals for funding research (Paper IWC/33/18)

- 25.6 Consideration of advance budget estimates for 1982/83 (Paper IWC/33/9)
- 25.7 Other matters (Paper IWC/33/19)
    - 25.7.1 Publications
    - 25.7.2 Staff inspection
    - 25.7.3 Amendment of Financial Regulations
    - 25.7.4 Commission's archives
    - 25.7.5 Signature of legal documents
    - 25.7.6 Modification of the Headquarters Agreement between the Government of the UK and the IWC

26. Additional Working Languages at Meetings of the Commission

27. Date and Place of Annual Meetings 1982 and 1983
(*Rules of Procedure, Rule B.1.*)

28. Adoption of Report of Finance and Administration Committee
(to be circulated as Paper IWC/33/10)

29. Revision of the International Convention for the Regulation of Whaling, 1946
(*Chairman's Report of the 32nd Meeting, paragraph 29*)
    - 29.1 Report of Reykjavik Meeting, 6–9 May 1981 (Paper IWC/33/20)
    - 29.2 Action arising

30. Co-operation with other Organisations
    - 30.1 Co-operation with the proposed Commission for the Conservation of Antarctic Marine Living Resources
    - 30.2 Observers' Reports from other meetings (Paper IWC/33/11)
        - 30.2.1 ICES
        - 30.2.2 ICCAT
        - 30.2.3 IATTC
        - 30.2.4 CITES

31. 32nd Annual Report
(Paper IWC/33/12 Draft)

32. Election of Chairman
(*Rules of Procedure, Rule D.1.*)

33. Election of Vice-Chairman
(*Rules of Procedure, Rule E.1.*)

34. Any Other Business

Chairman's Report of the Thirty-Third Annual Meeting

1. DATE AND PLACE

The thirty-third Annual Meeting of the Commission was held at the Metropole Hotel, Brighton, 20–25 July 1981. The proceedings were conducted by the Chairman of the Commission, Mr T. Asgeirsson (Iceland).

2. REPRESENTATION

Commissioners and delegates attended from thirty member governments. These included the People's Republic of China, India, Jamaica and Uruguay, who had joined since the previous meeting, and Costa Rica and St Vincent and the Grenadines who joined during the course of this meeting. Dominica, also a new member, was not represented, while Canada was present in an observer capacity only, having given notice of withdrawal with effect from 30 June 1982.

Observers were present from eight non-member governments:

Belgium, Colombia, Egypt, Finland, Federal Republic of Germany, Republic of Ireland, Kenya and Portugal.

Observers were also present from eight inter-governmental organisations:

Commission of the European Communities (CEC)
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
Food and Agriculture Organisation of the United Nations (FAO)
Inter-American Tropical Tuna Commission (IATTC)
International Council for the Exploration of the Sea (ICES)
International Commission for the Southeast Atlantic Fisheries (ICSEAF)
United Nations Environment Programme (UNEP)

from the International Union for the Conservation of Nature and Natural Resources (IUCN)

and from forty-nine international non-governmental organisations listed in Appendix 1.

3. ADDRESS OF WELCOME

An address of welcome was given on behalf of the United Kingdom Government by Mr Jerry Wiggin, Parliamentary Secretary to the Ministry of Agriculture, Fisheries and Food, who commented that the extensive agenda for the meeting demonstrated the rapidly growing concern throughout the world for conservation and the environment. The United Kingdom believed that knowledge of whales was inadequate to enable catch limits to be set at sustainable levels and that the method of killing whales was unsatisfactory. It was, therefore, proposing an indefinite ban on commercial whaling and, if that should fail, similar restrictions on commercial whaling for those areas and species considered by the United Kingdom to be at the greatest risk, namely, the North Atlantic and sperm whales.

Mr Wiggin emphasised that the United Kingdom recognised that some countries have a legitimate interest in commercial whaling and that its proposal was for a moratorium which implied that, provided certain conditions were met, a resumption of whaling could be considered in the future.

Mr Wiggin concluded by drawing attention to recent United Kingdom legislation affording total protection to all cetaceans within British fishery limits.

4. OPENING STATEMENTS

In accordance with past practice, opening statements by Commissioners and Observers were distributed in written form, but the Commissioners from the new member governments of India, People's Republic of China, Jamaica, Uruguay, St Vincent and the Grenadines, and Costa Rica were also given the floor for verbal presentations.

5. ADOPTION OF AGENDA

The Provisional Annotated Agenda had been distributed 60 days in advance of the meeting with some items undecided in the order in which they would be considered. On the proposal of Australia, seconded by Sweden, the UK, the USA, the Netherlands and France, it was agreed to adopt the Agenda with the discussion on Revision of the Present Management Procedures as item 6, followed by Proposals for Banning Commercial Whaling as item 7, and item 8, Implementation of a World-wide Ban on Whaling. Items 6 to 24 were referred to the Technical Committee for consideration in the first instance, with the instruction that it should report back to the Plenary Session when the first three items were completed.

6. REVISION OF THE PRESENT MANAGEMENT PROCEDURES

The Technical Committee Working Group on Revised Management Procedures had held two sessions during the year in Tokyo and Rome, which resulted in the presentation of four proposals for consideration by the Commission. These represented alternative recommendations due to the failure of the meetings to reach agreement. In Technical Committee the Seychelles withdrew its proposal, since this had failed as an attempt to reach a compromise during the Rome session.

The Technical Committee discussed the US proposal at length. This was designed to overcome recognised uncertainties in the present procedures. These include problems of stock identification, with assessment models, the insufficiency of data, the inter-relationships in the marine ecosystem and delays in recognising declines in stocks often due to problems associated with CPUE analyses. The Special Working Group of Scientists had put forward a number of recommendations for a revised management procedure which were embodied in the US proposal, including a key provision that for whale stocks in a stable environment and for which sufficient information is available, a target level is identified and management measures are aimed at bringing the stocks to that level in a set period of years.

Denmark received confirmation that this proposal applied only to commercial whaling, and Japan noted that the Scientific Committee had not finished discussing the questions raised and believed that it is premature to make hasty Schedule amendments. It still saw problems in the applications of the scheme and was concerned over its discriminatory nature concerning commercial and subsistence whaling. It commented on the difficulties of assessing initial population levels particularly when only part of a population is available for study by a coastal state, and was concerned that whaling was required to stop after five years if the initial population size was not established.

Norway commented on the central role of management procedures in the work of the IWC. It noted that the Working Group had agreed on certain procedures and objectives but believed there was a need for further developments and improvements in the management schemes because of certain difficulties in their practical application.

Iceland and Spain expressed support for the positions adopted by Japan and Norway, and several delegations spoke of the need to try and bridge the differences between the proposals rather than to engage in confrontation between them. The USSR stressed the need for a new reliable replacement for the old procedures.

The Technical Committee recommended the US proposal by a majority vote, although a number of delegations believed further discussion was desirable.

In the Plenary Session, after two adjournments of the subject to allow time for informal consultations hosted by the USA, the Commission adopted a Resolution (Appendix 2) put forward by the USA and seconded by Norway which outlines a procedure for future work by consultations between interested governments so that agreed proposals can be considered at the next Annual Meeting.

7. PROPOSALS FOR BANNING COMMERCIAL WHALING

7.1 Indefinite ban/moratorium on all commercial whaling

By a majority vote the Technical Committee recommended an amendment to the Schedule which would have the effect of placing a moratorium on all commercial whaling. This proposal was put forward by the UK because of its concern over past management failures, uncertainties in present assessments and management activities related to an inadequate knowledge of the whales, and the lack of satisfactory methods of killing. The proposal was seconded in the plenary session by the UK, the USA, Sweden, France and New Zealand. Japan stated its opposition to the proposal, on the grounds that under international customary law every State has the right to make use of the natural resources on the high seas as well as within its own zone of jurisdiction. These rights are recognised in the Whaling Convention. In addition, the Scientific Committee has recommended quotas for certain stocks so that a total moratorium on commercial whaling only is not justified and is also contrary to its interpretation of Article V of the Convention.

Norway emphasised its long-standing policy of scientific management on a stock by stock basis, which does not accord with the present proposal. It also questioned the legality of the only criterion proposed for determining if whaling should continue, that of it being commercial or not.

Spain supported the views of Japan and Norway, believing that such general and political decisions should defer to science. Peru shared similar views, and the USSR also concurred, adding that such a disguised ban on whaling undermines co-operation within the Commission, would reduce research activities, and called the future of the Commission into doubt. The Republic of Korea also opposed the proposal since it lacked a convincing scientific basis, and it believes the present protection ensures that there is no clear risk of depleting any whale stock.

South Africa spoke as a nation which stopped whaling in 1975 and has subsequently strengthened its national legislation to protect cetaceans. It has contributed towards intensified research and attempts to take a responsible attitude. But there is no clear scientific basis for a moratorium and it would therefore abstain. Mexico stressed its strong conservation position, but would also abstain because of the sovereignty of states within their coastal zones.

Argentina emphasised the need to find a mid-point between the opposing views, while New Zealand called for the benefit of the expressed scientific doubt and uncertainty to be given to the whales.

Brazil stated that it is phasing out its whaling operations but reserved the right to continue in the meantime, and Chile also indicated that it will take no more whales.

Finally, the USA affirmed its continuing commitment to whale protection and an indefinite moratorium on commercial whaling in a message from its President. This position is backed by administrative powers to take action against non-cooperating nations.

On being put to the vote, the proposal received 16 in favour, 8 against, with 3 abstentions, and therefore failed to reach the three-quarters majority necessary to amend the Schedule.

7.2 Indefinite Ban on Commercial Whaling in the North Atlantic

The Technical Committee recommended, by a majority vote, an amendment to the Schedule proposed by the UK designed to introduce a commercial moratorium in the North Atlantic area. This was seconded in Plenary Session by Sweden and the USA.

The UK stated that in its view the failure of the overall moratorium proposal made it even more important that this North Atlantic proposal be adopted. It believes that the data base is worse in the North Atlantic than some other areas and yet substantial catch limits are set for the whaling operations. It noted that fin and sei whales are only caught in this area and it believes that the only prudent course of action is for a moratorium to be instituted.

This view was supported by the USA, who reviewed the history of whaling in the North Atlantic and pointed to the closure of many operations through depletion of the stocks. Jamaica expressed its conviction by this account, and Sweden also voiced its support because of the lack of data, to implement the CITES decision on fin and sei whales and because of the non-IWC whaling in the area.

Iceland spoke against the proposal, arguing that the reasons advanced against a total moratorium are equally applicable in this case. It sees it as a discriminatory measure with no scientific basis. The Icelandic whaling operation since 1948 has been very severely limited by government controls, leading to stable catches and recommendations from the Scientific Committee for continuing catch quotas.

Denmark and Spain also noted the geographical discrimination of the proposal and Spain stated its concern for conservation in the North Atlantic. This concern is reflected in its strict control over catches and the collection and provision of data since joining the Commission in 1979. It would prefer to see other conservation measures based on scientific evidence.

The proposal received 15 votes in favour, with 8 votes against and 4 abstentions. It therefore was not adopted as an amendment to the Schedule, since it did not achieve the necessary three-quarters majority.

7.3 Commercial Moratorium on Pelagic Catch of Minke Whales

A French proposal to ban the taking of minke whales by factory ships after the 1983/84 season was adopted by a majority vote in the Technical Committee, and was seconded in the plenary session by Jamaica.

France commented that minke whales are now the most heavily exploited of the great whales, that females are reproducing at an earlier age and it believes that there may be an increase in perinatal mortality. Comparison with other species suggests that there could be problems of mortality and reproduction which, related to calculations of MSY, all give reason for taking cautious action in setting catch limits while necessary research goes on so as to avoid minke whales meeting with the same fate as blue and humpback whales. It believes that the best course of action is to delay the imposition of the ban on catching, to allow time for redeployment of the fleets affected.

Japan considered that the proposal was an insult to its delegation, considering the efforts its Government has made to obtain knowledge of this species in the international programmes which have been mounted in the Southern Hemisphere. It regarded the French proposal to be contradictory, since it does not advocate zero catch but rather an end to factory ship operations, which is also a discriminatory procedure.

The USSR agreed with Japan that there is no scientific basis for a moratorium, since the scientific evidence on minke whales is the best for all whales and they are in robust condition. The USA indicated that it believes there is scientific information available supporting the moratorium proposal, and South Africa spoke of its active participation in the minke whale surveys which have shown the stocks to be comparatively large. It suggested the uncertainties in assessment could be taken into account when setting catch limits.

The proposal was then put to the vote, but failed to receive the three-quarters majority necessary to amend the Schedule, with 13 votes in favour, 9 against and 5 abstentions.

7.4 Commercial Catching of Sperm Whales

A composite proposal from France, the Netherlands, Seychelles and the UK to amend the Schedule so as to set catch limits for sperm whales at zero as a provisional measure and subject to review at any time was adopted by the Technical Committee on a majority vote.

The Seychelles, speaking on behalf of the four countries, identified this action as an appropriate response to the depletion of some stocks and the uncertainty of assessments. It noted that there are readily available substitutes for sperm whale oil, and international concern has led to trade in sperm products being prohibited by CITES and the import of sperm whale products will also be banned by the EEC from 1982.

Iceland pointed out that the Scientific Committee had recommended caution and catch limits no greater than those set last year, and Japan considered that each stock should be looked at individually. This view was shared by Norway and Spain.

When the proposal came before the Plenary Session, the Netherlands on behalf of the four proposers put forward an amendment designed to overcome difficulties expressed by some delegations. This was seconded by Jamaica and supported by the UK despite its preference for the original moratorium proposal.

The amendment took the form of a new paragraph to replace paragraphs 16 and 17 of the Schedule:

'Catch limits for sperm whales of both sexes shall be set at zero in the Southern Hemisphere for the 1981/82 pelagic season and 1982 coastal seasons and following seasons, and at zero in the Northern Hemisphere for the 1982 and following coastal seasons; except that the catch limits for the 1982 coastal season and following seasons in the Western Division of the North Pacific shall remain undetermined and subject to decision by the Commission following special or annual meetings of the Scientific Committee. These limits shall remain in force until such time as the Commission, on the basis of the scientific information which will be reviewed annually, decides otherwise in accordance with the procedures followed at that time by the Commission.'

It was suggested that this amendment be reflected by zero in Table 3 of the Schedule, except for the Western Division of the North Pacific which will remain undetermined, marked with a dash and with the following footnote:

'No whales may be taken from this stock until catch limits including any limitations on size and sex are established by the Commission.'

Japan proposed a special meeting at a time and place to be agreed by the Commission and stated that its government was prepared to host the Special Meeting of the Commission if agreed. Several delegations expressed their view that the Special Meeting would be more conveniently held in England, and it was left to the Secretary to make the necessary arrangements for a Special Scientific Meeting and a Special Meeting of the Commission about March 1982. The Commission also agreed to the Japanese suggestion that the Scientific Committee should be instructed specifically to consider the effect of the present catch on the Western Division stock of sperm whales in the North Pacific.

The amended proposal was then put to the vote and received the necessary three-quarters majority to amend the Schedule, with 25 votes in favour, 1 against and 3 abstentions.

Chile stated that its vote in favour did not pre-judge its position regarding coastal state jurisdiction.

Iceland then asked for the 1981 sperm whale catch limit in the North Atlantic of 130 to be spread over two years, 1981 and 1982, as a means to facilitate the industry's adjustment to a ban on sperm whaling. This was expressed in the form of a footnote to Table 3 of the Schedule to read:

'Provided that the remainder of 130 male sperm whales from the 1981 coastal season may be taken during the 1982 coastal season.'

This wording was suggested by the Seychelles, seconded by France and Spain, and adopted unanimously by the Commission.

8. IMPLEMENTATION OF A WORLD-WIDE BAN ON WHALING

The Technical Committee adopted by a majority vote an Australian proposal for an amendment to the Schedule for a phased reduction in commercial whaling over five years. Australia stated that it believes that stocks have been greatly reduced by past catching and that those now given protection show little or no signs of recovering. Whaling is extending to the smaller cetaceans, but scientists cannot reach agreement in their assessments because of inadequate knowledge. The industry is jeopardising the resource which is an international heritage. It also was concerned over the evidence of serious breaches of IWC regulations by two member countries, with products imported by a third, which had been reported to the Commission's Infractions Committee. The inhumanity of whaling was another reason for taking this action, which can be reconsidered at any time by the IWC.

Japan indicated that it refuted a number of points made, and in particular believes that this proposal is a contravention of customary international law and the International Convention for the Regulation of Whaling 1946. The ensuing discussion between Australia, Japan, Norway and India on the balance between jurisdictional rights and duties brought out the different interpretations of the balance which exists, although it was agreed that the Whaling Convention itself is the basis for Commission action.

Denmark indicated that it considered the proposal should apply only to commercial whaling, and in the Plenary Session, Australia, seconded by the USA, France and Sweden added an amendment to clarify that this is the case.

On being put to the vote the amended proposal received 15 votes in favour, 8 against with 4 abstentions, and so failed to receive the three-quarters majority necessary to amend the Schedule.

9. CONSIDERATION OF PROTECTED SPECIES

9.1 Review of Status

The Scientific Committee reported on the degree to which IWC actions had resulted in the intended recovery of protected species. Eleven stocks were identified which had been monitored over a period of years, three of which showed increases, but the monitoring period was too short to show any trends in the remaining eight. No other stocks had been systematically studied.

The Scientific Committee recommended that this subject form a priority item in its agenda next year, and this was endorsed by the Technical Committee and approved by the Commission.

9.2 Possible Amendments to the Schedule

Sweden proposed a new paragraph in the Schedule designed to identify protected species including fin and sei whales. It advanced four basic reasons for the proposed action, namely, the inadequacies of the present management procedures; the unassessed consequences of non-IWC whaling; requirements of aboriginal/subsistence whaling; and harmonization with other international agreements.

Iceland indicated that it believes the arguments already advanced against the moratoria proposals are equally relevant in this case and emphasized that the Scientific Committee had recommended catch limits for exploited stocks of fin and sei whales.

Spain also questioned a number of conclusions drawn by Sweden, and Norway spoke of the need to act in conformity with scientific advice.

The Technical Committee adopted the proposal by a majority vote, but in the Plenary Session the Seychelles, seconded by the USA, proposed an amendment to delete fin whales from the list of protected species to be more consistent with scientific advice. This was accepted by Sweden.

Japan emphasised the conflict still existing between the amended proposal and the recommendations of the Scientific Committee, and on being put to the vote, the amended proposal failed to receive a three-quarters majority with 14 votes in favour, 8 against with 6 abstentions, and so was not adopted as an amendment to the Schedule.

10. WHALE SANCTUARIES

10.1 Scientific Research in the Indian Ocean Sanctuary

The Seychelles reported on the research programme which it is co-ordinating in the Indian Ocean Sanctuary established by the Commission. This includes an aerial survey by a conservation group and assistance in data analysis by US scientists. A planning meeting for further research will be co-sponsored by the Seychelles and the Netherlands and will be held in the Netherlands in the autumn. The IWC is also providing financial support for that meeting and a document will be submitted from the Scientific Committee.

The Technical Committee endorsed a Resolution proposed by Oman concerning communication between the IWC and the Indian Ocean Coastal States. In Plenary Session, Chile, Argentina, Mexico, Peru, and Brazil all expressed their reservations concerning some of the concepts embodied in the preambular paragraphs, to which Japan also objected.

South Africa, seconded by the Seychelles, suggested that only the operative part of the Resolution should be accepted, and following extensive amendments put forward by India and the Netherlands, the Commission adopted the revised wording (Appendix 3).

10.2 Examination of the General Concept and Characteristics of Whale Sanctuaries

Australia proposed that certain information covering the species involved, together with management and research data, should be required to be submitted prior to the establishment of any proposed whale sanctuary.

Following a broad discussion in Technical Committee, including the position of small cetaceans and coastal states' rights, it was agreed that because there are more than just scientific considerations involved, a Technical Committee Working Group should be established, convened by Prof. Ovington (Australia).

The Commission endorsed the formation of this Working Group and also agreed that the Secretary should write to all Contracting Governments, inviting them to participate and in particular to submit comments on the Australian proposal. All of this material would then be available to the Scientific Committee at its next annual meeting for comment on the scientific aspects before consideration and preparation of a report by the Working Group in the week preceding the next Annual Meeting of the Commission. Argentina emphasized that the Scientific Committee should only deal with the scientific aspects.

Jamaica submitted a Resolution intended to designate a Northwest Atlantic sanctuary. It spoke of the need for positive action to protect cetaceans, but Japan pointed out that the area involved includes many 200 mile fishery zones, which raised some important issues. Further discussion noted the inclusion of small cetaceans in the proposal, and the Technical Committee finally agreed that the Jamaican proposal should be postponed until after the general review of the concept of whale sanctuaries had taken place.

Jamaica re-introduced its proposal in the Plenary Session, seconded by the USA which spoke of the benefit for the humpback populations in the area. However, after Denmark, Mexico, Japan and Peru expressed reservations and Chile spoke of the need for further study of the judicial aspects, Jamaica withdrew the proposal before a vote called for by Argentina could be taken.

11. WHALE STOCKS AND CATCH LIMITS

11.1 Geographical boundaries

11.1.1 Bryde's whale stocks in the Southern Hemisphere

The Scientific Committee recommended the following stock boundaries, including a new stock, the South African Inshore, which were endorsed by the Technical Committee and approved by the Commission:

Southern Indian Ocean
  20°E to 130°E, south of the Equator
Solomon Islands
  150°E to 170°E
  20°S to the Equator
Western South Pacific
  130°E to 150°W, south of the Equator
  (excluding the Solomon Islands Stock area)
Peruvian
  [unchanged]
Eastern South Pacific
  150°W to 70°W, south of the Equator
  (excluding the Peruvian stock area)
South African Inshore
  30 nm seawards off the south west coast of South Africa from 25°S latitude down and around the coast to 25°E longitude
South Atlantic
  70°W to 20°E, south of the Equator

11.1.2 Minke whale stocks in the North Pacific

The Scientific Committee had agreed to define these areas at the next meeting and therefore made no recommendation now. This was accepted by the Technical Committee and agreed by the Commission.

11.2 Southern Hemisphere 1981/82 Pelagic Season and 1982 Coastal Season

The Chairman of the Scientific Committee presented the report of his Committee on the several stocks involved and the Technical Committee and the Commission commented and took action as indicated.

11.2.1 Sei whales

The Scientific Committee had no new data to alter previous assessments and recommended that the stocks in Areas I to VI should remain Protected Stocks. The Technical Committee endorsed this recommendation which was agreed by the Commission.

11.2.2 Minke whales

The Scientific Committee considered various sub-divisions but ultimately presented results for the present six management Areas. There was a majority view recommending two possible sets of catch limits for Areas I and III–VI and an alternative view expressing a more cautious approach, with catch limits set no greater than those adopted last year.

The Technical Committee considered a series of figures based on last year's catch limits. Japan pointed out that the figures are not in accordance with the recommendation by most of the Scientific Committee. There is evidence of availability of higher catches since stock size estimates have increased over the past three years, and the dissenting scientists did not suggest a need to reduce the catch from last year's level.

Following discussion of the scientific analyses, particularly with respect to the uncertainty in estimates and the general reliability of the replacement yield values, the Seychelles, USA and Jamaica urged a cautious approach, while Japan, Brazil and USSR favoured the majority recommendation of the Scientific Committee.

By a majority vote the Technical Committee then adopted the proposed figures.

For Area II the Scientific Committee had no agreed estimates of stock size and noted that a proposed cruise in the next season should give better estimates next year. It therefore made no recommendation.

The Technical Committee agreed by a majority vote to recommend the same figure as last year, after Japan and the USSR expressed their view that there is no need to be particularly conservative, noting in particular an increase in the Brazilian CPUEs.

The Technical Committee also endorsed the recommendations of the Scientific Committee with respect to obtaining improved data for the Brazilian minke whale operations, further study on sightings estimates, and implementation of new assessment and management Areas.

After discussion among Commissioners, Japan, seconded by Spain and the USSR, proposed in Plenary Session an amended set of figures for the catch limits as follows:

Area I	886	IV	1,548
II	1,190	V	1,131
III	2,093	VI	1,254

It further proposed a 5% allowance between Areas, with the maximum catch not to exceed 8,102.

As France had proposed a moratorium on catching minke whales it called for a vote, and the amendment received 18 votes in favour, with 1 against and 10 abstentions, thus obtaining the three quarters majority required to amend the Schedule.

11.2.3 Fin whales

The Scientific Committee agreed there is no reason to change the present classification and the Technical Committee agreed and the Commission confirmed that fin whales should remain Protected Stocks.

11.2.4 Blue whales

The Commission accepted the recommendations of the Scientific Committee endorsed by the Technical Committee that these stocks should remain protected, and that a re-analysis of stocks should be undertaken.

11.2.5 Humpback whales

The Technical Committee endorsed and the Commission agreed with the recommendations of the Scientific Committee that stocks should remain protected and that the current status of the stocks off Peru should be surveyed.

11.2.6 Right whales

The Scientific Committee recommended that all stocks should remain protected. This was agreed by the Commission after endorsement by the Technical Committee together with three further recommendations on systematic sighting surveys, the need to obtain information on the stock off Argentina and studies of historical records.

11.2.7 Bryde's whale

Peruvian stock

The Scientific Committee re-assessed this stock and recommended classification as IMS with a catch limit of 244.

Peru put forward a proposal to allow the uncaught portion of its 1981 quota (102 whales) to be added in two equal parts to the catch limit recommended by the Scientific Committee in 1982 and 1983. This request was made in association with a change in the whaling season, which it intended to start in November rather than January each year. The Technical Committee discussed at length the two elements of the change in season and the adjustment of the catch limits. There was general agreement that it was the prerogative of Contracting Governments to set the season and it agreed to recommend that a flexible approach should be taken by the Commission in recognising the legal difficulty involved concerning the extent of catching within any twelve month period. However, there were several expressions of concern over the concept of adding an uncaught quota in any one year to the following season's catch limit.

Finally, the Technical Committee by a majority vote and without setting a precedent agreed to recommend a catch limit of 244.

In the Plenary Session, Peru asked that 76 whales uncaught in the 1981 season should be added to the 1982 catch limit. The Seychelles noted that whaling operations had been disrupted by a border conflict and proposed a form of words as an appropriate amendment to the Schedule. This retained the present classification as SMS and added a footnote to the catch limit, which after some working changes to accommodate various legal points was adopted by consensus in the Commission as follows:

SMS 244[1]
76[2]

[1] Available to be taken in the six month period starting in November 1981.

[2] Special remainder from 1981 coastal season that may be taken in the six months period starting in November 1981 making a total of 320 whales which may be taken during this period pursuant to this and the immediately preceding footnote.

Peru was requested to look at the definition of 'coastal season' to avoid perpetuating the problem, ready for further consideration in the Infractions Sub-committee next year.

Other Bryde's stocks

No new information was available to the Scientific Committee, and on the recommendation of the Technical Committee the Commission adopted the following classifications and catch limits:

Western South Pacific	IMS	237	Southern Indian Ocean	IMS	197
Solomon Islands	IMS	0	South Atlantic	—	0
Eastern South Pacific	IMS	188	South African inshore	—	0

11.2.8 Sperm whales

Because of the lack of time, it was not possible for the Scientific Committee to undertake assessment of the stocks, and the Technical Committee recommended that they should be unclassified, with zero catch limits.

The Commission concurred with this action as described under Agenda Item 7.4.

11.3 North Pacific 1982 season

11.3.1 Sei whales

Sightings from Japanese cruises suggest a slow recovery of this stock, and the Scientific Committee recommended that it remain protected, which was endorsed by the Technical Committee and agreed by the Commission.

11.3.2 Minke whales

The Commission noted that the Scientific Committee will provide definitions for the stock boundaries of minke whales in the North Pacific at the next meeting. The Scientific Committee will also give specific attention next year to classifying minke whale stocks in the Northern Hemisphere in a coherent and consistent way.

Sea of Japan – Yellow Sea – East China Sea

The Scientific Committee had no significant new information and the Commission agreed to maintain the block quota of 3,634 for 1980/84, with a maximum of 940 in any one year, together with provisional classification as SMS. This followed discussion in the Technical Committee that the stock be unclassified.

The Commission also accepted the recommendations of the Scientific Committee endorsed by the Technical Committee that past Republic of Korea log book data should be analysed and that age and reproductive material is collected from this stock.

Okhotsk Sea – West Pacific
The Commission agreed, on the Scientific Committee's recommendation endorsed by the Technical Committee, to retain the block quota of 1,678 for 1980/84 with a maximum of 421 in any one year with continued classification as SMS, on the basis of the continued stability of the CPUE. It also recommended that an attempt be made to refine the long series of CPUE data.

Remainder
The Technical Committee endorsed the Scientific recommendation for IMS classification with a zero catch limit, and this was accepted by the Commission.

11.3.3 Fin whales
The Scientific Committee received no new information and recommended continued protection. This was agreed by the Technical Committee and the Commission.

11.3.4 Blue and humpback whales
The Technical Committee recommended continued protection for both these species on the advice of the Scientific Committee, and this was endorsed by the Commission.

11.3.5 Right whales
The Scientific Committee believes that apart from the remnant of the Okhotsk Sea stock, continued existence of viable stocks in the rest of the North Pacific is in doubt. It recommended that the People's Republic of China should be asked to provide data on the status of right whales off China, with details of any past catches. The People's Republic of China indicated that they are not whaling at present, and have only taken a few minke whales in the Yellow Sea in the past, but there are no statistics available.

The Technical Committee endorsed and the Commission adopted the Scientific Committee's recommendation to continue protection status.

11.3.6 Gray whales
The Technical Committee recommended that the Western Stock remain protected, and this was accepted by the Commission.

11.3.7 Bryde's whales
The Scientific Committee clarified stock boundaries which were adopted by the Commission as follows:

East China Sea Stock
  West of the Ryuku Island chain
Western Stock
  West of the 160°W meridian of longitude
  (excluding the East China Sea stock area)
Eastern Stock
  East of the 160°W meridian of longitude

East China Sea
The Scientific Committee has never assessed this stock, but recommended that the present catch limit should not exceed the average annual catches from 1955–74 of 19. The Technical Committee agreed to retain the classification as SMS with this catch limit, and this was seconded in the Plenary Session by Japan.

The USA noted that 7 large whales were caught this year by the Republic of Korea, 4 of which were identified as fin whales. Since there have been no recent catches of Bryde's whales in the area by Japan or the Republic of Korea, it proposed a zero catch limit to prevent any future problems of identification. This was seconded by Sweden, Jamaica and Uruguay.

After discussion of this amendment, including comment by Japan on the conflict with the unanimous recommendation of the Scientific Committee, and a statement by the Republic of Korea that it is willing to accept international observers, the USA withdrew its amendment and the Commission agreed to the classification as SMS with a catch limit of 19.

Western
Re-analysis by the Scientific Committee resulted in a small change in the recommended catch limit to 507, and reclassification as IMS. This was agreed by the Technical Committee and endorsed by the Commission.

Eastern
This stock has never been exploited. The Scientific Committee recommended that it should remain IMS with a zero catch limit, and this was agreed by the Technical Committee and the Commission.

11.3.8 Sperm whales
The Scientific Committee reported that a data handling error had occurred last year in an assessment calculation which had now been corrected. Two new techniques have been developed subsequently, but there was still need for further close examination of these assessment methods.

Western
Assessments were attempted using a slightly different boundary for ease of data handling which resulted in two views: one that the results obtained could be used, the other hesitating to use them before further analyses are carried out. These differences were unresolved. The Scientific Committee therefore had no unequivocal advice to the Commission.

Japan spoke of its sperm whale catches from small coastal stations within two hundred miles of its coast. It outlined the economic and social consequences which would result if this operation was to cease. Catches were reduced last year following an analysis with which faults had been found later, and it pointed out that the two assessment models used this year are extremely complex. It believes that the present small catch cannot seriously endanger the stock and suggested that there should be no catch limit set now, and that a special meeting is needed on this specific subject. The USSR supported the Japanese position, pointing out that it is important to find the true state of the stock.

The Seychelles believes that the data indicate a decline in reproductive performance, and that the stock will continue to decline even in the absence of hunting. It therefore proposed a zero catch limit, which was adopted by a majority vote in the Technical Committee.

Further discussion in Plenary Session was subsumed in Agenda Item 7.4, in which the Commission agreed to leave the catch limits undetermined until special meetings of the Scientific Committee and of the Commission have been held.

Eastern
The Technical Committee recommended that the stock should remain unclassified, with a zero catch limit, and this was agreed by the Commission under Agenda Item 7.4.

11.4 North Atlantic 1982 season

11.4.1 Sei whales

Iceland – Denmark Strait

In the absence of any new assessment, the Scientific Committee recommended that this stock should remain SMS and with the block quota of 504 for 1980/85, the maximum catch not to exceed 100 in any one year. This was agreed by the Technical Committee and approved by the Commission.

Nova Scotia

There is no new information on this stock. The Technical Committee endorsed the recommendation of the Scientific Committee that it should remain protected, and this was agreed by the Commission.

Eastern

The Commission adopted the Technical Committee's recommendation that there should be no change, with the stock unclassified and with a zero catch limit.

Spain indicated that it believes sei/Bryde's whales have appeared in its past catches in this area, and gave notice that it will ask for a special permit catch of 12 of these whales, to confirm the species and to provide material for full biological analysis.

11.4.2 Minke whales

North Eastern

Following new analyses, the Scientific Committee recommended that the stock should remain SMS with a catch limit of 1,790. It also recommended that further CPUE analyses should be carried out. This was agreed by the Commission after endorsement by the Technical Committee which noted that the proportion of females in the catch is expected to be reduced by restrictions on the time and location of the whaling operations.

Central

Noting the lack of trend in the CPUE series, the Scientific Committee recommended that the stock continue to be classified provisionally as SMS with a catch limit of 320. This was endorsed by the Technical Committee and agreed by the Commission.

West Greenland

The Scientific Committee recommended that the stock remain classified as SMS with a block quota of 1,778 for 1981/85, with a maximum of 444 in any one year. It also recommended further work on the CPUE data. This was agreed by the Technical Committee and adopted by the Commission which noted the Scientific Committee view that there is no simple operational way of reducing the high percentage of females in the catch.

Canadian East Coast

There was no new information on this stock. The Technical Committee, on the recommendation of the Scientific Committee, agreed that it should remain unclassified, with a zero catch limit pending satisfactory estimates of stock size, and this was approved by the Commission.

11.4.3 Fin whales

East Greenland – Iceland

Several analyses by the Scientific Committee gave rather similar results, with an estimate of replacement yield of 158. The Scientific Committee recommended that the stock should be classified as SMS with this catch limit, rather than one based on the average catch over a long period. Since some estimates of stock size were below the conventional MSY level, the Committee also recommended that the catch limits be set for one year at a time, and that the stock be carefully monitored.

Iceland pointed out that it had applied national catch limits lower than those set by the Commission, which was evidence of its concern for a cautious approach to the utilisation of this stock. It asked for consideration from the Commission in adjusting to such a large reduction as recommended, and proposed that this might be taken in two steps, with half of the reduction this year, and therefore proposed a catch limit of 200. This proposal was defeated by a majority vote in the Technical Committee, which went on to adopt by a majority vote the figure of 158 recommended by the Scientific Committee after Iceland emphasized that it cannot accept such a big reduction in one step, and Japan questioned whether the extra 50 whales requested will seriously affect the stock.

In the Plenary Session Iceland proposed an amendment to the Technical Committee recommendation, of the same classification as SMS but with a catch limit of 194. This was seconded by Japan and the USSR and adopted as an amendment to the Schedule by 10 votes in favour to none against with 19 abstentions.

Spain – Portugal – British Isles

The Scientific Committee was still unable to carry out analyses using recent data, so that it has used catch and effort series from the 1920s. This resulted in two views: that the stock be classified SMS with a catch limit of 210, or that the apparently stable average annual catch during 1968–77 of 137 should be recommended.

France commented on the large number of young fin whales below minimum size reported this year, and the USA on the long extrapolation involved in the scientific assessment and the gaps in the data. It therefore proposed a zero catch limit which was adopted by a majority vote in the Technical Committee, although Spain pointed out that there is no scientific basis for a zero catch limit, and Iceland and Norway referred to the Scientific Committee figures of 137 or 210.

The Technical Committee's recommendation was seconded by France and the USA in Plenary Session where Spain proposed an amendment for a catch limit of 210 which was seconded by Japan and the USSR. France and the USA re-emphasized their concerns over the problems of assessing this stock, and were supported by Sweden and St Lucia.

The UK expressed its misgivings over the choice which lay before the meeting, but suggested that in the wider context of the integrity of the Commission it could support the figure of 210, not for its own sake but rather than have no catch limit set at all. This position was shared by Norway, Denmark, Argentina and Uruguay. The Commission then agreed to the classification as SMS with a catch limit of 210 by consensus, the USA, France, St Lucia, and Jamaica recording their reservations.

Nova Scotia

In the absence of new information, the Scientific Committee recommended PS, and this was agreed by the Technical Committee and adopted by the Commission.

West Greenland
It was agreed to continue classification as SMS with a catch limit of 6.

West Norway
It was agreed that this stock should remain protected.

Newfoundland – Labrador and North Norway
The Scientific Committee was unable to agree on recommendations for these presently unexploited stocks. Three proposals were supported: that the stocks should be unclassified with last year's catch limits; classified with zero catch limits; or IMS with zero catch limits.

Norway stated that the North Norway stock had been unexploited since 1971, and noted that the Scientific Committee will pay special attention to classifying North Atlantic fin whale stocks in a coherent and consistent way next year. It therefore proposed that for the present the North Norway stock continue as SMS with a catch limit of 61, and the Newfoundland – Labrador stock be classified as IMS with a catch limit of 90. This was agreed by the Technical Committee and adopted by the Commission.

11.4.4 Blue, Humpback and Right whales
The Technical Committee agreed with the Scientific Committee recommendation that these stocks should continue to be protected. It also endorsed the Scientific Committee recommendation that surveys of the right whale population in the Bay of Fundy area should be continued in view of proposals for accelerated industrial development. Both these recommendations were approved by the Commission.

11.4.5 Bryde's whales
The Commission agreed to a classification of IMS with zero catch limit from the Technical Committee.

11.4.6 Sperm whales
The Scientific Committee considered that none of the population estimates it had carried out were reliable, but agreed that stocks of both males and females have declined, although it was unable to agree on the extent of those declines. It recommended caution in the setting of catch limits, which should not exceed those set by the Commission last year, but an alternative view suggested that stocks should be classified as protected.

The Seychelles pointed out the paucity of data available, although this situation might improve if and when Portugal joins the IWC, since the majority of catches of females are taken under its jurisdiction. It proposed a zero catch limit in Technical Committee.

Iceland indicated that it was willing to accept a zero catch limit for 1982, but asked if its quota for this year of 130 sperm whales could be taken over the two years. It pointed out that it has shown responsibility in the past by reducing catches below the Commission's recommendations and by increasing the national minimum size limit to 40 feet.

Several delegations expressed their views on such a procedure, and Spain pointed out that it had imposed a voluntary cessation of its own sperm whale catches, and was also concerned over the take by non-IWC member governments.

The Technical Committee adopted by a majority vote the proposal for a zero catch limit, which in Plenary Session was agreed under Agenda Item 7.4 with a special footnote allowing Iceland to take the uncaught part of its 1981 quota during the 1982 season.

11.5 Northern Indian Ocean 1982 season

11.5.1 Minke whales
In the absence of information, the Scientific Committee recommended classification as IMS, with zero catch limits pending satisfactory estimates of stock sizes. This was agreed by the Technical Committee and the Commission.

11.5.2 Bryde's whales
The Technical Committee recommended that this stock should be unclassified, with zero catch limit, and this was agreed by the Commission.

11.5.3 Blue, Humpback and Right whales
On the advice of the Scientific Committee, the Technical Committee recommended and the Commission agreed that these stocks should remain protected.

12. ABORIGINAL/SUBSISTENCE WHALING

12.1 Management Principles and Guidelines for Subsistence Catches of Cetaceans by Indigenous Peoples
An *ad hoc* Technical Committee Working Group met in the week before the Annual Meeting, following a meeting of a Steering Committee held in Seattle in February 1981. The Working Group was convened by Prof. Ovington (Australia) and had a broad composition, including members of the Technical Committee, a representative of the Scientific Committee and representatives of the aboriginal peoples concerned, the latter being very willing to co-operate. The Working Group had not always reached unanimous agreement and the differing views which were expressed are contained in its report.

The Technical Committee endorsed three recommendations which were adopted by the Commission that:

1. the Report of the Technical Committee Working Group on Development of Management Principles and Guidelines for Subsistence Catches of Whales by Indigenous (Aboriginal) Peoples be forwarded to Contracting Governments for comment by 31 January 1982;
2. the Steering Committee of the Working Group be re-established to review such comments as are forwarded through the Secretariat;
3. a decision should be made by correspondence between the members of the Steering Committee on whether it might be necessary to convene the full Working Group again in order to resolve any major problems should any arise. Otherwise the Steering Committee should prepare and forward the comments to the 34th Annual Meeting without the need for a further meeting.

The Commission took note of the hope expressed by Prof. Ovington that a further meeting would, in fact, be unnecessary.

12.2 Documentation of the utilisation of the meat and products of any whales taken for aboriginal/subsistence purposes
The Commission noted a document prepared by the USA outlining studies relating to Alaska Eskimo whaling which will be reported to the 34th Annual Meeting.

12.3 Bering Sea stock of bowhead whales
The Scientific Committee noted with great concern that the IWC quota for 1980 had been exceeded by eight strikes. It concluded that even if there is no kill the population may

only be stable or even decreasing and reaffirmed its view of the last four years that to reduce the risk of extinction no catch should be taken. The Scientific Committee recommended, therefore, that the only safe course for the Commission is for the catch limit to be zero. The Scientific Committee recognised, however, that the Commission set last year a three-year quota for this stock and recommended that should the regime continue, removals should be of sexually immature animals to maximise reproduction in the short term, and that they should be taken in a manner which would reduce the struck and lost rate to zero.

In reponse to a question from the Netherlands as to the efficiency of the co-operative agreement with the Alaskan Eskimos, the USA commented that the arrangement appears to be quite satisfactory and could perhaps set an important precedent.

The UK stated that whilst the Commission should be free to judge the effects of measures taken by a Contracting Government in pursuance of obligations incurred through its membership of the Commission, it would be unwise to probe too closely into the domestic arrangements made by national authorities. Norway concurred with this view but stressed that the responsibilities of the United States in the matter under discussion should be in no way diminished.

The Technical Committee took note of the report of the Scientific Committee without endorsing any of its recommendations. In the Plenary Session, Sweden put forward a Resolution commending the Inupiat people on their efforts and urging them to restrict catches to immature whales with the minimum of loss. This was seconded by the Netherlands and Australia.

The USA, through a representative of the Alaskan Eskimo Whaling Commission, agreed to recommend these proposals to its whalers. The Netherlands noted the present catches and the progress that has been made in co-operation with the Eskimos, and looked forward to a reduction in the catches in the future to allow the stock to recover. It also asked for information on the impact of industrial development on the whales' habitat.

Australia, backed by Denmark, spoke of the genuine attempt by the aboriginal people and the US Government to resolve this very difficult issue, and Spain emphasized that the world is watching to see what is happening to the only really endangered species.

The Commission then unanimously adopted the Resolution (Appendix 4).

12.4 East Pacific stock of gray whales

The Scientific Committee recommended the continued classification of the stock as SMS with an unchanged catch limit. Jamaica welcomed the comments of the Scientific Committee and commended the USSR on its research effort relative to this stock. The Technical Committee recommended and the Commission approved by consensus that the stock be classified as SMS with a catch limit of 179 to be taken by aborigines or a Contracting Government on behalf of aborigines. The USSR and Mexico stated their intention to continue and expand their research efforts respectively.

12.5 West Greenland stock of humpback whales

The Scientific Committee had concluded that this stock is still substantially depleted and that present estimated removals are a significant proportion of the recruitment. It recommended, therefore, that:

1. every effort be made to reduce the number of removals;
2. the study of the problem of net entanglement should be continued;
3. all humpback whale stocks should remain protected;
4. all scientists with access to either live or dead humpback whales should be encouraged to attempt to obtain photographs of the colour pattern of the ventral surface of the tail flukes, and to exchange these photographs with other interested observers in the area. A catalogue of 1,000 tail fluke photographs is already available for the northwest Atlantic, and the comparison of photographs is proving a useful method of identifying individuals.

The Technical Committee unanimously endorsed these proposals, which were similarly approved by the Commission.

Denmark, in commending the Report of the Scientific Committee and seconding these proposals, stated that it could not support the other of the Scientific Committee's recommendations which was for the removal of the exemption allowing 10 humpbacks to be taken annually off Greenland. It drew attention to cultural traditions, the pattern of hunting in that area which required exploitation of what was available at the time and did not easily permit the substitition of other species, and the difficulties of communication leading to genuine problems with regulation of the hunt. Denmark is carrying out whale sighting cruises which it hoped would support the view expressed by hunters that humpback whales are more abundant than a few years ago.

The Netherlands, supported by the UK, felt that the situation is similar to the bowhead problem with a stock in grave danger and a clear recommendation from the Scientific Committee for a zero catch. It recalled consistent infractions over previous years and enquired what Denmark was doing to prevent this and to reduce the catch below 10.

Denmark stated that all this information was available in the Reports of the Infractions Sub-Committee and the Aboriginal/Subsistence Working Group. The Danish Government was concerned over the problem and had a system whereby every whale caught had to be reported immediately to the Government. It was confident that the allowable catch would not be exceeded this year.

The Technical Committee made no recommendation with respect to the removal of the humpback exemption, and the Commission took no further action.

13. SMALL CETACEANS

13.1 Consideration of the Commission's responsibilities for small cetaceans

Australia introduced a proposed amendment to the Resolution adopted by the Commission at its last Annual Meeting which it believed was a purely technical modification to recognize that the Scientific Committee as an organ of the Commission should act and be addressed through the Commission rather than directly.

Mexico stated that it does not believe small cetaceans within coastal waters are within the IWC's jurisdiction or competence. This view was shared by Chile and Brazil. Mexico also made clear that the information provided by Mexico to the Scientific Committee concerning small cetaceans is only for scientific information and does not in any way represent a recognition by Mexico that the IWC is the forum in which to consider these species. There was an exchange of views on the effect of the proposed Australian amendment and Norway suggested that the Technical Committee should recognize that the amendment is restricted to communication and is not related to the Commission's competence.

Finally, the Technical Committee agreed to put this position to the Plenary, where there were further statements of their positions by several member governments. In particular, Argentina, Chile, Japan, Mexico, Peru, the USSR and Uruguay all made clear that they do not believe small cetaceans are within the jurisdiction or competence of the IWC.

13.2 Report of the Scientific Committee

The Scientific Committee noted that direct and incidental catches by IWC members of small cetaceans are estimated to total 112,000. It recommended that:

—the northern bottlenose whale should remain protected and that a recommended research programme should be carried out;
—the white whale and the narwhal be listed in Schedule paragraph 1, though some thought this recommendation inappropriate;
—research be encouraged in both species and that various stocks should be protected;
—killer whales on the coast of Norway be unclassified with zero catch limit pending assessment and identification of stocks, and if the fishery continues there should be improved reporting of effort and research;
—Southern Hemisphere killer whales should be classified IMS with a zero catch limit, and the USSR be requested to report on its large sample from the Antarctic;
—fishing effort should be reported and studies encouraged on pilot whales in Japan and the Faroes;
—striped dolphins off Japan are reassessed;
—member nations collect and submit full statistics on small cetacean catches as previously requested.

The Technical Committee took note of the report of the Scientific Committee, and adopted by a majority vote a Resolution proposed by the USA concerning white whales and narwhals in Canada. The USA spoke on its recognition of the jurisdictional problems relating to small cetaceans, and seconded with Sweden the Resolution in the Plenary Session. It was recognised that Canada had specifically requested scientific advice and several members expressed their serious concern over the stocks involved. Denmark, Chile, Japan, Mexico and the USSR all stated their reservations before the Resolution (Appendix 5) was adopted by 13 votes in favour to 8 against with 8 abstentions.

Uruguay emphasised that its vote in no way affected its strong support for sovereign rights within the 200 mile Exclusive Economic Zone.

Norway placed on record that it has established national regulations for the take of killer whales from its coast according to previous scientific advice. Since the advice this year is significantly different it will study the matter very seriously and reserved its position in the meantime.

The Netherlands, seconded by Sweden, Switzerland and the USA, proposed that for 1982 the northern bottlenose whale should be classified as a Protected Stock with a zero catch limit, and this was unanimously agreed by the Commission.

14. MEASURES TO DISCOURAGE WHALING OPERATIONS OUTSIDE IWC REGULATIONS

14.1 Report of the Working Group on Non-IWC Whaling

The Report of the Technical Committee Working Group on Non-IWC Whaling which met in the week preceding the Annual Meeting, following a steering committee meeting held in London in March 1981, was presented to the Technical Committee by its convenor, Mr Stewart (New Zealand). The recommendations from this report were extracted in the form of a Resolution (Appendix 6) which was endorsed by the Technical Committee and adopted by consensus in the Commission. The Commission also agreed that the Working Group should continue to complete any outstanding matters.

14.2 Prohibition on Importation of Whale Products from and Export of Whaling Vessels, Equipment and Expertise to Non-Member Countries

The proposal that certain measures adopted by Resolution last year should be implemented as amendments to the Schedule was also considered by the Working Group on Non-IWC Whaling. In accordance with the view of that group, the Technical Committee recommended by consensus that no further action be taken on this matter and this was noted by the Commission.

The United Kingdom reported that a ban on the trade of whale products by EEC countries will be introduced in January 1982.

14.3 Register of Whaling Vessels

The Commission received the second draft of the International Register of Whaling Vessels. Argentina and the People's Republic of China stated that vessels recorded under their flags are not registered as whaling vessels.

15. COMPUTING REQUIREMENTS

The Scientific Committee reported that the central computing facility now available closely matches the original proposal. The establishment phase is essentially complete but the compiling of the data bank is very time consuming, and will take another two years.

The Scientific Committee recommended that the Secretariat should express its appreciation of the contribution which the University of Cambridge Computing Service has made to its work. It also recommended the continuation of the development of the facility with the Senior Programmer/Analyst as a permanent member of the Secretariat.

The Technical Committee endorsed these proposals which were then approved by the Commission.

16. INTERNATIONAL DECADE OF CETACEAN RESEARCH

16.1 Report of the Scientific Committee

The Scientific Committee noted that the IDCR programme really began in 1975. It recommended that further research should be continued on a priority system, which is set out in its Report. In addition it recommended that the IWC should participate in the formulation and implementation of the research recommendations prepared under the FAO/UNEP Draft Global Plan of Action for the Conservation, Management and Utilisation of Marine Mammals. It further recommended that the Secretariat should prepare a review of the IDCR programme for UNEP.

The Scientific Committee reviewed research programmes undertaken during 1980/81 and plans for 1982 and indicated a revised funding procedure to be adopted.

The Commission adopted these proposals on the recommendation of the Technical Committee.

16.2 Whale habitats including reports from Governments on degradation of the marine environment

The Commission noted that no reports had been received.

Spain expressed its views on the contamination of the sea arising from industrial activity. As a state bordering a polluted sea it has particular concern that animals such as whales at high trophic levels are especially vulnerable to such pollution. It proposed a Resolution which was adopted by the Technical Committee.

Uruguay expressed its view that this was part of a global problem of the seas, and suggested that member governments should act in all international fora to combat pollution so as to develop and co-ordinate practical policies. A number of delegations expressed their support for this idea in principle, including seeking observer status in appropriate inter-governmental bodies, but there was also a view that IWC action should be restricted to cetaceans.

In the Plenary Session Denmark proposed the addition of wording to include adverse effects to whale stocks caused by shipping, offshore mining and drilling activity. This was seconded by Sweden and the USA, and there was then some discussion on the precise wording between Spain, Norway and the UK. Jamaica spoke on the effects of marine pollution caused by unseaworthy vessels, and the USA expressed concern for a newly discovered group of highly endangered right whales in an area off its Atlantic coast which will soon be open for oil leasing. The Resolution as amended (Appendix 7) was then adopted, Mexico recording its reservation.

The Commission further agreed, on the recommendation of the Technical Committee from the Scientific Committee, that appropriate sampling should be carried out and reported, and that an observer attend the ICES meeting in October 1981.

17. COLLATION AND DISTRIBUTION OF ANNUAL SUMMARY OF INTERNATIONAL RESEARCH ON CETACEANS BY THE COMMISSION

Australia introduced a paper developed to ensure that information on current or new research on cetaceans should be made known as widely as possible. It had been considered by the Scientific Committee and received general support, although some practical problems were raised. Australia particularly emphasized that in addition to the arrangements recommended by the Scientific Committee concerning government sponsored research, the Secretary should seek information from WWF, FAO and UNEP. Such information should be appended to the national Progress Reports submitted to the Scientific Committee, and although not printed in the Annual Report, should be collated and made available on request from the Secretariat.

On the recommendation of the Technical Committee the Commission adopted the proposal and agreed that for nationally and internationally funded research the following information should be summarized and distributed:

title of project;
intended period of operation and expected completion date;
summary of aims of project, including area and species to be studied;
address at which further information may be obtained;
address through which report may be available.

18. HUMANE KILLING

18.1 Report of Workshop Meeting of Invited Experts

The Technical Committee received the Report of the Workshop Meeting of Invited Experts, which contained some practical recommendations. The Scientific Committee noted a five year project funded by Norway, and expressed its concern that the otherwise comprehensive report did not adequately review current methods and technologies used in aboriginal/subsistence fisheries. It supported the proposal for a veterinary study in Iceland, which should include autopsy investigations.

The Commission noted this Report.

18.2 Collection of Data Required

The Commission noted a report on Japan's experiments on humane methods of catching whales during 1980/81.

18.3 Reports by Contracting Governments concerning Implementation of the Ban on the Use of the Cold Grenade Harpoon except to Kill Minke Whales

The Commission took note that there were no reports provided by governments.

18.4 Prohibition of the Use of the Cold Grenade Harpoon for Killing Minke Whales

Australia proposed an amendment to the Schedule forbidding the use of the cold grenade harpoon to kill minke whales from the 1981/82 pelagic and the 1982 coastal seasons. It spoke of the broadly held feeling that use of the cold grenade harpoon is cruel and unacceptable to civilised societies. An exception had been made for minke whales to allow time for an alternative method to be developed. It found difficulty in understanding how such cruelty could be allowed to continue.

Japan explained that a suitable alternative device had not yet been developed. Countries with expertise in weapon technology were not providing any assistance, but a new explosive was being tested. It emphasized that the whaling industry is not trying to kill whales inhumanely, it is not a sport fishery, but time should be given to develop new techniques.

India stated that it believes that the concept of humaneness applies to all whales regardless of their species or size, to the same extent as to humans. The technology must be available and it questioned if sufficient effort was being applied to find a solution. The world outside would applaud adoption of this proposal.

Norway indicated that it is well aware of the concern, but it had not found a practical solution, though it is embarking on a research programme. It was concerned that the explosive harpoon might cause more whales to be injured but not secured. The present methods are the only practical ones at the moment due to the small size of the minke whale, and the proposed amendment ignores supplementary killing methods, such as the large calibre rifles used in Norwegian fisheries. It gave an assurance that it would continue further investigations and adopt any suitable alternatives as soon as possible.

Iceland explained that its inshore fishermen cannot use explosives any more safely than some subsistence whale fisheries.

A number of delegations spoke in support of the proposal and the United Kingdom expressed the view that if the existing methods cannot be improved then whales should not be killed at all.

The Technical Committee recommended the proposed amendment by a majority vote, but after further discussion, the Seychelles proposed an amendment in Plenary Session to delay the starting date until the 1982/83 pelagic and 1983 coastal seasons in an effort to reach a workable compromise. This was seconded by Sweden, New Zealand, the USA, the Netherlands and Jamaica.

Japan again drew attention to the need for time both to develop a safe and effective alternative and to obtain authorisation for its use. It therefore recorded its reservation on the proposal, and Norway recorded its abstention because it cannot guarantee to find a safe and practicable alternative within the time limits set. Iceland associated itself with these comments.

The USA spoke in support of the proposal, believing that delay in improving killing methods has been due more to economic than technological considerations. Uruguay associated itself with these remarks, and Oman also shared this view, since the cold grenade harpoon minimises the meat rendered unusable. It therefore strongly supported the phasing-out proposal, as did Mexico, while the UK recalled the importance it attached to this question, following its initiatives for the partial ban adopted last year.

The USSR reserved its position, although it is actively studying alternatives to the auxiliary electrical shock technique currently used, and the Republic of Korea also entered a reservation before the Commission adopted by consensus the following amendment to the Schedule as an addition to paragraph 6:

> 'The killing for commercial purposes of minke whales using the cold grenade harpoon shall be forbidden from the beginning of the 1982/83 pelagic and the 1983 coastal seasons.'

19. CONSIDERATION OF CETACEAN BEHAVIOUR AND INTELLIGENCE AND THE ETHICS OF KILLING CETACEANS

The Secretary reported that papers arising from the meeting held in Washington DC in 1980 are being submitted for commercial publication.

The Chairman of the Scientific Committee reported that a workshop on behavioural studies will be held in Seattle 5–9 April 1982.

20. ADOPTION OF THE REPORT OF THE SCIENTIFIC COMMITTEE

The Chairman of the Scientific Committee indicated a number of recommendations that had not otherwise been brought before the Technical Committee and the Commission. These were noted and approved as appropriate:

- two proposals for special permit catches were not endorsed;
- member nations should be reminded of the need to provide catch information to BIWS promptly;
- support for BIOMASS programmes, data handling and future research;
- co-operation by sending an observer to CCAMLR:

Australia emphasised the importance of having an IWC representation at the meeting in Hobart in September 1981 and the Commission agreed that in this and similar situations it recommends the attendance of an observer without naming an individual.

- The Republic of Korea should continue to obtain photographs and baleen material from any large whales taken by its operations, but there is no need for the Commission to send an expert to assist in identification;
- a revised policy on publications had been developed to reduce cost to the Commission.

The Commission noted that the Scientific Committee recognised the difficulties faced by non-English speaking members, and the appreciation by the Scientific Committee of the work of the Secretariat during its meeting.

Norway commented on the sequence of discussion in dealing with management questions, for which new guidelines should be adopted, and requested a standardised format for recommendations in terms of majorities and minorities. The Seychelles supported these constructive suggestions.

21. REVISION OF THE SCHEDULE

21.1 Report of Technical Committee Working Group on Non-Contentious Items

The Report of this Working Group, convened by Mr Lemche (Denmark), which met immediately before the Annual Meeting, dealt with the following matters as indicated. The recommendations were endorsed by the Technical Committee and adopted by the Commission.

21.1.1 Paragraphs dealing with factory ship whaling

The Working Group recommended that the redundant paragraphs should be retained because they may become operative again in the future.

21.1.2 Style used to designate limits of the Indian Ocean Sanctuary

The Working Group recommended that the Secretariat should bring the Schedule into the most succinct and practical format with respect to designation of the limits.

21.1.3 Use of terms 'excluding' and 'except'

The Working Group recommended that the word 'except' should be used.

21.1.4 Policy on treatment of protected whales taken by accident

21.1.5 Review of description of whale processing

Both these items were referred to a working party, which recommended that Contracting Governments should consider these matters further and report to the next Annual Meeting. Some proposed wording for consideration under both items was developed.

21.1.6 Definition of 'local consumption'

This matter was referred to the Technical Committee by the Working Group. France spoke on the need to re-examine the words used in Schedule paragraph 15, in order to clarify the intent.

Japan pointed out some of the practical aspects of the wording involved and the Technical Committee agreed to report that there had been an exchange of views on this matter, and recommended that it should be considered again next year together with any scientific advice.

In Plenary Session, France proposed that a Technical Committee Working Group should be established to look at the definition. Australia supported this proposal, reminding the Commission that it will be reviewing the definition of local aboriginal consumption at about the same time. Denmark considered that the geographical aspects should be considered first, but the Commission agreed that the Scientific Committee should look at the scientific aspects of the minimum sizes authorised and the effects on stocks of catching smaller whales under this exception provision. The Scientific Committee would also be represented on the Working Group to be convened by France immediately before the next Annual Meeting.

22. INFRACTIONS AND REPORTS FROM INTERNATIONAL OBSERVERS, 1980 AND 1980/81 SEASONS

The Technical Committee set up an Infractions sub-committee convened by Dr Watson (Seychelles) and which was attended by representatives of 17 member governments. After careful study of the available documentation the sub-committee made a series of recommendations which were accepted by consensus in the Technical Committee and adopted by the Commission as follows:

Recommendation 1: That the Commission notes the information that Chile was conducting its own investigation into the use of a factory ship in contravention of Schedule provisions and would report to the Commission and asks the Chilean Government, following its own investigation, to take all necessary steps to prevent any such infraction, if substantiated, occurring again and to institute appropriate penalties.

Chile reported that as a result of an initial inquiry, the matter has now been taken to a justice tribunal which will apply appropriate sanctions if necessary. However, as it cannot predict the length of time the tribunal will last it cannot guarantee to report to the Commission within two months, although it will do so as soon as possible. Chile was also concerned that the non-governmental organisation which had reported the matter had not notified the Chilean authorities immediately. Had this been done, then the irregularities could have been stopped more quickly.

Recommendation 2: That the Commission considers making available an Adviser to the Republic of Korea to work with boat captains and gunners on the identification of baleen whales.

The Plenary Session modified the wording of this recommendation slightly to avoid any financial implications.

Recommendation 3: That the Commission urges the Contracting Governments of Chile, Peru and Spain to observe their obligations in terms of the Convention and submit Infractions Reports for the 1980 season to the Commission.

Spain reported that it had not submitted an infractions report last year as it had believed that a letter from the Commissioner was sufficient.

Recommendation 4: That the Commission urges the Spanish Government to ensure that size limits are strictly enforced and that appropriate penalties be imposed for such infractions.

Recommendation 5: That the Commission asks the Spanish Government to establish and submit information on the extent of local consumption of whale meat so that the Commission may more readily judge the validity of the Spanish proposal to exempt 11 fin whales (representing 5% of the 1981 catch limit) between the sizes of 15.2 metres and 16.8 metres, from consideration as infractions.

Recommendation 6: That the Commission requires that the Danish Government look very closely at the aboriginal catch of fin whales in West Greenland and attempts to institute a catch regime, perhaps by allocation of sub-quotas to separate communities, which would provide the necessary additional controls.

Recommendation 7: That the Commission urges the Danish Government to consider the introduction of a sub-quota system with built-in checks after the capture of each humpback whale in Greenland waters by any community.

Recommendation 8: That the Commission urges the United States Government to continue to make every effort to improve the efficiency of the hunt for bowhead whales off Alaska and to ensure that the strike limit is strictly observed.

Recommendation 9: That the Commission makes it clear that 'six consecutive months' in Paragraph 4b of the Schedule means a six month period, independent of the date of commencement.

The Commission agreed to record this definition in the record of this meeting.

Recommendation 10: That the Commission urges the Icelandic Government to continue to encourage the collection of further data from its minke whaling operations.

Recommendation 11: That the Commission urges the Governments of Chile, Peru and Denmark to submit outstanding Infraction Reports for 1979.

Recommendation 12: That the Commission asks the Secretariat to remind the Contracting Governments of Chile, China, Denmark, India, Oman, Peru and Switzerland of their obligation under paragraph 32 of the March 1981 Schedule to provide the Commission with copies of their laws and regulations concerning whales.

Recommendation 13: That the Commission asks the Scientific Committee to look at the checklist of information required under Section 6 of the Schedule and ensures that it meets its need for data to be supplied, and that Contracting Governments be asked to provide all information promptly and in full detail as outlined on the list after revision by the Scientific Committee.

Mexico stated that it wished to examine the checklist before commenting.

Recommendation 14: That the Commission considers again the definitions of 'factory ship' and 'land station' in the light of the licensing by Japan of a factory ship fixed ashore as a land station.

Japan provided additional information regarding the Ogasawara Island operations. In view of the rocky nature of the island the Japanese Government licensed this land station. The exact position of the station is contained within the terms of this licence and if it is moved this would be in contravention of Japanese domestic legislation.

The Commission noted that the definitions of 'factory ship' and 'land station' appear in the Convention itself, and it instructed the Technical Committee Working Group dealing with the definition of 'local consumption' also to consider these other terms. Denmark commented that the Working Group may be able to offer an interpretation relevant to the particular situation concerned.

Recommendation 15: That the Commission asks the Secretariat to remind Contracting Governments of their obligations under the Convention and note that non-provision of data could, in itself, be considered as an infraction.

The Infractions sub-committee appointed a small working group to examine the Spanish fin whale catches in 1980 which revealed that the catch limits had not been exceeded. However, it was noted that as all of the meat production was exported to Japan to fulfil existing contracts, the number of undersized whales for the season was 77 animals. Spain explained that 1980 had been an abnormal season for several reasons and that it regretted the infractions and had taken strict measures to ensure that they would not occur again.

The Seychelles drew attention to the fact that substantive material was being presented to, and discussed at, meetings of the Infractions sub-committee which was not available to the Commission in any other form. It pointed out that, because this material would be useful in assisting the Commission to discuss catch limits and quotas, it ought to be presented earlier.

The Seychelles suggested that in future the Report of the Infractions sub-committee appears on the Agenda directly before the item on Whale Stocks and Catch Limits. This view was supported by France.

23. INTERNATIONAL OBSERVER SCHEME

The Infractions sub-committee also discussed the International Observer Scheme and as a result made a number of recommendations which were endorsed by the Technical Committee and adopted by the Commission as follows:

Recommendation 1: That the Commission urges the Contracting Governments involved to enter into observer agreements, which would provide greater surveillance of:

(a) Danish aboriginal operations in Greenland;
(b) Korean operations; and
(c) Chilean operations.

And that steps be taken, under the existing bilateral observer agreement, to provide increased coverage of Japanese land stations.

Recommendation 2: That the Commission takes all steps necessary to fill the gaps in the Inuit Observer Scheme left by Canada's withdrawal from the Commission.

Recommendation 3: That the Commission asks the Governments of Denmark and the USA to co-operate in providing an International Inuit Observer Scheme for Greenland.

Recommendation 4: That the Commission be asked to explore the possibility of a general South American Observer Scheme and other possibilities of ensuring adequate surveillance of whaling operations in Brazil, Chile and Peru.

Brazil confirmed its willingness to accept an International Observer. However, for economic reasons it would be unable to supply an observer under a reciprocal agreement.

Spain reported that it had entered into an agreement with Iceland and that the Icelandic observer had arrived in Spain one week before the start of the season.

The USA expressed its continuing support for expansion and improvement of the Observer Scheme and urged all member countries to contribute so that every whaling operation is covered.

24. FINANCE AND ADMINISTRATION

The Commission adopted the report of its Finance and Administration Committee, convened by Mr Tresselt (Norway), and attended by representatives of 14 member governments. The Commission approved a number of recommendations arising from this report as detailed below. Specific support was expressed by France, Jamaica, the UK and Denmark.

24.1 Provisional Financial Statement 1980/81

The Finance and Administration Committee reviewed the provisional financial statement for 1980/81 which was approved, subject to audit, by the Commission. It was noted that income is likely to be higher than estimated, partly due to increased membership during the year. Financial contributions are still outstanding from a number of Contracting Governments, which may cause cash flow problems if not remedied.

The Committee recommended that payments owed by Panama should be maintained as a debt still to be recovered. Denmark commented on the presence in the meeting of a former Panamanian delegate now representing Ecuador, and suggested he might be approached on the matter.

Denmark also proposed that a rule should be adopted whereby a government which had not paid its contribution within one year of the due date should no longer be entitled to vote. It was agreed that this idea should be considered at next year's meeting.

24.2 Estimated Budget 1981/82 and forecast for 1982/83

The basic budget for 1981/82 provides for the existing level of activities to be maintained, although the Secretariat workload will increase significantly with the recent additions to the membership.

The salary levels of the Secretary and Executive Officer should be reviewed having regard to the changes in their responsibilites and workloads, and it was recommended that this be carried out by the Chairman on the basis of comparable UN and other UK based international organisations.

The Secretariat should continue investigations on the possible use of word-processors, and it was recommended that the Secretary should be authorised to purchase or lease such equipment if suitable, at a cost not significantly in excess of £10,000.

The recommended basic budget of £335,366 was approved for 1981/82. This included a withdrawal from the reserves while still leaving sufficient to cover the Commission's running costs for six months, and resulted in lower contributions from governments.

The forecast budget for 1982/83 of £353,999 provides for a similar level of activity with an allowance for inflation. The Commission noted that the Secretariat is at present benefiting from an extremely favourable rent for its accommodation which can be expected to increase several-fold when reviewed in 1985.

24.3 Supplementary Budget

Three major items were considered in the supplementary budget.

The Commission had agreed (Item 15), on the advice of its Scientific Committee, to the continuation and development of the computing capability. With savings from the previous year this will cost approximately £11,000 in 1981/82.

Research recommended by the Scientific Committee required £26,810 to be raised from contributions to carry out whale marking, a North Atlantic assessment cruise and other programmes.

The Scientific Committee also recommended that funds should be provided to hold or support a number of meetings. An additional £22,900 was required for this purpose.

In addition to these items, the Commission added a sum of £20,000 to cover the costs of the Special Meeting which it decided should be held in March 1982 (Item 7.4).

24.4 Methods of Calculating Contributions from Contracting Governments

The Commission decided last year that further consideration should be given to two alternative methods of calculating national contributions to the budget, to produce a more equitable distribution of costs amongst members. After extensive discussion in the Finance and Administration Committee it was agreed to adopt a slightly modified version of one of these alternatives, which is based on the accumulation of shares allocated for membership; commercial and aboriginal/subsistence whaling operations; and delegation size at the last Annual Meeting attended (interpreters and other professional support staff excluded). The new method is given in Appendix 8.

Following an intervention by Denmark, it was agreed that the Danish whaling shares will be on the basis of an aboriginal/subsistence fishery. All such classifications are open to review in the future.

24.5 Research Funding

The Finance and Administration Committee reviewed the present method of funding the Commission's research programme, and considered various alternatives which had been suggested. Some views were expressed that the present system was satisfactory, others that equal contributions or allocations proportional to the general contributions should be provided by all members in cash or facilities. The Scientific Committee had expressed concern that insufficient funds had been made available by the Commission, and yet there was criticism within the Commission of the data on whale stocks.

After considerable discussion there was general agreement, in principle, that the Commission should consider an increase in funding for scientific research. There was also agreement that the Commission will continue to examine this question.

24.6 Other Matters

24.6.1 Publications

The cost of publications represents a high proportion of the Commission's total expenditure, although UK printing costs are particularly low at the moment. The Finance and Administration Committee expressed some concern about the escalating costs of producing the Annual Report, and discussed possible reductions in the quantity of material published (particularly the scientific material), a possible lowering in the present very high quality, and the potential for increasing sales.

It was agreed that the Scientific Committee should continue to review its material for publication with a view to economy wherever possible; that the Secretary should explore further the scope for reducing printing costs, and report back next year; and that the Secretary is authorised to negotiate trade discounts to the best financial advantage to the Commission.

24.6.2 Staff Inspection

The staff inspection carried out in April 1981 by the UK Ministry of Agriculture, Fisheries and Food found that the organisation and procedures of the Secretariat were broadly appropriate for the work involved and that no change in the numbers or levels of staff had been recommended. The suggestion that word-processors might be used advantageously by the Secretariat was noted. Appreciation for the work carried out by the MAFF was expressed. The recommendations of the inspection were endorsed, and the Secretary was instructed to review staffing levels from time to time to ensure that they are kept in line with any future changes in workload.

24.6.3 Amendment of Financial Regulations

The Commission's financial advisers had drawn attention to a serious weakness in its Financial Regulations D2 and D3 where the date by which annual contributions from Contracting Governments must be paid is determined as 'within 60 days of the receipt of the . . . request from the Secretary', and the definition of arrears is expressed as 'more than two years from the date of receipt of the request'.

Since the date of receipt of any document despatched by mail from the Secretariat is uncertain and usually not known to the Secretary, it was suggested that payment should become due and arrears be determined by reference to the date of the request itself. To be consistent with the procedure for notification of Schedule amendments and also allow a reasonable amount of time for postal delivery, a 90 day period was proposed, and the Commission agreed to amend the Financial Regulations as follows:

Regulation D2—first sentence. Delete 60 and insert 90 before the words 'days of' and substitute the word 'date' for 'receipt'.
Regulation D3—Delete the words 'receipt of'.
—Delete 60 and insert 90 before the words 'days notice'.

The revised text of Section D is shown in Appendix 9.

24.6.4 Commission's Archives

The Commission's archives include bound volumes of the Annual Reports and the formal records of the Commission meetings, and files containing correspondence and other material generated and received by the Secretariat in the day to day business of the Commission. It is becoming difficult to store this material safely within the Secretariat, and it was agreed that one set of the bound volumes and historic, legal or scientific material on file should be deposited with an appropriate body such as the UK Public Records Office, after proper review and with adequate safeguards for requisition.

24.6.5 Signature of Legal Documents

In order to facilitate certain of the Commission's business, the Commission's legal advisers had suggested that there should be a statement which specifically indicates that Rule

F.2(e) of the Rules of Procedure, setting out the Secretary's duty to perform such other functions as may be assigned to him by the Commission or its Chairman, includes execution of legal documents.

Therefore, the Commission agreed that under Rule of Procedure F.2(e) the Secretary is assigned the function of witnessing legal documents executed under the Commission's seal.

24.6.6 Modification of Headquarters Agreement

The Foreign and Commonwealth Office of the UK had drawn attention to an anomaly in the Headquarters Agreement made between the UK Government and the IWC when the permanent Secretariat was established in 1976. To bring the Commission into line with other Intergovernmental organisations based in the UK with respect to its immunities and privileges, the Commission agreed

1. to approve the modification of the Headquarters Agreement in accordance with the proposal made by the Foreign and Commonwealth Office as follows: 'to amend Article 2(f) of the Headquarters Agreement to read '. . . persons recruited locally *and* assigned to hourly rates of pay'.'
2. to authorise the Secretary to take the necessary action to give effect to the modification from 1 September 1981 including a formal Exchange of Letters.

24.6.7 List of Contracting Governments

In response to a suggestion that it would be helpful if delegates could be provided with a list of Contracting Governments showing the dates of adherence, the representative of the United States Government, the depository, offered in the future to make such a list available shortly before Annual Meetings; this would be sent to the Secretariat for distribution.

24.6.8 Appointment of Commissioners and Alternatives

The Finance and Administration Committee considered the question of formalities relating to the appointment of Commissioners and the nomination of deputies, alternatives, experts and advisers at meetings of the Commission.

The Committee recalled Rule A1 of the Rules of Procedure, and stressed that notification of the name of the Commissioner should be furnished to the Secretary promptly by Contracting Governments, directly or through their Diplomatic Missions.

For the purpose of accreditation to plenary meetings it was proposed that the names and status of all members of delegations should be forwarded to the Secretary before the start of the meeting, or immediately upon the appointment of a Commissioner during a meeting. Notification of the Commissioner, any deputy, alternate, expert or adviser may be made by cable and may be accepted provisionally by the Secretary, subject to formal confirmation by the end of the second day of any meeting for which notification by cable would be relevant.

The Commission agreed that a Commissioner may designate any deputy, alternate, expert or adviser whose name has been duly notified, to act in his absence pursuant to Rule C.1 of the Rules of Procedure.

The Committee considered the suggestion made in Technical Committee for the establishment of a Credentials Committee, but concluded that if the above arrangements were adhered to such a body would be unnecessary.

Spain emphasised the need to call these formalities to the attention of governments, and the Commission agreed that the Secretary should do this in good time before the Special Meeting.

25. ADDITIONAL WORKING LANGUAGES

The Finance and Administration Committee considered at length a proposal from the Spanish speaking members of the Commission for the progressive introduction of Spanish as an additional working language of the Commission. This included certain minimum requirements for the 34th Annual Meeting, and ultimately the use of that language as an additional official language of the Commission.

In subsequent discussion it was suggested that French should also be considered for adoption on the same basis, and that the feasibility of adding Russian and Chinese should be considered.

There was great sympathy with the difficulties of non-English speakers at meetings, but concern was expressed about the additional costs to the Commission which would be involved.

Although some members were in favour of an immediate start on a limited basis, others stressed that they preferred a full study and costing before an informed discussion at the next Annual Meeting, since this is such a significant step. Preliminary and tentative estimates of costs for introducing two or four additional working languages ranged from £50,000 to £70,000.

In the Plenary Session, Spain emphasised the importance of this issue, and supported a step-by-step approach to the introduction of other languages. This position was shared by France, Chile, Mexico, Costa Rica and Argentina.

The UK, the USA and the Netherlands all spoke of the need to be more certain about the costs which may be incurred, and France suggested that a ceiling be placed on the expenditure. The USSR was against a gradual approach, preferring all working languages to be considered together, and Denmark referred to the present Rules of Procedure to ask if only those members who wished to speak in another language should bear the costs of interpretation or if these costs should be spread over the whole budget. Brazil and New Zealand both supported the view that more background should be provided before taking a decision, because of the financial implications.

Spain proposed that two or three tri-lingual interpreters (English, Spanish and French) should be made available at the next Scientific Committee meeting. France and Mexico supported this idea, although it was pointed out that Japan and the USSR have for long provided their own interpreters, and Norway suggested that up to £10,000 might be spent in this way. Australia suggested that the Spanish speaking countries could set up this experiment on their own.

After further re-iteration of the points previously raised, the Commission eventually agreed to establish a Working Group, convened by Spain, to look into the whole question. Member governments were asked to put forward any proposals, views or ideas during the next year for distribution by the Secretary before the Working Group met immediately before the 34th Annual Meeting.

26. DATE AND PLACE OF ANNUAL MEETING, 1982 AND 1983

In the absence of an invitation from a Contracting Government, the Finance and Administration Committee recommended that the next Annual Meeting be held in Brighton. It recognised the practical difficulties in moving the date forward to June, because of the Scientific Committee's preference to meet in Cambridge, and the Commission therefore accepted the recommendation to meet in the week beginning 19 July 1982, preceded by a week of Technical Committee Working Groups.

Consideration was given to the possibilities of going back to London as the venue, and the Secretary was asked to investigate the availability of the IMCO building for the 1983 meeting.

27. REVISION OF THE INTERNATIONAL CONVENTION FOR THE REGULATION OF WHALING, 1946

The Commission received the report of the Preparatory Meeting to Improve and Update the International Convention for the Regulation of Whaling, 1946, hosted by the Government of Iceland in Reykjavik, May 1981.

Denmark commented that this had been a more successful session than the earlier meeting in Copenhagen because the discussion had not been concerned with wording but the principles involved. It proposed that a contracting government should be urged to continue the initiative, and this was seconded by Japan.

Norway commented on the tensions experienced in the Commission which are also reflected in the report, and Australia wondered if there was need for a spell without meetings. Argentina shared this view, because of the delicate stage of the Law of the Sea Conference. Jamaica spoke on the two major interest groups represented, those concerned with whaling and others concerned with the survival of whales, although these are not necessarily in conflict. The UK had reservations about the usefulness of holding another meeting, but Spain believed the difficulties experienced in the present meeting proved the urgent need to proceed with the revision and updating process. It identified four essential points—the object and purposes of the Convention; the jurisdictional problem; decision taking; and membership of the organisation.

The USA remarked on the fact that any member is free to offer to host a meeting, and to develop terms of reference, so that discussions of the kind which took place in Reykjavik could be pursued. The Commission agreed to leave the matter as it is for member governments to take note of what had been said.

28. CO-OPERATION WITH OTHER ORGANISATIONS

28.1 Commission for the Conservation of Antarctic Marine Living Resources

Australia spoke on the meeting which it will host, as depository, in Hobart in September 1981, to facilitate the early establishment of the proposed Commission. The IWC had been invited to attend in an observer capacity.

The USA supported the attendance of an IWC representative, because of the close co-operation which is expected to develop between the two organisations, and the Commission agreed that Prof. Ovington should be nominated.

Argentina and Chile both reserved their positions on this matter.

28.2 Observers Reports From Other Meetings

The Commission received reports from the observers who had attended meetings of the International Council for the Exploration of the Sea, International Council for the Conservation of Atlantic Tuna, Inter-American Tropical Tuna Commission, Convention on International Trade in Endangered Species of Wild Fauna and Flora, and FAO Committee on Fisheries.

It was agreed that the Secretary should continue to inform Commissioners of all the observers who will represent the Commission at other meetings.

29. THIRTY-SECOND ANNUAL REPORT

The Commission adopted the draft 32nd Annual Report, subject to amendment to reflect the changes in membership which had occurred since it was written and distributed in advance of the meeting.

30. ELECTION OF CHAIRMAN AND VICE-CHAIRMAN

Mr T. Asgeirsson (Iceland) retired as Chairman of the Commission at the end of the meeting, having completed his three years term of office. On the proposal of Australia, seconded by Denmark, France and the USA, Mr E. H. Iglesias (Argentina) was unanimously elected as Chairman.

Mr M. C. Mercer (Canada) had resigned as Vice-Chairman of the Commission on the notice of withdrawal from the Convention by his government. Mr E. Lemche (Denmark) was proposed by Sweden, seconded by the USA and unanimously elected as Vice-Chairman.

31. ILLEGAL ACTS OF VIOLENCE

Under Any Other Business; Japan introduced a proposed Resolution calling for action by Contracting Governments against and reporting to the Commission of illegal acts of violence against whaling operations and government representatives. This was seconded by Spain and the USSR.

The USA supported this Resolution and noted that 32 NGOs at the meeting had disassociated themselves from such acts. A number of other delegations supported the spirit of the Resolution, but expressed some difficulties with the legal aspects, especially with respect to extra-territorial legislation. These included New Zealand, the UK, Oman, France, Denmark, Argentina and Chile. Japan emphasised that its wording was based on a Resolution adopted by the Commission three years ago dealing with action against non-IWC whaling, but recognising now that the present proposal had received the support expressed, it was prepared to withdraw its Resolution. Australia went on record as not condoning any illegal activity, but it could not go so far as to support the spirit of the Resolution because of legal considerations and fundamental philosophical political difficulties.

32. AMENDMENTS TO THE SCHEDULE

The amendments to the Schedule adopted by the Commission are given in Appendix 10.

LIST OF APPENDICES

Appendix
1. International Non-Governmental Organisations Represented by Observers
2. Resolution on Developing Revised Management Procedures
3. Resolution on Communication between the IWC and the Indian Ocean Coastal States
4. Resolution to the Government of the United States on the Bering Sea Bowhead Whale
5. Resolution Concerning White Whales and Narwhals
6. Resolution to Implement Recommendations of the Technical Committee Working Group on Non-IWC Whaling
7. Resolution Relating to Pollutants in Whales
8. New Method of Calculating Contributions from Contracting Governments
9. Revised Financial Regulations, Section D Contributions
10. Amendments to the Schedule

Appendix 1

INTERNATIONAL NON-GOVERNMENTAL ORGANISATIONS REPRESENTED BY OBSERVERS

African Wildlife Leadership Foundation
American Cetacean Society
Animal Protection Institute of America
Antarctic and Southern Ocean Coalition
Assembly of Rabbis
Campaign Whale
Centre for Action on Endangered Species
Centre for Environmental Education
Commission of the Churches on International Affairs of the World Council of Churches
Connecticut Cetacean Society
European Environmental Bureau
Fauna and Flora Preservation Society
Friends of the Earth
Greenpeace International
Innuit Circumpolar Conference
Institute for the Study of Animal Problems
International Environmental Advisors Inc.
International Federation of Institutes for Advanced Study
International Fund for Animal Welfare
International Institute for Environment and Development
International League for Animal Rights
International League for the Protection of Cetaceans
International Ocean Institute
International Primate Protection League
International Transport Workers' Federation
International Youth Federation for Environmental Studies and Conservation
Leviathan International
League Against Cruel Sports
Marine Action Centre
Monitor International
Monitor
Natur og Ungdom
People's Trust for Endangered Species
Prevention of Cruelty to Animals and Plants International
Royal Society for the Prevention of Cruelty to Animals
Save the Whales—Hawaii
Sea Shepherd Conservation
Sierra Club
Threshold Foundation Bureau
Whale Centers International
Whale Coalition
Whale Project
World Association of World Federalists
World Council of Indigenous Peoples
World Society for the Protection of Animals
World Wildlife Fund
Werkgroep Zeehond

Appendix 2

RESOLUTION ON DEVELOPING REVISED MANAGEMENT PROCEDURES

The International Whaling Commission:

RECALLING that a Working Group of the Technical Committee on Revised Management Procedures was established at the Commission's thirty-second Annual Meeting to examine the recommendations of the third Scientific Working Group

RECALLING FURTHER that the Technical Committee Working Group on Revised Management Procedures held two sessions prior to the thirty-third Annual Meeting

WELCOMING progress toward development of revised management procedures reflected in the Report of the Working Group and in informal discussions during the thirty-third Annual Meeting

RECOGNISING that final resolution of remaining issues relating to revision of the management procedures will require further efforts among members of the Commission

REAFFIRMING the importance of developing detailed proposals, including draft Schedule amendments, regarding the management procedures of the International Whaling Commission

Now, hereby:

CALLS upon interested governments to pursue consultations prior to the thirty-fourth Annual Meeting with the objective of achieving broadly agreed proposals on revised procedures for consideration at the thirty-fourth Annual Meeting that will enable the Scientific Committee subsequently to provide better advice to the Commission relative to management.

Appendix 3

RESOLUTION ON COMMUNICATION BETWEEN THE IWC AND THE INDIAN OCEAN COASTAL STATES

WITH REFERENCE to the proposal designating a region in the Indian Ocean as a sanctuary in which commercial whaling is prohibited—the region comprising the waters of the Northern Hemisphere from the coast of Africa to 100° East, including the Red and Arabian Seas and Gulf of Oman, and the waters of the Southern Hemisphere in the sector from 20° East to 130° East with the Southern boundary at 55° South.

BEING CONSCIOUS of the need to make a long term approach to the problem of preserving and increasing whale populations in areas sufficiently large for their needs.

NOTING that the Indian Ocean coastal states attending the meeting in the Seychelles on 15 April 1980 accepted the concept of the Indian Ocean Sanctuary.

MINDFUL of the fact that the success of this endeavour would require the co-operation of all states bordering the Indian Ocean and beyond.

The International Whaling Commission instructs the Secretary to communicate with the Indian Ocean States coastal to the Indian Ocean Sanctuary and keep them informed of the decisions made in the Commission with regard to the Sanctuary.

Appendix 4

RESOLUTION TO THE GOVERNMENT OF THE UNITED STATES ON THE BERING SEA BOWHEAD WHALE

RECOGNISING the danger of extinction faced by the Bering Sea bowhead whale and the consequences for the Inupiat culture.

MINDFUL of the recommendations of the Scientific Committee which again note the high risk to the stock, recommend zero quota and ask that any catch should be restricted to sexually immature whales (i.e. less than 12 m long) and that they be taken in a manner that will reduce the struck and lost rate to zero.

ENCOURAGED by the Co-operative Agreement entered into by the US Government and the AEWC and the good will and effort shown by the Inupiat people of Alaska.

CONCERNED at the very high proportion of the struck quota allocated to the 1981 season.

THE IWC COMMENDS the Inupiat people of Alaska on their efforts to control the hunt, and their essential contribution of finance and effort in the gathering and provision of data and research.

URGES them to restrict the existing quota to sexually immature whales and to reduce the numbers of whales struck but not landed to zero as quickly as possible.

Appendix 5

RESOLUTION CONCERNING WHITE WHALES AND NARWHALS

The International Whaling Commission

URGES the Government of Canada to take account of the advice and recommendations of the Scientific Committee and undertake immediate research and management action to protect those stocks of white whales and narwhals taken by persons under its jurisdiction;

REQUESTS the Government of Canada to continue to advise the Scientific Committee through the Commission of the Canadian research and management program relevant to white whales and narwhals and, in particular, of the measures undertaken to prevent taking from the severely depleted stocks of white whales;

REQUESTS the Secretary to transmit copies of this Resolution and the Report of the Scientific Committee to the Government of Canada for consideration.

Appendix 6

RESOLUTION TO IMPLEMENT RECOMMENDATIONS OF THE TECHNICAL COMMITTEE WORKING GROUP ON NON-IWC WHALING

The International Whaling Commission

Taking note of the consensus view at its 32nd Annual Meeting that whaling operations outside the International Whaling Convention have adverse effects on the objects of the Convention;

Having received the report of the Technical Committee Working Group on non-IWC whaling, and

Concerned at the lack of information on the extent of such operations revealed in the report, DECIDES

1. To urge member Governments to provide the Secretary with information on the present status of vessels on the draft register of whaling vessels by 31 May 1982, and to take the appropriate steps to update the Lloyds Register of Shipping in this respect.
2. To urge all member Governments to supply the Secretary with information, where this is available, concerning the period during which such vessels were engaged in whaling operations.
3. To ask member Governments to provide the Secretary with statistics of all imports and exports of whale products in the same detail as contained in customs' statistics.
4. To instruct the Secretary to consult the appropriate authorities in countries with large insurance markets on the question of insurance carried by vessels operating outside the IWC and in particular on the question of vessels listed for one purpose, but in fact carrying out whaling operations.
5. To adopt the following procedure in respect of information concerning non-member countries:
   a. if the Secretary receives information to the effect that whaling is being carried out by a country which is a non-member of the Commission, he should institute inquiries as to the correctness of that information;
   b. if the Secretary has reason to believe that whaling is being undertaken but he does not have adequate information as to the number, size, sex and location of the whales taken and as to the vessels and the equipment being used in the operation, he should approach the Government concerned and request the additional information;
   c. if the Government concerned is unable to supply this information, the Secretary, with the Chairman's concurrence should seek the agreement of that country to allow a qualified representative to visit the country concerned to assist in obtaining the information.
   d. the Secretary should ensure that all available information resulting from these enquiries is promptly transmitted to the Scientific Committee and the Commission and should inform the Commission if the Government concerned has been unable to receive a representative of the Commission.

Appendix 7

RESOLUTION RELATING TO POLLUTANTS IN WHALES

The International Whaling Commission

NOTES the serious threat to whale stocks, especially sperm whales, caused by increasing levels of heavy metals, PCBs and other organochlorides detected in cetaceans,

NOTES the possible effects on whale stocks which may be caused by shipping and off-shore mining and drilling activities, and

CALLS UPON members of the Commission to encourage national scientific programs in such matters and to provide to the Scientific Committee relevant data resulting from national research or from relevant international organisations in the field of oceanography and marine pollution.

Appendix 8

NEW METHOD OF CALCULATING FINANCIAL CONTRIBUTIONS

The total amount required in contributions is divided among the Contracting Governments according to the number of shares which each accumulates, shares being allocated on the following basis.

Membership	6 shares
For any number of land stations or 'small type whaling' operations in the last completed season	3 shares
For any number of aboriginal/subsistence whaling operations during the last completed season	2 shares
For each factory ship operation in the last completed season	2 shares
Annual Meeting representation (based on the last Annual Meeting at which any Contracting Government was represented)	
5–12 delegates	1 share
13–18 delegates	2 shares
19 or more delegates	3 shares

Notes

1. There shall be no limit to the number of shares any Contracting Government may accumulate.
2. For the purpose of assessing Annual Meeting representation, professional interpreters or specialised personnel with equivalent qualifications should not be counted as delegates.

The number of shares which each Contracting Government has currently accumulated under the formula is shown in Annex A. Relevant background information is given in Annex B.

Appendix 8

Annex A

TABLE SHOWING SHARES ACCUMULATED BY CONTRACTING GOVERNMENTS FOR THE FINANCIAL YEAR 1981/82 FOR THE PURPOSES OF ASSESSING FINANCIAL CONTRIBUTIONS

	Membership shares	Land Station/ 'small-type whaling' shares (1980)	Aboriginal/ subsistence whaling shares (1980)	Factory ship shares (1980 and 1980/81)	Meeting attendance shares (1981)	Total
Argentina	6	0	0	0	0	6
Australia	6	0	0	0	1	7
Brazil	6	3	0	0	0	9
Canada	6	0	0	0	0	6
Chile	6	3	0	0	0	9
China, P. R. of	6	0	0	0	0	6
Costa Rica	6	0	0	0	0	6
Denmark	6	0	2	0	1	9
Dominica	6	0	0	0	0	6
France	6	0	0	0	0	6
Iceland	6	3	0	0	0	9
India	6	0	0	0	0	6
Jamaica	6	0	0	0	0	6
Japan	6	3	0	2	3	14
Korea, R. of	6	3	0	0	1	10
Mexico	6	0	0	0	0	6
Netherlands	6	0	0	0	1	7
New Zealand	6	0	0	0	0	6
Norway	6	3	0	0	1	10
Oman	6	0	0	0	0	6
Peru	6	3	0	0	0	9
Phillipines	6	0	0	0	0	6
St Lucia	6	0	0	0	0	6
St Vincent and the Grenadines	6	0	2	0	0	8
Seychelles	6	0	0	0	0	6
South Africa	6	0	0	0	1	7
Spain	6	3	0	0	1	10
Sweden	6	0	0	0	0	6
Switzerland	6	0	0	0	0	6
USSR	6	0	2	2	0	10
UK	6	0	0	0	1	7
USA	6	0	2	0	3	11
Uruguay	6	0	0	0	0	6
	198	24	8	4	14	248

Appendix 8

Annex B

NUMBERS OF DELEGATES AT THE 33RD ANNUAL MEETING OF THE INTERNATIONAL WHALING COMMISSION, 1981

(excluding interpreters)

Argentina	2
Australia	6
Brazil	1
Canada	3
Chile	3
China	4
Costa Rica	2
Denmark	8
Dominica	0
France	4
Iceland	4
India	1
Jamaica	2
Japan	25
R. of Korea	5
Mexico	4
Netherlands	5
New Zealand	3
Norway	10
Oman	2
Peru	3
Philippines	0
St Lucia	3
St Vincent and the Grenadines	1
Seychelles	4
South Africa	5
Spain	6
Sweden	3
Switzerland	1
USSR	3
UK	9
USA	21
Uruguay	1

TYPES OF WHALING OPERATIONS CARRIED OUT BY CONTRACTING GOVERNMENTS

	Land station or 'small-type whaling' 1980	Aboriginal subsistence whaling 1980	Factory ship operations 1980/81 and 1980
Brazil	Land Station		
Chile	Land Station		
Denmark		Minke whales and Humpbacks (Greenland)	
Iceland	Land Station + Small-type		
Japan	Land Stations + Small-type		Antarctic 1
Korea, Rep. of	Land Stations + Small-type		
Norway	Small-type		
Peru	Land Station		
Spain	Land Station		
USSR		Gray whales (Arctic)	Antarctic 1
USA		Bowhead and gray whales (Bering Sea/ Arctic)	

Appendix 9

REVISED FINANCIAL REGULATIONS, SECTION D CONTRIBUTIONS

D. Contributions

1. As soon as the Commission has approved the budget for any year, the Secretary shall send a copy thereof to each Contracting Government (in compliance with Rules of Procedure, Rule H2), and shall request it to remit its annual payment forthwith.

2. Payments shall be in pounds sterling, drafts being made payable to the International Whaling Commission and shall be deemed to be payable in full within 90 days of the date of the said request from the Secretary, but it shall be open to any Contracting Government to postpone the payment of any increased portion of the amount until the following 1st March. The Secretary shall not make available any Commission documentation, excluding individual correspondence, to a Contracting Government whose annual payments have fallen into arrears for more than two years* from the date of the request referred to under Rule D1, such documentation to be reserved for provision at such time as the amount in arrears is settled in full. The Secretary shall report at each Annual Meeting the position as regards the collection of annual payments.

3. If annual payments have fallen into arrears more than two years* from the date of the request referred to under Rule D1, interests (10%) are also calculated on the amount of arrears from the day following the first 90 days notice and are paid for the benefit of the IWC Research Fund.

4. New Contracting Governments whose adherence to the Commission becomes effective during the first six months of any financial year shall be liable to pay the full amount of the annual payment for that year, but only half that amount if their adherence falls within the second half of the financial year.

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* For the purposes of these Financial Regulations the term 'more than two years' shall be interpreted to mean 'two years and one day or more'.

Appendix 10

INTERNATIONAL CONVENTION FOR THE REGULATION OF WHALING AMENDMENTS TO THE SCHEDULE ADOPTED AT THE 33RD ANNUAL MEETING OF THE INTERNATIONAL WHALING COMMISSION

A. SUBSTANTIVE AMENDMENTS (changes and new wording in italics)

1. Paragraph 6. Add new wording as follows:

   'The killing for commercial purposes of minke whales using the cold grenade harpoon shall be forbidden from the beginning of the 1982/83 pelagic and the 1983 coastal seasons.'

2. Paragraph 9(d). Revise as follows:

   'Geographical boundaries in the North Pacific

   The geographical boundaries for the sperm and Bryde's whales stocks in the North Pacific are:

   Sperm whale stocks (unchanged)

   Bryde's whale stocks

East China Sea Stock
West of the Ryuku Island chain

Western Stock
West of the 160°W meridian of longitude
(**excluding the East China Sea stock area**)

Eastern Stock
East of the 106°W meridian of longitude
(**excluding the Peruvian stock area**)'

3. Paragraph 9(e). Revise as follows:

'Geographical boundaries for Bryde's whales stocks in the Southern Hemisphere

Southern Indian Ocean
20°E to 130°E
south of the Equator

Peruvian
[unchanged]

Solomon Islands
150°E to 170°E
20°S to **the Equator**

Eastern South Pacific
150°W to **70°W**
south of the Equator
(excluding the Peruvian stock area)

Western South Pacific
130°E to 150°W
south of the Equator
(excluding the Solomon Islands stock area)

South Atlantic
10°W to 20°E
south of the Equator
(excluding the South African inshore stock area)

South African Inshore
30 nm seawards off the south west coast of South Africa from 25°S latitude down and around the coast to 25°E longitude.

4. Paragraph 11. Revise as follows:

'The number of baleen whales taken in the Southern Hemisphere in the **1981/82** pelagic season and the **1982** coastal season shall not exceed the limits shown in Tables 1 and 2. However, in no circumstances shall the sum of the Area catches exceed the total catch limit for each species.'

5. Paragraph 12. Revise as follows:

'The number of baleen whales taken in the North Pacific Ocean and dependent waters in **1982** and in the North Atlantic Ocean in **1982** shall not exceed the limits shown in Tables 1 and 2.'

6. Paragraph 13(b). Revise last sentence as follows:

'The number of gray whales taken in accordance with this sub-paragraph in 1982 shall not exceed the limit shown in Table 1.'

7. Tables 1 and 2. Amend as shown in Annex A.

8. New Paragraph 16, to replace existing Paragraphs 16 and 17.

'Catch limits for sperm whales of both sexes shall be set at zero in the Southern Hemisphere for the 1981/82 pelagic season and 1982 coastal seasons and following seasons, and at zero in the Northern Hemisphere for the 1982 and following coastal seasons; except that the catch limits for the 1982 coastal season and following seasons in the Western Division of the North Pacific shall remain undetermined and subject to decision by the Commission following special or annual meetings of the Scientific Committee. These limits shall remain in force until such time as the Commission, on the basis of the scientific information which will be reviewed annually, decides otherwise in accordance with the procedures followed at that time by the Commission.'

9. Table 3. Amend as shown in Annex A.

B. CONSEQUENTIAL AMENDMENTS

1. Paragraph 9(a). Amend to read:

'Areas relating to Southern Hemisphere baleen whales **except Bryde's whales** are those waters between the ice-edge and the Equator and between the meridians of longitude listed in Tables 1 and 2.'

2. Renumber all paragraphs from 18 onwards, and make consequential changes to paragraph numbers referred to in

Paragraphs 3 and 19(a): delete reference to paragraph 17. Sub-paragraph 24(a): sub-paragraph 21(b) to read **20**(b). Sub-paragraph 24(b): paragraph 24 to read **23.**

C. OTHER AMENDMENTS

Paragraphs 7 and 8.

All latitudes and longitudes to read in the style 100°E, 55°S etc.

Appendix 10

Annex A

Table 1

Baleen whale stock classifications and catch limits (excluding Bryde's whales)

		Sei		Minke		Fin		Blue	Hump-back	Right Bowhead, Pygmy Right	Gray	
Area	Longitudes	Classi-fication	Catch limit	Classi-fication	Catch limit	Classi-fication	Catch limit	Classi-fication	Classi-fication	Classi-fication	Classi-fication	Catch limit
SOUTHERN HEMISPHERE—**1981/82** pelagic season and **1982** coastal season												
I	120°W–60°W	PS	0	—	**930**	PS	0	PS	PS	PS	—	—
II	60°W–0°W	PS	0	—	**1,249**	PS	0	PS	PS	PS	—	—
III	0°–70°E	PS	0	—	**2,198**	PS	0	PS	PS	PS	—	—
IV	70°E–130°E	PS	0	—	**1,625**	PS	0	PS	PS	PS	—	—
V	130°E–170°W	PS	0	—	**1,187**	PS	0	PS	PS	PS	—	—
VI	170°W–120°W	PS	0	—	**1,317**	PS	0	PS	PS	PS	—	—
Total catch not to exceed:					**8,102**		0	0	0	0		
NORTHERN HEMISPHERE—**1982** season												
ARCTIC		—	—	—	—	—	—	—	—	PS	—	—
NORTH PACIFIC												
Whole region		PS	0	—	—	PS	0	PS	PS	PS	—	—
Okhotsk Sea–West Pacific Stock		—	—	SMS	421[1]	—	—	—	—	—	—	—
Sea of Japan–Yellow Sea–East China Sea Stock		—	—	SMS[2]	940[3]	—	—	—	—	—	—	—
Remainder		—	—	IMS	0[4]	—	—	—	—	—	—	—
Eastern Stock		—	—	—	—	—	—	—	—	—	SMS	179[5]
Western Stock		—	—	—	—	—	—	—	—	—	PS	0
NORTH ATLANTIC												
Whole region		—	—	—	—	—	—	PS	PS	PS	—	—
West Greenland Stock		—	—	SMS	**444**[6]	SMS[2]	6	—	—	—	—	—
Newfoundland–Labrador Stock		—	—	—	—	IMS	90	—	—	—	—	—
Canadian East Coast Stock		—	—	—	0[7]	—	—	—	—	—	—	—
Nova Scotia Stock		PS	0	—	—	PS	0	—	—	—	—	—
Central Stock		—	—	SMS	320	—	—	—	—	—	—	—
East Greenland–Iceland Stock		—	—	—	—	SMS	**194**	—	—	—	—	—
Iceland–Denmark Strait Stock		SMS	100[8]	—	—	—	—	—	—	—	—	—
Spain–Portugal–British Isles Stock		—	—	—	—	SMS	**210**	—	—	—	—	—
Northeastern Stock		—	—	SMS	1,790	—	—	—	—	—	—	—
West Norway–Faroe Islands Stock		—	—	—	—	PS	0	—	—	—	—	—
North Norway Stock		—	—	—	—	SMS	61	—	—	—	—	—
Eastern Stock		—	0	—	—	—	—	—	—	—	—	—
NORTHERN INDIAN OCEAN		—	—	IMS	0	—	—	PS	PS	PS	—	—

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[1] The total catch of minke whales shall not exceed 1,678 in the five years 1980 to 1984 inclusive.

[2] Provisional listed as SMS for **1982.**

[3] The total catch of minke whales shall not exceed 3,634 in the five years 1980 to 1984 inclusive.

[4] Pending a satisfactory estimate of stock size.

[5] Available to be taken by aborigines or a Contracting Government on behalf of aborigines pursuant to paragraph 13b.

[6] The total catch of minke whales shall not exceed 1,778 in the five years 1981 to 1985 inclusive.

[7] Pending submission of data leading to an adequate assessment.

[8] The total catch of sei whales shall not exceed 504 in the six years 1980 to 1985 inclusive.

Table 2

Bryde's whale stock classification and catch limits

	Classification	Catch limit
SOUTHERN HEMISPHERE—**1981/82** pelagic season and **1982** coastal season		
South Atlantic Stock	—	0
Southern Indian Ocean Stock	IMS	197
South African Inshore Stock	**—**	**0**
Solomon Islands Stock	IMS	0
Western South Pacific Stock	IMS	237
Eastern South Pacific Stock	IMS	188
Peruvian Stock	SMS	244[1] (76[2])
NORTH PACIFIC—**1982** season		
Eastern Stock	IMS	0[3]
Western Stock	**IMS**	**507**
East China Sea Stock	SMS[4]	19
NORTH ATLANTIC—**1982** season	IMS	0[3]
NORTHERN INDIAN OCEAN—1982 season	—	0

[1] **Available to be taken in a six months period starting in November 1981.**

[2] **Special remainder from 1981 coastal season that may be taken in a six months period starting in November 1981 making a total of 320 whales which may be taken during this period pursuant to this footnote and footnote 1.**

[3] Pending a satisfactory estimate of stock size.

[4] Provisionally listed as SMS for **1982.**

Table 3

Toothed whale stock classification and catch limits

		Sperm		Bottlenose
Divisions	Longitudes	Classification	Catch limit	Classification
SOUTHERN HEMISPHERE **1981/82** pelagic season and **1982** coastal season				
1	60°W–30°W	—	0	—
2	30°W–20°E	—	0	—
3	20°E–60°E	—	0	—
4	60°E–90°E	—	0	—
5	90°E–130°E	—	0	—
6	130°E–160°E	—	0	—
7	160°E–170°W	—	0	—
8	170°W–100°W	—	0	—
9	100°W–60°W	—	**0**	—
NORTHERN HEMISPHERE—**1982** season				
NORTH PACIFIC				
Western Division		—	—[1]	—
Eastern Division		—	0	—
NORTH ATLANTIC		—	**0**[2]	PS[3]
NORTHERN INDIAN OCEAN		—	0	—

[1] No whales may be taken from this stock until catch limits including any limitations on size and sex are established by the Commission.

[2] Provided that the remainder of 130 male sperm whales for the 1981 coastal season may be taken in the 1982 coastal season.

[3] Provisionally listed as PS for **1982** pending the accumulation of sufficient information for classification.

Report of the Scientific Committee

The Committee met at 9.00 am on 27 June 1981 and following days at New Hall, Cambridge, under the Chairmanship of J. L. Bannister.

A list of participants is given in Annex A.

1. CHAIRMAN'S WELCOME AND OPENING REMARKS

The Chairman welcomed the Committee members and invited participants; observers from several organisations were present. The Committee stood in silence in memory of Dr Y. Fukuda, who had been a member of the Committee from 1970 to 1978 and whose death had occurred in February, 1981.

2. APPOINTMENT OF RAPPORTEURS

Donovan was appointed rapporteur with the assistance of various members as appropriate. Chairmen of sub-committees appointed rapporteurs for their meetings.

3. ADOPTION OF AGENDA

The Agenda adopted is shown in Annex B.

4. ARRANGEMENTS FOR MEETING

4.1 Meeting procedure, establishment of sub-committees, and time schedule

The Committee agreed to a work schedule proposed by the Chairman. In accordance with Rule C1 in the Rules of Procedure, four sub-committees (minke, sperm, other baleen whales and protected species and aboriginal/subsistence whaling) had been appointed at last year's meeting; a fifth (small cetaceans) remained as a standing sub-committee (and see Item 10.4). An additional sub-committee (management) was established, particularly to discuss Items 8.1, 8.2, 8.4 and 13.1. Reports arising are dealt with under the relevant Agenda Items and as Annexes:

Annex D	Report of the sub-committee on sperm whales
Annex E	Report of the sub-committee on minke whales
Annex F	Report of the sub-committee on other baleen whales
Annex G	Report of the sub-committee on protected species and aboriginal/subsistence whaling
Annex H	Report of the sub-committee on small cetaceans

The Committee gave consideration to the Commission's charge (*Rep. int. Whal. Commn* 32: 28) that it should consider ways of reducing its workload. The recommendations are given in Annex I.

4.2 Computer arrangements

As in previous years, the University of Cambridge generously granted the IWC a high priority of access to the University IBM 370/165 computer. For the 1981 meeting, in addition, the computer laboratory set up a network node at New Hall, which permitted several terminals to use one line simultaneously. Altogether five terminals and a graph plotter were made available. Despite the improved facilities, the use of the network led to a reduced cost compared with the 1980 meeting.

Access to remote computers was possible over the public switched telephone network, but almost all work was in fact run in Cambridge.

5. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS

5.1 and 5.2 Documents submitted and progress reports on research

Lists of documents, progress and other reports available are appended as Annex C.

5.3 Reports of Special Meetings and Workshops

5.3.1 Sightings Workshop

The report of this Workshop is given in SC/33/Rep 1.

5.3.2 Special Meeting on Southern Hemisphere Minke Whales

The report of this meeting is given in SC/33/Rep 3.

5.3.3 Killer Whale Workshop

The report of this workshop is given in SC/33/Rep 4.

5.3.4 Management Procedures

The report of this meeting (IWC/33/13) is discussed under Item 8.1.

The attention of sub-committee chairmen was drawn to recommendations 1(a–e) on page R6 of that report, which the Committee agreed should be acted upon at this meeting.

5.3.5 Workshop on Humane Killing Techniques

The report of this Workshop (IWC/33/15) is discussed under Item 13.2.

5.3.6 US Workshop on Humpback Whales of the Western North Atlantic

The report of the IWC observer, Tillman, is given in SC/33/PS9. It was discussed by the sub-committee on protected species and aboriginal whaling (Annex G).

5.4 Scientific Permits

5.4.1 1980–81 Reports

No scientific permits were issued for 1980–81.

5.4.2. 1981–82 Advance Review (also see Annex F, p. 91)

(a) Danish application to take up to nine fin whales off the Faroes.

The Committee reviewed the research proposal outlined in SC/33/RP3. It was not thought that biological samples obtained from nine whales per year would add greatly to present knowledge. However, it supports other elements of the total research proposal with some qualification regarding the tagging (Annex F, p.91).

The Committee does not endorse the proposal for a special permit.

(b) Chilean application to take at least 100 sei whales.

The Committee reviewed the proposal outlined in SC/33/Ba10. It recommends that other kinds of work, including the compilation and analysis of earlier data, and further development of national expertise should precede any research catches. Any future proposal should be more detailed and carefully justified.

The Committee does not endorse the proposal.

5.5 Previous season's catches and other statistical material

Statistical material prepared at the Bureau of International Whaling Statistics under the direction of E. Vangstein was presented to the meeting. The Committee noted that several countries had not provided the Bureau with information in time for it to be included in these statistics, although some of the missing data were available in national Progress Reports. The Committee recommends that member nations be reminded of the need for prompt provision of catch information to the Bureau, if the Committee is to carry out its stock assessment work satisfactorily.

5.6 Marking

5.6.1 Progress of the International Scheme including the Commission's contribution to costs

Brown presented a report (Annex J) which summarised whale marking during 1980 and 1981 and reviewed the current position regarding stocks of marks and funding for the International Marking Scheme. The Committee endorsed the report.

The Secretary reported that it was the Commission's policy to only supply marks for those projects which could be expected to provide recoveries. This was supported by the Committee.

It was also agreed that during the coming year a small working group of Free (Convenor), Brown and Ivashin, should examine the possibility of storing all the marking data from the Soviet and International schemes in the IWC computer system.

5.6.2 Reports of special cruises—minke whales

The report of the Southern Hemisphere minke whale cruise undertaken in Area V under the IDCR programme is given in SC/33/MiS19 (and see Item 7.1.4).

5.7 Sightings programme—data reports from commercial operations 1980–81

The Secretary reported that no information had been received.

5.8 Indexed List of Scientific Committee Publications

Donovan reported that the 'List of Scientific Documents' had been updated to include papers from last year's Scientific Committee meeting. The Commission's publications are included in the ASFIS (Aquatic Sciences and Fisheries Information System) data bank and the Secretariat has access to ASFIS publications via the Library of the British Antarctic Survey.

6. CO-OPERATION WITH OTHER ORGANISATIONS

6.1 FAO

Gulland reported that the remaining volumes arising from the FAO/ACMRR Meeting in Bergen in 1976 should be published by the end of the year. The biological data requested by the Commission last year has now been sent to the IWC Secretariat. FAO has worked in co-operation with UNEP on the draft Global Plan of Action (see 6.2 below). Attention was drawn to the report of the FAO Working Party on the Management of Fisheries which referred to all aspects of management not simply scientific matters. Of particular interest are sections on multi-species fisheries and on fisheries for krill and other species which are directly relevant to the ecology of whales. The annual FAO review of Fisheries resources includes a special section on marine mammals this year (Gulland: Review of the State of World Fishery Resources, COFI, 81/mf5). He also reported that the UN Conference on the Law of the Sea is coming to a close and it is hoped that the Treaty, which includes specific paragraphs on marine mammals, will be signed in 1982.

The IWC Observer's report on the FAO Committee on Fisheries discussion of the draft Global Action Plan for the Conservation, Management and Utilisation of Marine Mammals is given in IWC/33/11E.

6.2 UNEP

In the absence of a representative from UNEP, Holt informally reported on the activities of UNEP during the past year. A UNEP representative will be present at the Commission Meeting. The revised Global Plan of Action has been completed and considered by the UNEP Governing Council in May 1981. The proposed action had been generally supported by member states and delegations had urged that the first phase of the Plan be implemented during 1981–83. UNEP is anxious to see the Commission involved in this wherever appropriate, and the Committee noted that an approach would be made by UNEP to the Commission.

6.3 IUCN

Beddington reported that the report of the workshop on the interactions between fisheries and marine mammals would be ready in August. IUCN is co-sponsoring the meeting on research programmes for the Indian Ocean Sanctuary being held in Amsterdam later this year (see Item 8.3.1).

6.4 IATTC

Hammond reported to the sub-committee on small cetaceans on the activities of IATTC with respect to cetaceans (Annex H).

Perrin reported on the IATTC meeting that was held in Washington, D.C., 28–29 October 1980 (IWC/33/11C) at which he represented the Commission as an observer. In particular he noted:

(a) although negotiations continue, at present there is no management regime in place for yellow fin tuna in the eastern tropical Pacific. Mexico, with the second largest landings from the area, has withdrawn from the IATTC;

(b) analysis of sightings shows a sharp decline over the period 1977–79 in density and size of schools of the eastern spinner dolphin, *Stenella longirostris*, although the finding is tentative;

(c) member nations did not agree to adopt a series of measures for minimizing dolphin deaths but did agree to take them under advisement; and

(d) although the CPUE of tuna has declined in recent years, and the fishing effort is greater than the level that would yield MSY, there is no concern about possible collapse of the fishery, because of the very weak relationship thought to exist between stock size and recruitment at present population level.

The next annual meeting of the IATTC will be in Paris, France in October, 1981. The IWC has been invited to observe the meeting. The Committee recommends that the Secretary should review the agenda for the meeting and attend if appropriate.

A meeting of IATTC scientific staff and invited experts was held in Managua, Nicaragua, 6–10 April 1981 to review existing information on the dolphin-tuna association and discuss possible research approaches to further understanding the mechanisms, ecology and management implications of the association. Perrin again represented the Commission and his report is given in IWC/33/11C.

6.5 CITES

Rudge thanked those members of the Scientific Committee who had helped in the revision of the 'World Review of Cetacea' which was presented to the CITES meeting in New Delhi. He reported that the UK National Conservancy Council which had funded the original work was unable to provide additional funds for its updating. The Committee believed that an annual review would be useful and agreed that this should be carried out by the Secretariat in conjunction with sub-committee convenors and Klinowska. Updated pages would be circulated to the Committee after each Annual Meeting.

Last year the Committee recommended that the Commission responds to special requests for information from CITES by referring to the views of the Committee as expressed in its report. The Secretariat forwarded the relevant parts of the report of CITES in response to a request for information regarding certain proposals to place cetaceans on the CITES appendices. The report of the IWC observer at the New Delhi CITES meeting is given in IWC/33/11D. The CITES meeting placed sperm, sei and fin whales on Appendix I.

Berney reported that the CITES Secretariat was involved in a review of all species not under the jurisdiction of any state, and that the Commission would be asked to participate in a committee to examine this. The Scientific Committee recommends that the Secretary should represent the Committee at this meeting.

6.6 BIOMASS

Allen reported on the 2nd meeting of the BIOMASS Technical Group on Data Statistics and Resource Evaluation (SC/33/Rep 1). The group had hoped to obtain sightings data during FIBEX (First International BIOMASS Expedition) which would be of value in examining the relation between the distribution of whales and that of krill. This would be valuable in the understanding of the functional relationship between these animals in the Antarctic ecosystem. Advice on cetacean sightings techniques was given to FIBEX by the IWC Working Group on Sightings Techniques (SC/33/Rep 2). A meeting is being held in Hamburg in September 1981 to examine data obtained from FIBEX and consider how it can best be stored and retrieved. The Committee noted that although nine of the eleven nations participating in FIBEX were IWC member nations only the Japanese vessel contained experienced whalers. Ohsumi reported that because of the lack of a detailed format for sightings data, Japan had been unable to send the resultant data to the BIOMASS centre. It was agreed that he would consult with Free in order to determine a suitable format to present at the Hamburg meeting.

The Committee recommends:

(a) that the IWC continues to give as much support as possible to the BIOMASS programme;

(b) that the IWC gives all possible support to the establishment of a BIOMASS Data Centre and to the esablishment of links to assist scientists working in either IWC or BIOMASS programmes to have access to data stored in both systems;

(c) that the IWC should continue to co-operate with BIOMASS at the scientific level by sending representatives to appropriate meetings. In particular the Committee recommends that Free should attend the Hamburg meeting on its behalf and that Allen should attend the 3rd BIOMASS Technical Group Meeting if he is available.

(d) that the IWC should seek for the Committee to be represented at any planning meetings for SIBEX in order to help co-ordinate any cetacean research.

6.7 CCAMLR

The Secretary reported that he had been unable to obtain support for the workshop recommended by the Technical Committee Working Group on the Implications for Whales of Management Regimes for Other Marine Resources (*Rep. int. Whal. Commn* 31: 29).

The Commission has been asked to send an observer to a CCAMLR meeting in Hobart, Australia in September. The Committee recommends that Allen attends the relevant parts of that meeting.

7. INTERNATIONAL DECADE OF CETACEAN RESEARCH (IDCR)

The Committee discussed the history and origins of IDCR. The Scientific Committee had originally proposed, in 1972, in response to the call for a moratorium by the 1972 UN conference in Stockholm, that 'instead of a moratorium, support should be sought for a decade of intensified research on cetaceans, particularly as regards problems relevant to their conservation' (*Rep. int. Whal. Commn* 23: 38). The Commission adopted the proposal at its 1972 meeting (*Rep. int. Whal. Commn* 24: 26) when it was moved that an *ad hoc* Committee should be established 'to determine ways in which such a programme can be implemented and that this Committee be instructed to contact all other appropriate national and international groups and organisations and in particular FAO to determine their interest in sponsoring such an international programme'. The first detailed proposals for IDCR were reported in December 1974 (*Rep. int. Whal. Commn* 26: 116–79). In view of this background the Committee agreed that IDCR should be considered to have started in 1975.

The Committee agreed that future research should be organised on two levels:

(a) Continuation of the IDCR programme in which priority would be given to projects relevant to management, although all cetacean research would be considered. IDCR programmes would be those which fulfil at least one of the following criteria:

(i) requiring co-operation between national groups;
(ii) requiring funding from more than one national group;
(iii) providing information valuable in studies on stocks other than the one to which they are primarily directed.

(b) As part of a general international programme of cetacean research in co-operation with non-IWC nations and international organisations. In particular, the UNEP Global Plan of Action, (see 6.2) has produced a series of research recommendations and the Committee urges the Commission to endeavour to ensure its participation in their formulation and implementation. Any IWC research programmes should eventually be integrated into the Global Plan.

Holt reported that a special session of UNEP would take place in 1982, to review the status of the recommendations made at the Stockholm Conference in 1972. As IDCR was originally set up in response to this Conference, the Committee recommends that during the year the Secretariat should prepare a review of the programme and its achievements to date in consultation with the Committee Chairman, the Vice-Chairman, Holt and Ohsumi, for transmission to that session.

7.1 Review of results 1980—81

7.1.1 Icelandic Whale Research Facility

Jónsson reported that the facility had now been established and that advice was being sought on the nature of the equipment which should be provided. In the event of a large number of requests for space at the station, the Icelandic Government would seek advice from the Commission regarding the priority of projects, as had been requested by the Committee last year (*Rep. int. Whal. Commn* 31: 54). Brodie reported on the excellence of the facility and the co-operation extended to researchers by whaling personnel.

7.1.2 Azores Sperm Whale Project

Funds have been provided by the Commission for this project and the Committee looks forward to receiving a report of the research to be carried out this summer.

7.1.3 Sperm Whales of the Southeast Pacific

Last year the Commission, on the recommendation of the Scientific Committee, agreed to finance completion of a further section of the work by Clarke and co-workers on Division 9 sperm whales. Half the funds allocated were transferred to Clarke but, due to problems unrelated to the project encountered by workers in Mexico, completion of the analyses and writing up the results has been delayed.

7.1.4 Southern Hemisphere minke whale assessment cruise, Area V

A report of this cruise is given in SC/Jn81/MiS19, and discussed in SC/33/Rep 3. Financial support for the project was provided principally by the Japanese and Soviet governments who provided scouting vessels (estimated in the case of the two Japanese vessels to represent an expenditure of $1,200,000). Further support was provided by South Africa (R24,000) and Australia (A$6,000). The Committee wishes to express its appreciation of this support and to stress the value of such co-operative ventures.

7.2 Proposals 1981–82

7.2.1 Southern Hemisphere minke whale assessment cruise

Best reported that plans were being made for the 1981/82 cruise to cover Area II. Three to four vessels would be available and the costs would be borne by Japan and the USSR. In addition it was hoped that one of the vessels would spend four to six weeks on the Brazilian minke whaling grounds before proceeding to the Antarctic. A working group met during the course of the Brighton meetings to plan the co-ordination of objectives and procedures. Funds may be sought for the travel and subsistence of participating scientists.

7.2.2 North Atlantic cruise

An *ad hoc* group was formed under the joint-chairmanship of Tillman and Harwood to plan a programme for 1982. The group also met during the course of the Brighton meetings. Its report is given in Annex K. Funds will be required.

7.2.3 Age determination and interspecies comparison of baleen whales using the aspartic acid racemisation method (SC/33/RP2)

The Committee agreed that this project should be considered under the procedure set up at last year's meeting (*Rep. int. Whal. Commn* 32: 55, Item 7.3).

7.2.4 Examination of logbooks from Antarctic fin whaling

The Committee examined the proposal for a study of logbooks from Antarctic fin whaling given in Annex F (page 91). It recommends that the Secretary contact people and institutions which may be able to assist such work. If necessary money designated for contingencies (Item 7.4.4) should be used.

7.2.5 Humane killing study in Iceland

This is discussed under Item 13.2. Travel funds are sought.

7.2.6 Killer whales in the northeast Atlantic

The Government of the Netherlands has contributed Dfl.10,000 (about £2,100) to the IWC Research Fund with the suggestion that it be spent 'on such activities as may be recommended by the Scientific Committee with regard to the conservation of small cetaceans'.

The Committee agreed following a recommendation by the small cetacean sub-committee (Annex H) that the Secretary should contact relevant countries seeking submission of research proposals for field studies to identify killer whale stocks in the northeast Atlantic. It noted that photographic and passive acoustic surveys appear to be the most promising methods for this work.

7.2.7 Biochemical analysis of Southern Hemisphere minke whale samples

The Committee supported a proposal to provide financial support to Wada to assist in the electrophoretic analysis of samples from Southern Hemisphere minke whales, in order to determine as soon as possible the usefulness of the technique for stock identification of cetaceans.

7.3 Funds available

The Secretary reported that the Research Fund had stood at between £50,000 and £90,000 during the year, most of which had been designated for specific projects by the contributors. Of the undesignated funds £6,279 had been used to provide support for research projects according to the procedure adopted last year (*Rep. int. Whal. Commn* 32: 55).

7.4 Funding procedures

The Committee reviewed the system instigated last year to assess and recommend funding for research projects submitted to the Commission. It agreed that last year's system of circulating applications to sub-committee members for review between meetings was unsatisfactory and recommends that the following procedures be adopted:

(1) all requests for funding should reach the Commission at least two months prior to the Annual Meeting. Projects would then be examined by the relevant sub-committee and the full Committee;
(2) in the event of a large number of proposals the policy should be to provide partial funding for a number rather than near total funding for a few;
(3) if there are no funds available for a project which is considered worthwhile by the Committee, then the Secretary will write a letter of endorsement on behalf of the Committee to the originator(s) of the proposal;
(4) A sum of money, not exceeding 10% of the research allocation in any one year, should be added to it and designated for contingencies, to be available throughout the year, particularly to support projects arising out of Special Meetings or Workshops at a maximum level per project of £500. Allocation of this money would be the responsibility of the Secretary in consultation with a small sub-committee to be appointed by the Committee annually for the purpose;
(5) the following two main priority listings should each be taken into account equally, but in order of priority under each section as indicated:
    (a) Nature of project
        (i) multinational projects;
        (ii) projects which contribute generally to the management of particular species of cetaceans or cetaceans as a whole;
        (iii) projects carried out by one country in the territory or on the animals of another to provide general information;
        (iv) projects involving information to manage species exploited by another country.
    (b) Species
        (i) most exploited stocks;
        (ii) environmentally threatened stocks;
        (iii) other stocks.

8. MANAGEMENT PROCEDURES

8.1 Reports of Technical Committee Working Group Meetings on Revised Management Procedures, February/March 1981 and May 1981

As a preface to deliberations concerning the four proposals for revised management procedures put forward by IWC/33/13, the Committee discussed the conceptual approach to management presented in paper SC/33/Mg2. This document examined a series of possible trajectories of whale population abundance resulting from different management policies. It pointed out that, while one might possibly define a band of trajectories which met the proposed objectives for management (page T17 in IWC/33/13), one would not be able to distinguish, on scientific grounds, any one policy within that acceptable band as being better than another.

Consequently the document concluded that the Committee could not recommend any one policy from among a series of acceptable policies as being correct; the Committee could only advise which policies resulted in trajectories which were inconsistent with the proposed objectives.

In subsequent discussions, several participants pointed out that the document brought out a fundamental question about the nature of the decision-making process within the Commission, i.e. where are decisions to be made? Some members felt that the current management procedure tended to give too much of the responsibility for decision-making to the Scientific Committee. Other members noted that this apparent tendency was the result of the Commission's earlier desire to increase its reliance upon the advice of the Scientific Committee.

The Committee noted that the specific scientific advice on currently exploited stocks requested by IWC/33/13 (p. R6) comprised the information exactly needed to determine the trajectories discussed in SC/33/Mg3. While it was agreed that the requested information would be provided to the extent possible, the Committee noted that an inadequate data base for several stocks would prevent full compliance. Moreover, it was agreed that, in providing advice on the optional trajectories requested, the Committee must also spell out the implications of these options, particularly emphasising the long term risks involved, if any.

In accordance with IWC/33/13 (p. R6), three governments had forwarded to the Chairman of the Scientific Committee specific comments or questions regarding the scientific content and implications of the four management proposals being put forward. These are given in Appendix 1.

The Canadian request concerning small cetaceans was forwarded to the small cetacean sub-committee for action. The report of that group (Annex H) contains the advice requested.

In taking up the questions from the USA on the proposed management procedures, the Committee agreed that only four of the five questions contained sufficient scientific content to warrant an answer. At issue was question 'B' concerning the provision of incentives for undertaking needed research. The Committee agreed that, while it was desirable to improve the scientific basis for management and, hence, to reduce uncertainties in assessments, the establishment of incentive programmes was not a scientific matter, but rather fell within the purview of the Technical Committee. Therefore the Committee decided not to contrast the four proposals with respect to incentives for undertaking research, and only the remaining four questions were used as appropriate criteria.

With respect to the Japanese comments and questions, the Committee agreed that question (3) concerning management based on fixed rates of exploitation was also not an appropriate basis for contrasting the four proposals. Indeed it was believed that this concept constituted a fundamental basis for developing another possible management regime. The Committee decided that further review and comment was needed of this concept as put forward by Ohsumi's paper presented at the Rome session, entitled 'Fixed exploitation rate and its practicality for management procedure of whale stocks'. However, the press of other issues did not allow time for this review.

The remaining two Japanese questions were added to the list of those used in contrasting the four proposals. It was agreed to modify the resulting six questions by removing non-operational terms which could only be defined subjectively. The agreed questions were as follows:

(1) Does the proposal provide safeguards which account for uncertainties in assessment models and for the quantity and quality of information used by those assessments?
(2) Does the proposal delay the implementation of revisions of catch limits or stock classifications resulting from new assessments?
(3) Does the proposal provide specific, operational guidance for classifying stocks and for determining catch limits?
(4) Does the proposal provide procedures for smoothing changes in catch limits resulting from new assessments?
(5) Does the proposal make allowance for the flat-topped nature of yield curves when setting reference/target levels?
(6) Does the proposal take account of cumulative losses in catch, as against future gains in replacement yield, resulting from the speed with which the stock is moved toward a reference/target level?

A review of the four proposals for revised management procedures using these six criteria, is given with comments in Table 1.

Noting that Annex O to the Scientific Committee's report of two years ago (*Rep. int. Whal. Commn* 29: 99–101) summarised a number of problems arising under the current management procedure, it was suggested that this might also be used as another basis for discussing the merits of the four proposals. However, a lack of time prevented this discussion from taking place.

8.2 Moratorium proposals

8.2.1 Conditional ban/moratorium on commercial whaling

Under this Agenda Item the Committee discussed the proposals put forward by the UK and the USA, having been informed that the proposal for a world-wide ban on all whaling did not contain material requiring review by the Scientific Committee.

The Committee noted that it had previously reviewed similar proposals and that the best summaries of differing views were given in *Rep. int. Whal. Commn* 30: 46–8 and in *Rep. int. Whal. Commn* 31: 57–8.

The Committee further noted that one aspect of the balance of advantages and disadvantages to these proposals depended very largely on the research effort which would be made during a conditional ban or moratorium. In reviewing the experience of countries in which whaling had ceased, the Committee noted that the level of cetacean research had both increased and decreased. In circumstances where research had increased, some members expressed the belief that such programmes had been spurred by increased public interest in whales, by problems arising from increased human use of nearshore marine ecosystems, or by increased recognition of the non-consumptive values of whales. In circumstances where research had decreased, some members believed that this resulted from a lowering of research priorities when no industry existed. The Committee was still unable to agree whether a moratorium or conditional ban would have the effect of increasing or decreasing the build up of scientific information and understanding which will aid in improving the management of the whale stocks.

8.2.2 Moratorium proposals

The Committee considered the several moratorium proposals which are on the Commission's Agenda. It agreed that, apart from in the French document, IWC/33/21, there was little new scientific content in the documents supporting these proposals. In the time available the Committee therefore briefly examined IWC/33/21 in which a moratorium on the commercial exploitation of sperm and minke whales was proposed. Some members pointed out that the document, and particularly its Appendix A, identified some of the important problems faced in assessing and setting catch limits although most of the problems had at one time or another been considered at least implicitly by the Committee. Some members felt that these problems should be studied in greater depth. Other members felt that there were statements in the document which were incorrect or required substantiation. Yet others considered that there was little in the documentation to provide a scientific basis for a moratorium on sperm or minke whaling.

Although the Committee had agreed that it would only discuss the new scientific aspects of the documentation of the moratorium proposals and therefore only discussed IWC/33/21, some members believed that there are substantial scientific reasons to support the several moratorium proposals (North Atlantic, sperm, minke). Other members believe there are no scientific grounds for any blanket moratoria, either by region or by species.

8.3 Whale sanctuaries

8.3.1 Indian Ocean—scientific research proposals

The proposed international meeting of scientists to plan a programme of monitoring and research for marine mammals in the Indian Ocean (*Rep. int. Whal. Commn* 31: 59) will be held in Amsterdam in September 1981. The Committee adopted the report (Annex L) produced by the sub-committee set up last year to develop research proposals and as agreed it will be presented at the meeting by the Committee chairman or his representative. Invitations to participate will be sent by the Netherlands and the Seychelles who are co-sponsoring the meeting.

8.3.2 Other areas—including scientific aspects of their establishment

Anderson presented IWC/33/25 which had been prepared by Australia for the Technical Committee. There will be a meeting (see 8.3.1) in Autumn which is likely to cover research aspects of sanctuaries. It was agreed that individual members of the Committee would pass on their comments directly to Anderson.

8.4 Previously unexploited or little known stocks

For the past two meetings the Committee has attempted to develop a simple protocol giving guidelines useful to those planning or authorising any take under special permit, particularly where damage to a sensitive stock might occur through the sampling process itself. On reviewing one proposal for such a protocol (Annex K, *Rep. int. Whal.*

Table 1

Comparison of four proposals for revised management procedures
(PL = present level, RL = reference or target level, IL = initial level,
RY = replacement yield, MSYL = MSY level, CL = catch limit)

Criterion	Tokyo Appendix 6 (Japan) IWC/33/13: T20–T25	Rome Annex 6 (USA) IWC/33/13: R17–R19	Rome Annex 7 (Iceland) IWC/33/13: R20	Rome Annex 8 (Seychelles) IWC/33/13: R21–R22
Safeguards for assessment uncertainties and for quantity and quality of information.	see footnote 1	Basic CLs are reduced by fixed percentages depending on number of available estimates of PL and RY.	Scientific Committee is to take account of quality of data when assessing likelihood of stock abundance changing appreciably or in a direction reducing RY.	MSY or RY reduced to 90% as an allowance for uncertainties.
Delays in implementing revisions of catch limits or stock classifications[2]	Classification subject to review once every five years. CLs remain unchanged for 5 years in absence of scientific evidence to contrary and will be reviewed once in every 5 years thereafter. Changes in CLs may not exceed 10% of present CL.	Transitional CL calculated as average of the CLs for current year and previous year, but is not to be used if cessation of whaling required.	Changes in CLs to be kept small with a general guideline of not more than 10% per year unless stock will become reduced to protection status (as currently defined) in 5 years, in which case a scheme of catches will be adopted to avoid that reduction.	Permitted catches from unclassified stocks shall be based on such advice as is available from the Scientific and Technical Committees but in any case increase in catches above current levels of catch limit shall not be permitted. May not change CLs by more than 20% each year, unless Scientific Committee advises a greater change is required to prevent stock passing into protected category.
Specific operational guidance for classifying stocks and determining catch limits.	(1) Five categories defined according to state of knowledge of PL, RY, MSYL or IL. Presently protected stocks included in first category. Accounts for expanding stocks.	(1) Uses RL = 70% IL for baleen whales and 95% IL and 50% IL respectively for male and female sperm whales as basis for classification. Five categories defined on basis of knowledge regarding RY, PL, RL. Specific protection category is defined, and whaling cannot be initiated until acceptable estimate of PL. Accounts for expanding stocks.	(1) No specific categories are defined. Protection status remains as currently defined. No RL is established.	(1) Uses MSYL or RL = 70% IL as basis for classifying. Similar to current management procedure in definitions of 5 categories, using position of PL relative to RL as basis. A specific protection category is defined. Accounts for expanding stocks. Acceptable estimate of PL required before whaling begins.
	(2) RY or fixed exploitation rate used as basis for setting CLs. MSYL or IL not essential for determining CLs. Regime takes account of relative position of PL to RL (MSYL or 70% IL), where RL known, in determining adjustments to RY or size of fixed exploitation rates. If PL>RL, sets CL>RY to reduce population to MSYL in 10 years. Protection level at 40% RL for currently utilized stocks and at RL for presently protected stocks.	(2) RY used as basis for setting CLs. If PL>RL sets CL>RY to bring stock to RL in 10 years. If PL<RL, sets CL<RY to return stock to RL in 5 years. If cannot bring back in 5 years then classify as protected.[3]	(2) CLs kept at present levels unless Scientific Committee advises it is likely that stock abundance will change appreciably or in direction which will reduce RY. The words 'likely' and 'appreciably' are undefined.[4]	(2) Uses modified form of current management procedures to set CLs with MSY or RY as basis.[5] If PL<RL, sets CL<RY to bring stock back to RL in 5 years. If initial management stock, sets CL>RY to bring stock to RL in 10 years.
Procedures for smoothing changes in catch limits resulting from new assessments.	Specifies that yearly changes may not exceed 10% of present CL.	Transitional CL calculated as average of the CLs for current year and previous year, but is not to be used if cessation of whaling required.	Changes in CLs to be kept small with a general guideline of no more than 10% per year.	May not change CLs by more than 20% each year, unless Scientific Committee advises a greater change is required to prevent stock passing into protected category.

(continued overleaf)

Table 1 (continued)

Criterion	Tokyo Appendix 6 (Japan) IWC/33/13: T20–T25	Rome Annex 6 (USA) IWC/33/13: R17–R19	Rome Annex 7 (Iceland) IWC/33/13: R20	Rome Annex 8 (Seychelles) IWC/33/13: R21–R22
Allows for flat-topped nature of yield curves in setting target levels.[6]				
Accounts for cumulative losses relative to future gains in replacements.	When PL<RL and the stock is moved towards RL, the length of time to reach RL is not regarded as important. This results in lower changes in catches at the cost of deferring the time at which maximum yield can be taken.[7]	When PL<RL, the stock is moved to reach RL within 5 years. This results in faster recovery of the stock at the cost of greater changes in catches.[7]	see footnote 8	When PL<RL, the stock is moved to reach RL within 5 years. This results in faster recovery of the stock at the cost of greater changes in catches.[7]

[1] Some members asserted that the Japanese proposal (Tokyo Appendix 6) was not responsive to the safeguards criterion since the catch limit would depend only on the best estimate of stock status and would not be affected by assessment uncertainties and by quantity and quality of information.

Other members pointed out that the problems of uncertainties in assessment models and of the quantity and quality of information should be resolved in the process of each stock assessment on a stock-by-stock and case-by-case basis, but not in the management procedures.

[2] Some members noted that errors in assessments may or may not result in delays.

Other members pointed out that the uniform safeguard schemes of Rome Annex 6 (USA) and of Rome Annex 8 (Seychelles) would introduce delays in implementing the revision of catch limits or stock classifications resulting from new assessments.

[3] Some members pointed out that there is ambiguity in setting CLs for Exploitable Expanding Stocks because of the undefined term 'precise' which is the keyword in CL determination (see Rome Annex 6, 10 (a) (2) and 11 (b) (1) and (3)).

Other members responded that the term 'precise' refers to present target level (for stocks in an expanding or expanded environment) but the classification is based on initial target level and hence the procedure is fully specified.

[4] The Committee pointed out that it would be necessary to define the words 'likely' and 'appreciably' to achieve an operational scheme (see Rome Annex 7, (1) and (1) (b)).

[5] The Committee found that no method is provided to set CLs where PL>RL and no estimate of MSY is available (see Rome Annex 8, 10 (i) (a)).

[6] Some members of the Committee were unable to find any characteristics of the proposals with respect to the setting of target levels which related to the allegedly flat-topped nature of yield curves.

Other members pointed out that the Japanese proposal (Tokyo Appendix 6) takes full account of the flat-topped nature of the yield curve for whales which gives the yield close to MSY for a wide range (60–80% IL) of stock levels. Thus they believed the Japanese proposal does not regard the RL as an absolute goal to be achieved within a fixed period of time at all costs, nor does it require the cessation of exploitation even when PL<RL, through a range of stock levels much wider than the other proposals.

[7] The relative effects of the two proposals (Tokyo Appendix 6 versus Rome Annexes 7/8) on the value of the long term catch will depend upon both biological and economic factors and may be different in different cases.

[8] Most members believed that this proposal (Rome Annex 7) was not responsive to this criterion. Some other members believed that the proposal was responsive and that the following annotation should be made: 'Changes in catch limits should be kept small (see Rome Annex 7, (2)).'

Commn 30: 130), the Committee noted that there were two cases with which a protocol must be concerned: currently unexploited stocks with no information available, previously exploited stocks with little recent information available. The Committee agreed that to take into account these two cases any statement on this matter should be entitled: 'insufficiently known stocks that are not now exploited and may or may not have been exploited in the past'. It was noted that the determination of sufficiency of information would be made by the Commission on the advice of the Scientific Committee. Several views were expressed concerning the nature of a simple protocol or procedure. However, after extensive discussion, the Committee was unable to reach any firm conclusions on the nature or content of such a protocol or procedure at this time.

8.5 Role of the Scientific Committee

As last year, the Chairmen of sub-committees were reminded of the Commission's charge that major changes from previous recommendations should be adequately documented and explained in the Committee's Report. The matter is discussed further under Item 4.1 and in Annex I.

9. WHALE STOCKS, STATUS AND REGULATORY MEASURES

9.1 Minke whales (also see Annex E and SC/33/Rep 3)

9.1.1 Southern Hemisphere

This is a summary of the results and recommendations presented in SC/33/Rep 3. Various sub-divisions of the Southern Hemisphere were considered but ultimately results were presented for the present six management Areas. Direct sightings estimates were available for Areas III, IV and V from the IDCR cruises and for Areas I and VI from Japanese surveys. Mark-recapture results were available for Areas III and IV. Results from fitting observed and expected catches were obtained for Areas III–VI; the runs for Area III and one of the runs for Area VI gave no fit to the observed catch data. Using coastal sightings as indices of abundance, fits were obtained for

Areas II and III but these were considered poor and were discarded.

(a) Areas I, III–VI

Taking into account the average proportion of females in the catch by Area, over the past three years, most of the Committee recommends that the catch limits for Areas I and III–VI should be given as either the replacement yield by sex or as a total figure based on the average proportion of females in the catch. The two sets of values are given below:

Recommended catch limits

Area	Catch by sex: Male RY	Catch by sex: Female RY	Total catch limits to help ensure that the female RY is not exceeded
I	601	578	1,179[1]
III	1,519	1,782	2,784
IV	720	836	1,548
V	918	1,008	1,504
VI	840	829	1,669[1]

[1] The proportion of females in the catch is less than 0.5 and so the total is given as the sum of the two replacement yields.

However, some members of the Committee shared the concerns expressed in Annex M, regarding the problem faced for several years in assessing Southern Hemisphere minke whale stocks, in particular inconsistencies of stock estimates between methods and years and uncertainties in estimating RY. In view of this those members believe that the Commission should adopt caution in setting catch limits for these stocks and in particular not set catch limits greater than those adopted last year.

(b) Area II

No agreed stock size was found for Area II. Some members believed that as the large value (127,000—1982 exploitable stock size calculated by the programme BALEEN) was disregarded an extrapolation procedure provided a reasonable estimate for the population (56,358). They noted the lack of trend in the CPUE series. Estimates of Replacement Yield by sex and by total allowing for unbalanced catches by sex are:

Male RY: 856; Female RY: 1,092; Total limits: 1,583

These values for Area II are slightly different from those calculated in SC/33/Rep 3 for the reasons documented in Annex N.

Some other members noted the inconsistent results obtained from last year's and this year's attempts to estimate abundance by extrapolating estimates from one Area to another and concluded that the use of relative abundance indices was an inappropriate procedure for estimating the stock size of Area II. They believed that in the absence of a proper assessment it was not possible to provide scientific advice as to catch limits for Area II.

The Committee noted that a proposed IDCR cruise to Area II in 1981/82 was likely to provide a better basis for assessments next year.

(c) Allowance system

The Committee was unable to agree on a recommendation regarding the allowance system.

(d) Comparison with last year's results

The Committee draws the Commission's attention to the following reasons for the differences between the estimates given above and those obtained last year. Comparisons can only be made for Areas II, IV and VI for which advice was provided last year (see Table at foot of page).

For Area IV the lower stock size is particularly due to an estimate from the programme BALEEN relatively lower than the sightings and marking estimates and which has a much narrower confidence interval than last year. The increase in stock size in Area VI is due to the adoption of the results from the programme BALEEN and the rejection, in comparison, of the previous point estimate based on sightings. The general increase in the percentage that RY is of the total stock is due largely to the adoption of a lower value for M, but the specific pattern of the catches is also important (see Area IV).

(e) Other recommendations

The Committee makes the following recommendations with respect to obtaining improved data for the Brazilian minke whaling operations:

(i) the catcher log books should be examined from 1966 onwards to determine the number of days and hours worked in each month. The number of hours worked each month could be ascertained as the time that the catcher left port until it returned;
(ii) the identity of the vessels which operated during the early period of minke whaling and their characteristics should be clarified;
(iii) the locations of the catches for each month for at least some of the years should be determined. This could be in the form of catch per 5° square;
(iv) it can be seen from the time budget data that the time spent travelling to the whaling ground varies from month to month and between the 1979 and 1980 seasons. Whether this navigation time includes an element of searching should be clarified, i.e. is it the time taken from leaving port to start chasing the first whale? If this is so then it would be more appropriate to record searching time as beginning at the time when the vessel reaches the 100 fathom line since this is reported to be the edge of the whaling ground;
(v) there are some discrepancies between the BIWS length statistics and the statistics presented in

Area	Exploitable population: 1981 calculated in 1980[1]	Exploitable population: 1982 calculated in 1981	Total replacement yield: 1980	Total replacement yield: 1981	RY as a percent of total stock: 1980	RY as a percent of total stock: 1981	RY as a percent of total stock: 1980 with M = 0.0687
III	74,837	88,218	1,534	3,301	2.05	3.74	3.86
IV	80,579	44,376	2,869	1,556	3.56	3.51	2.85
VI	26,892	54,142	590	1,669	2.19	3.08	2.99

[1] *Rep. int. Whal. Commn* 31: 120–121, tables 1–3.

SC/33/ProgRep Brazil and these should be reconciled if possible (especially the years 1968, 1977 and 1980). (The 1966, 1967, 1969 and 1970 length distributions are not published in the BIWS);

(vi) chasing times for sperm whales during the seasons 1979 and 1980 should be determined;

(vii) basic data such as sea state, visibility and wind force throughout the last few seasons should be compiled to determine whether any corrections for these factors may be required.

The Committee also recommends that (a) further work on the effect of the random movement of whales on sightings estimates be carried out before the next meeting; and (b) further work regarding the implementation of new assessment (particularly Area α) and management Areas be carried out before the next meeting.

9.1.2 North Pacific

It was agreed to retain the present three stock areas and the Committee recommends that effort be continued to obtain samples for comparative biochemical studies.

(i) Sea of Japan-Yellow Sea-East China Sea

In 1979 the Commission, on the advice of the Scientific Committee, established a block quota of 3,634 whales for the period of 1980/84 with a maximum of 940 in any one year. The Committee agreed that it had no significant new information on which to give any additional advice to that which was provided last year.

The Committee recommends that past RoK log-book data be analysed to obtain an index of boat-days. It also recommends that age and reproductive material be collected from this stock.

(ii) Okhotsk Sea-West Pacific stock

As last year the Committee recommends, on the basis of the continuing stability of the CPUE, that the block quota of 1,678 for the period 1980–84 be retained with a maximum catch of 421 in any one year, and that the stock continue to be classified as a SMS.

It also recommends that an attempt be made to refine the long series of CPUE data.

There is no undue imbalance between the sexes in the catches from either of these stocks.

(iii) Remainder of the North Pacific

Given the lack of data for assessments the Committee recommends that the stock remain classified as an IMS with zero catch limit.

It was noted that the precise boundaries of the North Pacific stocks are not defined and it was agreed that the definitions should be provided at the next meeting.

9.1.3 North Atlantic

Further mark returns supported the present definition of the Northeastern stock. There is no further information on the other stocks and it was agreed to retain the same four stock Areas as last year.

(i) Northeastern stock

Results from marking and recaptures give an estimate of total stock size of 121,000 and an available stock size of 60,532. Noting this figure, simulation studies and the lack of trend in CPUE data, the Committee recommends that this stock should remain classified as a SMS with a catch limit of 1,790. It also recommends that an attempt be made to find a CPUE series that could incorporate the more refined data of recent years and that these data should then be used in the assessment studies.

The percentage of females in the catch of 1980 was 56.3%. Restrictions on operations, by time and location, have been in force for two years and it is expected that this will reduce the previous high percentage of females in the catch.

(ii) Central stock

New biological and catch per effort data are available from Icelandic catches and Norwegian catches but refined indices of abundance have only been available for recent years. In response to recommendations made last year a marking programme was started but bad weather prevented any whales being marked. The programme will continue in 1981.

Noting the lack of trend in the series of CPUE data the Committee recommends, as last year, that the stock be provisionally classified as a SMS with a catch limit of 320. There is no undue imbalance between the sexes in the catch from this stock.

(iii) West Greenland stock

New biological and catch per effort data are available for this stock. Marking was attempted in 1980 but only one minke whale was marked. Given the lack of trend in the CPUE series the Committee recommends, as last year, that the stock remain classified as a SMS with a block quota of 1,778 over the period 1981–85 with a maximum of 444 in any one year. It also recommends that an attempt be made to reconcile the two sets of CPUE given in *Rep. int. Whal. Commn* 31: 108.

No data are available on the proportion of females in the 1980 catch by the Greenlanders, but *Rep. int. Whal. Commn* 30: 195 gives an average figure of about 0.68 since 1950. The proportion in the Norwegian catch was 0.81 in 1980. Catch data by month and region over the period 1976–80 were investigated and it is the Committee's view that there is no simple operational way of reducing this high percentage.

(iv) Canadian east coast stock

There is no new information on this stock and the Committee recommends, as last year, that the stock remains unclassified with a zero catch limit pending satisfactory estimates of stock size.

9.1.4 North Indian Ocean stocks

There is no information on which to designate or to set catch limits. The Committee recommends that minke whales in this region be classified as IMS with zero catch limits pending satisfactory estimates of stock size.

9.1.5 General

It is noted that next year, the Committee will pay specific attention to classifying the Northern Hemisphere minke whale stocks in a coherent and consistent way.

9.2 Sperm whales

The Committee was informed that when the techniques of *Rep. int. Whal. Commn* 31:747–60 were applied to North Pacific pelagic sperm whale catch data at the 1980 Annual Meeting, a data handling error affecting the calculation of relative catchabilities (selectivities) had been made, as outlined in Annex D. When this error was corrected, it was found that a better fit to the data had been obtained with the incorrectly calculated selectivities. This implied that the technique was failing to find the best fit to the data.

Two new techniques have been developed since the last meeting, in which selectivities are assumed to be purely length specific (SC/33/Sp3) or age specific (SC/33/Sp5). The sub-committee agreed that, prior to the use of either technique for assessments during this meeting, both should be subject to close examination. The report of a subgroup set up to examine these techniques is given in Annex D, Appendix 2; further comment is to be found in Annex D, Section 5.

As the suitability for use of either method depends on the catch and associated biological data available for each stock, the sub-committee agreed that their use should be examined on a stock by stock basis. The sub-committee also agreed that the results of the sensitivity tests recommended in Annex D, Appendix 2 should be examined for each stock for which either method is used.

The Committee agreed that a working group should correspond during the following year on further development of these techniques, as proposed in Annex D, Section 5.

9.2.1 Southern Hemisphere, Division 1–8

Because of lack of time, it was not possible to undertake assessments of these stocks.

9.2.2 Southern Hemisphere, Division 9

Because of lack of time, it was not possible to undertake assessments of this stock.

9.2.3 North Pacific

Although there were no biological reasons to change the existing stock boundary shown in *Rep. int. Whal. Commn* (Special Issue 2): 67 Fig. 1, due to geographical imprecision in the recording of catch length frequencies the Committee agreed that a stock assessment for the Western North Pacific stock of sperm whales should be attempted using a boundary at 160°W. Population estimates for a Western Stock with this boundary are likely to be slightly higher than those obtained using the old boundary.

For population estimation purposes, the biological parameters shown in Table 1, Annex D were adopted.

The Committee agreed that estimates of population size for the Western Stock could not be calculated using catch and effort data, due to still unresolved difficulties in their interpretation and pooling (see *Rep. int. Whal. Commn* 31: 81).

An *ad hoc* working group was set up to examine the estimates obtained using the two estimation techniques described in Annex D. Their report is given in Annex O. The Committee noted that after a lengthy and detailed discussion, two alternative views were expressed in the *ad hoc* group:

> some of the members felt that, even though strict comparison was not possible, a better fit had been obtained using the CB technique than had been obtained using the ST technique, as indicated by comparing the sum of the three entries in the SS (sum of squares) column of Table 1, Appendix 1 with the approximate minimum sum of squares indicated in Figs 1 and 2 of Appendix 2. Believing that the estimates obtained using the CB technique satisfied each of the three agreed criteria (in Annex D) and that the ST technique had satisfied none of these criteria, they felt that the initial and 1981 population estimates obtained using this technique should be adopted;
>
> others believed that it was not possible to compare the results any further or to determine the appropriateness of either model from sums of squares because no direct comparisons of results on the same data series were available. They believed that a further analysis of the two models should involve:
>
> (i) execution of the two programs employing the same data series, so that results were strictly comparable;
> (ii) careful study of the available data sets and further refinement if possible; and
> (iii) a check of the behaviour of each model relevant to the availability and validity of the data sets.

Last year the Committee had agreed that in the model validation process, comparisons of observed and expected pregnancy rates should be made for Divisions 3, 5 and 9. Comparisons using the revised CB method have been made between predicted and observed pregnancy rates in the Western North Pacific and in Division 5. The Committee agreed that similar comparisons should be made for the CB method for Divisions 3 and 9, and for the Western North Pacific and Divisions 3, 5 and 9 for the ST technique.

Best and Clark thought neither method could be judged on the basis of predicted pregnancy rates, as these were determined entirely by the sperm whale model and the starting population estimate. While theoretical and predicted pregnancy rates might therefore be taken to choose one population estimate over another, they believed there was so much noise in the data and so much uncertainty concerning the model that this was not practical.

In these circumstances the Committee, being unable to resolve the differences between these views, agreed that it was unable to provide unequivocal advice to the Commission on stock size, classification and catch limits for the Western North Pacific stock.

Some members believed that rather than making hasty recommendations based on incomplete conclusions as was the case last year, efforts should be made to resolve the differences between the alternative views as soon as possible.

Other members believed that applying the CB technique leads to results from which it can be concluded on the basis of the same arguments that the recommendations made in 1980 by the Committee (with Japanese scientists dissenting) should again be submitted to the Commission, namely 'that males be classified as a Protected Stock with a zero catch limit, and that a zero catch limit be set for females'.

While accepting that the CB estimates of 1910 and 1981 population size should be adopted, yet others believed that it was inappropriate at this stage to proceed to stock classification and catch limits in view of the current uncertainty in the sperm whale model and its parameters with regard to predictions of pregnancy rates.

9.2.4 North Atlantic

In the absence of new data, the Committee agreed to treat North Atlantic sperm whales as one stock for assessment purposes. As last year, in the absence of direct data, the parameters for the Southern Hemisphere shown in Table 2, Annex D, were adopted.

Population estimation was attempted using Icelandic catch length data and new CPUE data from Spain and the Azores using the POPDYN procedure with results as shown in Table 3 of Annex D. However, due to uncertainties in the assumption in the methods used and the biological parameters adopted, the Committee considered that none of the population estimates were reliable.

The Committee agreed that the new catch and effort data available at this meeting support the conclusions reached last year that the stocks of both males and females have declined. However, it was unable to agree on the extent of that decline. Some members believed that there had been a serious decline in stock sizes, while others believed such a conclusion was unwarranted, and that the stocks may be near optimal levels.

The Committee agreed that the data and population estimates did suggest a greater decline in male than in female stocks. It recommends caution in the setting of catch limits for this stock, and that they should not exceed those set by the Commission last year.

However, several members expressed the view that the CPUE data for the Azores and Spain taken together showed that both males and females had been reduced to well below protection level and should be thus classified; evidence for this is presented in Annex P, paragraphs 8 and 9.

9.3 Other baleen whales (also see Annex F)

9.3.1 Fin whales, Southern Hemisphere, Areas I–V

The Committee agreed that for the time being there is no reason to change last year's projections (*Rep. int. Whal. Commn* 31: 129). It therefore recommends that all stocks should remain protected.

9.3.2 Fin whales, Southern Hemisphere, Area VI

In the absence of any information to alter the assessment carried out last year (*Ibid* p. 122), the Committee recommends that this stock should remain protected.

9.3.3 Fin whales, North Pacific

The Committee recieved no information to change its decision of last year and recommends that this species remains protected in the North Pacific.

9.3.4 Fin whales, North Atlantic

Though some new information was available on stock identification, no changes in stock definition are recommended. In the stock analyses, new information was available for and attention was therefore focused on, the East Greenland – Iceland and Spain – Portugal – British Isles stocks.

(i) East Greenland – Iceland stock

This was again analysed by a model similar to BALEEN with, however, improved CPUE data and better input values for the biological parameters, although these are in part derived from Southern Hemisphere values. Last year there were two sets of CPUE data and uncertainty over the biological parameters; the analyses led to two quite different results and the Committee was unable to agree on a single recommendation.

This year the several model results are rather similar and imply that the classification should remain Sustained Management. The catch limit in the past has been based on the average catch over a long period under the assumption that the CPUE was stable. The more detailed analysis referred to above shows that this is not correct. However, the model does provide an estimate of replacement yield of 158. The Committee therefore recommends that this stock be classified as a Sustained Management Stock with a catch limit of 158. In view of the fact that some estimates of stock size were below the conventional MSY level, the Committee recommends that catch limits be set one year at a time and that the stock be carefully monitored.

(ii) Spain – Portugal – British Isles stock

This was analysed primarily by methods similar to those used in the last two years though additional catch and effort information was available. The Committee was still unable to carry out a proper standardisation of recent effort data, so the analyses depend on catch and effort series of the 1920s. They are improved in using more complete catch data and additional runs have been made to explore alternative possibilities. On the basis of what some judge to be the best output of the model they recommend that the stock be classified SMS with catch limit 210.

Other members believed that the assessments attempted contained such uncertainties and problems that they did not provide a scientific basis for recommendations either for classification or for catch limits. They noted the average annual catch from Spanish land stations was 137 in the period 1968–77 during which the catch regime was apparently more or less stable; if the Commission wishes to set a catch limit on the basis of recent stable catches they believe that 137 would be an appropriate number.

(iii) Nova Scotia stock

In the absence of any new information, the Committee recommends that this stock remains protected.

(iv) West Greenland stock

The Committee recommends that this stock remains classified as a Sustained Management stock with a catch limit of 6.

(v) West Norway stock

The Committee recommends that this stock remains protected.

(vi) Newfoundland-Labrador stock (N-L) and (vii) North Norway stock (N-N)

The Committee was unable to agree on recommendations for these presently unexploited stocks. Three proposals were supported:

(a) that the stocks should be unclassified and retain the catch limits of last year: N-L, 90; N-N, 61;
(b) that the stocks should be unclassified with catch limits of zero;
(c) that the stocks should be classified as Initial Management Stocks with catch limits of zero.

The Committee noted that next year it would pay specific attention to classifying the North Atlantic fin whale stocks in a coherent and consistent way.

9.3.5 Sei whales, Southern Hemisphere

A relatively large number of sei whales were seen by Japanese scouting vessels in Area I off Chile last season (SC/33/ProgRep Japan) but no estimate of abundance was obtained. The Committee had no new information to alter its reassessment for Area I carried out last year (*Rep. int. Whal. Commn* 31: 129) and recommends that this stock remains protected. Similarly there were no new data for

Areas II–VI and the Committee recommends that these also remain protected.

9.3.6 Sei whales, North Pacific

Continuing Japanese sightings cruises suggest a slow recovery of the stock. The Committee recommends that this stock remains protected.

9.3.7 Sei whales, North Atlantic

(i) Iceland stock

In the absence of any new assessment, the Committee recommends that this stock remains classified as a Sustained Management Stock with a block quota of 504, for the period 1980–85, the annual catch not to exceed 100.

(iii) Nova Scotia stock

There was no new information concerning this stock and the Committee recommends that it should remain protected.

(iii) Northeast Atlantic Stock (or stocks)

Lacking any assessment, the Committee was unable to recommend a classification or catch limit.

9.3.8 Bryde's whales, Southern Hemisphere

The Committee clarified the boundaries proposed last year and suggested two new stocks—South African inshore and North Indian Ocean.

The proposed boundaries are shown in Annex F, Fig. 1.

The two proposed new stock areas are defined as follows:

(i) the South African inshore stock area extends 30nm seawards off the southeast coast of South Africa from 25°S latitude down and around the coast to 25°E longitude;

(ii) the North Indian stock area is that part of the Indian Ocean north of the equator.

All Bryde's whale stock boundaries are tentative.

Only the Peruvian stock was assessed at this year's meeting, primarily using updated sightings estimates and models similar to those used for North Pacific Bryde's whale stocks. The Committee recommends that this stock is classified as an Initial Management Stock with a catch limit of 244. Other classifications and catch limits remain unchanged and are given in Annex F, Table 4.

9.3.9 Bryde's whales, North Pacific

The Committee clarified the boundaries of these stocks as shown in Annex F, Fig. 1. The East China Sea stock area is divided from the western North Pacific stock area by the Ryuku Island chain. These stock boundaries are tentative. The East China Sea stock is presently classified as a Sustained Management Stock with a catch limit of 19 based on average annual catches during the period 1955–74 but no catches have been taken since. As the Scientific Committee has never assessed this stock, the Commission may wish to move it to unclassified status, but in any case the present catch limit should not exceed 19.

The Western North Pacific stock was reanalysed and updated along similar lines to those carried out last year. The reanalysis results in a very small change from last year's catch limit of 510. The Committee recommends that this stock be reclassified as IMS with a catch limit of 507. The Eastern North Pacific stock has never been exploited and should remain an Initial Management Stock with a catch limit of zero.

9.3.10 Research and other proposals

The Committee notes with approval the plan of Spain to undertake tagging and perhaps sighting later in 1981. It believes that continued sighting and tagging on the Peru Bryde's whale stock would be useful.

The Committee recommends that the Commission support an analysis of effort data using log book records from Antarctic whaling before 1970 and utilising this in a reanalysis of southern fin whale stocks (see Item 7.2.4).

It is recommended that the Republic of Korea continues to obtain photographs and baleen material from any large whales taken by its operations but the Committee sees no need for the Commission to send an expert to Korea to assist in identification of these animals as proposed in 1979 and 1980.

9.4 Other Protected Species and Aboriginal/Subsistence whaling

9.4.1 Bowhead whales

The Committee noted that the Alaskan Eskimo harvest for 1980 was 16 landed and 34 struck (IWC quota 18 landed and 26 struck).

The Committee noted with great concern that despite the official closure of the 1980 hunt on 27 May, five crews from Kaktovik and Nuiqsut villages had engaged in bowhead whaling during September and October, during which 3 bowheads were struck and 1 landed. The IWC quota had thus been exceeded by 8 strikes.

In the Spring 1981 hunt, 14 animals had been landed and 25 struck.

During the Spring 1981 migration, the total number of whales passing the ice camps was estimated to be between 2,025 and 2,459 animals, with a best estimate of 2,242 animals, depending on whether conditional sightings were classed as duplicates or new whales respectively. These figures include allowance for periods when no watch was kept, and as some of these were substantial it is possible that the interpolations used were imprecise. However some of these periods coincided with times when the lead was closed. Hence the 1978 estimate of 1,783 to 2,864 animals for this stock is still considered the most accurate.

An updated estimate of the 1848 population size of the Bering/Chukchi Sea stock of bowheads was 9,000 to 18,000. However, the magnitude of the early bowhead catch (about 15,000 in the first four decades of the pelagic fishery) suggested to the Committee that the initial population size probably lay nearer the top end of the range given than the lower.

The present population could therefore be estimated as 10 to 32% of its initial size, taking the two extremes of the highest N1978 estimate and lowest N1848 value and the lowest N1978 estimate and highest N1848 value. Because of the magnitude of the early pelagic kill, the Committee believed that the present population size is more likely to be nearer 10% than 32% of its initial size.

In considering the status of this population, the Committee drew attention to the following:

(a) the best estimate of present gross recruitment rate (from aerial calf counts) is 3.4%;

(b) assuming 75% mortality of struck and lost animals the 1980 harvest represents 1.3% of the best estimate of present population size (2,264).

Given the estimates of adult natural mortality rate made for other baleen whale species apart from minke whales (4–8.5%), the Committee concluded that even if there is no kill the population may only be stable or even decreasing. Therefore any kill whatsoever will increase the risk of this already small population declining further. The Committee reaffirms its view of the last four years that to reduce the probability of extinction of the population, no catch should be taken. The Committee therefore recommends as the only safe course for the Commission that the catch limit be zero.

Given that the Commission last year decided to set a three-year quota for the Bering Sea bowhead population, and if it decides to continue this regime, the Committee strongly recommends that removals of any kind should be (a) of sexually immature animals (less than 12m long) in order to maximize reproduction in the short term and (b) taken in a manner that will reduce the struck and lost rate to zero to minimize total removals.

The Committee recommends that other populations of the species should also be protected from all hunting.

9.4.2 Right whales

The Committee believes that apart from the remnant of the Okhotsk Sea stock, the continued existence of viable stocks of right whales in the rest of the North Pacific is in doubt.

The Committee recommends that the People's Republic of China should be asked to provide data on the status of right whales off China together with details of any past catches.

In the North Atlantic, 26 right whales were seen in 1980 in the Bay of Fundy, together with another possible 40 outside the Bay. The Committee recommends that surveys of this population be continued, especially in view of proposals for accelerated industrial development in the area.

Seventy-four right whales were seen off Western Australia and 166 right whales off South Africa during aerial surveys in 1980.

The Committee recommends that sightings vessels in transit to and from the Antarctic should undertake systematic surveys in the following area where concentrations of right whales are believed to occur, i.e. 40°–50°S, 170°–130°E, from November to February.

No information was available from Argentina on the status of this species off Peninsula Valdez. The Committee repeats its requests of last year for information on population size and trends to be made available, and recommends that the Secretary contact the relevant Argentine authorities.

The Committee further recommends that:

(a) all right whale stocks should remain protected; and
(b) as last year, studies of historical records should be undertaken to reconstruct the pattern of exploitation in the eighteenth and nineteenth centuries.

9.4.3 Blue whales

The Committee recommends that:

(a) blue whale stocks should remain protected in all oceans; and
(b) that a re-analysis of Southern Hemisphere blue whale stocks (both 'normal'—Series B and C—and pigmy—Series D) should be undertaken. The latter study will be facilitated now that catch and effort data for the Southern Hemisphere are available on computer tape at the IWC. This study can be executed at the same time as the proposed log-book study for Southern Hemisphere fin whales (see Item 7.2.4).

9.4.4 Humpback whales

A new estimate of the initial population size for the northwest Atlantic humpback whale of 4,230 was presented in SC/33/PS14, based on a historical reconstruction of the catch. A workshop held in New England during 1980 (SC/33/PS9) concluded that the current population of humpback whales overwintering in the West Indies is at least 2,000. This population is therefore substantially below its initial level.

A total of 13 humpback whales was landed in Greenland in 1980. It was explained that in early July reports of the landing of 10 humpbacks were received, and although an immediate instruction was given to stop catching, later reports revealed that in fact 12 had been caught before the date on which catching ceased. One further humpback was landed after the season had been closed.

On the eastern coast of Newfoundland during 1980 there were 61 reported encounters of humpback whales with fishing gear, resulting in the known death of 17 animals. Due to under-reporting it was estimated that 20 humpback whales might have died. Warning devices attached to gear (principally visual and either passive or active acoustic devices) had not proved entirely successful in reducing the rate of entanglement.

The Committee noted that (excluding possible catches at Bequia and St Lucia/St Vincent, for which no data were available) the estimated total removals for humpback whales in the North Atlantic in 1980 was 33. This represents 1.7% of the lowest reasonable estimate of current population size. A conservative estimate of gross recruitment rate might be the number of calves seen on Silver, Navidad and Mouchoir banks in 1980 (57—SC/33/PS2) as a proportion of the minimum population estimate of 2,000, i.e. *ca.* 3%. Present estimated removals are therefore a significant proportion of this recruitment rate. As the present population is believed to be still substantially below its initial level, the Committee recommends that every effort be made to reduce the number of removals. In spite of Canadian investigations and efforts towards solving the problem, the number of reported deaths due to entanglement in fishing gear has remained at a high level. The Committee recommends the continuation of the study of the incidence of net entanglements and means to reduce the mortality resulting therefrom. Until such time as more reliable estimates of population size, recruitment, trends in abundance, stock identity and loss rates in the fishery are available, the Committee recommends that the exemption for a Greenland catch of 10 humpback whales be removed (as previously recommended). The Secretary is requested to contact the responsible authorities in Bequia, St Lucia and St Vincent to determine whether humpback whaling is continuing.

The Committee also recommends that:

(a) all humpback whale stocks should remain protected,
(b) the current status of the humpback whale stocks off Peru should be surveyed as soon as possible,
(c) all scientists with access to either live or dead humpback whales should be encouraged to attempt to obtain photographs of the colour pattern of the ventral surface of the tail flukes, and to exchange these photographs with other interested observers in the area. A catalogue of 1,000 fluke photographs is already available for the northwest Atlantic, and the comparison of photographs is proving a useful method of identifying individuals.

9.4.5 Gray whales

The Soviet catch of gray whales for its aboriginal people totalled 179 animals in 1980. Females again predominated in the catch (71.4%). The USSR was concerned about this imbalance, and would work towards adjusting the sex-ratio in the catch and reducing the proportion of pregnant females to the extent possible. The Committee urges them to continue investigating means by which the sex-ratio of the catch could be adjusted, although the inherent difficulties of the situation are recognised. The Committee welcomes the substantial increase in the amount of information and materials collected from the Soviet harvest in 1980, especially the age and reproductive material, and the information on feeding and behaviour. The Committee recommends continuation of studies in the breeding lagoons, as well as in the sea in their immediate vicinity, in order to understand the pattern of habitat usage by gray whales during their breeding season.

Two gray whales were landed by US eskimos in 1980 (SC/33/ProgRep USA), so that total known removals from the stock were 181. This represents 1.16% of the best estimate of current size (15,587 animals). A new simulation model of the population history of the Californian gray whale indicated that the initial population size might have been 24,000 animals, reduced to just under 12,000 by 1800. If the estimate of initial stock size is accepted, then the present population is at 64.9% of its initial level, and 13% above the estimated MSY level. According to the model, the predicted net recruitment at this population level is about 3.5% (compared to an average rate of population increase observed between 1967 and 1980 of 3.7%). Consequently the population should continue to increase despite the current level of the harvest.

The Committee recommends that the Eastern Pacific stock of gray whales should remain in the Sustained Management category. Any catch should be held at the same level as the average of the last five years (i.e. 179 animals), for the following reasons:

(a) the high proportion of females in the catch;
(b) the present assessment of initial stock size is very sensitive to certain parameters such as the size of the aboriginal catch prior to 1800; and
(c) further growth of this stock should be encouraged in order to increase the possibility of repopulation of the area once occupied by the Korean stock.

Because the Californian gray whale stock is the stock for which the most information on recovery rates is available, the Committee strongly recommends that periodic systematic counts of gray whales (possibly restricted to a key period of the migration wave) should be continued, in order to maintain adequate monitoring of the stock.

9.4.6 Consideration of protected species

In view of the matters raised under Commission Agenda Item 9, the Committee reviewed the degree to which the actions of the Commission in extending protection have resulted in the intended recovery of the species concerned.

The Committee concluded that there were essentially two categories of protected stocks, those that had been or were being systematically monitored by programmes directed towards measuring population trends (Table 2) and those for which only non-systematic or incidental observations were available. There were only 11 stocks which were being or had been systematically monitored. It was important to note that all these studies had commenced relatively recently, the longest series dating from 1967. Only three were believed to provide evidence of a significant trend, and all indicated an increase. The remaining 8 stocks had only been studied from 1 to 5 years, so that it was too soon to reach reliable or significant conclusions.

There are a number of incidental observations available from scouting vessels, whale catchers and other vessels, that have not been collected in a systematic fashion (at least as regards the protected species). These results are obviously more difficult to interpret, although some attempts have been made in the past. In some cases (Eastern North Pacific right whales, Spitsbergen bowheads) sightings are extremely few and any recovery of the stock is obviously doubtful. On the other hand there are indications that some populations may be increasing under protection (e.g. Californian blue whales). For most of the others the data base is insufficient or too erratic to allow any interpretation of trends.

The Committee recognises the importance of this subject, and recommends that it form a priority item for next year's agenda for this group. National groups are encouraged to analyse any available historical or recent data for a protected stock that will clarify (a) initial unexploited population levels, (b) trends in population

Table 2

Stocks of protected species for which systematic monitoring is being or has been executed.

Species	Stock	Method	Period covered	Annual trend[1]	Source
Gray whale	East Pacific	Shore counts	1967–79	+2.5%[2]	Reilly *et al.* (SC/32/PS4)
Gray whale	East Pacific (Mexico)	Aerial and shore counts		*	Fleischer (pers. comm.)
Right whale	Southern Africa	Aerial counts	1969–79	+7%	Best (SC/32/PS4)
Right whale	Western Australia	Aerial counts	1976–	*	SC/33/ProgRep Australia
Right whale	Argentina	Aerial and shore counts	1970?–	+ ?	Payne (unpubl.)
Right whale	North Atlantic	Aerial counts	1980–	*	Tillman (pers. comm.)
Bowhead	Bering/Chukchi Seas	Shore counts	1978–	*	SC/33/PS4
Humpback	Western Australia	Aerial counts	1976–	*	SC/33/ProgRep Australia
Humpback	Eastern Australia	Aerial and shore counts	1978–	*	SC/33/ProgRep Australia
Humpback	Northwest Atlantic	Aerial counts	1980–	*	Tillman (pers. comm.)
Humpback	Northwest Atlantic	Shipboard counts	1977–	*	SC/33/PS9
All species	North Pacific	Shipboard counts	1978–	*	Yamamura (pers. comm.)

[1] Over the period of monitoring.
[2] If simultaneous removals considered, trend becomes +3.7%.
* Insufficient information available (see text).

size, or (c) current population levels, the results to be submitted to the 1982 meeting.

9.4.7 Aboriginal/subsistence fisheries

The Committee considered the five items from the Agenda of the forthcoming meeting of the *ad hoc* Technical Committee Working Group on Subsistence Whaling, on which it believed that scientific advice might be required:

Item 7.1 Scientific Committee advice on population sizes, trends, and yields of stocks of whales subject to aboriginal hunting in relation to natural and manmade factors directly affecting them.

The Committee considered that such advice should be provided on a stock-by-stock basis.

Item 7.2 Consideration of catch limits where on biological grounds catches should be reduced or suspended.

The Committee considered that it was unable to provide any general criteria for such catches because (a) they should be considered on a stock-by-stock basis, (b) the size of the minimum viable population for each species was unknown, and (c) adverse environmental changes could have considerable impact on populations depleted to very low levels.

Item 8.1 General consideration of data gathering and reporting requirements.

In recognition of the particular difficulties surrounding data collection in these harvests, the Committee recommends the following list of data requirements.

A. *Essential data* (from each whale landed)
1. Location, date and time of kill
2. Species
3. Length
4. Sex
5. If female, presence of milk
6. If female, presence of foetus
7. Degree of stomach fill

Extra data
8. Length and sex of foetus
9. Collection and preservation of both ovaries
10. Collection of at least one ear plug, tooth or bulla
11. Collection of an eyeball (frozen)
12. Collection of sample of stomach contents.

With regard to the latter biological data, the Committee strongly recommends that the maximum material possible should be collected from the landed catch in any aboriginal fishery, as often such catches may be the only source of material for the species concerned.

B. In addition, the Committee recommends that a simple form of primary effort measurement, such as number of boats or hunters involved and the length of the season, should be reported, and that the type of effort unit used should be stated.

C. Struck-and-lost rates in any aboriginal/subsistence fishery should be specified as follows:
(1) Struck, known to be killed but lost;
(2) Struck, lost alive but believed mortally wounded;
(3) Struck, lost alive but believed not to be mortally wounded.

(b) Research and monitoring requirements

The Committee concluded that the following were the biological requirements of any basic management scheme for an aboriginal/subsistence harvest, and recommends their inclusion in such a scheme.

Essential requirements
(1) Knowledge of population size and identity;
(2) Estimate of yield;
(3) Knowledge of population trends.

Extra data
(4) Population status (relative to initial).

Items 10.1 and 10.2 Developing of guidelines for the management of subsistence harvest stocks—Biological considerations—Research efforts.

Although some members of the Committee felt that it should be prepared to comment on these Items, other members felt that it was inappropriate to comment on them at this stage.

10. SMALL CETACEANS
(also see Annex H)

Directed and incidental catches by IWC members of small cetaceans reported to the Scientific Committee, BIWS or published are listed in Appendix 3 of Annex H. The estimated total is 112,006 dolphins, porpoise and small whales. The small cetaceans sub-committee concentrated in its deliberations on the white whale and narwhal (in response to the explicit request by Canada) and on the killer whale (as proposed last year). Other species and fisheries were only surveyed for new developments.

10.1 Status of stocks

10.1.1. Northern bottlenose whale

No new information was available on this Protected Stock.

10.1.2 White whale

The Committee reviewed available information for white whale stocks in Cook Inlet, Bering Sea, Chukchi Sea, Beaufort Sea, Mackenzie Delta, Barents Sea, White Sea, Okhotsk Sea and High Arctic and the Western Hudson Bay stock but concentrated its attention on the heavily-impacted Eastern Hudson Bay, Ungava Bay and Cumberland Sound stocks.

The Committee recommended last year that the Cumberland Sound stock be classified as a Protected Stock, with zero catch limit. That recommendation was not acted upon by the Commission, and 43 whales were taken from the stock in 1980. Present size is estimated at 600–700, approximately 12–14% of original. Because the available information is not adequate for estimating net reproductive rate, e.g. there is no data-based estimate of natural mortality rate, the Committee can make no estimate of replacement yield or MSY level. In any case, the stock is far below the MSY level and should be fully protected (see Recommendations below).

The situation is similar for the Ungava Bay stock (at <500 whales, estimated at <20% of original) and the Eastern Hudson Bay stock (at <500 whales, estimated at <10%), and these stocks should also be fully protected.

The Western Hudson Bay stock is estimated to be at 80–90% of its original size of about 10,000. Estimates of the original size are not available for the other stocks presently exploited by Canada (High Arctic and Beaufort-Mackenzie) but they are thought to be closer to original size than are the three depleted stocks discussed above and not in a crisis situation. Recent takes ranged from 1.0 to 5.6% of present population size (see Table 1 in Annex H).

Because of the lack of estimates of net reproductive rate it was not possible to make the 5-year projections requested by the Canadian government. It is clear, however, that continued takes of recent size (ranging to 44% or more of present population) may well result in extinction of some stocks, in particular the Ungava Bay and eastern Hudson Bay stocks, in a very few years. In part, the problem seems to be that the hunters have recently acquired very powerful outboard engines that allow them to reach the estuarine areas quickly, making the hunt more practical than it was formerly.

In addition to recommending protection for some stocks of white whales, the Committee urges Canada and the other nations taking white whales to collect and report more complete catch statistics and to expand research to better define stocks and estimate vital rates (see Recommendations).

10.1.3 Narwhal

There was no new information available that would allow assessment of status of stocks, estimation of replacement or other yields, or the projections requested by Canada. There is persuasive evidence for the existence of one main stock that winters in Davis Strait and summers in northern Greenland and the Lancaster Sound region, with possibly a very much smaller stock inhabiting northwestern Hudson Bay. Present takes from the main stock are thought to be on the order of 3–6% of the present population of up to 20,000. Research of the type described above for the white whale is also needed for this species, although the situation is less urgent.

10.1.4 Killer whale

The Committee received and reviewed the report of the recent Workshop on Identity, Structure and Vital Rates of Killer Whale Populations (SC/33/Rep 4).

The workshop concluded that while killer whales may be found in nearly every area of the world's oceans, concentrations are mainly near coasts and in high latitudes. Morphometrics and colouration may be useful tools in defining some type of geographic or ice-edge/open water units, but existing evidence of a high degree of isolation over a few hundred miles for animals in coastal waters of the eastern North Pacific suggests that broader-scale stock areas as used for larger species may be inappropriate for killer whales. Given the extreme stability of local populations and the possibly low reproductive rates evidenced by the available data, any exploitation can be expected to have very long-term impacts on population size and structure.

Based on a long catch history, the killer whales in the eastern North Atlantic were provisionally recommended by the Committee last year to be classified as a Sustained Management Stock with catch limit of 52, pending review this year of information necessary for identification of stocks and assessment of their status (*Rep. int. Whal. Commn* 31: 68). The Commission did not act on the recommendation, but Norway voluntarily limited the catch in 1980 to 52 animals.

The conclusions of the workshop indicate that the take may be from one or a few localized stocks, and in any case, the available data are still inadequate for stock assessment. For these reasons, the Committee believes that the killer whales off the coast of Norway should be designated as an Unclassified Stock with zero catch limit and makes recommendations for necessary research (see Recommendations).

Information available on Southern Hemisphere killer whales from the workshop is still inadequate to define stocks for management. Data and analyses are inconclusive with respect to the six to eight longitudinally-defined stocks proposed by Mikhalev *et al.* (1981). Various data do indicate that at least two and possibly more forms of killer whales exist in the Antarctic. An estimate of total abundance south of 60°S, based on sightings data from the IDCR minke whale cruises and sightings data from Japanese scouting vessels is 254,900. There are problems with some of the assumptions of the method used, however, especially with that of uniform distribution of density of killer whales within 5° squares close to the ice. The data and analyses will be re-examined during the coming year.

Lacking a basis for delineating stocks, there is no basis for catch limits. Pending results of more research of the type done elsewhere on population structure and stock identity, the Committee believes that there should be no catches of Southern Hemisphere killer whales (see Recommendations).

Analysis and stratification of the sample of killer whales taken by the USSR in 1979/80 may help to clarify the situation, but at present no identification of separate stocks can be made.

10.1.5 Pilot whales

The Committee notes an increased take of short-finned pilot whales in Japanese drive fisheries. It is unclear whether the 1980 figure represents an increase in takes or simply a better reporting system. The status of the stock(s) has not been assessed, and the Committee urges that Japan implement a reporting system by village and a summary of historical fishing effort, abundance and composition of catches.

The same comments apply to the large catches of long-finned pilot whales in the Faroes.

10.1.6 Striped dolphin

The Committee notes with concern that the reported catch of striped dolphins in Japan increased greatly in 1980 to 16,344 from 2,193 in 1979. The population in 1974 was at less than 50% of estimated original of more than 404,000. MSY at that time was estimated to be 4,140–6,530. The take of over 16,000 is clearly far more than the sustainable yield.

The Committee is extremely concerned about this severe over-exploitation of the striped dolphin population. There is a clear need for re-assessment of the populations of this and other species taken in the drive fisheries and for management of these presently unmanaged stocks on a scientific basis.

The small cetaceans sub-committee also reviewed new information for several other directed fisheries and considered incidental takes (Annex H).

10.2 Recommendations for research and management

The small cetaceans sub-committee prepared an extensive list of recommendations (see Annex H). Only those the Committee believes most important are listed here, although the Committee endorses the remaining (research) recommendations in principle.

10.2.1 Northern bottlenose whale

The Committee again recommends that the research programme recommended for the northern bottlenose whale in 1977–78 be carried out and that the stock remain classified a Protected Stock with zero catch.

10.2.2. White whales and narwhals

(1) The Committee notes that the status of most small cetaceans in the IWC remains unresolved and that a resolution adopted at the 1980 meeting of the Commission (*Rep. int. Whal. Commn* 31: 31, Appendix 8) established an interim working arrangement for continuation of the work of the small cetaceans sub-committee and provision of scientific advice to the member governments. The resolution also calls for provision of data and analyses to the Scientific Committee by member governments. The Committee recognizes that advice promulgated under the present working arrangement has resulted in expansion of national research programs on some species and adoption of voluntary internal catch limits for some stocks. Nonetheless, most members of the Committee believe that for scientific reasons the white whale and narwhal should be managed on the same basis as the other Arctic whales, although some members believe that making this recommendation is inappropriate. Common factors affecting scientific management are summarised in Annex H. Most members of the Committee recommend that the white whale and narwhal be listed in the Schedule (paragraph 1) thus:

'white whale' (*Delphinapterus leucas*) means any whale known as white whale, beluga, belukha
'narwhal' (*Monodon monoceros*) means any whale known as narwhal, sea unicorn

and that stock classifications and catch limits be set in accordance with the Commission's management procedures. Ivashin expressed the opinion that this recommendation is inappropriate in view of the resolution of last year by the Commission; Øritsland, Kapel, Brodie and Ohsumi wish to be associated with this view.

(2) The Committee notes the responsive and considerable expansion of studies of populations of white whales and narwhals in Canadian and Greenland waters and recommends that Canada and Denmark be encouraged to continue this very important work, giving particular attention to stock identity, migration, abundance, calf production, collection of complete and accurate catch statistics, and collection of age and reproductive samples from as many animals as possible.

(3) Noting the seriously depleted status of the stocks summering in Cumberland Sound and the importance to the species of estuarine calf-rearing grounds (estimated to be at less than 14% of original size), Ungava Bay (less than 20% of original) and eastern Hudson Bay (less than 10% of original), the Committee recommends that each of these separate stocks be classified as a Protected Stock with zero catch, and that the critical habitat of these stocks be recommended for protection.

10.2.3 Killer whales

(1) The Committee last year recommended that because of a long history of catches the killer whales in the northeastern Atlantic be classified provisionally as a Sustained Management Stock, pending review of identity and status of stock(s) at this year's meeting. Data necessary to establish identity and assess status of the stock(s) are still not available. In addition, the catch data and new information on the size and nature of stocks elsewhere indicate that the recent takes on the northern coast of Norway may have come from one or a few localized stocks rather than from an overall northeastern Atlantic stock. For these reasons, the Committee recommends that the killer whales on the coast of Norway be designated an Unclassified Stock with zero catch limit, pending identification of stocks and assessment of their status.

(2) Because available effort data are inadequate for CPUE analyses, the Committee recommends that should the fishery continue, improved reporting of effort be initiated. Such reports should include at least: time leaving port, time returning to port and estimated time searching.

(3) Noting that passive acoustic and photographic enumeration techniques have produced successful results in defining killer whale populations in other areas, the Committee recommends that use of such techniques be considered for use in delineating the stocks in the northeastern Atlantic and Antarctic.

(4) Because of the continuing uncertainty over stock identities, and consequently the abundance of any Southern Hemisphere stock, the Committee again recommends that the stock(s) be classified as an Initial Management Stock with a catch limit of zero.

(5) Noting that a large sample (916) of killer whales was taken in 1979/80 by the USSR and has not yet been fully reported on, the Committee recommends that the USSR be requested to provide suitable report(s) to next year's meeting of the Committee. The report(s) should include analysis of reproductive data and specimens collected, analysis of morphometric, meristic and colour-pattern data, exact locations of catches, sightings and catch per effort data, and information on hunting strategy and tactics, especially as they may relate to possible sex, age or size bias in the samples from the catch and to possible biases in sighting effort. If possible, samples for morphological analyses should be stratified by age.

10.2.4 Pilot whales

Noting that takes of short-finned pilot whales (in Japan) and long-finned pilot whales (in the Faroes) were larger in 1980 than in 1979, and that the status of these stocks has not been assessed, the Committee recommends that Japan and Denmark (Faroes) be encouraged to provide to the Scientific Committee summaries of historical fishing effort, and to initiate studies of abundance and of composition of catches.

10.2.5 Striped dolphin

Noting that there is the possibility that drive fisheries in Japan are overexploiting a population of striped dolphins, and noting that the population is at present unmanaged, the Committee urges that the status of the stock(s) be reassessed to provide the scientific basis for appropriate management action.

10.2.6 Statistics

Catch statistics provided to the Scientific Committee or to BIWS by member nations are incomplete or inadequately detailed. The Committee again recommends that member nations be requested to collect and submit full statistics as detailed in *Rep. int. Whal. Commn* 30: 124. Member nations known to have taken small cetaceans but which did not report the takes or reported them incompletely include Argentina (Incidental), Australia (I), Brazil (I), Canada

(Directed and I), Chile (I), France (D,I), Iceland (Live-capture), Republic of Korea (I), Mexico (I, L), Netherlands (I), Peru (I), Spain (I), UK (I), USA (D, I, L) and USSR (I).

10.3 Plans for the 1982 meeting

The Committee noted that the sub-committee on small cetaceans plans to concentrate on dolphin stocks in the eastern tropical Pacific and the eastern tropical Atlantic, and dolphin stocks taken by the Japanese drive fisheries. The Committee urges that relevant studies and data reports be submitted to next year's meeting.

10.4 Status of the sub-committee on small cetaceans

The Committee agreed that the small cetacean sub-committee should remain a standing sub-committee.

11. DATA COLLECTION, STORAGE AND MANIPULATION

11.1 Central computer facilities

11.2 Exchange and centralisation of existing data

Free presented a progress report on the IWC computing and data facility, which is available as IWC Technical Note No. 9. A summary of the principal conclusions and recommendations follows.

The setting up of the central computing facility has closely matched the original proposal (*Rep. int. Whal. Commn* (Special Issue 2): 125–6). The establishment phase is now essentially complete and requires no further financial provision. However, the process of compiling the data bank is proving more time-consuming than envisaged, chiefly because of poor coding of non-IWC material. Considerable progress is being made in correcting and documenting source tapes, but it is expected that another two years will be needed to complete the coding and checking of the majority of data.

Free reported that his visit to BIWS in Norway had resolved all outstanding problems with the format of the Southern Hemisphere master tapes, which were now being released in fully corrected versions.

A new system is in operation at the IWC which can code tabular information far faster and more efficiently than conventional methods. The Committee agreed that this system should be used to code some of the large body of data to be provided by Japanese scientists and to update the BIWS data tapes.

The University of Cambridge continues to offer an excellent inexpensive service to the IWC throughout the year. In addition, special arrangements were made to provide the greatly expanded computing facilities available at the 1981 meetings of the Scientific Committee. The Committee therefore recommends that the Secretary express its appreciation of the major contribution which the assistance of the Computing Service had made to its work.

Documentation on various aspects of the IWC computing facility and, in particular, the revised data sets, is now being published as a series of IWC Technical Notes, which are available on request from the Secretariat. This format is especially suitable for information which is either provisional or too specialised to warrant publication in the Annual Report.

The Committee recommends that Free attends the post-FIBEX data interpretation workshop in Hamburg (Agenda Item 6). Free reported that he will be visiting the South-West Fisheries Centre, La Jolla, USA, at the invitation of Dr T. Smith to discuss data handling.

The Committee noted that several computing and data compilation projects had been proposed; a working group, convened by Tillman, will meet during the Brighton meetings to discuss priorities. The group will consider questions of procedure raised by Free concerning the status and validation of computer programs used in assessments.

The Committee thanks Free for his work on their behalf and recommends that he should continue the development of the IWC computing facility as a permanent member of the Secretariat.

11.3 Review of biological material awaiting treatment

Information on biological material awaiting treatment is given in the reports of the sub-committees.

12. EFFECTS OF POLLUTION ON WHALE POPULATIONS, INCLUDING SMALL CETACEANS

The small cetaceans sub-committee reviewed new information on effects of pollution and industrial development (Annex H). The Committee supports the view expressed by ICES that studies of pollution should not only deal with levels but also with effects, and that anatomical and histological information should be included in reports so that possible confounding effects of infections etc. may be examined. The efforts of ICES to standardise assay techniques were noted. The report of the IWC observer to the 68th ICES meeting is given in IWC/33/11A.

SC/33/Ba1, examined DDT and PCB contamination in North Atlantic fin whales. Although the detected levels were not considered to be harmful by the authors, they considered them to be high for a species with a low metabolic rate and occupying a low trophic level. Comparison with an earlier Canadian study (Addison, Zinck and Ackman, 1972, *J. Fish. Res. Bd Can.* 29: 349–55) revealed lower levels of DDTs and higher levels of PCBs. The former are associated with agricultural chemicals while the latter are associated with industrial pollution. It was pointed out that the situation could be expected to be worse in toothed whales which occupy a higher trophic level.

The Committee recommends

(i) that member nations should ensure that appropriate sampling and analysis is carried out, particularly with respect to toothed whales;

(ii) that relevant studies should be listed in Progress Reports; studies of particular interest should be presented more fully;

(iii) that the IWC should co-operate with ICES on this matter; in particular it recommends that Harwood should be the IWC representative at the ICES meeting in Woods Hole, USA in October at which pollution will be discussed.

The Committee agreed that next year this Agenda Item should be expanded to include the effects of industrial development and environmental degradation (in particular see Annex G, pp. 104–112).

13. BEHAVIOURAL STUDIES AND HUMANE KILLING

13.1 Proposals for 1981–82 meeting on behavioural studies

In 1980 the Commission accepted a recommendation endorsed by the Technical Committee that a behavioural workshop be established in 1981/82 by the Scientific Committee for further detailed examination of those matters identified as being of greatest significance to the assessment and management of cetaceans. Tillman confirmed that he would convene the proposed workshop in Seattle during 5–9 April 1982. A small steering group was formed to prepare a tentative agenda, list of participants, and budget for the workshop.

13.2 Report of the Technical Committee Workshop on Humane Killing Techniques

Gambell introduced the report of the workshop held in Cambridge in November 1980 (IWC/33/15). Yamamura reported verbally on the results of the Japanese experiments with penthrite during the last season which were mentioned in the report. He also noted that the average death time for minke whales had been reduced from 5.2 to 3.4 minutes using an improved electrical lance. A full report will be submitted to the Technical Committee. In January 1981, Norway announced that it is funding a five year project to improve killing techniques in its small type whaling operations (SC/33/ProgRep Norway).

The Committee noted that this otherwise comprehensive workshop report did not adequately review current methods and technology used in aboriginal/subsistence fisheries. As pointed out in SC/32/PS22 a variety of techniques are used in such fisheries, ranging from harpoon guns in the Greenland humpback fishery to hand harpoons and lances in Portuguese sperm whaling. A full treatment of the humane killing issue for aboriginal/subsistence fisheries should address the problems inherent in this wide range of technologies. The Committee therefore believes it is appropriate that the matter be considered further by the IWC *ad hoc* Working Group on Management Principles in Subsistence Whaling.

Best asked whether the statement that M99 would be left as toxic residues was based on experimental evidence and was told that it was not. He also drew attention to the experience in Australia where two stranded rorquals had been despatched with explosive charge placed on the neck.

The Committee endorsed the report and its recommendations.

Parry reported on a proposal to send a British veterinarian to Iceland to extend the work carried out there by Rowsell (*Rep. int. Whal. Commn* 30: 59). The Committee supported the proposal but stressed that any such project must ensure that those whales for which death times are collected are also autopsied. Information from such a study will also be of relevance to the struck-and-lost problem in the Alaskan bowhead fishery.

14. ANNUAL SUMMARY OF NATIONAL RESEARCH PROPOSALS

The Committee reviewed IWC/33/25, in particular the recommendation that a summary of recently completed but unpublished projects and current and proposed projects on cetaceans supported by Contracting Governments, be appended to national progress Reports, and that similar information be sought from organisations such as WWF, FAO and UNEP.

While many members support the aims of the proposal (in particular to reduce duplication of research effort) the Committee believes that there would be considerable practical problems in implementing the proposal as formulated; the administrative practicality of the proposal should be examined by the Technical Committee. The Committee recommends that as recommended last year (*Rep. int. Whal. Commn* 31: 70) national groups be encouraged to report wherever possible, on at least all government sponsored research both recently completed, current and proposed. Such information (or details of publications or newsletters which contain such information) should be appended to the national Progress Reports; it would not be printed in the Annual Report, but collated information should be available on request from the Secretariat.

15. PUBLICATION ARRANGEMENTS

A subgroup was established during the meeting to review publication policy in view of the comments in last year's Scientific Committee Report (Item 16, *Rep. int. Whal. Commn* 31: 70) and the Commission's Report (Item 26.2(b), *Rep. int. Whal. Commn.* 31: 27), where the Committee was asked to include in its review of publications policy consideration of methods of reducing costs.

The subgroup consisted of five sub-committee convenors (Best, Horwood, Kirkwood, Perrin, Tillman), Braham, Donovan, Gambell, Ivashin, Leatherwood, Mitchell, Ohsumi; Bannister was Chairman.

Based on that subgroup's review, the Committee recommends that the following policy be adopted:

(i) The Scientific content of the Annual Report should constitute in effect the 'report of proceedings' of the Committee's work during the year;

(ii) The Annual Report should include, as at present
  - the Report of the Committee's Annual Meeting
  - Report(s) of Special Meeting(s)
  - Progress Reports on Cetacean Research (prepared by National groups and submitted in the agreed format to the Committee at its Annual Meeting)
  - Reports of sub-committees appointed to review the major species or stocks.

(iii) In addition, in place of the present published 'Papers submitted to the Scientific Committee', selected 'key' papers should be published in full. At the same time a complete list of titles should be included. Titles of papers not published would be accompanied by appropriate annotations (abstract/summary/resumé, as authors wish).

(iv) The following procedure should be adopted for selection of 'key' papers:
  - each sub-committee will review all documents submitted, and select those which, for example, are specifically referred to in the sub-committee report, or have made some other substantial contribution to the sub-committee's work;
  - the sub-committee may suggest ways in which particular selected papers may be improved; in the case of long papers especially, it may suggest ways in which they may be shortened;
  - papers selected by the sub-committees will then be referred to an 'Editorial Board', appointed annually from members of the Scientific Committee, but including the Secretary and Scientific Editor. The Board shall have final responsibility for deciding which papers shall be published;

- papers selected for final publication will be subject to review by 2 persons appointed on the basis initially of advice from the sub-committee. Such review will be under the control of the Scientific Editor, acting within Editorial Board policy. A footnote to any published paper will indicate that a review has occurred, and by whom;
- no key paper, except in exceptional extenuating circumstances, will be more than 10 printed pages long;
- where a key paper requires considerable editing or revision before publication, resulting in alterations to conclusions or other substantial material, a note to that effect will be appended to each publication.

(v) In addition to the Annual Report, two other compilations should be available to the Committee at Annual or other meetings.
 (a) full sets of copies of all papers submitted to previous meetings, in an agreed format;
 (b) sets of tabular data, both computerised and in other forms, in an agreed format.

(vi) Copies of papers submitted to the Committee, whether published or not, shall be available on request to the Secretariat, at an agreed fee. An appropriate note to this effect will appear in each Annual Report.

Given the experience of some sub-committees already at this meeting, it is unlikely that any immediate large reduction in number of papers published will be achieved if this procedure is adopted; there should, however, be some economies through shortening of some papers. Nevertheless the proposed procedure, if adopted, should permit the scientific standard of published papers to be raised, without either increasing the costs of publication unduly, or reducing the ability of future workers to review the background of previous decisions in detail.

16. FUTURE MEETINGS AND THE NEED FOR SPECIAL STUDIES

(i) Conference on Cetacean Reproduction (and see Annex H, p. 113)

The Committee notes that the Conference will take place in La Jolla, California from 28 November to 7 December 1981. The Workshop following the Conference is fully subscribed. The USA is providing $24,000 for the conference and the Committee recommends that the Commission provides the additional £6,000 required. It also recommends that a member of the Secretariat attends the Conference.

(ii) Workshop on Behaviour

This is discussed under Item 13.1.

(iii) AEWC Meeting on bowhead whales

The AEWC (Alaskan Eskimo Whaling Commission) intend to hold a meeting on the biology of the bowhead whale, in Anchorage, Alaska, before January 1982. The Committee recommends that it should be represented at this meeting by the Convenor of the sub-committee on protected species and aboriginal whaling (Best) or if he is unavailable, another member of that sub-committee.

(iv) Right Whales

The Committee notes that the sub-committee on protected species and aboriginal/subsistence whaling has agreed to give special consideration to right whale stocks, particularly those in the Okhotsk Sea/Sea of Japan, Northwest Atlantic, South Atlantic and around Australia (Annex G, p. 104). If the response is too great to be handled at next year's annual meeting, then consideration might be given to holding a special meeting in 1982/83.

(v) Logbook studies of Antarctic fin whaling

This is discussed under Item 7.2.4.

17. INITIAL AGENDA FOR 1982 MEETING

A number of items were noted for inclusion, or priority in discussion in this report. Members were asked to advise the Chairman of any new items for inclusion in the next meetings agenda.

18. OTHER BUSINESS

18.1 Representation at the Technical Committee Meeting on non-IWC whaling

The Committee recommends that Allen attends this meeting on its behalf.

18.2 Other meetings of interest

The following meetings were drawn to the attention of the Committee:

18.2.1 3rd Theriological Congress, Helsinki, August 1982

This will include a symposium on marine mammals chaired by Dr. Yablokov.

18.2.2 4th Bi-Annual Conference on Marine Mammals, San Francisco, December 1981

Further information can be obtained from Tillman.

18.2.3 7th Annual Meeting of the Mexican Society for Marine Mammal Research in Mexico, La Paz, Baja California, February 1982.

Further information can be obtained from Fleischer.

18.3 Language

Early in the meeting, the Committee recognised the difficulties faced by non-English speaking members in following the discussions in both plenary sessions and sub-committees. It also recognised the difficulties faced when insufficient time was allowed for them to study documents produced during the meeting, especially those produced towards the end of the meeting.

19. ELECTION OF OFFICERS

Bannister and Tillman were re-elected as chairman and vice-chairman respectively. The following were appointed to convene sub-committees at next year's meeting:

Kirkwood; sperm whales
Tillman; minke whales
Chapman; other baleen whales
Best; protected species and aboriginal/subsistence whaling
Perrin; small cetaceans

20. OTHER BUSINESS

The Committee wished to record its appreciation of the long hours, hard work and prompt service of the Secretariat during the meeting.

Annex A

List of Participants

AUSTRALIA
K. R. Allen
G. R. V. Anderson
J. L. Bannister
G. P. Kirkwood
W. de la Mare

BRAZIL
J. da Rocha

CANADA
E. D. Mitchell
P. Brodie
K. Hay
K. Finley

CHILE
R. Maturana

DENMARK
F. O. Kapel

FRANCE
M. Pascal
M. Mackintosh

ICELAND
J. Jónsson
J. Sigurjónsson

JAPAN
I. Ikeda
M. Kakibaya
F. Kasamatsu
H. Kato
S. Misaki
M. Miyahara
N. Nakamura
S. Ohsumi
T. Saito
Y. Shimadzu
K. Shirakihara
S. Tanaka
J. Tedori
S. Wada
K. Yamamura

KOREA
J. W. Choi
Y. Gong

MEXICO
L. Fleischer

NETHERLANDS
J. G. van Beek

NEW ZEALAND
M. Donoghue

NORWAY
I. Christensen
T. Øritsland
C. J. Rørvik

PERU
J. Valdivia

SEYCHELLES
S. J. Holt

SOUTH AFRICA
P. B. Best

SPAIN
A. Aguilar
E. de Salas
C. Sanpera

UK
S. G. Brown
J. Harwood
A. R. Hiby
J. Horwood
M. Klinowska
C. Lockyer
A. R. Martin
A. J. B. Rudge

USSR
R. G. Borodin
M. V. Ivashin
Y. Riyazantsev

USA
T. Albert
K. Balcomb
H. Braham
D. G. Chapman
W. G. Clark
G. Jarrell
S. Mizroch
W. F. Perrin
M. F. Tillman

IWC
G. Donovan
C. A. Free
R. Gambell

INVITED PARTICIPANTS
J. Beddington
J. Berney (CITES)
D. Butterworth
J. Cooke
M. Dahlheim
R. Duguy
J. Gulland (FAO)
P. Hammond
S. Leatherwood
R. V. Walker

OBSERVERS
W. J. Jordan (PTES)
J. Gordon-Clark (MAC)
P. Spong (Greenpeace)
P. Vodden (RSPCA)
M. Schultz (IYFESC)

Annex B

Agenda

1. Chairman's welcome and opening remarks.

2. Appointment of rapporteurs.

3. Adoption of agenda.

4. Arrangements for meeting:
    4.1 Meeting procedure, establishment of sub-committees, time schedule.
    4.2 Computer arrangements.

5. Review of available documents and reports.
    5.1 Documents submitted.
    5.2 Progress Reports on Research.
    5.3 Reports of Special Meetings and Workshops:
        5.3.1 Sightings Workshop.
        5.3.2 Minke Whale Workshop.
        5.3.3 Killer Whale Workshop.
        5.3.4 Management Procedures.
        5.3.5 Humane Killing.
    5.4 Scientific Permits:
        5.4.1 1980–81: reports.
        5.4.2 1981–82: advance review.
    5.5 Previous season's catches and other statistical material.
    5.6 Whale Marking:
        5.6.1 Progress of International Scheme including Commission's contribution to costs.
        5.6.2 Reports of special cruises—Minke whales.
    5.7 Sighting programme—data reports from commercial operations 1980–81.
    5.8 Indexed list of Scientific Committee publications.

6. Co-operation with other organisations, e.g. FAO, UNEP, SCAR, IUCN, CITES, CAMLR, IATTC.

7. International Decade of Cetacean Research (IDCR):
    - 7.1 Review of results 1980–81.
    - 7.2 Proposals 1981–82.
    - 7.3 Funds available.
    - 7.4 Funding procedures.

8. Management Procedures:
    - 8.1 Reports of Technical Committee Working Group Meetings on Revised Management Procedures, February/March 1981 and May 1981.
    - 8.2 Moratorium proposals.
    - 8.3 Whale sanctuaries:
        - 8.3.1 Indian Ocean—Scientific research proposals.
        - 8.3.2 Other areas—including scientific aspects of their establishment.
    - 8.4 Previously unexploited or little known stocks.
    - 8.5 Role of the Scientific Committee.

9. Whale stocks, status and regulatory measures:
    - 9.1 Minke whales:
        - 9.1.1 Southern Hemisphere.
        - 9.1.2 North Pacific.
        - 9.1.3 North Atlantic.
    - 9.2 Sperm whales:
        - 9.2.1 Southern Hemisphere, Divisions 1–8.
        - 9.2.2 Southern Hemisphere, Division 9.
        - 9.2.3 North Pacific.
        - 9.2.4 North Atlantic.
    - 9.3 'Other baleen whales':
        - 9.3.1 Fin whales, Southern Hemisphere, Areas I–V.
        - 9.3.2 Fin whales, Southern Hemisphere, Area VI.
        - 9.3.3 Fin whales, North Pacific.
        - 9.3.4 Fin whales, North Atlantic.
        - 9.3.5 Sei whales, Southern Hemisphere.
        - 9.3.6 Sei whales, North Pacific.
        - 9.3.7 Sei whales, North Atlantic.
        - 9.3.8 Bryde's whales, Southern Hemisphere.
        - 9.3.9 Bryde's whales, North Pacific.
    - 9.4 'Other protected species' and aboriginal/ subsistence whaling.
        - 9.4.1 Bowhead whales.
        - 9.4.2 Right whales.
        - 9.4.3 Blue whales.
        - 9.4.4 Pygmy blue whales.
        - 9.4.5 Humpback whales.
        - 9.4.6 Gray whales.

10. Small cetaceans.

11. Data collection, storage and manipulation:
    - 11.1 Central computer facilities.
    - 11.2 Exchange and centralization of existing data.
    - 11.3 Review of biological material awaiting treatment.

12. Effects of pollution on whale populations, including small cetaceans.

13. Behavioural studies and humane killing:
    - 13.1 Proposals for 1981–1982 meeting on behavioural studies.
    - 13.2 Report of Technical Committee Workshop.

14. Annual summary of national research proposals.

15. Publication arrangements.

16. Future Meetings and the need for special studies.

17. Initial Agenda for 1982 meeting.

18. Other business:
    - 18.1 Representation at Technical Committee Meeting on non-IWC whaling.
    - 18.2 Other meetings of interest—3rd Theriological Congress, Helsinki, August 1982.
    - 18.3 Language.

19. Election of officers.

Annex C

List of Scientific Committee Documents

SPERM WHALES

SC/33/Sp

1 MIKHALEV, Yu. A. Subjective and objective assessments of the laminations in the sperm whales teeth.

2 ZAHL, S. Comment on the Beddington and Cooke age-specific assessment model for the sperm whale population.

3 COOKE, J. G. and BEDDINGTON, J. R. Further development of an assessment technique for male sperm whales based on length data from the catches.

4 DUBIN, V. N. and MIKHALEV, Yu. A. Distribution of calcium into the sperm whales teeth.

5 SHIRAKIHARA, K. and TANAKA, S. Reconstruction of the Beddington and Cooke age specific model and some comments on their models for sperm whales.

6 SHIRAKIHARA, K. and TANAKA, S. Population estimation of the North-west Pacific stock of sperm whales.

MINKE WHALES

SC/33/Mi

1 CHRISTENSEN, I. and RØRVIK, C. J. Updated estimate of the northeast Atlantic stock of minke whales 1974–1979.

2 CHRISTENSEN, I. Catch and effort and the sex composition in the Norwegian minke whale fishery 1976–1980.

3 JONSGARD, A. The food of minke whales (*Balaenoptera acutorostrata*) in northern North Atlantic waters.

4 DORSEY, E. M. Exclusive home ranges in individually identified minke whales, *Balaenoptera acutorostrata*.
5 KAPEL, F. O and LARSEN, F. Norwegian minke whaling off West Greenland 1976–1980, and data on biological parameters.
6 SIMONSEN, V., KAPEL, F. O. and LARSEN, F. Electrophoretic variation in the minke whale, *Balaenoptera acutorostrata* Lacépède.
7 GONG, Y. On the distribution of minke whales in Korean waters.
8 OHSUMI, S. Minke whales in the coastal waters of Japan in 1980 and population assessment of Okhotsk Sea—West Pacific stock.
9 SIGURJÓNSSON, J. Icelandic minke whaling 1914–1980.

OTHER BALEEN WHALES (fin, sei, Bryde's)

SC/33/Ba
1 AGUILAR, A. and JOVER, L. DDT and PCB Residues in the fin whale, *Balaenoptera physalus*, of the North Atlantic.
2 IVASHIN, M. V. To the problem on the population structure of the Bryde's whales (*Balaenoptera edeni* Anderson) inhabiting the Southern Hemisphere.
3 CLARK, W. G. Historical rates of recruitment to Southern Hemisphere fin whale stocks.
4 MARTIN, A. R. Pregnancy rates of fin whales in the Icelandic catch.
5 MARTIN, A. R. The influence of date and position of capture on the length of fin whales taken by Iceland.
6 TILLMAN, M. F. Mark-recapture estimates of abundance for the western Northern Pacific stock of Bryde's whale.
7 LOCKYER, C. Preliminary investigation of some anatomical characters of fin whale earplugs collected from different regions of the N.E. Atlantic.
8 COOKE, J. G. and BEDDINGTON, J. R. The fin whale in Icelandic waters: growth, reproduction and sustainable yields.
9 VAN BEEK, J. A note on the East Greenland—Iceland fin whale stock assessments in 1980.
10 MATURANA, R. Study of the living pattern of the sei whale.

PROTECTED SPECIES AND ABORIGINAL/ SUBSISTENCE WHALING (bowhead, right, blue, humpback, gray)

SC/33/PS
1 IVASHIN, M. V. and VOTROGOV, L. M. Tagging of gray whales, *Eschrichtius robustus*.
2 WHITEHEAD, H. Populations of humpback whales in the northwest Atlantic.
3 JONSGARD, A. Bowhead (*Balaena mysticetus*) surveys in arctic northeast Atlantic waters in 1980.
4 KROGMAN, B., SONNTAG, R., RUGH, D., GROTEFENDT, R. and PRIEBE, G. Population estimation of the western Arctic stock of the bowhead whale.
5 MARQUETTE, W., NERINI, M. K., BRAHAM, H. W. and MILLER, R. V. Bowhead whale studies, Autumn 1980 to Spring 1981: Harvest biology and distribution.
6 CUBBAGE, J. and RUGH, D. Bowhead whale length estimates and calf counts in the eastern Beaufort Sea 1980.
7 BREIWICK, J. M. and MITCHELL, E. D. Estimated initial population size of the Bering Sea stock of bowhead whales (*Balaena mysticetus*) from logbook and other catch data.
8 REILLY, S. B. Gray whale population history: An age-structured simulation.
9 TILLMAN, M. F. Report on activities of a U.S. Workshop on Humpback Whales of the western North Atlantic.
10 BLOKHIN, S. A. The results of the investigations of the gray whales of the California—Chukchi population taken in the waters of the Chukchi Peninsula in 1980.
11 BERZIN, A. A. and DOROSHENKO, N. V. Distribution and abundance of right whales (Balenidae) in the North Pacific Ocean.
12 SWARTZ, S. L. and JONES, M. L. Demographic studies and habitat assessment of gray whales, *Eschrichtius robustus*, in Laguna San Ignacio, Baja California Sur, Mexico.
13 LIEN, J. Whale collisions with inshore fishing gear in Newfoundland.
14 MITCHELL, E. and REEVES, R. Catch History, Abundance, and present status of northwest Atlantic humpback whales.
15 BOGOSLOVSKAYA, L. S., VOTROGOV, L. M. and SEMENOVA, T. N. Distribution and feeding of gray whales in the waters of the Chukotka Peninsula in Summer and Autumn of 1980.
16 BOGOSLOVSKAYA, L. S., VOTROGOV, L. M. and KRUPNIK, I. I. Bowhead whales off the Chukotka: Migrations and aboriginal whaling.
17 BALCOMB III, K. C. and NICHOLS, G. Western North Atlantic humpback whale census near Hispaniola—Winter 1980.
18 FLEISCHER, L. A. Aerial surveys of California gray whales in Laguna Ojo De Liebre, Baja California, Mexico, 1980.
19 KRAUS, S. D. and PRESCOTT, J. H. Preliminary notes on the occurrence of the North Atlantic right whale *Eubalaena glacialis*, in the Bay of Fundy.

SMALL CETACEANS

SC/33/SM
1 SMITH, T. Changes in size of three dolphin populations (*Stenella* spp) in the eastern tropical Pacific. [Withdrawn.]
2 OGNETOV, G. N. and POTELOV, V. A. The peculiarities of the white whale, *Delphinapterus leucas*, distribution and population dynamics in the White Sea.
3 ALLEN, R. and GOLDSMITH, M. D. Dolphin mortality in the eastern tropical Pacific incidental to purse seining for yellowfin tuna, 1980.
4 EASTON, D., KLINOWSKA, M. and SHELDRICK, M. C. A preliminary analysis of the British stranding records of the harbour porpoise (*Phocoena phocoena*).
5 ABBOTT, R. M., KLINOWSKA, M. and EVANS, P. G. H. Analysis of the sightings records of the harbour porpoise (*Phocoena phocoena*) in British waters. [Withdrawn.]

6 PERRIN, W. F. and OLIVER C. W. Time/Area distribution and composition of the incidental kill of dolphins and small whales in the U.S. purse-seine fishery for tuna in the eastern tropical Pacific, 1979–1980.
7 BRODIE, P. F. Growth and age determination of the beluga, *Delphinapterus leucas*, based on a captive specimen.
8 Canadian research and management proposals related to narwhal and beluga, 1981.
9 FINLEY, K. J. MILLER, G. W., ALLARD, M., DAVIS, R. A. and EVANS, C. R. The white whales (*Delphinapterus leucas*) of northern Quebec: distribution, abundance, stock identity and catch history.
10 FINLEY, K. J. and MILLER, G. W. The 1979 hunt for narwhals (*Monodon monoceros*) and an examination of harpoon gun technology near Pond Inlet, northern Baffin Island.
11 DUGUY, R. and HUSSENOT, E. Occasional capture of Delphinids in the N.E. Atlantic.

MANAGEMENT

SC/33/Mg
2 GULLAND, J. A. Commission objectives and the choice of management procedures.
3 IKEDA, I. The target levels in the management procedures of whale stocks.

OTHER

SC/33/O
1 AGUILAR, A. and SANPERA, C. Reanalysis of Spanish sperm, fin and sei whale catch data (1957–1980).
2 BOGOSLOVSKAYA, L. S. and VOTROGOV, L. M. Mass wintering of birds and whales in ice lanes in the Bering Sea.
3 KIRKWOOD, G. P. Some statistical aspects of the Beddington and Cooke estimation technique.
4 HAY, K. Aerial line-transect estimates of abundance of humpback, fin and long-finned pilot whales in the Newfoundland – Labrador Area.
5 COOKE, J. G. and BEDDINGTON, J. R. Biases in estimates of total mortality rates from age data and how to avoid them.
6 JONSGÅRD, A., CHRISTENSEN, I. and RØRVIK, C. J. Catch statistics for minke whales (*Balaenoptera acutorostrata*) and killer whales (*Orcinus orca*). Caught by Norway in 1980.
7 RICE, D. W. and WOLMAN, A. A. Whale census in the Gulf of Alaska, June–August 1980.
8 IVASHIN, M. V. and VOTROGOV, L. M. Occurrences of baleen and killer whales in the waters off the Chukotka Peninsula.
9 KELLER, R. W., LEATHERWOOD, J. S. and HOLT, S. J. Indian Ocean cetacean survey, Seychelle Islands, April through June, 1980.
10 LEATHERWOOD, S., TODD, F. S., THOMAS, J. and AWBREY, F. T. Incidental records of cetaceans in Southern Seas, January and February 1981.
11 LEATHERWOOD, S., GOODRICH, K. and KINTER, A. L. Respiration patterns and 'sightability' of whales.
12 KAPEL, F. O. and LARSEN, F. Whale sightings from Norwegian small type whaling vessel off West Greenland June–August 1980.
13 HOLT, S. J. The protection of species.

PROGRESS REPORTS

SC/33/ProgRep

Australia
Brazil
Canada
Chile
Denmark (Greenland)
France
Iceland
Japan
Korea
Mexico
New Zealand
Norway
Peru
Seychelles
South Africa
Spain
UK
USA
USSR

REPORTS

SC/33/Rep
1 Biomass Technical Group on Data Statistics and Resource Evaluation.
2 Report of the Workshop on the Design of Sightings Surveys.
3 Report of the Scientific Committee Special Meeting on Southern Hemisphere Minke Whales.
4 Report of the Workshop on Identity and Structure of Killer Whale Populations.

OTHER DOCUMENTS

IWC/33/
11 Observers Reports on:
  A. ICES
  B. ICCAT
  C. IATTC
  D. CITES
  E. COFI
13 Report of the Technical Committee Working Group on Revised Management Procedures.
15 Report of the Workshop on Humane Killing Techniques for Whales.
21 Proposals for a moratorium on the commercial exploitation of sperm whales and minke whales.
24 Australian proposal, Agenda Item 10.2. Examination of the general concept and characteristics of whale sanctuaries.
25 Australian proposal, Agenda Item 17. Collation and distribution of Annual Summary of National Research on Cetaceans by the Commission.
22 Proposal by Seychelles. A pause in commercial whaling for sperm whales.

Annex D

Report of the Sub-Committee on Sperm Whales

Members:

Kirkwood (Convenor)

Allen
Aguilar
Beddington
Best
Bannister
Butterworth
Clark
Cooke
Donovan
Harwood
Hiby
Holt
Ikeda
Jónsson
Kasamatsu
Kato
De la Mare
De Salas
Martin
Maturana
Misaki
Mitchell
Miyahara
Nakamura
Ohsumi
Sanpera
Sigurjónsson
Shimadzu
Shirakihara
Tanaka
Valdivia
Wada
Yamamura

1–4. GENERAL

1. Kirkwood was appointed Chairman.
2. Clark was appointed rapporteur.
3. The Agenda adopted is shown in Appendix 1. It was agreed that priority in attempting assessments should be given to those stocks from which catches were being taken (i.e. Western North Pacific, North Atlantic and Southern Hemisphere Division 9), and within that constraint, that priorities were reflected in the order the stock areas appear in the Agenda. It was noted, however, that where appropriate, data from stock areas with a low assessment priority may be examined in the contexts of discussions on estimation techniques and biological parameters. The Chairman noted that the question of a moratorium on sperm whaling had been referred to the Management sub-committee, and would not be discussed by the Sperm Whale sub-committee.
4. The sub-committee had available to it the following documents pertaining to sperm whales:

SC/33/Sp1–6.
SC/33/O 1, 3, 5, 13.
SC/33/ProgRep Australia, Iceland, Japan, Peru, Spain, UK, USSR.

The sub-committee welcomed the availability of IWC catch master tapes for the Southern Hemisphere and North Pacific, described in IWC Technical Notes 5 and 7. The compilation of these data in this form has resulted from a large amount of work during the past year by Free, and the sub-committee wishes to formally record its appreciation of this work.

5. ESTIMATION TECHNIQUES

5.1 Techniques utilizing length or age distributions of the catches

In the assessments carried out at the last meeting of the sub-committee, new estimation techniques based on use of length or age distributions of the catches were used to estimate the sizes of the Western North Pacific and North Atlantic stocks of sperm whales. For the North Pacific, the techniques described by Beddington and Cooke (*Rep. int. Whal. Commn* 30: 747–60) were used, while a different computer program based on the same techniques written by Hiby was used for the North Atlantic.

Beddington reported on further work done since the 1980 meeting on the techniques described in *Rep. int. Whal. Commn* 31: 747–60. In applying the techniques to the North Pacific pelagic data set, an error had been made. The error occurred in reading the pelagic catch at length data, when incorrectly some identifiers were read as catches at length. This error applied only to the section of the programs which calculated the selectivities and resulted in 'incorrect' estimation of selectivities and hence incorrect estimation of population size associated with them. It did not affect the calculation of the residual sums of squares (the measure of goodness of fit to the data) or the calculation of the population trajectory for a given initial population size.

The other applications of the techniques to the North Pacific coastal data and Divisions 3, 5 and 9 in the Southern Hemisphere did not have this data error.

Correction of the data reading error produced a result essentially that described in SC/33/Sp5. However, inspection of this result, together with those obtained previously, indicated that the fit to the data was better for the combination of incorrectly calculated selectivities and lower population size. This implied that the method of calculating selectivities was failing to find the best fit to the data.

A new length specific technique had been developed which did guarantee the best fit to the data (SC/33/Sp3). This had been used on the data set for Division 5, where it produced very similar results to those obtained last year using the previous techniques. The new technique required a much more complete data set, which prior to the meeting was unavailable for the North Pacific.

Members expressed regret that these errors had been made, and it was agreed that before the revised technique in SC/33/Sp3 or an alternative method in SC/33/Sp5 could be adopted for use in performing assessments at this meeting, they should be subject to close examination.

Describing the general features of the revised technique in SC/33/Sp3, Cooke made the following points.

(i) The revised technique is purely length specific. This is required, as in order to ensure that the best fit to the data is found, it is necessary in the calculation of population trajectories to subtract the observed catches at length. While such data are available for the sperm whale catches in the North Pacific, the equivalent catch at age data for each whale caught are not available.

(ii) The technique now always finds the best fit to the data.

(iii) Better estimates of confidence regions are available from a modification of the original least squares technique.

(iv) The technique allows calculation of useful estimates of population sizes even in the presence of considerable variability in length compositions, as long as the reduction in population size due to catching over the period of exploitation is substantial.

(v) The natural mortality rate is not well estimated by the technique.

(vi) Simulations to determine the effect on estimates and confidence limits of variation of the underlying population model indicate that such variation leads to adverse effects.

Shirakihara explained that SC/33/Sp5 reviewed the derivation of the theory and computer implementation of the age specific technique in *Rep. int. Whal. Commn* 31: 747–60. He reported that a similar review of the length specific technique had not been attempted as he had not had a copy of the computer program. SC/33/Sp2 has noted a defect in the computation of age specific selectivities in *Rep. int. Whal. Commn* 31: 746–60, and has shown that the presumed age specific selectivity is really length specific selectivity. SC/33/Sp2 has proposed a method of calculating age specific selectivities based on polynomial regression. Shirakihara then reported that SC/33/Sp5 describes in detail a revised version of the age specific technique incorporating the proposed methods of SC/33/Sp2.

Beddington stated that, as described in *Rep. int. Whal. Commn* 31: 752, in the previous age-specific technique the calculation of age specific selectivities did involve some element of length specificity, but that this had not caused serious problems. In his view, this point had already been covered in *Rep. int. Whal. Commn* 31: 752.

Kirkwood reported the finding in SC/33/O 3 that on statistical grounds, the methods of maximum likelihood or minimum chi-square are preferable to the least squares method. He noted however, that given the large data sets to which the methods are to be applied, the major effect of these findings is to question the confidence regions determined using least squares, and that the effect on the population estimates themselves is likely to be minimal.

The sub-committee agreed that the most appropriate means of reconciling these different approaches was to charge a sub-group with the task of examining each method in detail. The report of this sub-group is given in Appendix 2.

Reporting on the discussions of the sub-group, Kirkwood outlined the basic differences between the two approaches that had been identified. He noted that the sub-group had referred back to the sub-committee the question on the appropriateness of assuming pure length and age specific selectivities.

In discussions on the relative merits of these assumptions, a range of views was expressed by members of the sub-committee. Some members felt that, due to the effects of size limits and the conscious selection of larger whales due to their greater value, selectivity was more likely to be length specific than age specific. Other members felt that in view of the high correlation between age and length, and our inability to determine whether various aspects of sperm whale behaviour affecting their catchability were determined by age or length, it was impossible to judge whether selectivity was length or age specific. Tanaka commented that in addition to the factors already mentioned, the estimated selectivities also depend on the assumed underlying model.

After some discussion, the sub-committee agreed that it was unlikely that selectivity was either purely length or age specific.

Beddington stated that in the analysis described in *Rep. int. Whal. Commn* 31: 90 for Division 3 sperm whales, different population estimates had been obtained for the two methods (age and length specific) of *Rep. int. Whal. Commn* 31: 747–90. He also stated that the results indicated a significant change in mean length at age. This implied that, at least for Division 3, the assumption of purely age-specific selectivity was refuted. Beddington noted, however, the caveat that this conclusion was based on methods that may not have found the best fit to the data, as he had previously reported.

Noting that with the availability of annual age-length data, it had been possible to examine the assumption of length or age specific selectivities, the sub-committee requested that Ohsumi provide, for the next meeting, the annual age-length data that were summarised in his age/length key of *Rep. int. Whal. Commn* 26: 295–300. Ohsumi stated that he would endeavour to meet this request, and suggested it may be possible to further subdivide the data by 10° square.

As there were no data allowing either assumption to be directly tested for the North Pacific or North Atlantic, the sub-committee agreed that it was impossible to exclude use of either method for these stocks on the grounds of its assumption of age or length specific selectivities.

The sub-committee discussed the conclusions of the sub-group with respect to the attainment of a best fit to the data by each method. It was agreed that, where full data of the observed length or age distributions on all catches were available, methods such as in SC/33/Sp3 that utilized these observed catches and always found a best fit to the data were clearly preferable, provided their assumptions were satisfied. The sub-committee noted with some concern that age specific methods such as in SC/33/Sp5 or length specific methods such as in *Rep. int. Whal. Commn* 31: 747–90, which utilized expected catches, may not find the best fit to the data.

Even in length specific models at least to some extent expected catches may have to be used if observed catch data in the fine detail required are not available.

It was agreed that if either method was used to estimate population sizes during this meeting, the results of sensitivity tests recommended by the sub-group should also be presented.

Estimation techniques based on catch length and age data promise to be extremely valuable, and the sub-committee encouraged those involved to continue work on their development. To facilitate this, it recommended that an *ad hoc* Working Group (Kirkwood, Beddington, Cooke, Tanaka, Shirakihara, Harwood, Hiby) should correspond throughout the coming year on further developments on these techniques.

The sub-committee commended the sub-group for its work, and agreed that both methods had been subjected to as close a scrutiny as was possible in the time available.

It was agreed that the suitability for use of either method to estimate stock sizes depended to a large extent on the catch and associated biological data available for that stock. Therefore no general preference could be stated for either method, except as recorded above. The use of either method should be examined on a stock by stock basis.

6. NORTH PACIFIC SPERM WHALES

6.1 Stock definition

After reiterating the previous considerations and discussions of the Sperm Whale sub-committee that led to the setting of the boundary between Eastern and Western North Pacific stocks of sperm whales (see figure, *Rep. int. Whal. Commn* 31: 847). Kirkwood reported that no new information on stock identity was available at this meeting. He noted that the reanalysis of North Pacific marking data that had been requested (*Rep. int. Whal. Commn* 31: 88) had not been done. As the data required for the analysis are now available, this analysis should be carried out.

Reviewing the available biological and marking evidence, the sub-committee agreed that on biological grounds, there was no reason to change the existing stock boundary line. However, Cooke reported that due to a lack of precision in the recording of the area to which catch length distributions applied, this stock boundary caused some problems. Specifically, catch length distributions for the area covered by 10° squares P25, 26 and N25, 26 were available only for those four squares combined. However, the previously agreed stock boundary cut through this large area, necessitating if it were retained some arbitrary splitting of the catch length data. He also reported that substantial catches had been taken in those squares. Cooke noted that a similar problem existed with the previous boundary between stocks in Zones L and M, although there the catches were not so large.

Because of the difficulties presented by the lack of geographical precision in the data, it was agreed that alternative boundaries should be considered for assessments at this meeting.

Mitchell noted that there was little evidence of migration of sperm whales through the Aleutian passes, and stated that it would be reasonable to treat whales in P25 and 26 as part of the Western stock. After some discussion, most members felt that the best solution to the data handling problem might be to take the boundary between the Eastern and Western stocks at 160°W. Mitchell noted that this boundary was similar to that suggested in *Rep. int. Whal. Commn* 27: 167–75.

Ohsumi stated his view that since it was difficult to sub-divide the catch length data and due to the mixing of males in high latitudes, the best approach was to treat the North Pacific as a single stock for the purposes of estimation of population sizes, and then sub-divide it for management purposes.

Due to the length of time required to calculate estimates for both the total and Western North Pacific, it was agreed that population estimates should only be presented for the Western North Pacific, with a stock boundary at 160°W.

The sub-committee noted that population estimates for a Western stock with a boundary at 160°W will be expected to be slightly higher than those obtained using the old stock boundary.

6.2 Biological parameters

As there was no new information available to the sub-committee on biological parameters for the North Pacific, the sub-committee agreed to adopt for the purposes of population estimation the biological parameters previously agreed for North Pacific sperm whales. These parameter values are shown in Table 1.

Several members expressed the view that there was poor agreement between observed and predicted pregnancy rates for several stocks examined last year (*Rep. int. Whal. Commn* 31: 84, 90, 92, 98, 101), and that this casts doubt on population projections into the future and on appropriate stock classification under the New Management Procedure. In view of the fact that, for the North Pacific stocks of sperm whales, this will not affect estimates of initial population sizes, it was agreed to defer discussion of this until the results of population estimation were available. Best requested that estimates for Division 3 be calculated using Durban CPUE data (*Rep. int. Whal. Commn* 31: 769–82), in order to examine further the comparison between observed and predicted pregnancy rates. These data had been revised from those presented at the last meeting.

Table 1

North Pacific sperm whales
Biological parameters

Average age at recruitment (1981)	♂	11
	♀	10
Average age at maturity (social maturity*)	♂*	25
	♀	10
Natural mortality rate	♂	0.066
	♀	0.055
Mean number of mature females available to a school master		10
Reserve male ratio		0.3
Pregnancy rates: unexploited		0.20
exploited		0.25
Density dependent exponent		1.4

6.3 Catch data

Prior to the meeting, Free had made available a master tape of catch length data from NP3 forms in as great a geographical detail as possible (IWC Technical Note No. 7). However, both methods discussed under agenda item 5 required the availability of catch length data for all catches in the North Pacific, and not all these data were recorded on NP3 forms. It was necessary, therefore, that these additional data be added to the NP3 form data. Details of the missing data and actions taken to complete the data set are given in Appendix 8.

Although this took considerable time during the meeting, complete catch length data for the North Pacific are now available.

In view of the still unresolved difficulties in interpretation and pooling of CPUE data for the Western North Pacific, it was agreed that estimates of population size in the North Pacific could not be calculated using CPUE data.

6.4 Assessment

Due to the length of time necessary to compile the full catch data set for the North Pacific in the form required, and to ensure the computer program implementing the techniques of SC/33/Sp5 was tested and available on the Cambridge computer, estimates of population sizes for the North Pacific have not been obtained.

Despite this, the sub-committee records its appreciation for the hard work put in during the meeting by Cooke, Free, Harrison and Tedori in attempting to fulfil this task.

SC/33/Sp6 presents an assessment of the Western North Pacific sperm whale stock, based on the methods described in SC/33/Sp5. Comments of the sub-committee on this method are given in section 5 of this report. The results presented in SC/33/Sp6 were not discussed by the sub-committee.

7. NORTH ATLANTIC SPERM WHALES

7.1 Stock definition

The sub-committee agreed, for the purposes of assessment, that North Atlantic sperm whales should be treated as a single stock.

7.2 Biological parameters

No new information on biological parameters for North Atlantic sperm whales was available, and the sub-committee agreed to adopt for assessment purposes the biological parameters used last year. These are shown in Table 2.

Table 2

North Atlantic sperm whales
Biological parameters

Average age at recruitment	♂	20
	♀	13
Average age at maturity (social maturity*)	♂*	25
	♀	10
Natural mortality rate	♂	0.066
	♀	0.055
Mean number of mature females available to a school master		10
Reserve male ratio		0.3
Pregnancy rates: unexploited		0.20
exploited		0.25
Density dependent exponent		1.4

7.3 Catch and effort data

Appendix 2 of SC/33/O 13 summarises new catch and effort data for three Azores land stations that took sperm whales. These data, available for the period 1949–67, detail catches by sex of sperm whales and corresponding effort data in the form of boat days, collected by Avila de Melo[1]. These effort data are an improvement on those previously available, as they now only include boat days when there was whaling activity on each island.

Noting that these data are admittedly somewhat crude in comparison with catch and effort data available for other stocks, the sub-committee agreed that estimation of sperm whale population sizes in the North Atlantic should be attempted using the male catch and effort data series.

The series used is shown in Appendix 4.

Catch and effort data were also available for Spanish operations in SC/33/O 1, and possible adjustments for seasonality are suggested in Appendix 7. The sub-committee agreed to attempt population estimation using the two alternative series of male catch and effort data described in Appendix 5. Several views were expressed as to which of the two proposed methods of deriving the male catch and effort data series should be used, but it was agreed that the differences between the two series were minor. The two series used are shown in Appendix 6.

De Salas informed the sub-committee that this year for the first time Spanish catch statistics had been complied from photocopies of actual whaling company records, rather than from statistical reports submitted by the company, as in the past.

Catch at length data for male sperm whale catches off Iceland were also considered suitable data with which to attempt estimation of North Atlantic sperm whale stock sizes.

7.4 Assessment

Separate estimates of the size of the North Atlantic stock were obtained using a variant of the length specific method of SC/33/Sp3 on Icelandic catches of males, and using the Azores and the two series of Spanish male catch and effort data. The results are detailed respectively in Appendices 3, 4 and 6, and are summarised in Table 3 below.

Table 3

Summary of population estimates for the North Atlantic Stock of sperm whales

	Appendix 3 (Iceland)	Appendix 4 (Azores)	Appendix 6[1] Spain (A)	Appendix 6[1] Spain (B)
		Exploitable males ('000s)		
1905	28.6	13.6	12.6	12.9
1981	19.1	3.8	2.3	2.7
% 1981/1905	67	28	18	21
		Mature females ('000s)		
1905	43.0	35.7	33.1	33.7
1981	38.9	19.7	15.7	16.7
% 1981/1905	90	55	47	50
		Exploitable females ('000s)		
1905	Not available	30.2	28.0	28.6
1981	Not available	18.5	15.2	15.9
% 1981/1905	Not available	61	54	56

[1] In calculating these estimates, inadvertently the 1977 catch and effort data were included, whereas the agreed data series described in Appendix 5 omits the 1977 data. These estimates will be re-calculated.

Several factors were identified for each method that indicated that the estimates shown in Table 3 could not be considered reliable. As outlined in Appendix 3, it is extremely likely that a crucial assumption of the length specific method of estimation used is violated, namely that length specific relative catchabilities remain constant over time. Also, the relative sparseness of the data, and the poor fit of expected to observed catches at length ensures that the confidence limits for the estimates obtained using this method are very wide.

The time series of predicted pregnancy rates obtained using each of the male catch and effort data series indicated pregnancy rates lower than in the unexploited stock between the early fifties and the present. The pregnancy rates were predicted to fall to a lowest level in the mid sixties of around 0.05 for the Azores catch and effort data and around 0.02 for the Spanish catch and effort data. The full series of predicted pregnancy rates are shown in Appendices 4 and 6. Although no observed pregnancy rate data were available for that period, the sub-committee believed that such predictions were very unlikely, and that the estimates of final population size and percentage of current to initial were therefore artificially depressed.

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[1] Da Cunha Avila de Melo, A. M. 1978. *Avaliacao da populacao de cachalotes (Physeter catadon* Linné 1758) *para a area do Atlantico medio-este, de 1949 a 1967.* 74 pages plus tables and figures. (In Portuguese.)

Of the estimates in Table 3, those using catch and effort data are especially sensitive to changes in the biological parameters used, and in particular the age at recruitment of 20 years for males was considered very unrealistic. Beddington and Cooke made the point that the sensitivity of the decline to changes in age at recruitment could not be assessed without a sensitivity test of the model. Accordingly they felt that the conclusion that the results were sensitive to this parameter and therefore unreliable was premature.

In view of the uncertainties in the assumption of a single stock and in the biological parameters adopted, and the additional factors outlined above, the sub-committee agreed that no reliable estimates of current or initial stock size could be obtained.

Not withstanding the uncertainties expressed, the sub-committee agreed that the two new series of catch and effort data support the conclusions reached last year that there had been a decline in stocks of both male and female sperm whales in the North Atlantic. However, the sub-committee was unable to agree on the extent of that decline. Some members, while acknowledging the uncertainties in the estimates, believed that they indicated there had been a severe decline in stock sizes. Others believed that such a conclusion was unwarranted, and that the stocks may now be near optimal levels.

The data and population estimates described above suggest a greater decline in male than in female stocks. Caution was urged in the setting of catch limits for 1982, particularly for males.

8. SOUTHERN HEMISPHERE, DIVISION 9 SPERM WHALES

Insufficient time was available to consider this agenda item. New data for this stock are given in SC/33/ProgRep Peru.

9. SOUTHERN HEMISPHERE, DIVISION 1–8 SPERM WHALES

Insufficient time was available to consider this agenda item.

10. FUTURE RESEARCH AND DATA COLLECTION

The sub-committee initiated discussions on this agenda item by reviewing progress on the research tasks identified in *Rep. int. Whal. Commn* 31: 87–8.

Southern Hemisphere

(i) Re-analysis of stock identity
Holt reported that with the availability of the consolidated Southern Hemisphere data set (IWC Technical Note 5), extraction of summaries similar to those extracted for minke whales this meeting would allow this analysis to proceed. He expected that the work would be completed by the next meeting.

(ii) Analysis of sightings estimates for Division 5 males
Kirkwood reported that further analysis of sightings data from Albany sperm whale spotting had been carried out as part of a pilot study examining the feasibility of re-introducing periodic sighting surveys comparable to those carried out in the past (see SC/33/ProgRep Australia). He reported that it was possible that the first such survey could commence in 1983.

(iii) Reading of Durban teeth
Best reported that all the teeth have now been cut and sectioned, and that some progress has now been made on ageing them. Work is proceeding on this.

(iv) Reading of Albany teeth
Harwood reported that the reading of the Albany teeth by one reader at the Sea Mammal Research Unit had been completed. Validation by another reader and compilation of annual age length keys should be completed this year. See also SC/33/ProgRep Australia.

North Pacific

(i) Application of Soviet age length key
Kirkwood reported that Allen and Free intended to correspond during the year in order that computer programmes CPOP and AGK, which perform the required analyses on age and length data, are completely re-written and revised. The Soviet data are now available on the Cambridge computer (IWC Technical Note 7).

(ii) Reanalysis of mark recapture data
This task required the availability of detailed data of catches by country by 10° square of whales over 40 ft in length requested in *Rep. int. Whal. Commn* 31: 88. These data are now available, but the reanalysis has not yet been attempted. The sub-committee urged that the analysis be completed by next meeting.

(iii) Assembly of information on schools
Allen reported that data on school sizes obtained on Albany sighting flights had been provided by Bannister. It was noted that provision of information on schools was now a requirement of the Schedule. Ohsumi reported that he had much data on schools, dating from a period prior to the Schedule requirement, but that these data existed only on forms and they had not been entered on computer. Gambell informed the sub-committee that the enhanced computing capabilities of the Secretariat now allowed such data to be coded and entered on computer at Cambridge. Ohsumi undertook to forward these data to Gambell.

Additional tasks (*Rep. int. Whal. Commn* 31: 88)
(i) Reading and analysis of teeth from Peruvian operations. Valdivia reported that a start had been made on cutting and sectioning the teeth, and that he hoped to have completed reading and analysis in time for the next meeting.
(ii) Further development of length and age specific estimation methods.

A number of papers addressing this topic were available at this meeting, and are discussed under agenda item 5 in this report.
(iii) Cross reading of teeth.
SC/33/Sp1 reports comparisons of reading of teeth by six Soviet scientists.

Tasks identified during this meeting.

(i) Entry of Japanese biological data onto computer
Ohsumi reported that, as for the information on schools, detailed biological data on each whale caught by Japanese vessels up to 1965 were available on forms at his laboratory, but that a limited budget precluded their rapid entry onto computer. As these data could now be processed at Cambridge, Ohsumi undertook to forward the data to Gambell. Similar data from 1965 are already available on the Cambridge computer.

The sub-committee was very appreciative of this new initiative, and welcomed the forthcoming availability of these data.

(ii) Further development of age and length specific estimation techniques
An *ad hoc* Working Group (see agenda item 5) should correspond during the year with a view to further development of these techniques. For the next meeting, Hiby and Harwood should provide full documentation of their version of the technique of SC/33/Sp3.

(iii) Revision of methods of estimation of ages at recruitment (Allen, Free)

(iv) North Atlantic biological data
Noting that at least one of the reasons for uncertainty in the assessment of North Atlantic sperm whales was the lack of information on biological parameters, the sub-committee urged that every effort be made to provide more biological data on North Atlantic sperm whales. It also agreed that analyses of existing data should be completed as soon as possible.

The sub-committee took note of the suggestion that the Spanish Government intended to undertake marking and sightings experiments on sperm whales in the North Atlantic this season if possible.

Research priorities
The sub-committee agreed that highest priority should be given to research directed at problems and areas of uncertainties encountered in attempting assessments of North Pacific and North Atlantic stocks of sperm whales and to a lesser extent Southern Hemisphere Division 9. However, it recognised that in some cases this required availability of comparative data from other stocks, the assessments of which have not been accorded high priority.

The sub-committee identified three major areas of research, to which it accorded high, but equal, priority.

(i) *Age and Length data*
The sub-committee noted that there is a large body of existing age-length data available in various forms in national laboratories, in the published literature, and with the IWC Secretariat.

In view of the increasing importance age and length data are assuming in the carrying out of assessments, the sub-committee recommends that, as far as possible, these data should be consolidated and entered onto the Cambridge computer. It also recommends that these data should be stored by year of capture of the whales, and in as fine a geographical breakdown as possible.

Noting the encouraging progress that has been made in cutting, sectioning and ageing of teeth collected by various national groups, the sub-committee recommends that the work continue as a matter of urgency.

The sub-committee also recommends that work continue on attempts to compile full catch length data for the North Pacific by 10° square.

(ii) *Stock identity*
Stock definition for North Atlantic sperm whales was identified as a major and continuing area of uncertainty. The sub-committee has already noted with pleasure the possibility of marking and sighting experiments on sperm whales by Spanish authorities. It was also pleased to receive a report of the possibility that some sperm whales might be marked off Iceland, although the major aim of such marking experiments would be fin whales.

The sub-committee urges that the proposed IDCR North Atlantic cruise described in *Rep. int. Whal. Commn* 31: 162–3 be undertaken as soon as possible. The sub-committee also believed that useful information on stock identity could be gathered from the proposed IDCR Azores Sperm Whale study of *Rep. int. Whal. Commn* 31: 54.

It hoped that marking of sperm whales off Peru (SC/33/ProgRep Peru) could continue.

(iii) *Sperm whale biology*
The sub-committee noted that the development of mathematical models and estimation techniques for sperm whales had somewhat outstripped the biological underpinnings of those models. A particular area of uncertainty was the effect on pregnancy rates of imbalances in the sex ratio of mature males and females.

The sub-committee recommends that further research be carried out to help elucidate this problem, however it recognises that this is a particularly difficult area of research.

Appendix 1

AGENDA

1. Appointment of Chairman
2. Appointment of rapporteur
3. Adoption of agenda
4. Review of documents and data
5. Estimation techniques
6. North Pacific sperm whales
7. North Atlantic sperm whales
8. Southern Hemisphere, Division 9 sperm whales
9. Southern Hemisphere, Division 1–8 sperm whales
10. Future research and data collection

Appendix 2

REPORT OF THE SUB-GROUP EXAMINING METHODS OF ESTIMATION

Members: Kirkwood (Chairman), Allen, Beddington, Butterworth, Clark, Cooke, Harwood, Hiby, De la Mare, Misaki, Nakamura, Shimadzu, Shirakihara, Tanaka.

The sub-group was given by the Sperm Whale sub-committee the task of providing advice on the most appropriate method of estimation of sperm whale population sizes utilizing detailed catch at length and/or age data. In so doing, it was requested to examine specifically the methods proposed in SC/33/Sp2, 3 and 5. The sub-group agreed to adopt a procedure in which each method was examined, step by step. For both methods, the basic underlying assumptions were to be identified, and the computational methods studied.

This report outlines the basic assumptions identified for each method and the comments of the group on them, as well as comments on several aspects of the computational procedures adopted. No attempt has been made to report in detail the full discussions on each method. These were, of necessity, extremely technical and very lengthy.

The group had before it SC/33/Sp3 which discussed a technique developed by Cooke and Beddington based on length data from catches, which was a revised version of those techniques described in *Rep. int. Whal. Commn* 31: 747–60; SC/33/Sp2 and 5 which reported comments (SC/33/Sp2) on the previous Beddington and Cooke technique and a new method developed by Shirakihara and Tanaka (SC/33/Sp5); and SC/33/O 3 that commented on some statistical aspects of the Beddington and Cooke techniques.

Taking Kirkwood's comments that the criticisms he raised (SC/33/O 3) were mainly directed to the calculation of confidence regions, the group decided to concentrate only on the two new estimation methods before it.

In the remainder of this report, the length specific method described in SC/33/Sp3 will be referred to as CB, the age specific method of SC/33/Sp5 as ST, and the previous length or age specific methods of *Rep. int. Whal. Commn* 31: 747–60 as BC.

Basic assumptions

Both the CB and ST methods are designed to estimate population sizes of male sperm whales by minimising the sum of squared differences between observed and expected catches by length. In so doing, both methods assume that the length or age specific selectivities (relative catchabilities) are invariant with respect of time. The underlying dynamics of the sperm whale population in both methods are assumed to follow that of the sperm whale model (*Rep. int. Whal. Commn* 31: 100–101).

The primary difference between the two methods is that in the CB method, the geographical distribution and probability of capture of a male sperm whale is solely a function of its length, while in the ST method, it is assumed to be solely a function of age. Thus the CB and ST methods may be distinguished as being respectively length specific and age specific methods.

With minor exceptions, data on the lengths of each male sperm whale caught are available, however only a small minority of male sperm whales caught have been aged. For age specific methods, this implies that in tracing the dynamic trajectory of a population for a given initial population size, it is necessary to subtract expected rather than observed catches by age. In length specific methods, however, actual observed catches by length may be subtracted from the population in tracing a dynamic trajectory, although it is necessary to incorporate a model of the growth process not required in the age specific method described.

Attainment of best fit to the data

As Beddington had already reported (see Report of the Sub-Committee on Sperm Whales, Annex D), in both the age and length – specific BC methods described (*Rep. int. Whal. Commn* 31: 747–60) it had been necessary to subtract expected rather than observed catches in generating the dynamic trajectory of population sizes for a given initial population size. With the trajectories calculated in this manner, the initial population size and other parameters were estimated by minimising the sum of squared differences between observed and expected catches at length. These methods were used with data on a number of stocks, including data on North Pacific pelagic catches, and the population estimates and minimum sums of squares were calculated.

It subsequently was discovered that there had been an error in handling these data, which affected the calculation of selectivities and hence the estimate of initial population size. When corrected, it was found, surprisingly, that the revised estimates obtained corresponded to a higher minimum sum of squares than previously obtained. This implied that the method used then may not necessarily find the best fit to the data, and thus the estimates obtained may be in error. As a consequence of this discovery, and with the advent of a full data set of catch length distributions for the North Pacific, the revised length specific method CB has been developed, utilizing observed catches, as described in SC/33/Sp3.

Beddington further reported that the data handling error had occurred only with the North Pacific pelagic data, and that the estimates obtained using North Pacific coastal data, and data from Southern Hemisphere Divisions 3, 5 and 9 were unaffected by data errors. He informed the group that in the time available, he and Cooke had only been able to use the revised technique on the Division 5 data. This led to very similar estimates of population size to those that had been obtained using the BC method (see SC/33/Sp3). As a consequence, it was apparent that the BC methods did not always find the best fit to the data in every case.

Beddington stated that the new CB method did always find the best fit. After discussing in detail the methods used to find the best fit, the group agreed that the CB method would always find the best fit, provided a thorough search was undertaken.

The ST method, which as described in SC/33/Sp2 and 5 is a development of the age-specific BC model, essentially differs from the age-specific BC model in the means by which selectivities are calculated. Following the suggestions of SC/33/Sp2, the ST method incorporates a slightly different method of calculating time averages of age specific selectivities, and utilizes a fifth degree polynomial approximation in order to estimate truly age-specific selectivities.

Tanaka expressed the view that the weight used in equation 21 of SC/33/Sp5 may not be the optimal weighting, but that he believed that the adopted weighting was reasonably close to optimal, in view of the many examples from fisheries data in which the standard deviation of the catch is approximately proportional to the catch. Some members felt that the weighting used appears to give approximately equal weight to each of the ratios S/C of selectivities to catches, and that this might not be entirely appropriate when the catch C is small, as the ratio would then have relatively high variability. Tanaka explained that in calculating the weighted average, the smaller catches by sub-area are excluded to avoid this effect.

The group agreed that the optimal weighting scheme was unknown, and that the weighting adopted was not unreasonable. However, it suggested that the sensitivity to different weightings should be examined. The group agreed that a weighting of $1\sqrt{C}$ should be tried (cf. *Rep. int. Whal. Commn* 31: 729–36), as well as the 1/C used in equation 21 of SC/33/Sp5.

The selectivities averaged over time in equation 21 of SC/33/Sp5 are estimated for each year by fitting a fifth degree polynomial. Estimates of age-specific selectivities for the North Pacific using the BC age-specific techniques showed fairly regular variations of selectivity with age. However, it was noted that the age-specific selectivities in SC/33/Sp5 are slightly differently defined to the BC selectivities. The group agreed that this method of estimating selectivities appeared to be an acceptable one.

These differences in calculation of age-specific selectivities aside, the ST method is essentially similar to the BC age-specific technique, and hence is likely to suffer from the same drawbacks as described above for the BC techniques utilizing expected rather than observed catches. The group agreed that the ST method of SC/33/Sp5 may not always find a fit to the data which is best with respect to all valid methods of calculation of selectivities within the model.

If for no other reason than to avoid these problems, the group agreed that it was always preferable to utilize observed rather than expected catches, if they were available.

Modelling growth

Unlike the ST (and BC) age-specific method, the CB method requires a model of the growth process. Briefly, the growth model used in the computer program listed in SC/33/Sp3 revolves around an underlying growth curve, which for the North Pacific is assumed to a quadratic between the age at which the mean length is 30 ft (the current minimum size limit), and age 40, after which no growth is assumed to take place. The mean growth curve is assumed to be invariant with time or degree of exploitation, and the distribution of lengths for a given age is assumed to have constant variance. The growth rate is assumed to depend solely on age, not length. Further details are to be found in *Rep. int. Whal. Commn* 31: 747–60.

The basic data that the group had available to judge the appropriateness of these assumptions was the smoothed age length key of Ohsumi (*Rep. int. Whal. Commn* 26: 295–300). It was pointed out that the fitted growth curve gave predicted mean lengths sometimes more than one foot higher than observed means between ages 20 and 35 years. However, it was recognised that at least the direction of this difference is to be expected, due to the exploitation bias in the age-length key. The group examined each of the assumptions listed above. It was agreed that the curve chosen probably gave an adequate description of mean growth. The group also agreed that there were no data to suggest any possible density dependence on growth.

Discussing the method used to calculate the mean age at 30 ft in the unexploited population, the group noted that some bias entered into this calculation, as of necessity an 'exploited' age-length key must be used to perform the calculation. The group agreed that this bias was likely to be slight. With respect to the mean maximum length, Cooke reported that as the program was currently set up, a mean maximum length calculated from Division 5 data was used. As the program alternatively allowed the estimation of this parameter, the group felt that this may be the more appropriate course to take.

There was considerable discussion on the assumption of constant variance, with several members expressing the view that it may be more biologically reasonable to assume an increasing variance with age. Noting the biasing effect of the various size limits on the observed age-length key as a reflection of the distribution of lengths at age, the group found few data with which to examine this assumption, and agreed that the assumption of constant variance could not be rejected or confirmed with the data available.

One of the combined effects of the various assumptions, including that the growth rate is dependent on age not length, is that if catching ceases, the precise shape of the distribution of length at age is maintained over ensuing years. The group agreed that this was biologically unreasonable, as natural variability alone would be expected to produce some blurring of this shape. After considerable discussion, the group agreed that while no general statement could be made, ignoring this expected blurring is not likely to bias the resulting population estimate downwards.

The group examined in detail the computational procedures used to model growth, and expressed concern over the report from Cooke that when the dynamics of the population were simulated for a number of years with zero catches, after around 20 years the calculated age and length distributions differed noticeably from those in the initial year. De la Mare suggested a modification of the technique that may help reduce this problem. It was agreed that if no noticeable differences were found in initial and final length and age distributions after simulation over a period of 100 years, there would be no cause for concern. The group agreed that De la Mare's suggestion should be incorporated into the program, and the simulation with zero catches rerun.

Hiby reported that he had written a computer program implementing the CB method that differed in the manner (but not background assumptions) in which growth is handled. He reported further that the problem in the CB computer program with simulations with zero catches did not occur with his program. This program had been written to handle North Atlantic sperm whale data.

Sensitivity tests

The group noted that, in addition to the basic assumptions of the two models listed earlier, there were uncertainties in the estimation of age-specific selectivities in the ST model, and in modelling growth in the CB model, that may be amenable to further examination via sensitivity tests. The group agreed that results of these tests should be examined before the techniques could be adopted for assessment purposes.

(i) As described above, in the ST model, there are various alternative methods of calculation of age-specific selectivities. In view of the agreement by the group that the ST model may not find the best fit to the data, separate estimations using the alternative weighting scheme described earlier should be produced.

(ii) For the CB model, a 100 year simulation with zero catches should be made.

(iii) Noting that the CB method critically depends on the appropriateness of the growth model, the group agreed that sensitivity tests for changes in the value of the fixed variance and of the estimated mean growth curve parameters should be carried out.

Conclusion

Each method studied by the group is quite complicated, both as a simulation and as an estimation procedure. After studying them as closely as possible in the time available, the group identified the concerns mentioned above. Subject to their satisfactory performance on the sensitivity tests, the group agreed that the methods were suitable for use at this meeting. It also considered that this class of methods is extremely promising, and urged further work on development and verification of such methods.

The group has not examined the computer programs implementing the methods.

The most basic difference between the CB and ST methods is in their assumption of either pure age or length specific selectivity. As ecological and technical considerations must be considered in discussing the appropriateness of these assumptions, the group referred this matter back to the Sperm Whale sub-committee for possible resolution.

Appendix 3

REVISED CALCULATION OF STOCK ESTIMATES FOR NORTH ATLANTIC SPERM WHALES

A. R. Hiby and J. Harwood

Last year we calculated estimates of the size of the North Atlantic stock of sperm whales (*Rep. int. Whal. Commn* 31: 843–6) using the length-specific version of what has come to be known as 'the Beddington-Cooke method' (*Rep. int. Whal. Commn* 31: 747–60). In that paper we calculated length-specific selectivities by dividing the sum of all animals at a particular length in the catch by the sum of all animals in that length-class in the simulated population.

This year Cooke and Beddington (SC/33/Sp3) have suggested two alternative methods for calculating selectivities which should guarantee that a global minimum is found. We have repeated the estimations performed last year calculating the selectivities in the way that they recommend. The other features of the estimation procedure are as described in *Rep. int. Whal. Commn* 31: 843–46, with an adult male mortality of 0.066. All recorded catches in the North Atlantic in this century were used and we minimized the sum of squared differences between the observed and calculated length structure of the Icelandic catch by varying the initial female stock size.

Although the different methods produced different estimates of the selectivities, the minimum sum of squares occurred with exactly the same initial population size in each case, and so the predicted population trajectories were identical with those shown in Fig. 2 of *Rep. int. Whal. Commn* 31: 844.

Even with the revised selectivities the predicted length structure of the catch did not correspond well with the observed length structure in the most recent years. The concerns expressed last year about the potential upward bias in these estimates due to changes in selectivity with time still hold.

The estimation process was also run again using the revised Spanish catches given in SC/33/O 1 and Madeiran catches for 1979 and 1980 supplied by the Secretariat. The results were:

Exploitable males

	1905	Current	% of initial	SS
1980 Data set	29,900	21,400	72	241.1
1981 Data set	28,600	19,100	67	236.7

The sensitivity of the estimates to variations in the parameters of the growth model were also investigated by independently varying the variance around the growth curve, the mean age at recruitment and the age at maximum length. Values used in the estimates shown above are indicated by an *. Variation in the minimum sum of squares was never more than ±5%.

	1905	Current	% of initial	SS
Variance				
V = 1	29,100	19,600	67	239.9
*V = 2	28,600	19,100	67	236.7
V = 3	28,700	19,200	67	237.0
Age at recruitment				
T_R = 19	30,600	21,000	69	245.7
*T_R = 20	28,600	19,100	67	236.7
T_R = 21	28,300	18,900	67	226.8
Age at maximum length				
T_{max} = 49	29,900	20,300	68	243.0
*T_{max} = 50	28,600	19,100	67	236.7
T_{max} = 52	33,100	23,700	72	228.8

A summary of the estimates obtained for male and female population sizes is given below.

	Exploitable males	Mature females
1905	28,600	43,000
1981	19,100	38,900
1981/1905	67	90

In simulations with these initial population sizes, the pregnancy rates are predicted to fall between 1971 and 1980, due to a predicted imbalance between the numbers of mature males and females. The maximum drop in pregnancy rate is around 5%.

Appendix 4

ESTIMATION OF NORTH ATLANTIC SPERM WHALE STOCK SIZES USING A CATCH AND EFFORT SERIES FROM THE AZORES

C. A. Free

Estimates of North Atlantic sperm whale population sizes were calculated using a catch and effort series from the Azores covering the period 1949–67. The estimation program POPDYN was run with the parameter values listed in the Report of the Scientific Committee, Annex D.

Two runs were attempted with the catch and effort data shown in Table 1, one with the full data set, and the other with the figures in brackets omitted, as there was some doubt about the comparability of data in those years. The resulting population trajectory that gave the best fit to observed catches for known effort is shown in Table 2, with the estimate of initial mature female population size being 35, 671. A plot of observed and expected catches by year is given in Fig. 1.

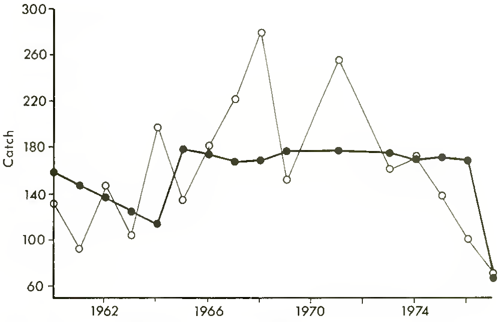

Fig. 1. Observed (○) and expected (●) catches (Azores CPUE data, 1949–67).

When the data for years 1950 and 1960 were omitted, the estimated initial mature female population size was 37,742. Due to the similarity of estimates for the two data series, the detailed results of this second run are not listed.

Table 1

Catch and effort data

Azores 3 Islands (from SC/33/O 13)

Input Data for POPDYN Runs

Year	male catch	Effort[1] (100 boat days)	Catch per unit effort
1949	118	70.66	1.67
(50)[2]	(157)	(51.64)	(3.04)
51	186	103.33	1.80
52	148	143.69	1.03
53	126	121.15	1.04
54	122	145.24	0.84
55	142	197.22	0.72
56	113	176.56	0.64
57	161	176.92	0.91
58	137	134.31	1.02
59	101	168.33	0.60
(60)	(85)	(128.79)	(0.66)
61	91	185.71	0.49
62	121	205.08	0.59
63	165	189.66	0.87
64	152	202.67	0.75
65	129	201.56	0.64
66	91	178.43	0.51
67	87	189.13	0.46

[1] Calculated as catch/CPUE from Table 3, SC/33/O 13.

[2] Figures in brackets omitted in one run.

Table 2

Time series of population components with best fit to given catches (Azores CPUE data 1949–67) with an estimated initial mature female population of 35,671. See report text for parameter values.

YEAR	FEMALE POPULATION			MALE POPULATION					CATCH		PRG
	IMM-UNEX	EXPLOITED	MATURE	IMM-UNEX	EXPLOITED	MATURE	H + RES	SUR-MAT	M	F	
1905	26534	30245	35671	37847	13632	9800	4637	5163	70	59	0.200
1906	26534	30190	35615	37847	13567	9750	4630	5120	150	128	0.200
1907	26532	30071	35497	37845	13430	9642	4615	5028	151	110	0.201
1908	26525	29977	35402	37838	13302	9534	4602	4932	190	171	0.201
1909	26515	29829	35255	37828	13145	9398	4583	4815	134	102	0.201
1910	26500	29755	35181	37813	13051	9302	4573	4728	192	176	0.202
1911	26482	29615	35040	37796	12908	9168	4555	4613	254	236	0.202
1912	26460	29425	34851	37774	12717	8997	4531	4466	258	294	0.203

(continued overleaf)

Appendix Table 2 (*continued*)

YEAR	-----FEMALE POPULATION------			----------------MALE POPULATION---------------					---CATCH---		---PRG---
	IMM-UNEX	EXPLOITED	MATURE	IMM-UNEX	EXPLOITED	MATURE	H + RES	SUR-MAT	M	F	
1913	26431	29191	34616	37746	12534	8829	4500	4329	143	132	0.203
1914	26393	29122	34548	37710	12470	8751	4491	4259	114	141	0.204
1915	26355	29049	34475	37673	12437	8697	4482	4215	121	157	0.204
1916	26316	28964	34390	37636	12400	8646	4471	4175	130	139	0.204
1917	26276	28901	34326	37597	12357	8597	4462	4135	149	123	0.204
1918	26238	28857	34278	37559	12299	8545	4456	4089	169	112	0.205
1919	26203	28825	34240	37520	12226	8481	4451	4030	143	112	0.205
1920	26171	28794	34202	37483	12182	8437	4446	3991	133	85	0.205
1921	26140	28788	34189	37446	12150	8402	4445	3957	116	82	0.205
1922	26114	28783	34177	37412	12136	8381	4443	3938	146	90	0.205
1923	26094	28769	34153	37378	12095	8342	4440	3902	165	69	0.205
1924	26079	28773	34145	37346	12039	8293	4439	3854	180	55	0.205
1925	26066	28788	34148	37316	11972	8236	4439	3797	225	72	0.205
1926	26056	28782	34134	37288	11867	8149	4437	3711	197	71	0.205
1927	26048	28773	34119	37261	11795	8082	4435	3646	190	59	0.205
1928	26041	28774	34115	37237	11733	8021	4435	3586	193	53	0.205
1929	26036	28779	34115	37215	11671	7961	4435	3526	192	61	0.205
1930	26032	28774	34107	37196	11612	7905	4434	3471	90	29	0.205
1931	26028	28799	34128	37178	11652	7924	4437	3487	62	23	0.205
1932	26027	28826	34154	37164	11714	7966	4440	3526	133	52	0.205
1933	26027	28825	34151	37155	11704	7962	4440	3522	242	77	0.205
1934	26027	28798	34123	37148	11589	7886	4436	3450	177	68	0.205
1935	26026	28782	34106	37141	11542	7856	4434	3422	294	110	0.205
1936	26025	28726	34049	37135	11388	7742	4426	3315	329	112	0.205
1937	26021	28671	33994	37127	11209	7599	4419	3179	606	121	0.205
1938	26015	28610	33932	37118	10782	7264	4411	2853	352	121	0.206
1939	26006	28552	33874	37107	10620	7105	4404	2701	328	116	0.206
1940	25996	28502	33823	37095	10490	6964	4397	2567	398	160	0.206
1941	25984	28413	33733	37082	10302	6783	4385	2397	288	122	0.206
1942	25967	28364	33685	37065	10229	6683	4379	2304	388	160	0.206
1943	25949	28282	33604	37047	10067	6538	4369	2170	563	237	0.207
1944	25928	28131	33454	37027	9752	6285	4349	1936	504	199	0.207
1945	25901	28025	33348	37001	9511	6074	4335	1739	412	159	0.207
1946	25870	27963	33284	36971	9372	5932	4327	1605	600	231	0.208
1947	25840	27836	33155	36941	9066	5672	4310	1362	572	207	0.208
1948	25807	27738	33053	36906	8805	5436	4297	1139	755	281	0.208
1949	25772	27574	32886	36868	8390	5099	4275	824	658	232	0.209
1950	25731	27465	32772	36824	8092	4833	4260	573	496	194	0.209
1951	25688	27396	32699	36778	7964	4673	4251	422	911	303	0.209
1952	25646	27226	32524	36730	7457	4277	4228	49	673	303	0.210
1953	25599	27064	32357	36676	7205	4034	4034	0	672	215	0.202
1954	25407	26993	32281	36476	6970	3812	3812	0	903	275	0.191
1955	25059	26867	32147	36120	6533	3473	3473	0	866	298	0.175
1956	24474	26725	31996	35530	6159	3158	3158	0	965	262	0.161
1957	23687	26622	31885	34746	5715	2816	2816	0	969	298	0.144
1958	22688	26488	31742	33758	5296	2484	2484	0	814	302	0.128
1959	21496	26354	31601	32588	5047	2242	2242	0	754	190	0.116
1960	20198	26332	31567	31321	4870	2054	2054	0	874	183	0.106
1961	18834	26315	31539	30000	4591	1832	1832	0	789	111	0.095
1962	17376	26364	31579	28597	4408	1669	1669	0	889	192	0.086
1963	15879	26330	31534	27163	4143	1487	1487	0	893	197	0.077
1964	14403	26290	31407	25686	3890	1313	1313	0	859	255	0.069
1965	12970	26195	31138	24175	3683	1161	1161	0	727	193	0.061
1966	11647	26160	30797	22653	3612	1070	1070	0	692	123	0.057
1967	10465	26125	30408	21168	3577	1003	1003	0	784	163	0.055
1968	9450	25974	29854	19735	3456	922	922	0	509	87	0.052
1969	8573	25780	29259	18338	3599	941	941	0	596	100	0.054
1970	7872	25472	28580	17059	3650	954	954	0	608	118	0.057
1971	7309	25038	27838	15881	3684	972	972	0	746	114	0.060
1972	6894	24510	27042	14800	3586	950	950	0	607	127	0.061
1973	6558	23910	26206	13776	3622	976	976	0	548	130	0.065
1974	6350	23270	25331	12884	3675	1012	1012	0	549	61	0.070
1975	6266	22647	24494	12129	3680	1046	1046	0	506	88	0.075
1976	6285	21972	23611	11523	3659	1093	1093	0	423	45	0.082
1977	6388	21305	22779	11061	3657	1180	1180	0	323	66	0.093
1978	6593	20591	21943	10777	3681	1307	1307	0	387	77	0.107
1979	6939	19850	21109	10693	3578	1398	1398	0	203	45	0.120
1980	7337	19146	20361	10743	3607	1553	1553	0	0	0	0.139
1981	7844	18500	19704	10967	3787	1790	1790	0	0	0	0.166
1982	8529	17860	19095	11434	3911	2023	2023	0	0	0	0.195
1983	9390	17264	18511	12109	3994	2234	2234	0	0	0	0.222
1984	10375	16707	17975	12960	4036	2426	2337	90	0	0	0.240
1985	11374	16190	17488	13875	4041	2593	2273	320	0	0	0.241
1986	12236	15696	17047	14698	4016	2723	2216	506	0	0	0.242

Appendix 5

NORTH ATLANTIC SPERM WHALES

CATCHES PER KNOWN EFFORT IN RECENT SPANISH OPERATIONS

Catch and effort data for sperm whales for Spanish operations between 1960 and 1979 are given in SC/33/O 11. The nominal sperm whale catch per unit effort can be biased by changes in the seasonal distribution of effort and by changes in the relative interest of the industry in fin whales and sperm whales. The latter change, in favour of fin whales, accelerated from 1978 when three large new vessels began to operate. 1977 was a year of very reduced operations (2 vessels only), during which there appears also to have been a concentration of fin whales. The data series is therefore truncated at 1976 for the purpose of sperm whale assessment.

There are two methods of deriving appropriate catch and effort data series from the available information, and it is proposed that both sets be used.

A. Total catches taken during the months July to October have been extracted from company records. The total number of boat days in these months each year has been derived from *Rep. int. Whal. Commn* 31: 641, Table 5. No adjustments for relative operating efficiency of the various vessels have been made. In 1970 and 1972 certain vessels worked only part of the July–October period, so these years have been omitted from this series. It is assumed that the number of days of operation was a constant (but unknown) fraction of the 'available' days during the selected period.

B. Total catches of males each year are available. The number of horsepower-days for each vessel throughout the year has been calculated. They have then been adjusted for seasonality, as described in Appendix 7 multiplying the total effort (1000's of HP boat days) by the seasonality correction factors for sperm whales given there.

The horse power correction has the effect of increasing overall efficiency in the period 1965–76 relative to that in 1960–65 by about 15%, with the exception of 1974 which is increased only by about 10% because of the short time of operation that year by the most powerful of the five vessels then in service.

It has been assumed that the number of days of actual operation during each season is a constant fraction of the available days from beginning to end of season, taking account of the fact that different vessels often started and finished on different dates in a particular year. It is also an implicit assumption that the seasonal pattern of frequency of operation is unchanged from year to year.

Since full data are available this series is complete from 1960 to 1976.

Appendix 6

ESTIMATION OF NORTH ATLANTIC SPERM WHALE STOCK SIZES USING TWO CATCH AND EFFORT SERIES FROM SPANISH OPERATIONS

Estimates of North Atlantic sperm whale population sizes were calculated using two catch and effort series for Spanish operations calculated according to methods A and B of Appendix 5. The estimation programme POPDYN was run with the parameter values listed in the Report of the Scientific Committee, Annex D, Table 2.

The catch and effort data used are shown in Tables 1 and 3 for methods A and B. The respective population trajectories giving best fit of expected to observed catches are shown in Tables 2 and 4, and plots of observed and expected catches shown in Figs 1 and 2.

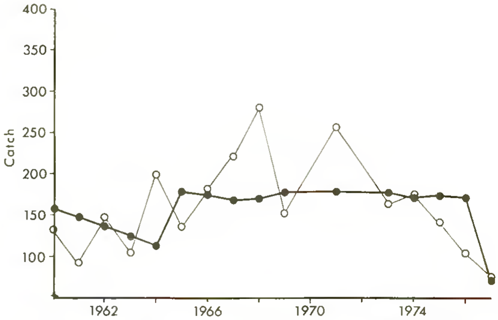

Fig. 1. Observed (○) and expected (●) catches (Spanish CPUE data, series A).

Table 1

Spanish catch (1905–79) and effort (1960–77) data, series A.

	CATCH				EFFORT		CATCH PER EFFORT		
	KNOWN EFFORT		TOTAL		KNOWN				
YEAR	MALE	FEMALE	MALE	FEMALE	ACTUAL	MODIFIER	MALE	FEMALE	TOTAL
1905	0.	0.	70.	59.	0.0	1.0000	0.0	0.0	0.0
1906	0.	0.	150.	128.	0.0	1.0000	0.0	0.0	0.0
1907	0.	0.	151.	110.	0.0	1.0000	0.0	0.0	0.0
1908	0.	0.	190.	171.	0.0	1.0000	0.0	0.0	0.0
1909	0.	0.	134.	102.	0.0	1.0000	0.0	0.0	0.0

(*continued overleaf*)

Table 1 (*continued*)

	------------ CATCH	------------			---- EFFORT ---		- CATCH PER EFFORT -		
	KNOWN EFFORT		TOTAL		KNOWN				
YEAR	MALE	FEMALE	MALE	FEMALE	ACTUAL	MODIFIER	MALE	FEMALE	TOTAL
1910	0.	0.	192.	176.	0.0	1.0000	0.0	0.0	0.0
1911	0.	0.	254.	236.	0.0	1.0000	0.0	0.0	0.0
1912	0.	0.	258.	294.	0.0	1.0000	0.0	0.0	0.0
1913	0.	0.	143.	132.	0.0	1.0000	0.0	0.0	0.0
1914	0.	0.	114.	141.	0.0	1.0000	0.0	0.0	0.0
1915	0.	0.	121.	157.	0.0	1.0000	0.0	0.0	0.0
1916	0.	0.	130.	139.	0.0	1.0000	0.0	0.0	0.0
1917	0.	0.	149.	123.	0.0	1.0000	0.0	0.0	0.0
1918	0.	0.	169.	112.	0.0	1.0000	0.0	0.0	0.0
1919	0.	0.	143.	112.	0.0	1.0000	0.0	0.0	0.0
1920	0.	0.	133.	85.	0.0	1.0000	0.0	0.0	0.0
1921	0.	0.	116.	82.	0.0	1.0000	0.0	0.0	0.0
1922	0.	0.	146.	90.	0.0	1.0000	0.0	0.0	0.0
1923	0.	0.	165.	69.	0.0	1.0000	0.0	0.0	0.0
1924	0.	0.	180.	55.	0.0	1.0000	0.0	0.0	0.0
1925	0.	0.	225.	72.	0.0	1.0000	0.0	0.0	0.0
1926	0.	0.	197.	71.	0.0	1.0000	0.0	0.0	0.0
1927	0.	0.	190.	59.	0.0	1.0000	0.0	0.0	0.0
1928	0.	0.	193.	53.	0.0	1.0000	0.0	0.0	0.0
1929	0.	0.	192.	61.	0.0	1.0000	0.0	0.0	0.0
1930	0.	0.	90.	29.	0.0	1.0000	0.0	0.0	0.0
1931	0.	0.	62.	23.	0.0	1.0000	0.0	0.0	0.0
1932	0.	0.	133.	52.	0.0	1.0000	0.0	0.0	0.0
1933	0.	0.	242.	77.	0.0	1.0000	0.0	0.0	0.0
1934	0.	0.	177.	68.	0.0	1.0000	0.0	0.0	0.0
1935	0.	0.	294.	110.	0.0	1.0000	0.0	0.0	0.0
1936	0.	0.	329.	112.	0.0	1.0000	0.0	0.0	0.0
1937	0.	0.	606.	121.	0.0	1.0000	0.0	0.0	0.0
1938	0.	0.	352.	121.	0.0	1.0000	0.0	0.0	0.0
1939	0.	0.	328.	116.	0.0	1.0000	0.0	0.0	0.0
1940	0.	0.	398.	160.	0.0	1.0000	0.0	0.0	0.0
1941	0.	0.	288.	122.	0.0	1.0000	0.0	0.0	0.0
1942	0.	0.	388.	160.	0.0	1.0000	0.0	0.0	0.0
1943	0.	0.	563.	237.	0.0	1.0000	0.0	0.0	0.0
1944	0.	0.	504.	199.	0.0	1.0000	0.0	0.0	0.0
1945	0.	0.	412.	159.	0.0	1.0000	0.0	0.0	0.0
1946	0.	0.	600.	231.	0.0	1.0000	0.0	0.0	0.0
1947	0.	0.	572.	207.	0.0	1.0000	0.0	0.0	0.0
1948	0.	0.	755.	281.	0.0	1.0000	0.0	0.0	0.0
1949	0.	0.	658.	232.	0.0	1.0000	0.0	0.0	0.0
1950	0.	0.	496.	194.	0.0	1.0000	0.0	0.0	0.0
1951	0.	0.	911.	303.	0.0	1.0000	0.0	0.0	0.0
1952	0.	0.	673.	303.	0.0	1.0000	0.0	0.0	0.0
1953	0.	0.	672.	215.	0.0	1.0000	0.0	0.0	0.0
1954	0.	0.	903.	275.	0.0	1.0000	0.0	0.0	0.0
1955	0.	0.	866.	298.	0.0	1.0000	0.0	0.0	0.0
1956	0.	0.	965.	262.	0.0	1.0000	0.0	0.0	0.0
1957	0.	0.	969.	298.	0.0	1.0000	0.0	0.0	0.0
1958	0.	0.	814.	302.	0.0	1.0000	0.0	0.0	0.0
1959	0.	0.	754.	190.	0.0	1.0000	0.0	0.0	0.0
1960	131.	0.	874.	183.	459.0	1.0000	0.29	0.0	0.29
1961	91.	0.	789.	111.	459.0	1.0000	0.20	0.0	0.20
1962	146.	0.	889.	192.	459.0	1.0000	0.32	0.0	0.32
1963	103.	0.	893.	197.	459.0	1.0000	0.22	0.0	0.22
1964	197.	0.	859.	255.	459.0	1.0000	0.43	0.0	0.43
1965	134.	0.	727.	193.	765.0	1.0000	0.18	0.0	0.18
1966	180.	0.	692.	123.	765.0	1.0000	0.24	0.0	0.24
1967	221.	0.	784.	163.	765.0	1.0000	0.29	0.0	0.29
1968	279.	0.	509.	87.	765.0	1.0000	0.36	0.0	0.36
1969	151.	0.	596.	100.	765.0	1.0000	0.20	0.0	0.20
1970	0.	0.	608.	118.	0.0	1.0000	0.0	0.0	0.0
1971	256.	0.	746.	114.	765.0	1.0000	0.33	0.0	0.33
1972	0.	0.	607.	127.	0.0	1.0000	0.0	0.0	0.0
1973	161.	0.	548.	130.	765.0	1.0000	0.21	0.0	0.21
1974	171.	0.	549.	61.	744.0	1.0000	0.23	0.0	0.23
1975	138.	0.	506.	88.	765.0	1.0000	0.18	0.0	0.18
1976	101.	0.	423.	45.	765.0	1.0000	0.13	0.0	0.13
1977	72.	0.	323.	66.	304.0	1.0000	0.24	0.0	0.24
1978	0.	0.	387.	77.	0.0	1.0000	0.0	0.0	0.0
1979	0.	0.	203.	45.	0.0	1.0000	0.0	0.0	0.0

Table 2

Time series of population components with best fit to give catches (Spanish series A CPUE data 1960–77) with an estimated initial mature female population of 33,054. See report text for parameter values.

YEAR	-----FEMALE POPULATION------			---------------MALE POPULATION---------------					---CATCH---		---PRG---
	IMM-UNEX	EXPLOITED	MATURE	IMM-UNEX	EXPLOITED	MATURE	H + RES	SUR-MAT	M	F	
1905	24588	28027	33054	35071	12632	9081	4297	4784	70	59	0.200
1906	24588	27971	32999	35071	12566	9031	4290	4741	150	128	0.200
1907	24586	27853	32880	35068	12430	8923	4274	4649	151	110	0.201
1908	24579	27758	32786	35062	12302	8815	4262	4553	190	171	0.201
1909	24569	27610	32638	35052	12145	8679	4243	4436	134	102	0.201
1910	24553	27536	32564	35036	12051	8583	4233	4350	192	176	0.202
1911	24536	27396	32424	35019	11908	8449	4215	4234	254	236	0.202
1912	24513	27206	32234	34998	11717	8278	4190	4088	258	294	0.203
1913	24484	26972	32000	34969	11533	8111	4160	3951	143	132	0.204
1914	24446	26903	31931	34933	11470	8032	4151	3881	114	141	0.204
1915	24407	26830	31858	34896	11437	7979	4142	3837	121	157	0.204
1916	24368	26745	31773	34858	11400	7927	4131	3797	130	139	0.205
1917	24328	26682	31709	34820	11357	7879	4122	3757	149	123	0.205
1918	24290	26638	31661	34781	11299	7826	4116	3710	169	112	0.205
1919	24254	26606	31623	34742	11226	7763	4111	3652	143	112	0.205
1920	24222	26575	31585	34704	11182	7719	4106	3613	133	85	0.205
1921	24191	26569	31572	34667	11150	7684	4104	3579	116	82	0.205
1922	24165	26565	31560	34632	11136	7663	4103	3560	146	90	0.205
1923	24144	26550	31536	34599	11095	7623	4100	3524	165	69	0.205
1924	24129	26554	31527	34567	11039	7575	4099	3476	180	55	0.205
1925	24116	26569	31531	34536	10972	7518	4099	3419	225	72	0.205
1926	24106	26563	31516	34507	10867	7431	4097	3334	197	71	0.205
1927	24098	26554	31501	34481	10795	7364	4095	3269	190	59	0.205
1928	24091	26554	31497	34456	10733	7303	4095	3209	193	53	0.205
1929	24085	26559	31497	34434	10671	7243	4095	3149	192	61	0.205
1930	24081	26555	31489	34414	10612	7187	4094	3093	90	29	0.205
1931	24078	26579	31510	34397	10652	7206	4096	3110	62	23	0.205
1932	24076	26607	31536	34383	10714	7248	4100	3148	133	52	0.205
1933	24076	26605	31532	34373	10703	7244	4099	3145	242	77	0.205
1934	24076	26578	31505	34366	10589	7168	4096	3073	177	68	0.205
1935	24075	26562	31487	34359	10542	7138	4093	3045	294	110	0.206
1936	24074	26506	31430	34352	10387	7024	4086	2939	329	112	0.206
1937	24070	26450	31374	34345	10209	6882	4079	2803	606	121	0.206
1938	24064	26389	31313	34335	9782	6548	4071	2477	352	121	0.206
1939	24055	26332	31254	34324	9619	6389	4063	2326	328	116	0.206
1940	24044	26281	31203	34312	9489	6249	4056	2192	398	160	0.206
1941	24032	26192	31113	34298	9302	6068	4045	2023	288	122	0.207
1942	24015	26143	31065	34281	9229	5968	4038	1930	388	160	0.207
1943	23996	26061	30984	34263	9066	5824	4028	1796	563	237	0.207
1944	23975	25910	30834	34243	8751	5572	4008	1563	504	199	0.208
1945	23947	25803	30727	34216	8510	5363	3995	1368	412	159	0.208
1946	23916	25741	30664	34186	8371	5221	3986	1235	600	231	0.208
1947	23886	25614	30534	34155	8065	4963	3969	993	572	207	0.209
1948	23852	25516	30433	34119	7804	4728	3956	772	755	281	0.209
1949	23816	25352	30265	34081	7389	4395	3934	461	658	232	0.210
1950	23774	25243	30151	34036	7091	4132	3920	212	496	194	0.210
1951	23731	25174	30077	33988	6963	3972	3910	62	911	303	0.210
1952	23688	25004	29902	33940	6456	3583	3583	0	673	303	0.194
1953	23393	24842	29735	33638	6203	3343	3343	0	672	215	0.183
1954	22937	24770	29658	33178	5968	3124	3124	0	903	275	0.171
1955	22349	24644	29524	32590	5532	2793	2793	0	866	298	0.154
1956	21544	24502	29373	31790	5157	2488	2488	0	965	262	0.138
1957	20554	24399	29261	30814	4714	2157	2157	0	969	298	0.121
1958	19370	24264	29118	29654	4294	1838	1838	0	814	302	0.104
1959	18012	24130	28976	28332	4045	1608	1608	0	754	190	0.091
1960	16563	24107	28942	26928	3868	1428	1428	0	874	183	0.081
1961	15063	24090	28914	25486	3589	1222	1222	0	789	111	0.069
1962	13487	24138	28952	23980	3406	1072	1072	0	889	192	0.061
1963	12020	24104	28775	22460	3141	908	908	0	893	197	0.052
1964	10609	24063	28502	20917	2888	756	756	0	859	255	0.044
1965	9252	23968	28095	19360	2681	624	624	0	727	193	0.037
1966	8011	23820	27627	17809	2609	545	545	0	692	123	0.033
1967	6913	23661	27119	16304	2574	487	487	0	784	163	0.030
1968	5977	23394	26458	14857	2453	423	423	0	509	87	0.027
1969	5181	23092	25766	13457	2596	430	430	0	596	100	0.029
1970	4540	22684	24999	12162	2646	438	438	0	608	118	0.030
1971	4022	22159	24178	10962	2680	451	451	0	746	114	0.032
1972	3637	21549	23314	9854	2582	437	437	0	607	127	0.033
1973	3329	20874	22417	8869	2558	458	458	0	548	130	0.036
1974	3130	20167	21495	8015	2544	480	480	0	549	61	0.040
1975	3031	19486	20621	7281	2488	498	498	0	506	88	0.043
1976	3012	18759	19712	6676	2411	522	522	0	423	45	0.048
1977	3050	18052	18858	6193	2357	575	575	0	323	66	0.056

(continued overleaf)

Table 2 (*continued*)

YEAR	FEMALE POPULATION			MALE POPULATION					CATCH		PRG
	IMM-UNEX	EXPLOITED	MATURE	IMM-UNEX	EXPLOITED	MATURE	H + RES	SUR-MAT	M	F	
1978	3161	17307	18006	5854	2335	642	642	0	387	77	0.065
1979	3355	16543	17162	5662	2191	678	678	0	203	45	0.073
1980	3566	15822	16398	5560	2183	767	767	0	0	0	0.087
1981	3843	15162	15723	5581	2330	934	934	0	0	0	0.110
1982	4250	14513	15091	5795	2427	1107	1107	0	0	0	0.137
1983	4796	13904	14489	6179	2487	1270	1270	0	0	0	0.164
1984	5447	13331	13931	6715	2511	1429	1429	0	0	0	0.192
1985	6191	12796	13415	7386	2503	1570	1570	0	0	0	0.220
1986	7010	12285	12937	8163	2469	1675	1675	0	0	0	0.244

Table 3

Spanish catch (1905–79) and effort (1960–77) data, series B

	CATCH				EFFORT		CATCH PER EFFORT		
	KNOWN EFFORT		TOTAL		KNOWN				
YEAR	MALE	FEMALE	MALE	FEMALE	ACTUAL	MODIFIER	MALE	FEMALE	TOTAL
1905	0.	0.	70.	59.	0.0	1.0000	0.0	0.0	0.0
1906	0.	0.	150.	128.	0.0	1.0000	0.0	0.0	0.0
1907	0.	0.	151.	110.	0.0	1.0000	0.0	0.0	0.0
1908	0.	0.	190.	171.	0.0	1.0000	0.0	0.0	0.0
1909	0.	0.	134.	102.	0.0	1.0000	0.0	0.0	0.0
1910	0.	0.	192.	176.	0.0	1.0000	0.0	0.0	0.0
1911	0.	0.	254.	236.	0.0	1.0000	0.0	0.0	0.0
1912	0.	0.	258.	294.	0.0	1.0000	0.0	0.0	0.0
1913	0.	0.	143.	132.	0.0	1.0000	0.0	0.0	0.0
1914	0.	0.	114.	141.	0.0	1.0000	0.0	0.0	0.0
1915	0.	0.	121.	157.	0.0	1.0000	0.0	0.0	0.0
1916	0.	0.	130.	139.	0.0	1.0000	0.0	0.0	0.0
1917	0.	0.	149.	123.	0.0	1.0000	0.0	0.0	0.0
1918	0.	0.	169.	112.	0.0	1.0000	0.0	0.0	0.0
1919	0.	0.	143.	112.	0.0	1.0000	0.0	0.0	0.0
1920	0.	0.	133.	85.	0.0	1.0000	0.0	0.0	0.0
1921	0.	0.	116.	82.	0.0	1.0000	0.0	0.0	0.0
1922	0.	0.	146.	90.	0.0	1.0000	0.0	0.0	0.0
1923	0.	0.	165.	69.	0.0	1.0000	0.0	0.0	0.0
1924	0.	0.	180.	55.	0.0	1.0000	0.0	0.0	0.0
1925	0.	0.	225.	72.	0.0	1.0000	0.0	0.0	0.0
1926	0.	0.	197.	71.	0.0	1.0000	0.0	0.0	0.0
1927	0.	0.	190.	59.	0.0	1.0000	0.0	0.0	0.0
1928	0.	0.	193.	53.	0.0	1.0000	0.0	0.0	0.0
1929	0.	0.	192.	61.	0.0	1.0000	0.0	0.0	0.0
1930	0.	0.	90.	29.	0.0	1.0000	0.0	0.0	0.0
1931	0.	0.	62.	23.	0.0	1.0000	0.0	0.0	0.0
1932	0.	0.	133.	52.	0.0	1.0000	0.0	0.0	0.0
1933	0.	0.	242.	77.	0.0	1.0000	0.0	0.0	0.0
1934	0.	0.	177.	68.	0.0	1.0000	0.0	0.0	0.0
1935	0.	0.	294.	110.	0.0	1.0000	0.0	0.0	0.0
1936	0.	0.	329.	112.	0.0	1.0000	0.0	0.0	0.0
1937	0.	0.	606.	121.	0.0	1.0000	0.0	0.0	0.0
1938	0.	0.	352.	121.	0.0	1.0000	0.0	0.0	0.0
1939	0.	0.	328.	116.	0.0	1.0000	0.0	0.0	0.0
1940	0.	0.	398.	160.	0.0	1.0000	0.0	0.0	0.0
1941	0.	0.	288.	122.	0.0	1.0000	0.0	0.0	0.0
1942	0.	0.	388.	160.	0.0	1.0000	0.0	0.0	0.0
1943	0.	0.	563.	237.	0.0	1.0000	0.0	0.0	0.0
1944	0.	0.	504.	199.	0.0	1.0000	0.0	0.0	0.0
1945	0.	0.	412.	159.	0.0	1.0000	0.0	0.0	0.0
1946	0.	0.	600.	231.	0.0	1.0000	0.0	0.0	0.0
1947	0.	0.	572.	207.	0.0	1.0000	0.0	0.0	0.0
1948	0.	0.	755.	281.	0.0	1.0000	0.0	0.0	0.0
1949	0.	0.	658.	232.	0.0	1.0000	0.0	0.0	0.0
1950	0.	0.	496.	194.	0.0	1.0000	0.0	0.0	0.0
1951	0.	0.	911.	303.	0.0	1.0000	0.0	0.0	0.0
1952	0.	0.	673.	303.	0.0	1.0000	0.0	0.0	0.0
1953	0.	0.	672.	215.	0.0	1.0000	0.0	0.0	0.0
1954	0.	0.	903.	275.	0.0	1.0000	0.0	0.0	0.0
1955	0.	0.	866.	298.	0.0	1.0000	0.0	0.0	0.0
1956	0.	0.	965.	262.	0.0	1.0000	0.0	0.0	0.0
1957	0.	0.	969.	298.	0.0	1.0000	0.0	0.0	0.0
1958	0.	0.	814.	302.	0.0	1.0000	0.0	0.0	0.0
1959	0.	0.	754.	190.	0.0	1.0000	0.0	0.0	0.0

Table 3 (*continued*)

YEAR	CATCH KNOWN EFFORT MALE	 FEMALE	 TOTAL MALE	 FEMALE	EFFORT KNOWN ACTUAL	 MODIFIER	CATCH PER EFFORT MALE	 FEMALE	 TOTAL
1960	190.	0.	874.	183.	436.0	1.0000	0.44	0.0	0.44
1961	159.	0.	789.	111.	440.0	1.0000	0.36	0.0	0.36
1962	248.	0.	889.	192.	411.0	1.0000	0.60	0.0	0.60
1963	137.	0.	893.	197.	443.0	1.0000	0.31	0.0	0.31
1964	273.	0.	859.	255.	432.0	1.0000	0.63	0.0	0.63
1965	253.	0.	727.	193.	833.0	1.0000	0.30	0.0	0.30
1966	255.	0.	692.	123.	770.0	1.0000	0.33	0.0	0.33
1967	344.	0.	784.	163.	740.0	1.0000	0.46	0.0	0.46
1968	319.	0.	509.	87.	640.0	1.0000	0.50	0.0	0.50
1969	214.	0.	596.	100.	708.0	1.0000	0.30	0.0	0.30
1970	284.	0.	608.	118.	645.0	1.0000	0.44	0.0	0.44
1971	315.	0.	746.	114.	697.0	1.0000	0.45	0.0	0.45
1972	217.	0.	607.	127.	745.0	1.0000	0.29	0.0	0.29
1973	226.	0.	548.	130.	701.0	1.0000	0.32	0.0	0.32
1974	315.	0.	549.	61.	657.0	1.0000	0.48	0.0	0.48
1975	299.	0.	506.	88.	766.0	1.0000	0.39	0.0	0.39
1976	205.	0.	423.	45.	747.0	1.0000	0.27	0.0	0.27
1977	82.	0.	323.	66.	374.0	1.0000	0.22	0.0	0.22
1978	0.	0.	387.	77.	0.0	1.0000	0.0	0.0	0.0
1979	0.	0.	203.	45.	0.0	1.0000	0.0	0.0	0.0

Table 4

Time series of population components with best fit to given catches (Spanish series B CPUE data 1960–77) with an estimated initial mature female population of 33,680. See report text for parameter values.

YEAR	FEMALE POPULATION IMM-UNEX	 EXPLOITED	 MATURE	MALE POPULATION IMM-UNEX	 EXPLOITED	 MATURE	 H + RES	 SUR-MAT	CATCH M	 F	PRG
1905	25053	28557	33680	35734	12871	9253	4378	4875	70	59	0.200
1906	25053	28501	33624	35734	12805	9203	4371	4832	150	128	0.200
1907	25051	28383	33506	35732	12669	9095	4356	4739	151	110	0.201
1908	25044	28288	33411	35725	12541	8987	4343	4643	190	171	0.201
1909	25034	28141	33263	35715	12384	8851	4324	4526	134	102	0.201
1910	25018	28066	33189	35700	12290	8755	4315	4440	192	176	0.202
1911	25001	27926	33049	35683	12147	8621	4296	4325	254	236	0.202
1912	24978	27736	32859	35661	11956	8450	4272	4178	258	294	0.203
1913	24949	27502	32625	35633	11772	8282	4241	4041	143	132	0.204
1914	24911	27433	32556	35596	11709	8204	4232	3972	114	141	0.204
1915	24873	27360	32483	35559	11676	8150	4223	3928	121	157	0.204
1916	24833	27276	32398	35522	11639	8099	4212	3887	130	139	0.204
1917	24794	27213	32334	35484	11596	8050	4203	3847	149	123	0.205
1918	24756	27168	32286	35445	11538	7998	4197	3801	169	112	0.205
1919	24720	27136	32249	35406	11465	7934	4192	3742	143	112	0.205
1920	24688	27105	32210	35368	11421	7891	4187	3703	133	85	0.205
1921	24657	27099	32197	35332	11389	7855	4186	3670	116	82	0.205
1922	24631	27095	32185	35296	11375	7834	4184	3650	146	90	0.205
1923	24610	27080	32161	35263	11334	7795	4181	3614	165	69	0.205
1924	24595	27085	32153	35231	11278	7746	4180	3567	180	55	0.205
1925	24582	27099	32156	35200	11211	7689	4180	3509	225	72	0.205
1926	24572	27093	32142	35172	11106	7603	4178	3424	197	71	0.205
1927	24564	27084	32127	35145	11034	7535	4177	3359	190	59	0.205
1928	24557	27085	32123	35121	10972	7475	4176	3299	193	53	0.205
1929	24551	27090	32123	35098	10910	7415	4176	3239	192	61	0.205
1930	24547	27085	32114	35079	10851	7358	4175	3184	90	29	0.205
1931	24544	27109	32136	35061	10891	7377	4178	3200	62	23	0.205
1932	24542	27137	32162	35048	10953	7419	4181	3238	133	52	0.205
1933	24542	27135	32158	35038	10942	7416	4181	3235	242	77	0.205
1934	24543	27109	32130	35031	10828	7340	4177	3163	177	68	0.205
1935	24542	27092	32113	35024	10781	7309	4175	3135	294	110	0.205
1936	24540	27036	32056	35017	10626	7196	4167	3029	329	112	0.206
1937	24536	26981	32000	35010	10448	7053	4160	2893	606	121	0.206
1938	24530	26920	31939	35000	10021	6719	4152	2567	352	121	0.206
1939	24521	26862	31880	34989	9859	6560	4144	2416	328	116	0.206
1940	24511	26812	31829	34977	9728	6419	4138	2282	398	160	0.206
1941	24498	26723	31740	34963	9541	6239	4126	2113	288	122	0.207
1942	24482	26674	31691	34946	9468	6139	4120	2019	388	160	0.207
1943	24463	26592	31610	34929	9306	5994	4109	1885	563	237	0.207
1944	24441	26441	31460	34908	8990	5742	4090	1652	504	199	0.208
1945	24414	26334	31354	34882	8749	5533	4076	1457	412	159	0.208
1946	24384	26272	31290	34851	8610	5391	4068	1323	600	231	0.208
1947	24353	26145	31160	34821	8304	5132	4051	1081	572	207	0.209

Table 4 (*continued*)

YEAR	FEMALE POPULATION			MALE POPULATION					CATCH		PRG
	IMM-UNEX	EXPLOITED	MATURE	IMM-UNEX	EXPLOITED	MATURE	H + RES	SUR-MAT	M	F	
1948	24319	26047	31059	34785	8043	4897	4038	860	755	281	0.209
1949	24283	25883	30891	34747	7628	4563	4016	547	658	232	0.209
1950	24242	25774	30777	34702	7330	4299	4001	298	496	194	0.210
1951	24199	25705	30704	34655	7202	4139	3991	148	911	303	0.210
1952	24156	25535	30529	34607	6695	3748	3748	0	673	303	0.199
1953	23929	25373	30362	34373	6443	3507	3507	0	672	215	0.188
1954	23535	25302	30285	33974	6208	3288	3288	0	903	275	0.176
1955	23004	25175	30151	33441	5771	2955	2955	0	866	298	0.160
1956	22250	25033	30000	32690	5397	2647	2647	0	965	262	0.144
1957	21307	24930	29888	31759	4953	2313	2313	0	969	298	0.126
1958	20167	24795	29745	30639	4533	1990	1990	0	814	302	0.110
1959	18847	24661	29603	29351	4285	1757	1757	0	754	190	0.097
1960	17432	24639	29570	27978	4107	1575	1575	0	874	183	0.087
1961	15962	24621	29541	26562	3828	1364	1364	0	789	111	0.076
1962	14412	24670	29580	25079	3646	1210	1210	0	889	192	0.067
1963	12930	24636	29439	23576	3380	1041	1041	0	893	197	0.058
1964	11500	24595	29201	22046	3127	883	883	0	859	255	0.050
1965	10122	24500	28826	20497	2920	745	745	0	727	193	0.043
1966	8858	24383	28388	18948	2849	662	662	0	692	123	0.039
1967	7736	24254	27908	17443	2814	601	601	0	784	163	0.036
1968	6776	24014	27272	15995	2693	532	532	0	509	87	0.033
1969	5956	23738	26602	14590	2836	542	542	0	596	100	0.035
1970	5296	23352	25855	13294	2886	552	552	0	608	118	0.037
1971	4765	22849	25052	12096	2920	565	565	0	746	114	0.039
1972	4369	22257	24202	10990	2822	549	549	0	607	127	0.040
1973	4052	21600	23319	9990	2814	572	572	0	548	130	0.043
1974	3849	20908	22406	9124	2816	598	598	0	549	61	0.047
1975	3753	20239	21539	8382	2775	621	621	0	506	88	0.052
1976	3743	19524	20633	7775	2711	650	650	0	423	45	0.057
1977	3797	18825	19782	7296	2669	712	712	0	323	66	0.065
1978	3933	18085	18931	6971	2657	796	796	0	387	77	0.077
1979	4167	17325	18086	6806	2523	845	845	0	203	45	0.086
1980	4426	16606	17323	6741	2524	951	951	0	0	0	0.101
1981	4762	15946	16649	6813	2678	1136	1136	0	0	0	0.126
1982	5242	15297	16021	7092	2780	1325	1325	0	0	0	0.154
1983	5871	14688	15420	7551	2845	1501	1501	0	0	0	0.181
1984	6609	14117	14865	8169	2872	1668	1668	0	0	0	0.210
1985	7441	13584	14354	8925	2867	1814	1814	0	0	0	0.237
1986	8346	13075	13884	9788	2834	1925	1805	120	0	0	0.244

Appendix 7

ADJUSTMENTS OF CPUE FOR SEASONALITY AND CATCHER PERFORMANCE IN SPANISH OPERATIONS

S. J. Holt

1. SC/33/O 13 Table A tabulates the mean dates of opening and closing of the whaling season, indicating considerable variability, and a substantial change after 1967.

SC/33/O 1 Fig. 1 gives cumulative data 1957–80 for catch of fin and sperm whales by ten day period. These, with information in SC/32/O 15 Table 5 concerning the dates of operation of each vessel and its characteristics, are used to derive a correction for the seasonal variation in CPUE.

From the dates of operation the number of days worked by each vessel in each ten day period each year can be estimated. There is a small error in this due to an average of 9 or 10 days of 'breakdown' each year by each vessel, which has been ignored because it cannot be allocated by ten day periods. It is assumed that these lost days are spread throughout the year randomly.

The amount of effort in each ten days each season is calculated as the number of 'Horse-power days'. (Note that at this stage it makes very little difference if H-P or tonnage is used as the correction factor.) These are accumulated through all seasons for which data were available 1960–79.

Ten-day catch data were not available for the same series of years, so the best approximation is to assume the seasonal catch distribution of 1960–79 is not very different from that in 1957–80. On this assumption the seasonal CPUE series of apparent densities are derived, given in Table 1.

2. By the same procedure the total number of 'H-P Days' operated per year can be derived. These are given in Table 2. From them we get the catch per H-P day as a crude abundance index.

Seasonality correction factors are derived by calculating,

Table 1

Ten-day period	Effort	Apparent density[1] Fin	Apparent density[1] Sperm
1–10.4	2.58		
11–20.4	12.22	0.65	0.33
21–30.4	18.49	0.76	1.24
1–10.5	19.86	0.65	1.61
11–20.5	23.35	1.03	1.93
21–31.5	44.69	1.32	3.22
1–10.6	50.80	1.36	3.58
11–20.6	62.16	1.32	3.84
21–30.6	63.73	3.20	4.44
1–10.7	66.02	4.03	3.71
11–20.7	66.02	5.24	3.91
21–31.7	72.63	6.32	3.80
1–10.8	66.02	4.32	4.20
11–20.8	66.02	4.60	5.54
21–31.8	72.98	5.52	4.29
1–10.9	67.09	3.43	3.96
10–20.9	67.09	3.99	2.82
21–30.9	68.24	3.24	2.84
1–10.10	69.01	1.88	2.69
11–20.10	69.01	1.43	3.70
21–31.10	75.91	1.58	2.15
1–10.11	69.01	1.06	1.17
11–20.11	69.01	0.61	0.99
21–30.11	69.01	0.81	1.17
1–10.12	60.32	0.25	0.85
11–20.12	32.68	0.18	0.52

[1] Apparent density is catch per 10,000 Horse-power days

for each year, the ratio of the mean apparent density in the period of operation that year to the mean apparent density in a 'standard' season. The latter was taken to be from 1 July to 30 November. Corrected abundance indices are calculated by dividing the crude index for each year by the corresponding correction factor. This is done for each species.

3. The results are shown graphically in Figs 1 and 2. Changes in season may affect the abundance indices by 10 to 20%. This is small in comparison with the annual fluctuations, and with the amount of correction that might be needed to take account of changes in catcher efficiency. The very large variations in catch per day, of both species together means that corrections are necessary taking into account a time budget, including allowance for the change in the daily number of hours of daylight through a long season in temperate latitudes.

4. Catch per boat per operating day, both species, changed little through the period. For example, in 1961 and 1978 it was 0.14 whales; in 1974, 0.10 whales.

Table 2

Year	Seasonality corrections Fin	Seasonality corrections Sperm	Effort	Corrected CPUE Fin	Corrected CPUE Sperm	Corrected CPUE Both
1960	0.836	0.958	45.47	3.34	4.36	7.70
1961	0.833	0.970	45.40	4.12	3.61	7.73
1962	0.851	0.917	44.79	1.31	6.43	7.74
1963	0.840	1.047	42.32	0.56	4.06	4.62
1964	0.801	0.934	46.20	1.59	7.11	8.70
1965	0.820	1.019	81.75	2.34	3.44	5.78
1966	0.820	0.934	82.41	1.58	3.64	5.22
1967	0.849	0.907	81.58	1.40	5.53	6.93
1968	0.976	1.040	61.56	1.76	5.70	7.46
1969	0.956	1.060	66.80	1.77	3.52	5.29
1970	0.977	1.045	61.71	3.17	5.24	8.41
1971	0.992	1.085	64.28	1.57	5.25	6.82
1972	1.008	1.119	66.58	1.46	3.17	4.63
1973	0.922	1.043	67.25	1.82	4.23	6.05
1974	0.891	1.020	64.44	2.09	5.71	7.80
1975	0.888	1.015	75.48	2.06	4.95	7.01
1976	0.859	0.980	76.22	3.50	3.87	7.47
1977	0.978	1.048	35.64	4.39	2.44	6.83
1978	0.976	1.041	131.83	3.59	0.86	4.45
1979	0.927	1.049	151.87	3.21	0.51	3.72

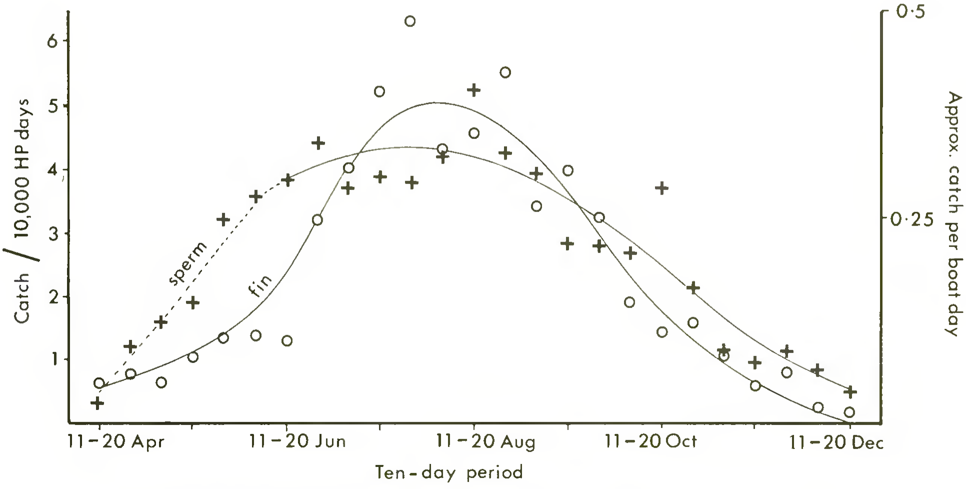

Fig. 1. Spain, seasonal indices of abundance, 1960–79: Fin whales (o) and sperm whales (+).

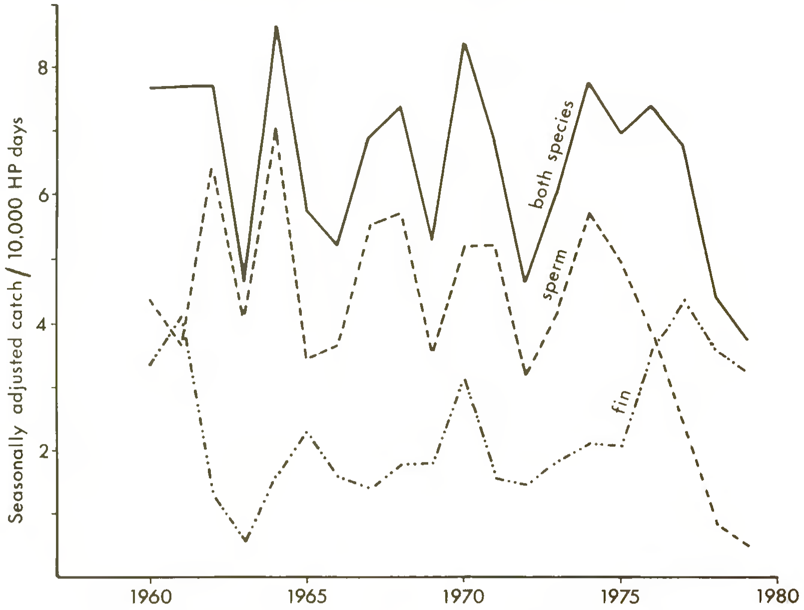

Fig. 2. Spain, annual indices of abundance, 1960-79.

Appendix 8

NORTH PACIFIC DATA SET

IWC Technical Note 7 gives details of the tape of NP form data which has recently been released. Although all data at present available have been coded, the forms themselves are known not to give a complete record. The NP1 and NP3 forms, listing catch and length data respectively, were checked during the meeting and the following gaps were discovered.

NP3—data missing

Japan coastal:	1946–48, part of 1980
Soviet pelagic:	1946–50, 1952–61, part of 1968
Soviet coastal (Kuril Islands):	part of 1953

The missing Japan coastal and Soviet coastal data were substituted for the purpose of running assessment programs by data from BIWS, except for the Soviet Pelagic 1946–48 data which are missing from both sources. The BIWS pelagic data are not subdivided in any way by area, but all Soviet pelagic catches in the period concerned occurred within the newly-defined Western Division. Unfortunately the 1954 data from BIWS mixes the Soviet and Japanese pelagic data, and so for assessment purposes the Soviet catches by length were estimated by scaling down the mixed data to make the total catch equal to the total Soviet catch. The missing part of the 1968 Soviet catch at length was created by scaling up the available data to make the total equal to the total catch.

NP1—data missing

Japan coastal:	1946–48
Bonin Islands (Japanese floating factory):	1946–52
Kuril Islands (Soviet coastal):	1948–61
Soviet pelagic:	1946, 1959

Comparison of total North Pacific catches obtained by summing over NP1 forms with corresponding totals given by Ohsumi (*Rep. int. Whal. Commn* (special issue 2): 17–18) showed that the forms were essentially complete in later years, but had on average about 3% of catches missing prior to the mid 1960's. Total catches for the new Western Division were estimated by summing the catch recorded on NP1 forms which took place to the west of the new boundary and then scaling up by the ratio of total catch for the whole North Pacific to the corresponding total catch on NP1 forms. This procedure involves assuming that data are omitted at random from the records, but in practice results in only a small adjustment to the NP1 totals.

The sub-committee agreed that a high priority should be given to further work on the North Pacific data in order to resolve remaining difficulties and ambiguities where possible.

Annex E

Report of the Sub-Committee on Minke Whales

Members: Horwood (Convenor), Allen, Best, Brown, Butterworth, Borodin, Chapman, Choi, Clark, Christensen, Donovan, de la Mare, da Rocha, Gambell, Gong, Hammond, Harwood, Hiby, Holt, Ikeda, Ivashin, Kapel, Kato, Kasamatsu, Kirkwood, Lockyer, Misaki, Miyahara, Mizroch, Ohsumi, Øritsland, Rørvik, Riazantsev, Shimadzu, Shirakihara, Sigurjónsson, Tanaka, Tillman, van Beek, Wada, Yamamura.

The Special Meeting on Southern Hemisphere minke whales had considered the assessment of those stocks so this sub-committee only needed to review the Northern Hemisphere stocks which it did by ocean.

1. NORTH PACIFIC

Relevant documents presented to the meeting were; SC/33/Mi7,8; SC/33/O 7,8; SC/33/ProgReps Republic of Korea, Japan, USA and USSR.

1.1 Stock Divisions

The division of the whales in the western North Pacific into the present two stock areas is based on a study by Omura and Sakiura (1956, *Sci. Rep. Whales Res. Inst.*). Ohsumi also informed the meeting that whalers said minke whales did not pass through the Soya Strait. Also separate fin whale stocks are found to the east and west of Japan and by analogy one might consider the present stock separation to be correct.

Wada reported that biochemical studies had been initiated and preliminary results indicated a difference between whales off the Japanese coast and those in the Antarctic. Logistic difficulties were hindering an investigation of minke whales in the Sea of Japan, Yellow Sea and East China Sea.

It was agreed that the present stock boundaries should be retained. It was recommended that effort be continued on attempting to obtain samples for comparative biochemical analyses.

1.2 Assessments

1.2.1 Sea of Japan – Yellow Sea – East China Sea

In 1979 the Commission classified this stock as a provisional SMS with a block quota of 3,634 over the period 1980–84 with the catch in any year not to exceed 940. The catch in 1980 was 925 (RoK) and 15 (Japan).

Last year the sub-committee urged that RoK data be examined to see if an index of boat-days could be obtained. SC/33/Mi7 presented effort data as boats by month for the 1980 season. Gong (*Rep. int. Whal. Commn* 31: 241) presented effort data as boats per year. It was agreed that such coarse measures of effort could not be utilised in a stock assessment. It was recommended that past log-book data (RoK) be analysed to obtain an index of boat-days. SC/33/Mi8 presented catch and effort data from the Japan fishery but as these have been very small they could not be used. Catches from this stock are given in Table 1.

Table 1

Sea of Japan – Yellow Sea – East China Sea – catches

	RoK	Japan	
1980	925	15	(this meeting)
79	906	15	(*Rep. int. Whal. Commn* 31: 110)
78	1,018	0	(Japan—Ohsumi, *Rep. int. Whal. Commn* 30: 307 Zone F + G and Rok—Brownell, *Rep. int. Whal. Commn* 31: 395)
77	1,033	2	
76	494	20	
75	561	41	
74	566	8	
73	882	20	
72	767	4	
71	730	16	
70	715	11	
69	386	32	
68	316	0	
67	335	15	
66	301	2	
65	247	20	
64	384	0	
63	291	0	
62	170	0	

It was noted that unless the historical series of effort can be refined it would be several years before a new index based on the log-book data could be used in an assessment. There was a discussion on the feasibility of aerial surveys of this stock but cost and logistic problems were thought to preclude such a survey.

1.2.2 Okhotsk Sea – West Pacific stock

In 1980 the Commission classified this stock as SMS with a block quota of 1,678 over the period 1980–84 with a maximum catch of 421 in any one year. In 1980 the catch was 364, all taken by Japan.

SC/33/Mi8 provided additional data on Japanese catch and catch per effort. The effort is in catcher-hours and has been measured since 1977. The figures below show the relationship between this refined catch per effort ($CPUE_3$) and the indices of catch per catcher day ($CPUE_1$ and $CPUE_2$) described by Ohsumi (*Rep. int. Whal. Commn* 31: 335).

Year	$CPUE_1$	$CPUE_2$	$CPUE_3$
1977	0.932	0.515	0.054
1978	1.515	0.837	0.082
1979	1.109	0.612	0.057
1980	1.189	0.650	0.057

SC/33/Mi8 presented an attempt to obtain estimates of minimum stock size by comparing model results with the catch per catcher day series. It was presented as an initial analysis and suggested a likely minimum estimate of about 30,000 whales. However, it was agreed that the variable nature of the CPUE made lower values likely. The contribution was appreciated but it was felt that the evidence was insufficient to warrant a change in the present advice. It was recommended that an attempt be made to refine the long series of CPUE data so that models could be fitted to the data.

It was agreed that the CPUE series (SC/33/Mi8; *Rep. int. Whal. Commn* 31: 335) showed no trend.

1.2.3 Remainder of North Pacific

It was noted that one minke whale of unknown sex was taken by the USA. No new information is available on this stock.

1.3 Sex composition of the catches

1.3.1 Sea of Japan – Yellow Sea – East China Sea

SC/33/Mi7 documented catch from RoK by month, region and sex. The proportion of females in the catch in 1980 was 0.37, this is slightly lower than that reported last year by Gong (*Rep. int. Whal. Commn* 31: 241–44).

1.3.2 Okhotsk Sea – West Pacific stock

In 1980 the percentage of females in the catch was 45% (SC/33/Mi8).

1.4 Catch limits and classification

1.4.1 Sea of Japan – Yellow Sea – East China Sea

Gong noted that the catch per boat figure for 1980 of 44.05 (SC/33/Mi7) could be added to his time series given in *Rep. int. Whal. Commn* 31: 241–44. He considered that the CPUE showed no trend over the last few years. The sub-committee agreed it had no significant new information on which to give any further advice than that provided last year.

1.4.2 Okhotsk Sea – West Pacific stock

On the basis of continuing stability of the CPUE series (SC/33/Mi8; *Rep. int. Whal. Commn* 31: 335), as last year, the sub-committee considered that the stock be classified as SMS with a block quota of 1,678 for the period 1980–84 with a maximum of 421 in any one year.

1.4.3 Remainder of the North Pacific

Given no information about this stock it was agreed that it should remain classified as an IMS with a zero quota.

1.5 Recommendations

1.5.1 Sea of Japan – Yellow Sea – East China Sea

In 1979 the Commission on the advice of the Scientific Committee established a block quota of 3,634 whales for the period of 1980–84 with a maximum of 940 in any one year. The sub-committee agreed that it had no significant new information on which to give any additional advice to that which was provided last year.

It is recommended that past RoK log-book data be analysed to obtain an index of boat-days.

It is recommended that effort be continued on attempting to obtain samples for comparative biochemical studies.

1.5.2 Okhotsk Sea – West Pacific stock

As last year the sub-committee recommends, on the basis of the continuing stability of the CPUE, that the block quota of 1,678 for the period 1980–84 be retained with a maximum catch of 421 in any one year, and that the stock continue to be classified as a SMS.

It is recommended that an attempt be made to refine the long series of CPUE data.

1.5.3 Remainder of the North Pacific

The stock to remain as IMS with a zero quota.

2. NORTH ATLANTIC

Relevant documents presented to the meeting were SC/33/Mi1–6 and 9; O 4, 6 and 12; SC/33/ProgReps from Canada, Denmark, Iceland and Norway.

2.1 Stock Divisions

The North Atlantic is presently divided into four stocks, (i) Northeastern stock, (ii) Central stock, (iii) West Greenland stock and (iv) Canadian East Coast stock. Mark returns have indicated that there is no mixing from the Northeastern stock into the Central stock. This is supported by another four marks placed in the Northeastern area and returned in 1980 (SC/33/Mi1). Biochemical samples from West Greenland have been studied for genetic variation (SC/33/Mi6) but this appears low. It is planned to collect samples from other parts of the North Atlantic for comparison. There was no further information on which to decide new stock boundaries and the previous four areas were accepted.

2.2 Assessments

2.2.1. Northeastern stock

In 1980 the Commission continued to classify this stock as SMS with a catch limit of 1,790. In 1980 the catch, all Norwegian, was 1,807.

SC/33/Mi1 reported on four new mark returns and updated the mark-recapture analysis of Christensen and Rørvik (*Rep. int. Whal. Commn* 31: 255–58). This gave estimates of

Total stock:	121,000	
Available stock:	60,532	39,457–94,866, 95% limits

Older animals do not appear as frequently as expected in the catch (Christensen and Rørvik, *Rep. int. Whal. Commn* 31: 259–62) and it is assumed that 60% of the total stock is on the whaling ground but only 50% of the total stock is available.

Rørvik reported that his model (*Rep. int. Whal. Commn* 31: 263–71) had been slightly changed since last year. Two series of CPUE (one 1960–73 and one 1952–75) were fitted by the model. The model assumes a constant pregnancy rate but an age of maturity decreasing linearly with stock size. Estimates of total stock for 1980 based on the two CPUE series were (i) 67,000 and (ii) 85,000. Rørvik (*Rep. int. Whal. Commn* 31: 263–71) found that, with the model, a total stock size of 67,000 is needed to sustain the present catch limits.

The simulation indicated an initial total stock (1930) of 100,000–115,000 animals. However, this estimate is largely dependent on the assumption of a constant carrying capacity.

SC/33/Mi2 presented five years of CPUE data based on catcher-days. They are variable but show no trend over this period.

In order to improve assessments it was recommended that an attempt be made to find a CPUE series that could incorporate the more refined data of recent years and this utilised in the model. It was reported that a major collation of Norwegian whaling statistics for the North Atlantic has been started but full results from this could not be expected for 2 to 3 years.

It was asked if ear-plugs could be read to validate the time series of ages at maturity that the model implicitly assumes. Christensen and Sigurjónsson reported that such information was almost impossible to obtain from the dark and fragile earplugs of this stock. The lack of availability of larger and older animals also presents a problem. Christensen said that there may be some evidence for a current increase in the age at maturity (*Rep. int. Whal. Commn* 31: 245–54).

2.2.2 Central Stock

This stock is classified as a SMS with a catch limit of 320. The 1980 catch was 120 by Norway and 201 by Iceland.

SC/33/Mi9 presented a review of minke whaling by Iceland. In particular an index of density was obtained based on catcher-days on the whaling grounds (CPHD) for the period 1977–80. This showed a poor relationship between indices based on estimated catcher-days within the season (CPUE and CPBD). Sigurjónsson reported that unreported studies showed an index of abundance in 1972 lower than the 1977–80 series. It was explained that over the past decade various factors had affected operational efficiency and caused difficulty in interpreting the effort measurements.

SC/33/Mi2 documented Norwegian catch per catcher day for the period 1976–80. These figures correct those of Table 1 in *Rep. int. Whal. Commn* 31: 108. Less refined indices of abundance are given in *Rep. int. Whal. Commn* 31: 108 and *Rep. int. Whal. Commn* 27: 382 for the period 1960–75.

Whale marking was attempted by Iceland but due to bad weather none were marked (SC/33/ProgRep Iceland). It is anticipated that the marking programme will continue in 1981. Sigurjónsson reported that all available age and reproductive material from minke whales caught by Iceland in 1977 and 1978 had been worked up. Analyses of this and the 1979–81 material would be presented by the Scientific Committee in 1982.

2.2.3 West Greenland stock

In 1980 the stock was classified as a SMS with a block quota of 1,778 for the period 1981–85, the catch not to exceed 444 in any one year. The 1980 catch was 75 by Norway and approximately 195 by Denmark.

SC/33/Mi5 documented biological studies and detailed investigations of the catch and effort by the catcher ship *Kato*. Table 7 of SC/33/Mi5 gives weather corrected CPUE from the *Kato* for the period 1976–80; they are very variable and show no discernible trend. SC/33/O 12 presented sightings data of minke whale and initial analyses of sightings to produce indices of abundance.

SC/33/Mi2 documents catch and effort on Norwegian ships. Marking was attempted in 1980 (SC/33/ProgRep Denmark) but only one whale was marked.

Rep. int. Whal. Commn 31: 108 gives a catch and effort series from Norwegian vessels. These figures are updated and corrected in SC/33/Mi2.

It was recommended that an attempt be made to reconcile the two sets of indices given in *Rep. int. Whal. Commn* 31: 108.

Kapel reported that the problems of age determination for this stock would be investigated further and that the collection of data from a Norwegian vessel and marking would continue next year.

2.2.4 Canadian East Coast stock

Last year the Commission did not classify this stock and set a zero quota pending an adequate stock assessment. One whale was taken by Canada in 1980 and of 12 whales known to have been trapped in fishing nets 9 were dead. The comments of Mitchell (*Rep. int. Whal. Commn* 31: 160) were noted.

The only new data on this stock were in SC/33/O 4 which reported on sightings by aircraft. It was concluded that estimates of minke whales were seriously underestimated by this survey.

2.3 Sex composition of the catches

2.3.1 Northeastern stock

The percentage of females in the catch of 1980 was 56.3% (SC/33/Mi2). Restrictions on operations, by time and location, have been in force for two years and it is expected that this will reduce the previous high percentage of females in the catch. This was noted with approval.

2.3.2 Central stock

In the 1980 catch the proportion of females in the Norwegian catch was 0.34 and in the Icelandic catch it was 0.41. The proportion in the total catch was 0.38.

2.3.3 West Greenland stock

No data are available on the proportion of females in the 1980 catch by the Greenlanders, but *Rep. int. Whal. Commn* 30: 195 gives an average figure of about 0.68 since 1950. The proportion in the Norwegian catch was 0.81 in 1980. Larsen and Kapel (SC/33/Mi5) investigated catch data by month and region over the period 1976–80 and there is no simple operational way of reducing this high percentage.

2.4 Classification and catch limits

2.4.1 Northeastern stock

Based on the analyses reviewed above, the stock should continue to be classified as a SMS with a catch limit of 1,790.

2.4.2 Central stock

Noting the lack of trend in the series of CPUE data the sub-committee recommended, as last year, that the stock be classified provisionally as a SMS with a catch limit of 320.

2.4.3 West Greenland stock

The sub-committee found no evidence to change the recommendation of last year of a block quota of 1,778 for the period 1981–85 with a maximum of 444 in any one year, and recommended that the stock remains as a SMS.

2.4.4 Canadian East Coast stock

Given no new information it was agreed this stock should remain as unclassified with a zero catch limit pending satisfactory stock estimates.

2.5 Recommendations

2.5.1 Northeastern stock

The stock continue to be classified as a SMS with a catch limit of 1,790.

An attempt be made to find a CPUE series that could incorporate the more refined data of recent years and this utilised in the model.

2.5.2 Central stock

As last year it is recommended that the stock should be provisionally classified as a SMS with a provisional catch limit of 320.

2.5.3 West Greenland stock

As last year the sub-committee recommended the block quota of 1,778 over the period 1981–85 with a maximum of 444 in any one year.

It was recommended that an attempt be made to reconcile the two sets of CPUE series given in *Rep. int. Whal. Commn* 31: 108.

2.5.4 Canadian East Coast stock

As last year the stock should remain unclassified with a zero catch limit pending satisfactory estimates of stock size.

2.5.5 General

It is recommended that, next year, more specific attention be given to classifying the Northern Hemisphere minke whale stocks in a coherent and consistent way.

It is recommended that, next year, the boundaries of the North Pacific stocks be more precisely defined for use by the Commission.

3. NORTH INDIAN OCEAN

There is no information on which to designate stocks or to set catch limits. It is recommended that whales in this region be classified as IMS with zero catch limits pending satisfactory estimates of stock size.

Annex F

Report of the Sub-Committee on Other Baleen Whales

Members: Chapman (Convenor), Aguilar, Allen, Brodie, Brown, Choi, Clark (rapporteur), Cook, Donoghue, Fleischer, Gong, Harwood, Holt, Ikeda, Jónsson, Kapel, Kasamatsu, Kato, Lockyer (rapporteur), Martin, Mizroch, Ohsumi, Øritsland, Rørvik, Sanpera, Sigurjónsson, Tillman, Wada, de Salas, Maturana, Valdivia.

Pertinent documents: SC/33/Ba 1–9; O 1, 5, 7, 9–13; PS7, 8; SC/33/ProgReps Canada, Denmark, Japan, Norway, Peru, Republic of Korea, Spain, USSR, UK.

1. SOUTHERN HEMISPHERE FIN WHALES, AREAS I–V

Clark (SC/33/Ba3) reported an attempt to obtain direct estimates of historical recruitment rates in Areas II–VI by decomposing early length compositions into age compositions and then back-calculating year-class and parent stock sizes by cohort analysis. The results unexpectedly showed a decline in recruitment rates during the period of exploitation but there remains some doubt about the accuracy of the length decompositions owing to possible length selection by the fishery and to large and inexplicable differences among available sets of age-length sampling data.

Chapman remarked that it would be worthwhile at some point to repeat the fin whale assessments with present methods, e.g. correcting effort in the way minke effort is now treated, but that for the time being there was no reason to change last year's projections (*Rep. int. Whal. Commn* 31: 129), which showed all stocks should remain protected.

Allen suggested, and the sub-committee recommended, that the Commission seek funds so that time budget data could be extracted from the logbooks of vessels that engaged in Antarctic fin whaling and these data used with present techniques to improve the assessments of the stocks of fin whales and other species.

2. SOUTHERN HEMISPHERE FIN WHALES, AREA VI

There was no information to change last year's updating of earlier assessments (*Rep. int. Whal. Commn* 31: 122) which indicated continued protection.

3. NORTH PACIFIC FIN WHALES

Japanese sightings had shown some increase between 1976 and 1978 followed by a large increase in 1979 (*Rep. int. Whal. Commn* 31: 783–92), leading the sub-committee to note last year that a reassessment should be done if the trend continued. In 1980, however, only one fin whale was sighted although the area surveyed was similar to 1979 (SC/33/ProgRep Japan). Ohsumi pointed out that the survey area was south of most of the summer range of the fin whale, which would naturally cause considerable variability among years in the rate of sightings.

Tillman reported on a US whale sighting cruise in the Gulf of Alaska in summer 1980 (SC/33/O 7). Although the cruise was designed and conducted so that line transect estimates of the abundance of several species could be obtained, the sightings of fin whales were so few (13 animals in 7 sightings) that the resulting estimate of 159 in the total area was not very reliable.

As in the case of Southern Hemisphere stocks, the meeting concluded that while a reassessment might be worthwhile at some point, for the time being the stock should remain protected.

In response to the concern expressed last year over Korean catches of unidentified large whales, Gong reported that the government had succeeded in shifting 70–80% of minke whale catches to the Yellow Sea where catches of large whales were less frequent than in the Sea of Japan, with the result that the number caught had decreased from 18 in 1979 to 7 in 1980. Of these 7, he had obtained and brought to the meeting photographs of 4, which were examined by several members and confirmed to be fin whales. The sub-committee recommended that photos (especially of head and baleen) and baleen samples be collected from all large whales landed in Korea, but sees no need for the Commission to send an observer as recommended last year.

4. NORTH ATLANTIC FIN WHALES

Lockyer (SC/33/Ba7, and summarized in Appendix 4 of this report) reported preliminary results of a comparative study of fin whale earplugs from various parts of the northeast Atlantic: North Norway, West Norway, Iceland and Spain. The features examined were colouration, shape in cross section, clarity and regularity of laminae, and presence or absence of accessory laminae. While the results so far are not adequate to distinguish stocks, the greatest differences were noticed between samples from Iceland and from Spain, and the least between Iceland and West Norway. As the study did not indicate a close connection between areas previously treated separately, and particularly between Iceland and Spain where management measures must be recommended this year, the sub-committee decided not to change any established stock definitions.

4.1 Nova Scotia stock

It is hoped that the aerial surveys being conducted under the US Cetacean and Turtle Assessment Program (CETAP) will provide information on this stock. There is no reason to change its classification as a Protected Stock.

4.2 Newfoundland – Labrador stock

Mitchell reported the results of aerial line transect surveys along the coasts of Newfoundland and Labrador in August 1980 (SC/33/O 4). While the survey covered most of the area of the former fishery, it probably covered only about a third of the summer range of the stock, which extends farther both seaward and northward. Because coverage was incomplete and no correction was made for animals not seen on the trackline, the estimate of 478 (s.d. 221) animals in the survey area is almost certainly less than the true stock size. As a comparison, the same survey's estimate of humpback abundance was about a third of estimates made in other ways.

Although this stock has not been exploited since the last assessment was made, it has been left in the Sustained Management category with a catch limit of 90. The sub-committee agreed with Chapman that the accuracy of this classification could no longer be relied upon, and that no classification could be made without more information on the present situation. If a catch limit is set, it should not exceed 90, last year's catch limit.

4.3 West Greenland stock

Though some sighting data were collected in 1980 (SC/33/O 12), they were not sufficient for an estimate of stock size. As small catches continue to be taken from this stock, the sub-committee recommended that it should remain in the Sustained Management category with the present catch limit of 6.

4.4 East Greenland – Iceland stock

Sigurjónsson explained the new data on Icelandic fishing effort that had been extracted from logbooks for the meeting. Time budget data for the last half of the 1979 and 1980 seasons had provided estimates of chasing and handling times by species, which in conjunction with logbook data on operation time and catch by species had yielded estimates of searching time for most boats in the fishery from 1951 to the present. In order to obtain the best measure of effort for fin whales, only the months June and July were considered, when the catch is mainly fin whales.

Obtaining a measure of total effort in each season required weighting each vessel's effort by its relative efficiency, and estimating relative efficiencies for all vessels over the entire series was difficult because there are no logbook data for the vessel that operated in 1961, which is the only link between the two groups of different vessels that operated before and after 1961. Hence it was necessary to calibrate the early and recent data on the basis of the catch per season of this and other boats rather than the catch per hour of searching.

Rørvik and Sigurjónsson had found that the relative efficiencies of various boats were fairly consistent within the early and late data, and believed that the calibrated series of standardized total effort was reliable at least from 1962. Cooke and Beddington preferred the method described in their paper SC/33/Ba8, which calculates a catchability coefficient for each vessel in the course of estimating stock size from changes in catch per effort and thereby avoids the problem of standardizing effort altogether.

It was decided to use the new effort series to obtain several estimates of stock size, trying both of the two treatments of vessel efficiency mentioned above and both the entire series 1951–80 and only the most recent part 1962–80 when the fleet changed little.

There was considerable discussion of the values of biological parameters to use in the model. Cooke and Beddington in SC/33/Ba3 had fitted a relationship between mean age at sexual maturity and pregnancy rate in the Antarctic, and then inferred from this relationship and Lockyer's (*Rep. int. Whal. Commn* 31: 389–94) data series on age at maturity in Iceland, an estimated series of pregnancy rates in the Icelandic stock. Martin (SC/33/Ba4) reported a careful study of Icelandic material that indicated the present pregnancy rate was 0.485, in agreement with the upper end of the range in SC/33/Ba8. The sub-committee therefore decided that the range of pregnancy rates to be associated with Lockyer's estimates of mean age at sexual maturity should be (0.33–0.48).

Mizroch questioned whether any increase in pregnancy rates had really occurred in the Antarctic, as her statistical analysis had not revealed much of significance. Beddington informed the meeting of unpublished work by another method that had revealed significant changes, and provided a summary of the results. Unfortunately the sub-committee did not have time to discuss these papers, and therefore did not make any judgment between them, except insofar as all the assessment runs included an increase in pregnancy rates.

Natural mortality rates also received considerable attention. Van Beek (SC/33/Ba9) believed that the conventional values for the Antarctic (0.035 for males, 0.045 for females) implied unreasonably high values of juvenile mortality as calculated from the balance equation. Other members commented that since there were no estimates of juvenile mortality other than from the balance equation, there was no reason to reject particular values. Clark (SC/33/Ba3) had estimated Antarctic mortality rates by semilog regressions on the latter parts of catch curves and found values for females in the range 0.04–0.06, which are likely biassed downward (SC/33/O 5). The apparent mortality of males calculated at increasing ages from Icelandic data suggests this value is 0.06 or less, and a corresponding graph shows the rate for females is slightly greater than that for males. Lockyer reported that recent age distributions in the catch also suggest a higher mortality among females, there being relatively fewer females over age 37 than males. Eventually the sub-committee decided on a value of 0.055 for males and 0.060 for females.

In all model runs it was assumed that the stock was in equilibrium in 1948, although it may have been still recovering from previous catches. The results are shown in Table 1. With the catchabilities calculated separately both the full and the recent effort series show a stock about 55% of initial size with a replacement yield in 1980 of 141. With the effort data pooled, the recent series produces results that are not greatly different, though the 1980 population is now 64% of initial and replacement yield is 175. However, the full series shows the stock growing rapidly despite present catches and soon to exceed its initial size. The meeting regarded the last set of estimates as unlikely, but regarded the other set of results from the pooled series and the common result based on separate catchabilities to be both plausible. There was some further discussion about the relative merits of the two ways of treating effort, but finally the group decided to average two results.

By this rule, the exploited stock size is estimated to be 12,102 in 1948 and 7,208 in 1981, or 60% of initial, and the replacement yield in 1980 is 158. (The RY estimate refers to 1980 rather than 1982 simply because the data on age at

Table 1

Assessments of East Greenland – Iceland fin whales

Calculation of vessel catchabilities

	Separate		Pooled	
Effort series	1951–80	1962–80	1951–80	1962–80
Exploited stock				
1948	11,418	11,643	19,246	12,785
1981	6,292	6,352	16,793	8,123
Ratio	0.55	0.55	0.87	0.64
RY in 1980	141	142	339	175

maturity are only available for year-classes through 1969; the difference between 1980 RY and 1982 RY is believed to be small.)

There was some discussion as to how the stock should be classified, but it was agreed to classify it as a Sustained Management Stock with a catch limit of 158. It was noted that some estimates were below the conventional MSY level, and the sub-committee recommended that catch limits should be set one year at a time and the stock carefully monitored.

4.5 North Norway stock

Like the Newfoundland – Labrador stock, the North Norway stock has been unexploited since 1971, and its classification in the Sustained Management category with a catch limit of 61 has simply been carried forward year after year. In these circumstances the sub-committee prefers to leave the stock unclassified. If a catch limit is set, it should not exceed 61.

4.6 West Norway – Faroes stock

This stock should remain protected. The sub-committee's review of a Faroese application for a special permit to take research catches is reported below (Section 10).

4.7 Spain – Portugal – British Isles stock

Aguilar (SC/33/O 1) presented a summary of Spanish data on catch, effort and catch composition over the period 1957–80, that had been obtained by the government from the industry during the year. (A complete set of the basic data was available at the meeting.) He noted that the mean length and proportion mature of fin whales had both increased over the period 1957–77, when the average catch was about 100 per year, so the sustainable yield in that period was presumably greater. The substantially larger catches of the last few years have been accompanied by a large drop in mean lengths, but this seemed too sudden to have resulted from a decline in stock size as it occurred in the same season in which the large catches began and before the end. Aguilar believed there must have been a change in the selection pattern.

Cooke commented on the secondary mode at 16 m in the early length distributions (1957–65) of female fins, and wondered if these might in fact be sei whales. Aguilar considered this unlikely as 16 m is extremely large for a sei whale in the North Atlantic. He believed that there were probably a few whales of other species recorded among the fin catches, but not many.

To calculate a consistent series of catch per effort data, Aguilar had corrected effort in catcher-days-worked (CDW) for changes in tonnage. Holt believed that horsepower was a more appropriate correction factor.

The sub-committee was not able to carry out a proper standardisation of the recent Spanish effort data. In addition to controversy over the best measure of fishing power, there were questions about seasonal factors, differences between stations and changes in relative interest as between fin and sperm whales, which were both objects of the fishery. Lacking a resolution of these issues, the recent Spanish catch and effort series was not used in any assessment.

Last year the sub-committee had assessed the stock on the basis of two short and crude catch per effort series referring to the 1920s, one from Britain and one from Spain (*Rep. int. Whal. Commn* 31: 128).

Holt (SC/33/O 13, Appendix 1) had done further research and reported a number of defects in the data used last year. Moreover he believed that the low catch rates when whaling resumed after the second world war both at Gibraltar and Scotland contradicted the model's prediction of a rapid recovery of the stock in the intervening years. Owing to lack of information on such factors as length of season and type of vessels operating, other members thought this last comparison was invalid at this time.

A group comprising Aguilar, Allen, de Salas and Holt examined catch and effort data based on the best information available, and agreed that in repeating last year's assessment recorded specified catches that had been omitted last year would be included. This led to only minor changes in the total catch series used. Hebridean catch per boat data were used unchanged. Revised data for the Gibraltar Strait fishery were used in place of the 'Spanish' data used in 1980.

The method (see Appendix 1) involved two stages: first, an estimate was obtained of the population size at the beginning of the period for which catch per effort data are available; second, using a population model incorporating density dependent recruitment, an initial population size was found whose population trajectory passed through the estimated population at the beginning of the data period. Iteration was necessary to make the recruitment rate consistent. Two density dependent assumptions were used: first, the usual modified logistic function with $M = 0.04$, $r_o = 0.095$ and $Z = 2.39$; second, a function fitted to the available data on changes in pregnancy rate (SC/33/Ba8) and Icelandic female age at maturity with population size. Values of M of 0.04 and 0.06 were used in the second model. For lack of time, the derivation of the second model was not discussed in any detail.

Estimates were made with both the Hebrides and Gibraltar Strait data sets. For the Hebrides the data starting at both 1922 and 1924 were used. The Gibraltar data did not give estimates if the data starting earlier than 1922 were used; the group was informed by Holt and Rørvik that there was uncertainty about the number of catchers operating and length of the season in the earlier years, so the data for 1921 and 1922 were not comparable with later years. The results of the analyses are shown in Table 2. Due to lack of time, the second method was not applied to these Gibraltar data.

Some members believed that as a natural mortality rate of 0.06 rather than 0.04 had been indicated by Icelandic data, the sub-committee should adopt the result obtained with the value and with the PA method, since this was based on observed changes in pregnancy rate and age at maturity rather than on an arbitrary function. This implies

Table 2

Assessments of the Spain – Portugal – British Isles stock for two data sources and two models (ML = modified logistic, PA = other model mentioned)

Source	Hebrides				Gibraltar
Period	1924–28			1922–28	1922–26
Population model	ML	PA	PA	ML	ML
M	0.04	0.04	0.06	0.04	0.04
r_o	0.095	0.071	0.121	0.095	0.095
P_{04}	10,665	12,145	10,620	9,800	11,500
P_{28}	2,015	2,315	2,146	1,161	3,004
P_{80}	9,297	5,009	7,807	5,978	9,551
$\% \frac{P_{80}}{P_4}$	77.8	41.2	73.5	61.0	93.1
MSYL	60.0	54.0	52.3	60.0	60.0
RY	212	198	210	259	171
MSY	248	154	239	228	268

a present stock size 73.5% of initial. These members proposed that the stock be classified provisionally in the Sustained Management category with a recommended catch limit equal to the corresponding estimated replacement yield of 210.

Because of problems in the catch per unit effort data dating back to the 1920s, and uncertainties about the history of total catches, other members thought it was not possible to classify the stock. They noted the average annual catch from Spanish land stations was 137 in the period 1968–77, and 209 in the period 1971–80.

Holt and van Beek concurred with the view that there was no good basis for the classification of this stock. Neither the calculations made nor the levels of recent catches provided a scientific basis for recommendation regarding the catch limit. The extremely unreliable forward extrapolations from the 1920s predicted stock abundances completely at variance with the catch rates experienced when land station whaling resumed after the second World War. This might be because of the sensitivity of the simulation to parameter values of the model, to errors of interpretation in the initial CPUE series (some of which had already been identified) and/or to the effects of substantial catches in the intervening years (up to 1,500 fin whales) which had not been taken into account.

The meeting identified the following problems that would have to be solved in order to improve assessments of this stock:

(i) Extracting consistent series of effort and corresponding catch in the 1920s to measure the change in relative abundance then, and reconstructing the most accurate series of total catches from the stock over the entire period of whaling.

(ii) Determining an appropriate model to use in calculating stock size backward and forward from the time of the base period in the 1920s.

(iii) Determining an appropriate measure of effort to be associated with recent catches.

(iv) Reviewing the evidence as to the identity and possible mixing of stocks in the Spain – Portugal – British Isles area.

5. SOUTHERN HEMISPHERE SEI WHALES, AREAS I–VI

There were no new data for Areas II–VI and therefore no reason to alter the Scientific Committee's 1979 recommendation that these stocks should be protected.

Japanese sighting cruises produced a relatively large number of sightings in Area I off Chile (SC/33/ProgRep Japan), but no estimate of abundance had been obtained from the observations. Chapman recalled that the sub-committee had reviewed Area I assessments last year (*Rep. int. Whal. Commn* 31: 129) and concluded that in Area I a small stock had been greatly reduced by fishing and would certainly have to remain protected.

The sub-committee's review of a Chilean application to take research catches is reported below (Section 11).

6. NORTH PACIFIC SEI WHALES

Continuing Japanese sighting cruises suggest a slow recovery. The stock should be reassessed eventually, but for the time being the sub-committee concluded it should remain protected.

7. NORTH ATLANTIC SEI WHALES

7.1 Nova Scotia stock

No new information was presented on this stock, which should remain protected.

7.2 Iceland stock

Sigurjónsson reported that a further 35 animals had been marked in 1980, and one of these recaptured in the catch of 100. (Eight sei whales had been marked in 1979.)

Rørvik commented that given the possibility of differences in availability by age and trends in recruitment, mark returns may be a more reliable basis of stock assessments than catch curves. Martin, however, was concerned that the large annual fluctuations in availability, length composition and sex ratio of sei whales around Iceland indicated the stock was not well mixed and therefore would not provide a reliable estimate from mark returns.

There being no new assessment this year, the sub-committee agreed that the stock should remain as at present in the Sustained Management category with a quota of 504 for the period 1980–85, no one year's catch exceeding 100.

7.3 Northeast Atlantic stock (or stocks)

Stock identities in this region are unknown, as is the true species identity of some reported catches. In particular, the Spanish catch of medium-sized baleen whales, averaging about 12 animals per year over the years 1957–80 and reported as sei whales (SC/33/O 1), may have been partly Bryde's whales. An observer will be at the station in future.

It was pointed out that as from 1981 no such whales may be taken as there is no information about them. Hence it is improbable that the observers will be able to identify them. The Spanish scientists expressed their interest in identifying the species and finding out if there are one or two involved. They expressed their interest in initiating research on the species, but pointed out that this might require a small quota.

Holt stated that Scottish catch per effort of sei whales in the earlier part of this century showed a decline similar to that of fin whales.

Lacking any sort of assessment the sub-committee was unable to recommend a classification or catch limit.

8. SOUTHERN HEMISPHERE BRYDE'S WHALES[1]

At the Chairman's request, Ohsumi in consultation with other members prepared a map (Fig. 1) to make precise the boundaries of the stocks defined for management purposes after last year's discussions (*Rep. int. Whal. Commn* 31: 124). The two stock areas not defined by lines of latitude and longitude are:

(i) East China Sea stock, divided from the Western North Pacific stock by the Ryukyu Island chain.

(ii) South African inshore stock, extending 30 nm seawards off the southwest coast of Africa from 25°S lat. down and around the coast to 25°E long.

All Bryde's whale stock areas are tentative. Ivashin (SC/33/Ba2) reviewed the problem of identifying the major oceanic stocks, and other members suggested that inshore stocks are likely to be found in areas such as West Australia, Brazil and Baja California, when more research is done. There is no evidence of stock separation across the Equator in the Indian Ocean, but for the time being a stock boundary has been placed there for management purposes by analogy with the Pacific.

Only the Peruvian stock was assessed at this year's meeting. Valdivia (SC/33/ProgRep Peru) provided data on sightings, catch and effort, that were used at the meeting to obtain several estimates of present stock size:

(i) Two De Lury estimates, one based on catch per day of vessel operation over the years 1973–81 and the other based on sightings per day over the years 1977–81, failed to yield significant slopes, although the present stock size estimates were similar to the survey estimates reported below.

(ii) Data from the 1980 survey considered at last year's meeting were reworked to obtain a strip estimate of total stock size of 11,316, which if 80% are of catchable size implies an exploitable stock of 9,053.

(iii) Sightings from two commercial trips and one research cruise in 1981 provided another strip estimate of total stock of 8,571 with 6,857 exploitable.

The sub-committee agreed to take the average of the two sighting estimates, i.e. an exploitable stock of 7,955[8,345] in 1980, as the basis of further calculations, which consisted of calculating stock size backward and forward according to the equation:

$$N_{t+1} = (N_t - C_t)e^{-M} + N_{t-10}(1 - e^{-M})$$

with M = 0.07. The term (t − 10) reflects an average age at recruitment of 10 years. Exploitation began in 1968, but before 1973 sei and Bryde's whales were not distinguished in the catches. Valdivia provided estimates of the species composition in those years, which along with the estimated exploitable stock size are shown in Table 3.

According to the figures, the present stock size is 7,890/10,924 = 72% [8,317/11,303 = 74%] of initial, so this is an Initial Management Stock with a recommended catch limit of (0.9) (0.04) (0.60) times the initial stock size or 236 [244] whales.

Valdivia stated that only 82% of the 1980 quota was taken due to the late start of the season. It was a consequence of a Commission rule and he showed evidence that the higher availability is from November to April. He suggested that the season be shifted and the remainder of the 1980 quota (18%) be allowed as an addition to the next year's quota. The sub-committee decided that these were questions for the Technical Committee to decide but that there are no scientific reasons against the suggestion.

One mark was recaptured off Peru on 22 March 1981 at 8°16′S, 82°45′W. Ohsumi reported that it was placed by a Japanese research vessel on 14 December 1980 at 9°32′S, 83°39′W.

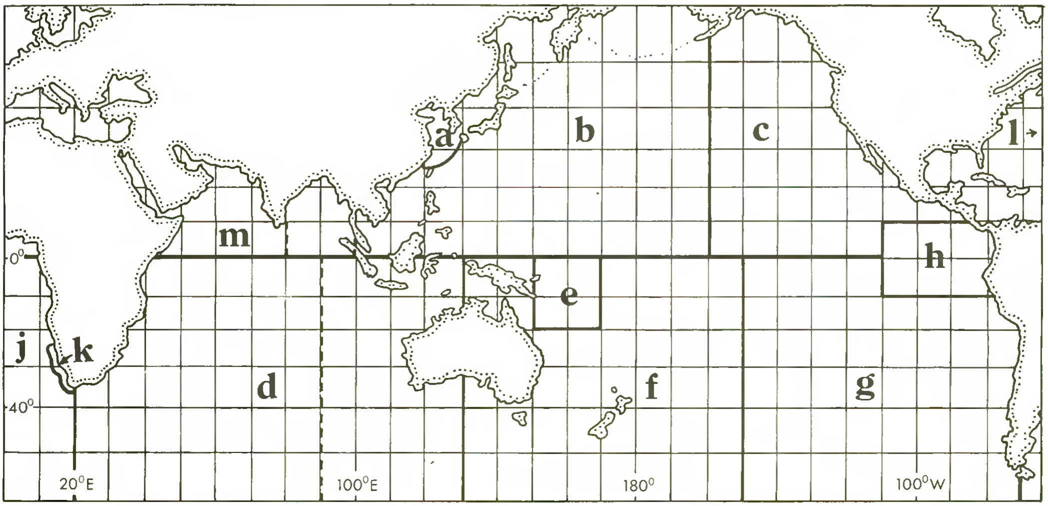

Fig. 1. Proposed stock boundaries for Bryde's whales: a, East China Sea; b, Western North Pacific; c, Eastern North Pacific; d, South Indian; e, Solomon Islands; f, Western South Pacific; g, Eastern South Pacific; h, Peruvian, j, South Atlantic; k, South African Inshore; l, North Atlantic; m, North Indian.

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[1] Editor's note. D. Chapman, convenor of this sub-committee, discovered certain arithmetic errors in Sections 8 and 9 of this report. The values which were originally used and presented to the full Scientific Committee and the Commission are shown in square brackets.

Table 3

Catches and estimated exploitable stock size of Bryde's whales off Peru

	Catch data			
Year	Sei & Bryde's	Estimated Bryde's	Known Bryde's	Stock
1968	317	300		10,924 [11,303]
1969	700	666		10,644 [11,130]
1970	363	350		10,042 [10,799]
1971	371	352		9,775 [10,473]
1972	301	285		9,525 [10,167]
1973			311	9,354 [9,944]
1974			450	9,170 [9,712]
1975			415	8,869 [9,366]
1976			398	8,621 [9,076]
1977			386	8,406 [8,821]
1978			297	8,216 [8,595]
1979			300	8,103 [8,467]
1980			215	7,955 [8,345]
1981			106	7,877 [8,288]
1982				7,890 [8,317]

None of the other Southern Hemisphere stocks was assessed at this meeting, and the sub-committee did not attempt to revise last year's advice on any of these stocks. The sub-committee had no information on the possible stock in the northern Indian Ocean and recommended it be classified as an Initial Management Stock with a catch limit of zero. Recommendations for all Southern Hemisphere stocks are shown in Table 4.

Table 4

Management recommendations for Southern Hemisphere Bryde's whales

Stock	Classification	Catch limit
Northern Indian Ocean	—	0
Southern Indian Ocean	IMS	197
Western South Pacific	IMS	237
Solomon Islands	IMS	0
Eastern South Pacific	IMS	188
Peruvian	IMS	236 [244]
South Atlantic	—	0
South African inshore	—	0

9. NORTH PACIFIC BRYDE'S WHALES

The Eastern North Pacific stock has never been exploited and remains in the Initial Management category with a zero quota. The East China Sea stock is presently in the Sustained Management category with a quota of 19 based on annual catches during the period 1955–74 (*Rep. int. Whal. Commn* 30: 65), but no catches have been taken since then. Several members felt that this stock should be unclassified for lack of adequate information. All agreed that the catch limit should not be increased, and that inquiries should be made about any catches by the People's Republic of China.

At this meeting the assessment of the Western North Pacific stock was updated. Several estimates of exploitable stock size were available:

Marking: Using recapture data provided by Ohsumi and estimating unreported Taiwanese catches, Tillman (SC/33/Ba6) calculated two estimates of stock size, one from the complete set of recaptures (1973–80) and the other from a more consistent subset (1975–80). On Best's suggestion, the estimates were revised at the meeting to allow for a 5% marking mortality, giving the following results:

Data series	Years	Midpoint	Estimate	95% Confidence limits
All returns	1973–80	1976	28,863	17,661–54,491
Consistent subset	1975–80	1977	22,404	13,545–43,922

Sighting: Ohsumi (*Rep. int. Whal. Commn* 31: 419) had previously obtained an estimate of 27,400 in 1976 based on Doi's sighting theory. At this meeting Chapman (Appendix 2) calculated a strip estimate of 13,353. Ohsumi noted that Japanese sightings in zones L & M had shown an increasing trend in abundance in the 1970's (*Rep. int. Whal. Commn* 31: 783–89).

Catch per effort: Analytical assessments of this stock have been problematical because Japanese and Soviet data show quite different trends and both are complicated by seasonal, areal, or operational effects. At last year's meeting the two series had been combined by geometric averaging (*Rep. int. Whal. Commn* 31: 124). This year Cooke (Appendix 3) used the method described in SC/33/Ba8, which fits to several series simultaneously, and obtained an estimate of 17,300 in 1970.

In order to estimate the 1970 stock sizes corresponding to the marking and sighting estimates in 1976–77, the change in stock size from year t to year t + 1 in the 1970s was approximated as

$$N_{t+1} = (N_t - C_t)e^{-M} + N_{1970}(1 - e^{-M})$$

with $M = 0.085$. In this calculation recruitment is at the replacement rate for the stock size in 1970. Since catches were relatively low before 1970, and the mean age at maturity is around seven years (*Rep. int. Whal. Commn* (special issue 1: 144)), this approximation should be adequate for back calculating the marking and sighting estimates from 1976 to 1970. (However, if recruitment rates have changed in response to reduced stock sizes, the approximation will be increasingly inaccurate after 1977, which will affect the forward calculations from 1970 to 1982 reported later.)

The table below shows all the estimates referred to 1970:

Method	Exploitable stock size	Averages	
Marking: 1. All recaptures	32,361	29,783	[29,918]
2. Consistent subset	27,205		
Sighting: 1. Doi's theory	31,167	23,262	[23,252]
2. Strip estimate	15,357		
Catch per effort	17,300		17,300

The sub-committee agreed that while some of these estimates could be assigned a variance and others not, they were all very imprecise and the three methods should be weighted equally to obtain a single 1970 estimate by averaging. This figure is 23,448 [23,490], which calculated forward to 1982 by the equation described above implies that next year the exploitable stock will number 17,365 [17,407]. Given the imprecision of the 1970 estimate and the inaccuracy of the equation by this time, it would not be proper to project further ahead than this. According to these estimates, present stock size is 74% of initial, and the stock should therefore be classified in the Initial Management category.

Following previous practice, the recommended quota is 90% of 4% of 60% of initial stock size, or 506 [507] if the average 1970 estimate is treated as the unexploited stock size. In fact some catches were taken before 1970, which would have reduced the stock somewhat by then.

10. DANISH APPLICATION FOR A SPECIAL PERMIT

Kapel explained a Faroese proposal (SC/33/RP3) to initiate a long-term study of fin whales, including historical research, sighting, marking, and an annual scientific catch of up to nine animals.

The sub-committee recognised that marking and recaptures might provide valuable information about stock identities in the northeast Atlantic. However, it noted that in view of the relatively small catches to be expected in the region as a whole, a very considerable proportion of the fin whales off the Faroes would have to be marked to offer much hope of obtaining conclusive evidence. It was not thought that the biological samples from nine whales per year would add greatly to present knowledge.

Other elements of the proposal—particularly sighting and historical research based on logbooks—were enthusiastically endorsed.

11. CHILEAN APPLICATION FOR A SPECIAL PERMIT

Maturana introduced a Chilean proposal to take at least 100 sei whales in 1982 for the purpose of obtaining biological data. Ohsumi recalled that a Japanese research vessel had conducted sighting and marking in Area I in 1980/81, which could be regarded as an appropriate preliminary to a research catch.

Several members noted that very little in the way of studies or even basic data had been provided from Chile's substantial previous catches of sei whales. It was recommended that other kinds of work, including the compilation and analysis of earlier data, and further development of national expertise should precede any research catches, and that any future proposal be more detailed and carefully justified.

12. FUTURE RESEARCH

The sub-committee has found the results of Peruvian sighting and marking cruises very useful in assessing the Bryde's whale fishery there, and looks forward to the longer and larger data series that can be obtained by continuing both kinds of work.

It noted with approval Spanish plans to initiate a marking program, and if possible to carry out sightings as well.

Appendix 1

AGENDA

Fin whales

1. Southern Hemisphere Areas I–V.
2. Southern Hemisphere Area VI.
3. North Pacific.
4. North Atlantic.
    (a) Newfoundland – Labrador.
    (b) Nova Scotia.
    (c) West Greenland.
    (d) East Greenland – Iceland.
    (e) North Norway.
    (f) West Norway – Faroes.
    (g) Spain – Portugal – British Isles.

Sei whales

5. Southern Hemisphere.
6. North Pacific.
7. North Atlantic.
    (a) Nova Scotia.
    (b) Iceland.
    (c) Spain.

Bryde's whales

8. Southern Hemisphere.
9. North Pacific.

Other Business

10. Danish application for a special permit.

Appendix 2

RECALCULATION OF SIGHTINGS ESTIMATE OF N. PACIFIC BRYDE'S WHALES BY LINE TRANSECTS METHODS

D. G. Chapman

The data given in Table 4 of SC/32/Ba9 was the basis of an estimate of the size of the population of Bryde's whales in the western North Pacific found in *Rep. int. Whal. Commn* 31: 124 Table 2 (13,300). This estimate was based on the exponential model but the goodness of fit of the exponential model was not tested. An X^2 test now shows that the model is rejected as with southern minke whale sighting data. The reason was similar—the number of observations in the zero interval was higher than expected under the model.

The sightings subgroup of the minke whale special meeting recommended that, in the circumstances, a strip estimate of the population be calculated. This was done as follows:

$$N = \text{average school size} \cdot \frac{\text{area}}{\text{length}} \cdot \frac{\text{no. whales in zero interval}}{\text{width of zero interval}}$$

$$= (3.02) \cdot \frac{(3{,}375{,}782)}{77{,}873} \cdot \frac{51}{0.5}$$

$$= 13{,}353$$

To estimate the number of whales in the exploited stock, the factor given in SC/32/Ba9 *Rep. int. Whal. Commn* 31: 419 (86.8%) was used.

$$N_{\text{EXPLOITED}} = (0.868)\,(13{,}353) = 11{,}590$$

(The factor 0.868 applies to the exploited coastal stock.) This estimate applies to approximately 1976.

Appendix 3

ESTIMATE OF WESTERN NORTH PACIFIC STOCK OF BRYDES WHALES FROM COMBINED SOVIET AND JAPANESE PELAGIC EFFORT DATA

J. G. Cooke

Catch data from Table 5 in SC/33/Ba6 were used together with effort data from Tillman. (*Rep. int. Whal. Commn* 31: 386 Tables 3 and 4).

As it is not clear that the catchability coefficients are the same for the Japanese and Soviet operations, catchabilities were calculated separately for each according to the method described in SC/33/Ba8.

The stock size was then estimated by the transformed least squares method described by Kirkwood (*Rep. int. Whal. Commn* 31: 729), on the assumption that the natural mortality rate is 0.085 and the annual recruitment is constant over the period (1970–80).

The best estimate for the exploitable stock in 1970 was 17,300 with lower 95% confidence limit 8,000 and no upper confidence limit.

The catchabilities corresponding to the best estimate are 2.1×10^{-5} CDW^{-1} for the Soviet operation and 7.5×10^{-5} CDW^{-1} for the Japanese operation. The time series of population for the best estimate is:

1970	17,300	1976	13,532
1971	17,172	1977	12,500
1972	16,340	1978	12,022
1973	16,270	1979	11,904
1974	15,717	1980	11,400
1975	14,631	1981	11,187

The overall fit is very poor—as evidenced by the very wide confidence limits—because the two series show very different trends.

Appendix 4

POPULATION ESTIMATES FOR FIN WHALES OF THE BRITISH ISLES – SPAIN – PORTUGAL STOCK

K. Radway Allen

1. INTRODUCTION

In 1980 population estimates were made for this stock (Allen, 1980) using the regression method described by Chapman (1974), based on the assumption that over the period of the regression the annual number of recruits remained constant. These estimates have been recalculated using revised data and a modification of the technique.

The revised total catches and catch per unit effort data are shown in Adjunct (a), the revision being made in consultation with S. J. Holt, A. Aguilar and E. de Salas. Only minor amendments were made to the total catches, these being to include additional catches which were omitted in 1980 but had since been identified. The catch per unit effort was again based on catch per boat day; data from the Hebrides were unchanged from 1980, but the 'Spanish' data used in 1980 were replaced by a series, based on the Gibraltar Strait fishery, given by Holt (1981).

2. METHODS

In the estimation procedure a modification of the Chapman technique (Allen, 1981) was used which makes it unnecessary to assume that the stock was unexploited at the beginning of the period of the regression (i.e. that total recruitment rate equals natural mortality rate) although the assumption of a constant number of recruits is retained.

This was used with the difference equation (1) to extrapolate the population trajectory forwards in time.

$$N_{t+1} = (N_t - C_t)e^{-M} + N_{t-d}f(N_{t-d})\,N_{t-d}f(N_{t-d})$$

Where N_t = population at beginning of year t.
C_t = catch in year t.
d = number of years from birth to recruitment.
$f(N_{t-d})$ = function determining the recruitment rate as a proportion of the recruited population in year (t–d).

This leads to an iterative procedure with the following steps:

(a) Select trial values for N at the unexploited level (N_o) and the beginning of the regression period (N_t),
(b) from these two values calculate the gross recruitment rate (r_t) at the beginning of the regression period,
(c) obtain an estimate of N_t,($\hat{N}_t$), by the regression technique,
(d) extrapolate from the trial N_o, using equation (1), to obtain a value of N_t,(N^x)
(e) Compare N_t and N^x_t and return to (a) with new trial values of N_o and N_t.

Iterative until $\hat{N}$ and N^x_t are sufficiently in agreement. Iterations were done manually, 3 or 4 cycles being usually required.

Two recruitment functions were used in the estimations:

(a) the modified logistic with the same values as in 1980, i.e. $M = 0.04$, $r_o = 0.095$ and $z = 2.39$, corresponding to an MSY level of 0.60 of initial population size
(b) an empirical cubic function fitted to approximate data on changes with population size in pregnancy rate and female age at maturity. These functions were fitted for $M = 0.04$ and $M = 0.06$, the method being described in Adjunct (b). The functions obtained were:

for $M = 0.04$
$r = 0.07242 + 0.01996P - 0.08462P^2 + 0.03186P^3$
for $M = 0.06$
$r = 0.12004 + 0.03807P - 0.17500P^2 + 0.07634P^3$
The corresponding MSY levels were 0.540 and 0.523 of initial population size respectively.

The delay between birth and recruitment to the mature or exploited population was taken as 5 years.

3. RESULTS

Using the modified logistic function (ML method) estimates were obtained from the Hebrides data both for the period 1922–28, the maximum for which comparable data were available, and for 1924–28, i.e. starting in the year in which catch per boat was at a maximum. For the Gibraltar data estimates could only be obtained using the data for the period 1922–26. All the estimates were obtained using $M = 0.04$.

The function based on pregnancy rate and age at maturity (PA method) was only applied to the Hebrides 1924–28 data but both $M = 0.04$ and $M = 0.06$ were used.

The results are summarised in Table 2 of the report of the sub-committee. The general shape of the population trajectory obtained with the ML method for the Hebrides 1924–28 data is similar for all estimates, with an abrupt decline to a low value in 1928 and a gradual climb to a maximum in about 1975, followed by a slight fall. The relative extent of the changes varies with the population models, and this can be seen in the Table which gives the calculated population sizes; initially (1904), at the minimum (1928), and recently (1980).

Adjunct (a)

TOTAL CATCH AND CATCH PER BOAT DAY FOR BRITISH ISLES, SPAIN AND PORTUGAL FIN WHALE STOCK

A. *Total catch*

Amended from *Rep. int. Whal. Commn* 31: 131, Table 1.

Year		Year		Year		Year	
1904	263	1921	323	1941	—	1961	110
1905	450	1922	853	1942	—	1962	35
1906	317	1923	1,392	1943	—	1963	16
1907	396	1924	1,719	1944	38	1964	38
1908	379	1925	2,015	1945	36	1965	116
1909	432	1926	2,015	1946	42	1966	85
1910	381	1927	630	1947	111	1967	80
1911	344	1928	139	1948	106	1968	92
1912	292	1929	73	1949	69	1969	126
1913	346	1930	—	1950	96	1970	158
1914	322	1931	—	1951	58	1971	93
1915	—	1932	—	1952	112	1972	90
1916	—	1933	—	1953	40	1973	73
1917	—	1934	66	1954	93	1974	57
1918	—	1935	—	1955	112	1975	220
1919	—	1936	—	1956	27	1976	290
1920	407	1937	—	1957	46	1977	164
		1938	—	1958	23	1978	502*
		1939	—	1959	42	1979	465
		1940	—	1960	86		

* Includes Sierra catches.

B. *Catch per boat per year*

	Hebrides			*Gibraltar*		
Source:	*Rep. int. Whal. Commn* 27: 422			Holt. SC/33/O 13 App. 1: 5–6		
Year	Catch	Boats	Catch per boat	Catch	Boats	Catch per boat
1921	—	—	—	323	3	107.67
1922	282	6	47.00	571	3	190.33
1923	312	7	44.57	1,080	3	360.00
1924	501	7	71.57	920	3	306.67
1925	315	7	45.00	715	3	238.33
1926	400	7	57.14	500	3	166.67
1927	261	7	37.29	—	—	—
1928	139	7	19.86	—	—	—

Adjunct (b)

CALCULATION OF THE ‘PA’ POPULATION LEVEL/RECRUITMENT RATE RELATIONSHIP

DERIVATION

If N = number of mature animals of both sexes then the number of recruits t_m years later is given by

$$R = 0.5Npe^{-Mt_m}\, e^{-(M_j-M)t_j}$$

where p = pregnancy rate,
M, M_j = adult and juvenile natural mortality rates,
t_m = age at maturity.
t_j = age up to which M_j applies.

Therefore the gross recruitment rate is

$$r = \frac{R}{N} = 0.5\, pe^{-Mt_m}e - (Mj - M)tj.$$

Putting $e^{-(M_j-M)t_j} = K$

we have

$$r = 0.5p\, k\, e^{-Mt_m}.$$

For equilibrium populations

$$r_1 = M$$

$$\therefore M = 0.5\, p_1 K\, e^{-Mt_{m1}}$$

and

$$K = \frac{2Me^{Mt_{m1}}}{p_1}$$

then if p and t_m are variable with relative population size (N)

$$r_N = \frac{MPN}{p_1}\, e^{-M(t_{m_n} - t_{m_1})}.$$

Thus if p_N and t_{mn} are known for different relative population levels a series of values of r_n can be calculated.

PARAMETER VALUES

Data on values of p and t_{m_n} for North Atlantic fin whales at various times are given in Cooke and Beddington (1981) and Martin (1981). These data relate to changes in the parameters with time rather than with relative population size. However it was decided, in consultation with J. R. Beddington, to employ them, with what is known of changes in the Antarctic fin whales, to construct tentative relationships between parameter values and population size for use as a basis for the present study. These relationships are shown in Fig. 1a.

The resulting parameter values are tabulated at 0.1 equilibrium population intervals in Table 1 together with the calculated values of r, using M = 0.04 and M = 0.06. These values are plotted in Fig. 1b., expressed as r − M.

Table 1

Values of pregnancy rate (p) and age at maturity (t_m) used to calculate the gross recruitment rates shown for M = 0.04 and M = 0.06

Relative population level	P	t_m	Recruitment rate M = 0.04	M = 0.06
0	0.48	6.0	0.073	0.121
0.1	0.48	6.0	0.073	0.121
0.2	0.48	6.0	0.073	0.121
0.3	0.48	6.6	0.071	0.117
0.4	0.48	7.3	0.069	0.112
0.5	0.48	8.0	0.067	0.108
0.6	0.45	8.7	0.061	0.096
0.7	0.42	9.4	0.055	0.081
0.8	0.39	10.1	0.050	0.077
0.9	0.36	10.8	0.045	0.068
1.0	0.33	11.5	0.040	0.060

FITTING THE FUNCTION

A smooth continuous function is biologically more plausible than the discontinuous relationships shown in Fig. 1a; it is also easier to handle in a simple model for calculating trajectories. The cubic functions given in the principal paper were fitted by a least squares method and have been plotted in Fig. 1b. In view of the approximation attached to the original points these areas are clearly an acceptable fit.

The MSY levels for these functions have been calculated by making use of the general relationship that if the net recruitment rate is given by

$$r - M = f(N)$$

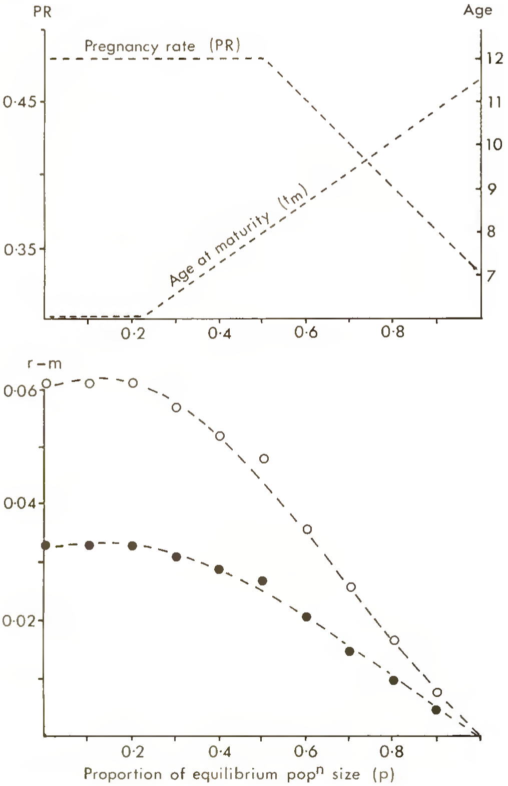

Fig. 1. For explanation see text. In the lower figure (b) for M 45 0.06, $r = 0.06004 + 0.03807p—0.17500p^2 + 0.07634p^3$ and for M = 0.04, $r = 0.03242 + 0.01996p + 0.08462p^2 + 0.03186p^3$.

then at MSY level

$$\frac{d(fN)}{dN} = -\frac{f(N)}{N}.$$

Applying this to the cubic relationship

$$r - M = a + b\,N + c\,N^2 + d\,N^3$$

where N is the relative population size, we find that the relative MSY level is given by the solution of

$$a + 2\,b\,N + 3\,c\,N^2 + 4\,d\,N^3 = 0$$

This equation has been used to calculate the MSY population levels given in the principal paper.

REFERENCES

Allen, K. R. 1980. British Isles, Spain and Portugal stock Appendix 6. *Rep. int. Whal. Commn* 31: 131.

Allen, K. R. 1981. A modified De Lury method of estimating populations. *Rep. int. Whal. Commn* 31: 683.

Chapman, D. G. 1974. Estimation of population size and sustainable yield of sei whales in the Antarctic. *Rep. int. Whal. Commn* 24: 82–90.

Cooke, J. G. and Beddington, J. R. 1981. The fin whale in Icelandic waters, growth, reproduction and sustainable yield. Paper SC/33/Ba8 presented to the IWC Scientific Committee, June 1981.

Holt, S. J. 1981. The protection of species. Paper SC/33/O 13 presented to the IWC Scientific Committee, June 1981.

Martin, A. R. 1981. Pregnancy rates of fin whales in the Icelandic catch. Paper SC/33/Ba4 (published in this volume).

Appendix 5

PRELIMINARY INVESTIGATION OF SOME ANATOMICAL CHARACTERS OF FIN WHALE EAR PLUGS COLLECTED FROM DIFFERENT REGIONS OF THE N.E. ATLANTIC

C. Lockyer

INTRODUCTION AND AIMS

The number of growth layers in ear plugs from fin whales has been found to be a useful means of determining age. At the 1973 workshop on age determination in baleen whales, a comparison of ear plugs from whales taken in different areas of the world revealed differences in clarity of layering. Data presented at that meeting indicated a decreasing order of sample readability (i.e. growth layer counts which are repeatable both by individuals and groups of individuals) as follows: Antarctic (80%), Canadian Antarctic (69%), North Pacific (65%), Iceland (65%) and Norway (North and West combined) lowest of all, although figures were not given (IWC, 1974). This last result was explained by the poor contrast between pale and dark laminae compared with that in ear plugs from other areas. Other difficulties which affected readability were the occurrence of irregular and incomplete laminae. It was suggested (IWC, 1974) that these variations between ear plug samples examined from different areas might 'reflect variations in these features between different populations'.

Preliminary studies on the morphology of ear plugs have been attempted on fin whale ear plugs from North West Atlantic (Mitchell and Kozicki, 1974), and from North Pacific, East China Sea and the Antarctic (Ichihara, 1959). Both studies suggested that the dimensions of ear plug and associated glove finger might be a useful indicator of stock identity in some areas, but these suggestions have not been followed up.

In this paper, preliminary results of a quantitative comparison of some characters of fin whale ear plugs from the North East Atlantic, namely North Norway, West Norway, West Iceland and North Spain, are presented.

MATERIAL AND METHODS

The following material in the form of uncut ear plugs, fixed and preserved in 10% neutral formalin, was available:

Locality	Seasons	Total no. plugs examined
Steinshamn (W. Norway)	1961, 1963	200
Skjelnan (N. Norway)	1961, 1963	71
Iceland	1980	399
Spain	1980	178
Total		848

Å. Jonsgård (Univ. of Oslo), K. Loftsson (Hvalür H. F., Iceland), J. Jónsson (Marine Research Institute, Reykjavik) and A. Aguilar (Univ. of Barcelona) kindly made available material for this study.

All ear plugs were well fixed and in good condition when examined. This was important, particularly because of the long storage time of the Norwegian collections. The glove finger, even if collected, was rarely still *in situ*. Most of the samples were of pairs of plugs. It appeared that, apart from the long storage time of the Norwegian ear plugs, all samples had been collected and preserved in a similar manner.

The general condition of each ear plug (e.g. damage, etc) was noted as was its shape prior to being cut longitudinally to the midline to expose the core. Once cut, other characters could then be assessed and measured. Each plug, regardless of whether or not it was one of a pair, was treated individually.

RESULTS

Total number of ear plugs from which data were gained are shown in Table 1.

Comparisons of individual characters between sexes, classes of maturity, and areas of sampling have been made throughout by the χ^2 – contingency test (Siegel, 1956) using the actual numbers observed. A probability of 5% or less was considered to be significant.

Initial investigations of possible variations between sexes for characters 1, 2, 3 and 4 in Appendix Table 1 showed no significant differences. The sex ratios were in fact approximately equal in the samples from Steinshamn, Iceland and Spain. Because of small sample sizes in some classifications therefore, sexes were subsequently combined throughout for all areas. Results are as follows.

1. Colour

In all areas the cores of ear plugs from mature animals were usually darker than those from immature animals. This is presumably an effect of the gradual compression of the core with age caused by the close layering of the mature layers. Ear plugs from the same whale were similar in colouration or shade.

Results of analysis for immature and mature whales are shown below.

Localities compared	Results of χ^2—Test Immature	 Mature
Steinshamn – Iceland	n.s.	n.s.
Steinshamn – Skjelnan	s. at 0.1%	s. at 2%
Steinshamn – Spain	s. at 1%	n.s.
Skjelnan – Iceland	s. at 0.1%	n.s.
Skjelnan – Spain	n.s.	n.s.
Spain – Iceland	s. at 0.1%	n.s.

Notes: n.s. = no significant difference, $p > 5\%$.
s. at n% = significantly different at $p < n\%$.

The colouration of mature ear plugs was similar for most areas although there was a significant difference between Steinshamn and Skjelnan. In the immature sample, however, similarities were observed only between Steinshamn and Iceland, and between Spain and Skjelnan. In all other area comparisons, significant differences were found.

The greater differences between localities found in the immature sample may be because a small age range is involved, and thus any age-related biasses are excluded.

2. Shape

Comparisons between localities of both immature and mature samples, and between immature and mature samples in the same locality revealed no significant differences. In addition, the shapes of ear plugs from the same animal were frequently different.

The oval section (type 1) was the most common shape in all localities, and the percentage occurrences of this type are shown below together with data from Mitchell and Kozicki (1974) for Northwest Atlantic fin whales.

Locality	Region	% incidence of oval shape (immature + mature)	Sample size
Steinshamn	W. Norway	57.3	199
Skjelnan	N. Norway	64.8	71
Iceland		66.1	395
Spain		63.5	178
Blandford	Canada (Mitchell and Kozicki, 1974)	66.4	363
Dildo		67.6	354
Williamsport		64.7	405
All localities	E and W Atlantic	65.0 (weighted mean)	1,965

All areas appear very similar, and one can only conclude, as did Mitchell and Kozicki (1974) that this particular character is not useful for stock identification, at least in the North Atlantic.

3. and 4. Accessory laminae and clarity of layers

The analyses were performed on data from ear plugs of immature whales and from the juvenile phase of growth of the ear plugs of mature whales. This eliminated problems caused by the often very different growth patterns present below the transition phase. The occurrence of various characters in the juvenile phase only are shown below:

Locality	Sample size	Presence of accessory laminae	Clear colour differentiation of laminae	Regular layer formation
Steinshamn	194	79.9%	36.1%	83.0%
Skjelnan	71	69.0%	42.3%	71.8%
Iceland	394	82.0%	51.5%	82.2%
Spain	176	89.2%	36.9%	91.5%

The Iceland ear plugs have the highest percentage of clear differentiation in layering (good contrast between pale and dark laminae); this supports the views expressed in IWC (1974). The incidences of the other two characters appear very close for Iceland and Steinshamn and are not significantly different, although the occurrence of the differentiation character is highly significantly different ($p < 0.1\%$). Iceland and Spain are significantly different for all characters. Iceland and Skjelnan were significantly different in all but the differentiation character. Steinshamn and Skjelnan were only significantly different in the regularity of layering. Skjelnan and Spain were highly significantly different ($p < 0.1\%$) on all but differentiation. Steinshamn and Spain differed significantly on all except differentiation.

It seemed possible, because of the mechanism of formation of the ear plug layers (Roe, 1967), that the three characters might be linked. When this was tested, they were found to be linked significantly in Iceland ($p < 5\%$), Spain ($p < 2\%$) and Skjelnan ($p < 1\%$), but not significantly in Steinshamn ($p < 10\%$).

DISCUSSION AND CONCLUSIONS

The results described here are preliminary and the possibility of association between characters has only tentatively been explored, and requires further more sophisticated analysis. However, the results do tend to support the suggestions in IWC (1974) that

(a) ear plugs from various localities can appear different, and
(b) ear plug characters may be useful in stock identity.

The present data suggest that certain characters in immature ear plugs are more useful than others (colouration of the core, and pattern, contrast and regularity of layering). Results on ear plug sectional shape are similar to those of Mitchell and Kozicki (1974) and this is not found useful as a character for stock identification.

On the basis of the characters analysed here (excluding shape), all four localities appear to differ to some extent. However, there are frequently similarities between West Norway and Iceland. Localities which most consistently differ are Iceland and Spain.

REFERENCES

Ichihara, T. 1959. Formation mechanism of ear plug in baleen whales in relation to glove-finger. *Sci. Rep. Whales Res. Inst., Tokyo* 14: 107–35.

International Whaling Commission. 1974. Report of the meeting on age determination in baleen whales. *Rep. int. Whal. Commn* 24: 62–8.

Mitchell, E. and Kozicki, M. 1974. Northwest Atlantic fin whales: the ear plug sample. *Rep. int. Whal. Commn* 24: 150–8.

Roe, H. S. 1967. Seasonal formation of laminae in the ear plug whale. *Discovery Rep.* 35: 1–30.

Siegel, S. 1956. *Non Parametric Statistics for the Behavioural Sciences.* McGraw-Hill Kogakusha, Ltd. 312 pp.

Annex G

Report of the Sub-Committee on Protected Species and Aboriginal Whaling

1. MEMBERS

Albert, Anderson, Balcomb, Bannister, Best (Convenor), Braham, Brown, Donovan, Finlay, Fleischer, Hiby, Holt, Ikeda, Ivashin, Jarrell, Kapel, Leatherwood, Mitchell, Miyahara, Nakamura, Ohsumi, Øritsland, Riazantsev, Tillman, Walker, Yamamura.

2. REVIEW OF PROTECTED STOCKS

2.1 Bowhead whales

2.1.1 Bering/Chukchi Seas stock

The sub-committee reviewed the data for the Alaskan eskimo harvest (SC/33/PS5). Relevant quotas and catches are given below.

	US internal allocation		Result	
Year	Landed	Struck	Landed	Struck
1980				
Spring	15	22	15	31
Autumn	0[1]	0[1]	1	3
Total	18	26	16	34
IWC quota	18	26		
1981				
Spring	—	28	14	25

[1] 1980 harvest terminated by US government 27 May.

The sub-committee noted with great concern that despite the official closure of the 1980 hunt on 27 May, five crews from Kaktovik and Nuiqsut villages had engaged in bowhead whaling during September and October, during which 3 bowheads were struck and 1 landed. The IWC quota had thus been exceeded by 8 strikes. It was noted, however, that in the hunt of spring 1981, the US allocation of 28 strikes had not been exceeded, and the sub-committee understood that because of an agreement by the Alaska Eskimo Whaling Commission (AEWC), it was unlikely that a situation similar to that in 1980 would recur. The level of participation (as measured by registered crews) in the spring hunt of 1981 was lower than in 1980 (93 vs 99). This spring 83 of the 93 registered crews participated in the hunt. No agreement on effort limitation has been reached.

Reported figures for the struck and lost rate were lower in 1980 than in 1979, but were still substantial (2.1 whales struck for each landed). The proportion of animals that die after being struck and lost is still unknown. It was understood that the AEWC will hold hearings with each captain at the end of each season to investigate the circumstances of each strike made. Some modifications of gear have been made (bomb casings being made of steel rather than brass, and the use of smokeless instead of black powder), but these had only been used by about one-third of the crews. Proposed modifications still to be made include the development of a more effective bomb and the development of radio transmitters attached to harpoon floats in order to facilitate location of whales struck and lost. A similar device was successfully tested in 1978 and 1979 during a cooperative investigation between NMFS and AEWC.

The proportions of females (78.6%) and adults 12 m or more in length (50%) in the harvest were higher than normal. The sub-committee noted the latter phenomenon with some concern, given its recommendation of last year that if any harvest was to be permitted, it should be of immature animals in order to maximise reproduction in the short term.

Three stranded bowheads had been reported in June and July 1980, but it had proved impossible for logistical reasons to examine these to determine the cause of death. The sub-committee recommended that every effort should be made in future to examine such strandings, to collect biological material and investigate the possible cause of death.

The bowhead migration in the spring of 1981 started earlier than usual due to early ice break up, the first whales past Point Barrow being reported on 11 April (SC/33/PS4). Ice camps were set up at the edge of the lead from 14 April to 2 June, and the effective survey time (57% of the total season) accounted for 74% of the time during which the lead was open. A total of 968 new, 190 conditional and 275 duplicate sightings was made by South Camp. The percentage missed by the South Camp was estimated as 37.7%, and the total number of whales to pass the ice camps was estimated to be between 2,025 and 2,459 animals, with the best estimate of 2,242 animals, depending on whether conditional sightings were classed as duplicates or new whales respectively. These figures include allowance for periods when no watch was kept, and as some of these were substantial it is possible that the interpolations used were imprecise. However, some of these periods coincided with times when the lead was closed. The 1980 estimate has been revised to account for an error in the percentage missed used last year, and a correction factor was developed to account for a reduced sighting distance during the periods of high whale congestion in the 1980 survey. The revised estimate became 2,247–2,671 whales for that year. Hence the 1978 estimate of 1,783 to 2,864 animals for this stock is still considered the most accurate.

There was considerable discussion about the proportion of the population that might be passing the ice camps outside the effective sighting range of the observer (estimated at 5 km). This was clearly dependent on the width of the lead at the time observations were made, but when the width was more than 5 km data from aerial transects of the lead suggested that a small proportion passed beyond 5 km from the near-shore ice edge (SC/33/PS5). With the small sample sizes available it was difficult to establish this proportion precisely, although a figure of 4–7% was mentioned in SC/33/PS5. No allowance had been made in the estimates of population size for this effect, which in any case was only applicable when the lead width exceeded 5 km: during the 1978 census the width varied from 1 to 11 km, averaging 2–5 km (Braham, *pers. comm.*). Comparison of the distributions of distances of whales seen from the ice edge by shore-based observers and aerial transects indicated a similar fall-off in density from the near shore ice edge, at least up to 4 km from the ice edge: within this range any decrease in the sighting efficiency of ice-based observers with distance therefore does not appear large. However the aerial data were a summation of observations made over 2 years under differing circumstances, and the sub-committee recommends that further comparisons of aerial and ice-based counts across the lead should be made.

Reviews of the available information on the percentage of calves in the population (SC/33/PS5 and PS6) suggested that aerial counts were generally higher and probably more reliable than ice or ship-based counts. If the calving season extends from March to June, the recent aerial surveys in the Beaufort Sea in August and September probably represented the most accurate determination of the proportion of calves in the population to date. On 3 such surveys a total of 23 calves was seen amongst 691 whales observed, or a calf production estimate of 3.4%.

The sub-committee had before it an updated estimate of the 1848 population size of the Bering/Chukchi Sea stock of bowheads (SC/33/PS7). This utilised the population model developed by Breiwick, Mitchell and Chapman (1980, *Fish. Bull., U.S.* 78(4): 843–53) but with more complete catch figures for the shore-based harvests from Marquette and Bockstoce (1980, *Mar. Fish. Rev.* 42(9–10): 5–19) and for the pelagic fishery from Bockstoce and Botkin (1980, Final Rep. to NMFS by Old Dartmouth Hist. Soc., 120 pp.). The sub-committee noted that an assumption used in this analysis, that all struck and lost whales subsequently died as a result of the injuries they received, may have been unrealistic, given the occasional discovery of old harpoons, etc. in animals taken in the harvest. Use of a lower mortality figure would have brought the estimates of initial population size down. However, the shore-based catch statistics are still incomplete, and revision of these upwards would produce a correspondingly greater estimate of initial population size. These two effects might at least partly compensate for each other. A historical take of bowheads by eskimos had occurred in Alaska prior to 1848, and although there were no estimates of the size of this take, the population in 1848 may have been somewhat lower than the true 'initial' level. The sub-committee considered the range of population estimates for 1848 given in SC/33/PS7 (9,000 to 18,000) to be sounder-based than those given in SC/32/PS6, and for the reasons given last year were unwilling to accept the higher estimates given in SC/32/PS16. However, the magnitude of the early bowhead catch (about 15,000 in the first four decades of the pelagic fishery) suggested to the sub-committee that the initial population size probably lay nearer the upper end of the range.

The present population could therefore be estimated as 10 to 32% of its initial size, taking the two extremes of the highest N_{1978} estimate and lowest N_{1848} value, and lowest N_{1978} estimate and highest N_{1848} value. Because of the magnitude of the early pelagic kill, the sub-committee believed that the present population size is more likely to be nearer 10% than 32% of its initial size.

SC/33/PS16 (based principally on reports from the inhabitants of coastal villages along the Chukotka peninsula) claimed that animals seen off Chukotka in summer either did not migrate past the northwest Alaskan coast or formed part of a separate population that summered in a different area (possibly the southern part of the Chukchi Sea and the northern part of the Bering Sea) to those that migrated past northwest Alaska. It was pointed out, however, that aerial and ship surveys to the Gulf of Anadyr, northern Bering Sea and the southern Chukchi Sea in June, July and August 1978 (Dalheim *et al.*, 1980. *Mar. Fish. Rev.* 42 (9–10): 51–57) had failed to find any bowhead whales. So far no survey of the southern Chukchi Sea had been possible (as part of the US/USSR Cooperative Bowhead Research Programme) during July/August when bowhead whales might be expected to be present. However, the sub-committee felt that there was no inconsistency between most of the Soviet observations and the existing spring and autumn migration routes postulated for the Bering Sea stock. Odd stragglers could be expected to occur at either end of the migration routes, and there was no clear evidence to date of a separate summering stock in the southern Chukchi Sea. Similar conclusions were reached in SC/33/PS11. Nevertheless the sub-committee recommended that aerial or vessel surveys should be undertaken by the USSR to determine the incidence and number of bowheads present near the Chukotka peninsula in summer. Radio-tagging and tracking of some of these individuals might help resolve this question.

In considering the status of this population, the sub-committee drew attention to the following:

(a) the best estimate of present gross recruitment rate (from aerial calf counts) is 3.4%;
(b) assuming 75% mortality of struck and lost animals the 1980 harvest represents 1.3% of the best estimate of present population size (2,264).

Given the estimates of adult natural mortality rate made for other baleen whale species apart from minke whales (4–8.5%: Ohsumi, 1979, *Rep. int. Whal. Commn* 29: 397–406), the sub-committee concluded that even if there is no kill the population may only be stable or even decreasing. Therefore any kill whatsoever will increase the risk of this already small population declining further. The sub-committee reaffirms the view of the Scientific Committee for the last four years that the only safe course for the survival of the population is for the take to be zero.

Given that the Commission last year decided to set a three-year quota for the Bering Sea bowhead population, and if it decides to continue this regime, the sub-committee strongly recommends that removals of any kind should be (a) of sexually immature animals (less than 12 m long) in order to maximize reproduction in the short term and (b) taken in a manner that will reduce the struck and lost rate to zero to minimize total removals.

In view of the risks to the bowhead whale inherent in the present proposed offshore oil and gas activities in the Bering, Chukchi and particularly the Beaufort Sea, the sub-committee recommends that research be continued to define precisely migration routes and critical habitats of the bowhead whale. This general concern is also applicable to stocks of the bowhead whale in the North Atlantic.

2.1.2 Okhotsk Sea stock

An aerial survey in August 1979 that produced counts of 55 bowhead whales in the Okhotsk Sea was extrapolated to give a population estimate of 150–200 animals (SC/33/PS11). The authors claimed that this population was increasing, as counts in 1979 were higher than in 1967 or 1974, although the survey techniques were not strictly comparable (the first two being vessel surveys).

The sub-committee recommends that this should continue to be Protected Stock.

2.1.3 North Atlantic stocks

Two cruises were made in the Barents Sea by a Swedish icebreaker in June–August and in August–September 1980, during which continuous daylight searching for whales revealed no live bowheads. One carcase, probably a bowhead whale, was seen (SC/33/PS3).

A long-dead carcase of a bowhead whale was also found 60 km from the shore near Obskaya Bay (West Siberian Sea) in August 1980 (Vasul'chuk and Yablokov, 1981, *J. Prirod* (3): 116).

A recent review of the history of the Spitsbergen stock was given by Reeves (1980, *Mar. Fish. Rev.* 42 (9–10): 65–96).

The sub-committee concludes that the continued existence of a viable Spitsbergen stock is in doubt.

Aerial surveys of West Greenland, in the Labrador Sea and Hudson's Strait in late March 1981 revealed several sightings of bowhead whales (Kapel, pers. comm.). The sub-committee looks forward to receiving further details of these sightings next year.

Between 15 October and 23 November 1980, 22 bowhead whales were seen migrating through Hudson's Strait: from their direction of movement 14 sightings could be assumed to be of different individuals (SC/33/SM9).

There were no new analyses of the status of the Davis Strait or Hudson's Bay stocks, and the sub-committee recommends that the results of recent shore counts and aerial surveys from Canada should be published.

The sub-committee recommends complete protection from all forms of hunting for these stocks.

2.2 Right Whales

2.2.1 North Pacific

No new information was available on the incidence of right whales in the Okhotsk Sea further to that given last year (SC/33/PS11).

There were no sightings of right whales from Japanese scouting boats or operating catcher boats in the western North Pacific during 1980 (SC/33/ProgRep Japan), although sighting effort had declined in recent years. There were no sightings of right whales in the Gulf of Alaska during a vessel survey from June to August 1980 (SC/33/O 7). A total of 3,100 miles of transect was steamed, including waters near Kodiak Island where a few sightings were made several years ago, and in inshore waters of the eastern Gulf of Alaska where historically right whales were taken.

In 300 hours of flying time off the Californian coast throughout 1980 no right whales were seen (Bureau of Land Management, 1981, Progress Report submitted to U.S. Dept. of Interior, Washington, D.C. by the Coastal Marine Laboratory, University of California, Santa Cruz, April 1981).

The sub-committee believes that apart from the remnant of the Okhotsk Sea stock (Berzin and Doroshenko, 1981, *Rep. int. Whal. Commn* 31: 451–55), the continued existence of viable stocks of right whales in the rest of the North Pacific is in doubt.

The sub-committee recommends that the People's Republic of China should be asked to provide data on the status of right whales off China together with details of any past catches.

2.2.2 North Atlantic

In SC/33/PS19 a total of 26 right whales is reported for the Bay of Fundy, together with another possible 40 outside the Bay. The sub-committee noted that this may represent a previously unsuspected breeding population, as 4 calves were reported. However, the sub-committee believed that the estimated lengths were large for young-of-the-year, and that the method of measurement (using average lengths of adult females and juvenile growth rates for southern right whales) may have led to incorrect conclusions. The sub-committee recommends that surveys of this population be continued, especially in view of proposals for accelerated industrial development in the area.

One right whale was reported in the Gulf of St Lawrence in 1980 (Sears, 1980, Mingan Island Cetacean Study, document presented to IWC archives), the first sighting in this area for many years.

The sub-committee had no new information on the status of the right whale in the northeast Atlantic.

2.2.3 Southern Hemisphere

A total of 74 individuals (including 13 calves) was seen in 5 flights between July and December off the south coast of Western Australia. Some of these may be resightings of the same individuals, but the maximum number seen on any one flight (29 including 3 calves in September) was greater than on any corresponding flight since surveys began in 1977. A series of photographs for comparison of callosity patterns was taken (SC/33/ProgRep Australia).

Reports of a concentration of right whales south of Australia by Japanese and Russian whalers have been current for several years. The sub-committee recommends that sightings vessels in transit to and from the Antarctic should undertake systematic surveys in the area where concentrations are believed to occur, i.e. 40°–50°S, 117°–130°E, from November to February.

Sightings of 177 right whales were reported from the New Zealand area, with strong seasonality in July. However, the exact positions of the sightings were not given (SC/33/ProgRep New Zealand).

During the annual survey off the South African coast, 166 right whales including 3 juveniles and 35 calves were seen in two days in September. This was the second highest total since surveys began in 1969. Photographs of callosity patterns from 35 cow-calf pairs were obtained (SC/33/ProgRep South Africa).

Japanese scouting vessels undertook very little searching in Series D and recorded no right whales in 1980/81 (SC/33/ProgRep Japan). The sub-committee noted, however, that 5 right whales were seen from USSR catchers in Area VB, which seemed very far south for the species.

No information was available from Argentina on the status of this species off Peninsula Valdez. The sub-committee repeats its requests of last year for information on population size and trends to be made available, and recommends that the Secretary contact the relevant Argentine authorities.

The sub-committee further recommends that:

(a) all right whale stocks should remain protected, and
(b) as last year, studies of historical records should be undertaken to reconstruct the pattern of exploitation in the eighteenth and nineteenth centuries.

2.3 Blue Whales

2.3.1 North Pacific

Japanese scouting boats saw 12 blue whales in Area IV N (40–50°N, 160°W–180°) and 1 in Area V M (30–40°N, 180°–160°E) in the summer of 1980 (SC/33/ProgRep Japan). No blue whales were seen on vessel surveys in the Gulf of Alaska during June, July and August 1980; at least until the early 1960's the immediate offshore waters were a major summer ground for blue whales (SC/33/O 7). In the June and November 1979 cruises of the *Regina Maris* off California, only 7 blue whales were seen (Balcomb, pers. comm.).

2.3.2 North Atlantic

Three blue whales were seen off West Greenland from a Norwegian small-type whaler in June to August 1980 (SC/33/O 12). The sub-committee did not have before it data on the sightings of blue whales off Iceland from catcher boats attached to the Icelandic land station, although it believed that such data had been collected. One blue whale was seen near Iceland in 1980 by a Norwegian small-type whaling vessel (SC/33/ProgRep Norway). In the Gulf of St Lawrence sightings were made of 44 blue whales during 1980, although it is highly probable that some of these sightings were of the same individuals (Sears, 1980, Mingan Island Cetacean Study). Balcomb (pers. comm.) reported one sighting of a blue whale on Georges Bank in May from the *Regina Maris*.

2.3.3 Southern Hemisphere

Japanese scouting boats saw 21 blue whales in the Antarctic during 1980/81. Seven of these were in Series B of Area V and 8 in Series B of Area I, and so were presumably of 'normal' blue whales. The remaining sightings were made north of 50°S in summer, and so were presumably of pigmy blue whales. Japanese catcher boats saw 15 blue whales in Series B of the Antarctic, 12 in Area V, 2 in Area IV and 1 in Area III, presumably all 'normal' blue whales (SC/33/ProgRep Japan). Yamamura reported that 3 blue whales were seen from the *Umitaka Maru* near the pack ice at 155°E during the 1980/81 summer.

Soviet catcher boats saw 36 blue whales in the Antarctic in the 1980/81 season, 26 in Area IV, and 5 each in Areas III and V: all of these were in Series B and thus presumably of 'normal' blue whales.

Three sightings of blue whales occurred in the New Zealand region in 1980/81 (SC/33/ProgRep New Zealand). During the 1980 whaling season (January–March, April–June), a total of 712 sightings of blue whales was made in 2,892 searching hours or 446 working days (SC/33/ProgRep Peru).

The sub-committee recommends that:

(a) blue whale stocks should remain protected in all oceans, and
(b) that a re-analysis of Southern Hemisphere blue whale stocks (both 'normal', Series B and C, and pigmy, Series D) should be undertaken. The latter study will be facilitated now that catch and effort data for the Southern Hemisphere are available on computer tape at the IWC.

2.4 Humpback whales

2.4.1 North Atlantic stocks

The sub-committee was pleased to receive the report of the US Workshop on Humpback Whales of the western North Atlantic held in New England in November 1980. The workshop concluded that the winter population in the West Indies was closer to 2,000 than 1,000, and allowing for absent animals is probably greater than 2,000. Fluke pattern matches suggest a Gulf of Maine/Nova Scotia stock that winters on Silver and Navidad banks and a Newfoundland/Labrador stock that winters in waters near Puerto Rico. A third stock may exist that winters near the lesser Antilles, Venezuela and the Virgin Islands, and that may spend the summer near Greenland, Iceland and Norway (SC/33/PS9).

Three documents before the sub-committee provided estimates of the present population size for part or most of these stocks. Separate shipboard estimates of the 1980 winter populations on Silver, Navidad and Mouchoir Banks gave values of 2,000–3,500 animals (SC/33/PS2) and not less than 1,923 whales (SC/33/PS17). These estimates were made at the same time from the same vessel but from different vantage points and using different methods of data collection and analysis. After reviewing the methodologies and receiving an addendum to SC/33/PS17, the sub-committee concluded that much of the difference between the estimates arose not so much from the methods as from the extrapolations used. At issue was what proportion of the largest bank (Silver) was suboptimal habitat for the whales due to coral reefs, and which the vessel had not been able to survey. The two papers adopted extreme assumptions, SC/33/PS17 that no whales were present in such areas (estimated to comprise 46% of the total bank), and SC/33/PS2 that similar densities occurred in such areas as were seen over the rest of the bank. Adjustment of one or other estimates to bring the assumptions into line produced similar estimates (i.e. that in SC/33/PS17 became 3,151). Independent (e.g. aerial) data to examine which assumption might be more correct were not available. At present, therefore, it is impossible to reconcile these two estimates. However, it seems reasonable to conclude that at least 2,000 humpback whales spend the winter on Silver, Navidad and Mouchoir banks. These estimates do not allow for absenteeism or early departures and late arrivals.

Mark-recapture analysis of humpback whale stocks in the northwest Atlantic (using matching of fluke pattern photographs) produced estimates of 905–1,400 in Bay de Verde, and 1,535–2,720 off the Newfoundland and Labrador coasts combined. Estimates for Silver Bank ranged from 3,071 to 3,360 (SC/33/PS2). The sub-committee was unfortunately unable to review these estimates because the basic data were not available.

During an aerial survey off the east coast of Newfoundland and southeastern Labrador in August 1980, 31 sightings of humpbacks were made, totalling 89 animals. Using line transect analysis the population of humpback whales was estimated as 738 ± 250 (s.e.). The assumption that all animals on the trackline were seen is likely to have been violated, and although the pod size used may have been biased upwards because of the greater sightability of large groups, it is possible that this is an underestimate.

SC/33/PS14 contained an estimate of initial population size for northwest Atlantic humpback whales in 1865 of 4,230 animals. The sub-committee reviewed the methods used and concurred that the result was probably a minimum value, for the following reasons: (a) the net recruitment rate used (0.046) may have been high, (b) only minimum known catches were used in some areas (e.g. West Greenland), and (c) conservative choices were made in estimating catches from production statistics, loss rates from available data, and in extrapolating numbers of vessels in the US pelagic fishery in the West Indies. The sub-committee recognised the value of this historical approach, and encouraged further analysis on similar lines.

In the Gulf of St Lawrence, 9 sightings of humpback whales were made in September and October, and observations of feeding behaviour were made (Sears, 1980, *Mingan Island Cetacean Study*). Inspectors or biologists on board small-type whalers saw 8 humpback whales off East Greenland and one in the Barents Sea during 1980 (SC/33/ProgRep Norway).

A total of 47 humpback whales was seen by a Norwegian small-type whaling vessel off West Greenland for June to August 1980 (SC/33/O 12). Most of these were seen in August off Godthaab, and were as abundant as fin whales in the area at the time. Four animals were marked.

A total of 13 humpback whales was landed in Greenland in 1980. Kapel explained that in early July reports of the landing of 10 humpbacks were received, and although an immediate instruction was given to stop catching, later reports revealed that in fact 12 had been caught before the date on which catching ceased. One further humpback was landed after the season had been closed. There were no data available on the proportion that might be struck and lost in this fishery, although Kapel reported that he believed it was small.

Kapel informed the sub-committee about research related to humpback whales in West Greenland: sightings similar to those reported in SC/33/O 12 are being made from the Norwegian catcher boat, and two special cruises dedicated particularly to humpback whale studies are being conducted in the same season (*Regina Maris*—Nichols, and *Nordstjernen*–Whitehead).

The sub-committee was pleased to receive details of the study of whale entanglement in fishing gear off the Canadian east coast that it had requested last year. During 1980 there were 61 reported encounters of humpback whales with fishing gear, resulting in the known death of 17 animals. Due to under-reporting it was estimated that 20 humpback whales might have died (SC/33/PS13). Figures for the number of whale encounters with fishing gear off Newfoundland in earlier years could have been under-estimated but there seemed to have been a real increase in their incidence since 1974. This could be the result of one or more of the following factors:

(a) population increase of humpback whales (however, probably too slow to be a major factor),
(b) dramatic growth of the Newfoundland inshore fishery (which has increased several-fold in recent years),
(c) depletion of offshore capelin stocks, causing humpback whales to move inshore (not strongly supported by data),
(d) change in the attitudes of fishermen (towards complaint rather than traditional acceptance), and
(e) replacement of natural with synthetic fibres in fishing gear, thus making it harder for whales to escape.

If (c) was an important contributory factor, then any recovery of the offshore capelin stocks might alleviate the problem: Hay reported that some signs of recovery were available this year. Warning devices attached to gear (principally visual and either passive or active acoustic devices) had not proved entirely successful in reducing the rate of entanglement (though interpretation of the trials was complicated—SC/33/PS13). Some decline in the extent of damage in nets fitted with such devices was apparent. Repositioning of traps and shortening of the leaders also seemed to show promise.

The sub-committee noted that (excluding possible catches at Bequia and St Lucia/St Vincent, for which no data were available) the estimated total removals for humpback whales in the North Atlantic in 1980 was 33. This represents 1.7% of the lowest reasonable estimate of current population size. A conservative estimate of gross recruitment rate might be the number of calves seen on Silver, Navidad and Mouchoir banks in 1980 (57—SC/33/PS2) as a proportion of the minimum population estimate of 2,000, i.e. *ca* 3%. Present estimated removals are therefore a significant proportion of this recruitment rate. As the present population is believed to be still substantially below its initial level, the sub-committee recommends that every effort be made to reduce the number of removals. In spite of Canadian investigations and efforts towards solving the problem, the number of reported deaths due to entanglement in fishing gear has remained at a high level. The sub-committee recommends the continuation of the study of the incidence of net entanglements and means to reduce the mortality resulting therefrom. Until such time as more reliable estimates of population size, recruitment, trends in abundance, stock identity and loss rates in the fishery are available, the sub-committee recommends that the exemption for a Greenland catch of 10 humpback whales be removed (as previously recommended). The Secretary is requested to contact the responsible authorities in Bequia, St Lucia and St Vincent to determine if humpback whaling is continuing.

2.4.2 North Pacific stocks

In the Gulf of Alaska, 190 humpback whales were seen during a vessel survey from June to August 1980 (SC/33/O 7). This had been extrapolated to provide an approximate population estimate of 306 animals for the Gulf region, excluding humpback whales known to occur simultaneously in bays and fjords and in southeast Alaska. It should therefore be considered a minimum estimate.

In the southern Chukchi Sea in September 1980, 23 humpback whales were seen on the US/USSR cooperative research cruise (SC/33/PS5), and 4 humpback whales were seen off Chukotka from August to October by a USSR catcher boat (SC/33/O 8). No humpbacks were seen by Japanese scouting boats during 1980, though catcher boats in Japanese coastal waters encountered two animals (SC/33/ProgRep Japan).

The sub-committee noted with disappointment the lack of information from studies on humpback whales in Hawaii and Alaska, but understood that the US government was funding a study of humpback habitat use in southeast Alaska in relation to boat traffic.

2.4.3 Southern Hemisphere stocks

In aerial surveys off the coast of Western Australia 86 humpback whales were seen in 8 flights in early August (SC/33/ProgRep Australia). Comparability of these counts with those in previous years was difficult because of observations of a different pattern of movement, but the counts were higher than in any of the three previous surveys. Off the east coast of Australia 16 humpback whales were seen in 12 flights during June and July. At three lookout stations in the same area, 92 humpback whales were seen. Both shore counts and aerial observations on the east coast are to continue.

Three humpbacks were sighted by catcher boats from Brazil in 1980 (SC/33/ProgRep Brazil). None has been seen off Chile by catcher boats from the land station since 1977 (SC/33/ProgRep Chile), while off Peru 9 humpbacks were seen in 1980. There were 126 sightings of humpback whales in the New Zealand area in 1980 (SC/33/ProgRep New Zealand). Within the Antarctic during the 1980/81 season, Japanese scouting boats found 127 humpback whales, 107 of which were in Area IB, while the catchers attached to the Japanese factory ship saw a total of 108 humpbacks, 60 of which were in Area IB (SC/33/ProgRep Japan). Soviet catchers and a scouting boat found 136 humpback whales, 73 of which were in Area IVB (SC/33/ProgRep USSR). US observers on board platforms of opportunity made 7 observations of 15 humpback whales (SC/33/O 10).

The sub-committee recommends that:

(a) all humpback whale stocks should remain protected,
(b) the current status of the humpback whale stocks off Peru should be surveyed as soon as possible,
(c) all scientists with access to either live or dead humpback whales should be encouraged to attempt to obtain photographs of the colour pattern of the ventral surface of the tail flukes, and to exchange these photographs with other interested observers in the area.

2.5 Gray whales

2.5.1 West Pacific stock

The sub-committee had no new information on this stock. It recommended that this stock of gray whales should remain a Protected Stock.

2.5.2 East Pacific stock

The Soviet catch of gray whales for its aboriginal people totalled 179 animals in 1980 (SC/33/PS10). The sub-committee welcomed the substantial increase in the amount of material and information collected from this harvest in 1980, especially the age and reproductive data, and believed that such information would considerably strengthen the basis for management. It was suggested that a study of the transition phase in the ear plugs would be particularly valuable in examining possible historical changes in the age at sexual maturity of this stock. Females again predominated in the catch (71.4%), and Ivashin spoke of the difficulties in selecting for males, mainly due to the segregation of different classes on the feeding grounds. The USSR was concerned about this imbalance, and would work towards adjusting the sex-ratio in the catch and reducing the proportion of pregnant fémales to the extent possible. The sub-committee urged them to continue investigating means by which the sex-ratio of the catch could be adjusted, although the inherent difficulties of the situation were recognised.

The sub-committee was also pleased to receive the detailed study of gray whale feeding and behaviour on the summering grounds off Chukotka (SC/33/PS15). It looks forward to seeing further quantitative and qualitative analyses of this material.

These Soviet studies could provide important complementary information to US studies of available food for gray whales in the Bering Sea (SC/33/ProgRep USA).

In 1980, 88 gray whales were marked with Discovery tags off Chukotka, making a total of 140 animals marked there since 1958 (SC/33/PS1). This programme was intended to show movements of whales within the summer feeding grounds, and the suggestion was made that similar marking should be undertaken on the winter feeding grounds. However, most members of the sub-committee felt that to be successful such a programme would require large numbers of animals to be marked, and that it might be preferable to use photographs of natural markings, a technique that was beginning to be used in the breeding lagoons (SC/33/PS12). Such a scheme (involving exchange of information between Soviet and North American workers) might be usefully discussed as part of any US/USSR Cooperative Research Programme. If Discovery tagging was to continue, it might be preferable to direct efforts to marking calves or yearlings with 0.410 marks in order to establish subsequent growth rates and calibrate age determination methods.

Two studies of gray whales in breeding lagoons in Baja California were available. The first (undertaken in Laguna San Ignacio) concentrated on population demography and whale movements within the lagoon, and benthic and productivity surveys were carried out to establish whether gray whales could feed substantially in the lagoon (SC/33/PS12). Human activities (mainly whale-watching) in the lagoon were also monitored. Although changes in the overall distribution or movement of whales attributable to human interference could not be detected, there were several instances of near-collisions between boats and whales or interactions with 'friendly' whales which were becoming increasingly vigorous.

Calibration experiments between observers in vessels and in aircraft, within a limited area of Laguna Ojo de Liebre indicated similar statistical reliability in counts of gray whales from both platforms. The proportion of animals below the water at the time of overflight varied from 17–34%, and although these could be detected in the clear, shallow-water system of the lagoons, under less favourable circumstances many of these animals might have been missed from an aircraft (SC/33/PS18).

The sub-committee recommended continuation of these studies in the breeding lagoons, as well as in the sea in their immediate vicinity, in order to understand the pattern of habitat usage by gray whales during their breeding season. It understood that under an agreement between the US and Mexican governments, aerial surveys (especially outside the lagoons) would be undertaken by the former and surface surveys (especially inside the lagoons) would be undertaken by the latter.

The sub-committee noted that the annual counts of migrating gray whales past the Californian coast had been discontinued. Because this is the stock for which the most information on recovery rates is available, the sub-committee strongly recommended that in order to maintain adequate monitoring, periodic systematic counts of gray whales should be continued, possibly restricted to a key period of the migration wave.

In response to its request of last year for a reanalysis of this stock and its productivity, the sub-committee had before it a simulation of the population history of the Californian gray whale (SC/33/PS8). The most likely trajectory of this model was an initial population of 24,000, reduced by aboriginal catches to just under 12,000 in 1800 and then further reduced by the lagoon fishery of the 19th century to a minimum of 1,300 animals in the 1870s. Recovery thereafter was slow until 1900, when the population began to recover rapidly so that it reached about 14,000 by the 1950s: due to the increase in catches at this time the rate of recovery slowed, but the population projection passed through the confidence limits of independent population estimates in 1967 and 1980.

Two gray whales were landed by US eskimos in 1980 (SC/33/ProgRep USA), so that total known removals from the stock were 181. This represents 1.16% of the best estimate of current stock size (15,587 animals). If the estimate of initial stock size given in SC/33/PS8 is accepted, then the present population is at 64.9% of its initial level, and 13% above the estimated MSY level. According to the model, the predicted net recruitment at this population level is about 3.5% (compared to an average rate of population increase observed between 1967 and 1980 of 3.7%). Consequently the population should continue to increase despite the current level of the harvest.

The sub-committee recommends that the Eastern Pacific stock of gray whales should remain in the Sustained Management category. Any catch should be held at the same level as the average of the last five years (i.e. 179 animals), for the following reasons:

(a) the high proportion of females in the catch,
(b) the present assessment of initial stock size is very sensitive to certain parameters such as the size of the aboriginal catch prior to 1800, and
(c) further growth of this stock should be encouraged in order to increase the possibility of repopulation of the area once occupied by the Korean stock.

3. CONSIDERATION OF PROTECTED SPECIES
(Commission Agenda Item 9)

This matter had been referred to the sub-committee so that consideration could be given to the degree to which the actions of the Commission in extending protection have resulted in the intended recovery of the species.

The sub-committee concluded that two categories of protected stocks could be recognised, those that had been or were being systematically monitored by programmes directed towards measuring population trends, and those for which only non-systematic or incidental observations were available. There were only 11 stocks which were being or had been systematically monitored (Table 1). It was important to note that all these studies had commenced relatively recently, the longest series dating from 1967. Only three were believed to provide evidence of a significant trend (measured over a decade or slightly more), all of which indicated an increase. The remaining 8 stocks had only been studied from 1–5 years, so that it was too soon (given the expected slow rates of change) to reach reliable or significant conclusions.

There are a number of incidental observations available from scouting vessels, whale catchers and other vessels, that have not been collected in a systematic fashion (at least with regard to the protected species). These results are obviously more difficult to interpret, although some attempts have been made in the past (Anon., 1980, *Rep. int. Whal. Commn* 30: 103–109). In some cases (Eastern North Pacific right whales, Spitsbergen bowheads) sightings are extremely few and any recovery of the stock is obviously doubtful: however, a much higher level of systematic searching would be required to establish this. Remnant populations may exist but remain unknown (to science) unless systematic surveys are undertaken on their behalf (e.g. Argentine right whales). On the other hand there are indications that some populations may be increasing under protection (e.g. Californian blue whales). For most of the others the data base is insufficient or too erratic to allow any interpretation of trends.

The sub-committee recognises the importance of this subject, and recommends that it form a priority item for next year's agenda for this group. National groups are encouraged to analyse any available historical or recent data for a protected stock that will clarify (a) initial unexploited population levels, (b) trends in population size, or (c) current population levels, the results to be submitted to the 1982 meeting.

Table 1

Stocks of protected species for which systematic monitoring is being or has been executed

Species	Stock	Method	Period covered	Annual trend[1]	Source
Gray whale	East Pacific	Shore counts	1967–79	+ 2.5%[2]	Reilly *et al.* (SC/32/PS13)
Gray whale	East Pacific (Mexico)	Aerial and shore counts		*	Fleischer (pers comm)
Right whale	Southern Africa	Aerial counts	1969–79	+ 7%	Best (SC/32/PS4)
Right whale	Western Australia	Aerial counts	1976–	*	SC/33/ProgRep Australia
Right whale	Argentina	Aerial and shore counts	1970?–	+ ?	Payne (unpubl.)
Right whale	North Atlantic	Aerial counts	1980–	*	Tillman (pers comm)
Bowhead	Bering/Chukchi Seas	Shore counts	1978–	*	SC/33/PS4
Humpback	Western Australia	Aerial counts	1976–	*	SC/33/ProgRep Australia
Humpback	Eastern Australia	Aerial and shore counts	1978–	*	SC/33/ProgRep Australia
Humpback	Northwest Atlantic	Aerial counts	1980–	*	Tillman (pers comm)
Humpback	Northwest Atlantic	Shipboard counts	1977–	*	SC/33/PS9
All spp	North Pacific	Shipboard counts	1978–	*	Yamamura (pers comm)

[1] Over the period of monitoring.
[2] If simultaneous removals considered, trend becomes + 3.7%.
* Insufficient information available (see text).

4. ABORIGINAL/SUBSISTENCE WHALING

In view of the meeting of the *ad hoc* Technical Committee Working Group on Subsistence Whaling scheduled for 13–15 July, the sub-committee examined the draft Agenda and documentation listed for that meeting. It identified six Agenda Items on which advice from the scientific committee might be required.

Item 7.1 Scientific committee advice on population sizes, trends, and yields of stocks of whales subject to aboriginal hunting in relation to natural and manmade factors directly affecting them.
The sub-committee considered that such advice should be provided on a stock-by-stock basis, as had been done in this report.

Item 7.2 Consideration of catch limits where on biological grounds catches should be reduced or suspended.
The sub-committee considered that it was unable to provide any general criteria for such catches because (a) they should be considered on a stock-by-stock basis, (b) the size of the minimum viable population for each species was unknown, and (c) adverse environmental changes could have considerable impact on populations depleted to very low levels.

Item 8.1 General consideration of data gathering and reporting requirements.
The sub-committee considered that in order to provide an adequate basis for assessment, the data required from aboriginal/subsistence catches was in principle the same as that required from commercial whaling. In recognition of the particular difficulties surrounding data collection in these harvests, however, it recommended the following list of data requirements.

A. *Essential data* (from each whale landed)
  1. Location, date and time of kill
  2. Species
  3. Length
  4. Sex
  5. If female, presence of milk
  6. If female, presence of foetus
  7. Degree of stomach fill

  Extra data
  8. Length and sex of foetus
  9. Collection and preservation of both ovaries
  10. Collection of at least one ear plug, tooth or bulla
  11. Collection of an eyeball (frozen)
  12. Collection of sample of stomach contents.

With regard to the latter biological data, the sub-committee strongly recommended that the maximum material possible should be collected from the landed catch in any aboriginal fishery, as often such catches may be the only source of material for the species concerned.

B. In addition, the sub-committee recommended that a simple form of primary effort measurement, such as number of boats or hunters involved and the length of the season, should be reported and that the type of effort unit used should be stated.

C. Struck-and-lost rates in any aboriginal/subsistence fishery should be specified as follows:

1. Struck, known to be killed but lost;
2. Struck, lost alive but believed mortally wounded;
3. Struck, lost alive but believed not to be mortally wounded.

Item 8.2 General consideration of research and monitoring requirements.
The sub-committee concluded that the following were the biological requirements of any basic management scheme for an aboriginal/subsistence harvest.

A. *Essential requirements*
  1. Knowledge of population size and identity;
  2. Estimate of yield;
  3. Knowledge of population trends.

  Extra data
  4. Population status (relative to initial).

Although some members of the sub-committee felt that it should also be prepared to comment on Items 10.1 and 10.2 (Developing of guidelines for the management of subsistence harvest stocks—Biological considerations—Research efforts), other members felt that it was inappropriate at this stage to comment on these Agenda Items.

5. RESEARCH PRIORITIES FOR 1982

In response to the Commission's request for a restructuring of the Scientific Committee's workload in considering all stocks every year, the sub-committee agreed on the following priority stocks that should be considered each year.

1. Bering/Chukchi Sea bowhead whales.
2. Eastern Pacific gray whales.
3. North West Atlantic humpback whales.

For most other stocks there was usually little available data and even fewer analyses. Consequently the sub-committee felt that (without rejecting any document that might be tabled on a particular stock), attention should be directed each year to one or more of the remaining stocks, with emphasis on estimates of initial and current population size and current trends in abundance.

For 1982 the sub-committee agreed that consideration should be given to right whale stocks, particularly those in the Okhotsk/Sea of Japan, the Northwest Atlantic, the South Atlantic and around Australasia. These had been chosen because it was known that data existed and was being or could be analysed to provide the information required. Such studies on right whales might provide a valuable comparison with the related bowhead whale. Although blue whales were considered by some members to be deserving of higher priority, it was felt that until the reanalysis of Antarctic data requested in 1980 and this year was carried out, there could be little data available for discussion.

A list of right whale projects was drawn up (Table 2), and the Convenor was asked to write to those people tentatively assigned projects to request their cooperation. If the response was too great to be handled at next year's Annual Meeting, then consideration might be given to holding a special meeting in 1982/83.

6. OTHER BUSINESS

Albert announced the intention of AEWC to hold a conference on the biology of the bowhead whale in Fairbanks, Alaska, before January 1982. The sub-committee recommended to the Secretariat that the IWC should be represented at this meeting.

Table 2

Proposed projects on right whales for 1982

Stock/Region	Description	Priority	Responsibility
Okhotsk/Sea of Japan	Catch history in Sea of Japan	A	Omura?
	Catch history of US vessels in Sea of Okhotsk	A	Henderson
	Russian catches in Sea of Okhotsk and review of present status	A	Ivashin
	Twentieth century sightings off Japan and analysis of abundance	A	Wada?
N.E. Pacific	Reconstruction of catch history	B	Bockstoce?/Henderson?
	Review of all 20th century records and sightings	B	Rice
N.W. Atlantic	Reconstruction of catch history	A	Mitchell/Reeves
	Current status and trends	A A	Watkins Winn
	Other 20th century records	A	Mead
N.E. Atlantic	Survey of literature on Basque fishery	B	Aguilar
	Review of all 20th century records and sightings	B	Brown
Australasian	Catch history of shore stations and/or pelagic fishery	A A	Dawbin Bannister
	Catch history in Indian Ocean	A	Martin
	Current status off Australia—all 20th century sightings and trends	A	Bannister
	Current status off New Zealand—all 20th century sightings and trends	A	Cawthorn
S. Atlantic	Catch history of British right whaling	A	Brown/?
	Catch history of French right whaling	A	Du Pasquier
	Catch history of Brazilian shore stations	A	Da Rocha—summary of Portuguese publications
	Catch history of African shore stations	A	Best/Ross
	Current status off South Africa	A	Best
	Current status off Argentina	A A	Payne Mermoz
S. Hemisphere	Analysis of Japanese sightings data on 19th century whaling grounds—raw data and effort to be provided	A	Ohsumi
General	Evaluation of data used in plotting Maury and Townsend's charts	B	Schuster Bannister? Winn

Annex H

Report of the Sub-Committee on Small Cetaceans

1. PARTICIPANTS, AGENDA AND INTRODUCTORY REMARKS

The meeting was chaired and the meeting report edited by Perrin. Members (M) of the Scientific Committee of the IWC and invited experts (E) attending all or part of the sessions were: Anderson (M), Balcomb (E), Braham (M), Brodie (M), Choi (M), Christensen (M), Dahlheim (E), Duguy (E), Finley (M), Fleischer (M), Gong (M), Hammond (E), Hay (M), Ivashin (M), Jarrell (M), Kapel (M), Kato (M), Klinowska (M), Leatherwood (E), Mitchell (M), Ohsumi (M), Øritsland (M), Wada (M), and Walker (E).

The draft agenda was discussed and approved with amendments (Appendix 1). Leatherwood and Walker were appointed as rapporteurs. Subgroups were convened and chaired as follows: abundance and stock assessments, Hammond; vital rates, Anderson; catch statistics, Dahlheim; and pollution and industrial development, Klinowska.

Due to time constraints it was agreed to concentrate on white whales, narwhals and killer whales and to simply highlight new information and problems on others. In addition to its usual charge, the sub-committee was asked to respond to a request to the Scientific Committee from Canada for scientific advice on five aspects of exploited white whale and narwhal populations within the extended fishing zone of Canada: (a) present stock sizes, initial stock sizes and present carrying capacity if considered different from initial; (b) replacement yields and sustainable yields, with comments if they are markedly different; (c) nature of assessments and comments on their general reliability; (d) 5-year or longer projections of the stock sizes given a continuation of current harvest levels; and (e) any other relevant infomation.

2. DOCUMENTATION

Documents available to the sub-committee and containing information on small cetaceans were SC/33/Prog Reps Australia, Brazil, Canada, Chile, Denmark (Greenland), France, Iceland, Japan, Korea, Mexico, New Zealand, Norway, Peru, South Africa, Spain, UK, USA and USSR; SC/33/Rep 4; IWC/33/11A–E; SC/33/SM2–4, 6, 8–11; SC/33/O 4, O 6 and O 8–O 12; and issues LXXXV and LXXXVI and the provisional issue LXXXVII of the International Whaling Statistics. Documents submitted to the sub-committee are listed in Appendix 2.

3. REVIEW OF NEW INFORMATION ON STOCKS, CATCHES AND STATUS

All takes of small cetaceans by IWC members for which statistics were available for the meeting are listed in Appendix 3. They total 112,006 dolphins, porpoises and small whales. Discussion was limited to species for which there is new significant information bearing on stock assessment and management.

3.1 Northern bottlenose whale

There was no new information available.

3.2 White whale

The distribution of the white whale is characterised by a disjunct circumpolar range with distinct concentrations occupying traditional, non-overlapping summering areas (IWC, 1980). These discrete groups are recognised as management units, or stocks, some of which are defined on the basis of morphometric differences, mainly in body size (Sergeant and Brodie, 1969; SC/33/SM9), and on responses (declines) of populations under hunting pressure without apparent recruitment from adjacent populations (Mitchell and Reeves, 1981; SC/33/SM9).

3.2.1 Distribution, migration, identity of stocks and abundance

(a) The Bering – Chukchi – Mackenzie area and Cook Inlet

Unpublished material cited in SC/33/SM9 indicates a population of 6–7,000 white whales in the Beaufort-Mackenzie Delta area. No new information was provided on other areas. The sub-committee again urges that studies be conducted to provide information on stock discreteness and on levels of take for the stock(s).

(b) Barents, Kara, White and Okhotsk Seas

SC/33/SM2 provided further evidence for the claim of Ognetov (1981) that the populations of the White, Barents and Kara Seas are all from one stock. Counts of animals in the White Sea ranged from a low of 232 in 1979 to a high of 1,570 in 1971 and were negatively correlated to severity of ice conditions in the Kara and Barents Seas. The information provided in 1980 and this year on the relation between White and Kara Sea white whales differs from previously published morphometric studies (Sergeant and Brodie, 1969). The new analyses indicate that whales from the two areas are not morphologically different. The sub-committee recommends that: (a) the Soviet data used by Sergeant and Brodie be compared with recent morphometric data (Ognetov, 1981) and that both sets be examined for any source of bias, and (b) if biases are absent or similar for the two data sets they be combined and re-analysed.

There is no new information on the Sea of Okhotsk population.

(c) Davis Strait – Baffin Bay, Cumberland Sound, and Hudson Bay – Ungava Bay

An estimate from aerial survey of 8,940 white whales wintering in Hudson Strait and Ungava Bay (SC/33/SM9) was regarded by the sub-committee as reasonable, though a probable under-estimate of the population. There was concern about the probability of duplicate counts, under-estimates and differences between counts from the two sides of the survey aircraft. It was recommended that, if possible, data be re-analysed, treating the two available transect sets or other strata as replicates to produce separate estimates, to provide information on variability.

Estimates were presented (SC/33/SM9) showing that white whales from western Hudson Bay, eastern Hudson Bay, and Ungava Bay over-winter together in pack ice in Hudson Strait. These animals separate in spring and migrate to their distinct, non-overlapping summering areas. Based on two pieces of evidence, these three groups should be considered separate stocks as defined above. First, the population levels of each stock have behaved independently, with little or no migration between regions. The West Hudson Bay stock has remained relatively stable at high numbers, while the other two stocks have separately suffered drastic declines due to heavy hunting. Second, the group have begun their summer migrations and are separated by the time of calving and calf-rearing (late May).

A further differentiation of these three stocks in the aggregate from that of Cumberland Sound has been made on morphometric grounds (SC/33/SM9).

The current and historic abundance of Canadian stocks and areas are given in Table 1.

3.2.2 Catches

The recent catches of white whales by Canada, Denmark and the USSR are presented in Tables 1 and 2. For selected stocks, Table 1 includes most recent catch figures and the rate of exploitation these catches represent.

3.2.3 Hunting loss rate

New information on loss rate was contained in SC/33/SM9. Losses in eastern Hudson Bay are minimal, because the whales are harpooned before they are shot and because the hunt takes place in clear, shallow water. In 1980 the sub-committee cited estimates of 20–60%, with higher values for deeper water (Seaman and Burns, 1981: 571). Because this problem is an important one for small stocks that are being harvested and for those stocks for which we have no reliable population size estimates, it is recommended that research on loss rates be carried out on white whales like that conducted on narwhals (SC/33/SM10).

3.2.4 Status

The sub-committee's consideration of status of stocks centred on new information available on populations in Hudson Bay and northern Quebec. It was noted that three stocks were severely depleted and continue to be exploited at high rates. The eastern Hudson Bay stock is estimated at less than 10% of original size, Ungava Bay at less than 20% of original, and Cumberland Sound at 12–14% of original (Table 1). The sub-committee concluded that these stocks should each be designated as a Protected Stock with zero catch.

The stock in the High Arctic in eastern Canada and western Greenland and that in the Beaufort Sea – Mackenzie River delta are at relatively high levels of abundance, and catches are relatively low. However, Canadian catch statistics are not complete, and the USA has not reported catch levels from the Beaufort Sea.

Little is known about stocks in the Bering and Chukchi Seas, the Barents – Kara – White Sea and Cook Inlet. The sub-committee recommends that the USA and USSR conduct research to determine identity of stocks, population sizes, and current exploitation rates.

3.2.5 Age determination and vital rates

There is valuable new information available on age determination. Results for several workers (Table 3) indicate that tooth reading techniques are comparable among them. Growth data for a captive animal support the hypothesis of two growth layer groups. (GLGs . . . terminology of Perrin and Myrick, 1980) per year (SC/33/SM7) and the sub-committee believes the hypothesis should be accepted on a provisional basis for the white whale.

Table 1

Historical and current abundance of currently exploited white whale stocks in Canada and Greenland. Unless otherwise noted, data are from SC/33/SM9 (A) or SC/33/ProgRep Canada (B)

	W. Hudson Bay	E. Hudson Bay	Ungava Bay	Cumberland Sound	High Arctic	Beaufort – Mackenzie
Historical	10,000 (Sergeant, 1973)	as many as 5,000 (A)	⩾ 1,000 (A)	5,000 (Mitchell and Reeves, 1981)	—	—
Current	8–9,000 (A)[1]	< 500 (A)[4]	< 200 (A)[4]	600–700 (SC/32/SM17)	10–20,000 (A)	6–7,000 (A)
% of original	80–90%	< 10%	< 20%	12%	—	—
1980 Quota	—	—	—	40 (B)	—	—
1980 Take	251[2] (B)	156 (1979) (B)[2]	88 (1979) (B)[2]	43 (B)	567[2] (B) and SC/33/ProgRep Denmark	85 (B)[3]
1980 Take as % current population	2.8–3.1%	> 31%	> 44%	6–7%	2.8–5.6%	1–1.5%

[1] Extrapolated from proportion of total numbers estimated in Hudson Strait which were thought attributable to W. Hudson Bay stock(s).

[2] Canadian catch figures not complete.

[3] Western Canada only, does not include Alaskan catch; Canadian catch figures not complete.

[4] Finley clarification of several figures used in SC/33/SM9.

Table 2

Available catch data for white whales in Canada, Greenland, and the USSR 1976–1980[1] (from SC/33/ProgRep Canada, SC/29, 30, 32, 33/ProgRep Denmark, Seaman and Burns, 1981 and Ivashin and Mineev, 1981).

	USSR					Canada[2]				Greenland		USA
	Vessel	Land-based				Canadian Arctic		Hudson Bay				
	White, Barents and Kara Seas	Gulf of Yenisey	White Sea	Barents Sea	Bering Sea	Eastern	Western	Eastern[3]	Western	Reported catch	Est. total catch	Reported catch
1976		170	302	38	21	239	154	546	146	1,059	1,200	—
1977	457	64	215		29	286	148	682	191	690	800	247
1978		19			32	161	127	297	118	519	600	177
1979		74	179		26	200	144	319	105	526	700	138
1980	60	81	75		20	133	85		124	264	550	—
Totals	517	408	771	38	128	1,019	658	1,844	684	3,058	3,850	562

[1] Grouping of catch by geographic area does not imply definition of stock.
[2] Canadian data are not complete because of incomplete reports from some villages and individual hunters.
[3] Catches from James and Ungava Bays and Northern Quebec are included with Eastern Hudson Bay.

Potential utility of other methods was discussed. Ageing based on assumed calving interval and count of ovarian scars is not possible because of high and variable corpora counts. Comparison of most recently deposited layers in teeth from animals caught at different seasons should be made. Such material is available or readily obtainable. Rates of racemization in aspartic acid of the eye lens nucleus could be determined from material currently available (Bada *et al.*, 1980).

Table 3

Estimated number of dentinal layers (GLGs) and age, assuming two GLGs/year, at attainment of sexual maturity

	Brodie (1971)		Sergeant (1973)		SC/33/SM9	
	GLGs	Age	GLGs	Age	GLGs	Age
Males	> 14	> 7	16–18	6.8	17–21	7.5–10.5
Females	9–11	4.5–5.5	8–13	4–6.5	11–13	5.5–6.5

3.2.6 Net reproductive rates and sustainable yields

After lengthy discussions, the sub-committee concluded that there is no good basis for estimating net reproductive rates in white whale populations. Estimates of gross annual reproductive rates exist (on the order of 10–12%—Anon., 1980), but data that would allow estimation of natural mortality rates are not available. A Leslie-matrix approach to very crudely approximate average adult natural mortality rate was considered for application to the body of age-frequency data in Sergeant (1973), but this proved not useful because the data do not conform to the assumption of constant mortality rate over the period represented.

Two estimates of sustainable yields do exist. Brodie *et al.* (1981) cited crude birth rates of 12–14% in the western Hudson Bay stock and estimated replacement yield for the Cumberland Sound stock by subtracting 4.5% natural mortality (by analogy with the long-finned pilot whale—Sergeant, 1962) from 12%, yielding 5% as 'surplus production'. This calculation was the basis for the quota of 40 whales that Canada internally set for 1980. Members of the group agreed that there is insufficient basis to suppose that natural mortality rates are the same in white whales as in pilot whales. Pilot whales are apparently later-maturing and longer-lived than white whales (age determination discussed above for white whale and in Sergeant (1962) for long-finned pilot whale) and may have different breeding systems, suggesting that the two species may have quite different mortality rates.

The second estimate of sustainable yield is that of Sergeant (1981), who regarded the 1949–1968 catch of white whales at Churchill, Seal River, and Whale Cove (all on western Hudson Bay) as 'nearly in balance with this population's natural increase'. He continued, 'if this is so, it follows that an annual catch of about 5% . . . would not be excessive'. However, the members of the sub-committee feel that this conclusion is questionable on several grounds, to wit:

(1) because there are no data on size of the population before the aerial survey of 1965, the rate of decline in abundance is unknown;
(2) there is no published evidence for the existence of a 'resident' stock said to be represented in 10% of the catches; and
(3) the decline in annual catch, 1951–68, and the decline in modal length of males in the catch (in spite of bonuses paid for larger animals) are indicative of exploitation of an unknown and not necessarily 'moderate' degree.

For these reasons, and pending further investigation of the catch history and status of the western Hudson Bay stock, the sub-committee believes that the 5% figure should definitely not be used as a 'rule-of-thumb' estimate of sustainable yield for white whale populations.

The group discussed and wishes to stress the importance of determining the way gross production may change with population density in the white whale. The sub-committee re-iterates the need for more comparative studies of calf ratios in greatly reduced stocks, such as the eastern Hudson Bay stock (estimated to be at 7% of original size) with those in stocks that may be closer to original size, such as the Cook Inlet or Lancaster Sound stocks. Because of the wide variation in water clarity and in behaviour in different areas, efforts should be given to developing methods for standardizing calf counts through quantifying sighting and behavioural conditions. Because of the selectivity inherent in existing fisheries, there is little hope of being able to estimate natural mortality rates through analysis of catch data.

The sub-committee also wishes to stress that the various estimates cited above, and below in the narwhal discussion, are for the most part point-estimates or ranges of point-estimates, they do not incorporate estimates of statistical variability. As such, they are very crude and should be considered as provisional only, pending availability of more extensive data sets that allow more sophisticated statistical treatment.

With respect to maximum sustainable yield, the sub-committee notes that current thinking is that in long-lived, probably K-selected large mammals (having low litter size and extended parental care) such as odontocetes, MSY level is most likely significantly higher than 50% of initial population size; that is, density-dependent responses to changes in population size are non-linear (for example, see Smith, 1979). Given the severely depleted status of the Cumberland Sound, Ungava Bay and eastern Hudson Bay stocks of white whales, and if it be assumed that reproduction increases with decreased density, it is certain that maximum sustainable yields for those stocks are greater than the current replacement yields. This suggests that a programme of provisional complete protection could result in significantly greater harvests in the long term.

3.3 Narwhal

3.3.1 Distribution, migration, identity of stocks and abundance

No new documents were available on distribution or stock identity. There is persuasive evidence for existence of one main stock in the Canadian Arctic, West Greenland and North Greenland (Mitchell and Reeves, 1981). Finley and Brodie reported, however, that there are frequent catches from northwestern Hudson Bay and that wintering animals may be found in eastern Hudson Strait. These two groups may belong to a smaller, separate stock that summers in northern and western Hudson Bay and winters in Hudson Strait as described for white whales (SC/33/SM9).

Kapel and Finley reported that aerial surveys were carried out in March-April 1981 in southern Baffin Bay – northern Davis Strait as well as in the Hudson Strait – southern Hudson Bay area, and that results are expected to be presented at next year's meeting. Narwhals were found widely distributed in cracks and holes in the pack-ice throughout Baffin Bay – Davis Strait.

Reported catches in recent years are presented in Table 4.

3.3.2. Catches

The actual take is probably more than reported. Although Canadian regulations require all landed narwhals, male and female, to be tagged, harvest statistics do not include lost or abandoned carcasses or unreported animals (SC/33/ProgRep Canada). In addition, kills of females are not likely to be reported (tagged), in order to reserve available tag quotas for tusked males (SC/33/SM10).

3.3.3 Hunting loss rates

In 1980 the sub-committee cited an estimate of loss rate of 50% (Mitchell and Reeves, 1981). Additional information presented in SC/33/SM10 indicates that loss rates can be variable, depending on the type of hunt and ice conditions. For example, in 1978 an ice ridge afforded hunters an elevation providing a good firing angle for inflicting fatal injuries (and high losses) at the ice edge hunt for narwhals. In 1979 there was no similar vantage point, and there appeared to be few losses, although many narwhals received superficial wounds. Such circumstances explain the high rate (23–42%) of scarring found on the landed catch of narwhals from northern Baffin Island.

3.3.4 Status

No new information was available concerning status.

3.3.5 Age determination and vital rates

New data on ageing presented by Hay (1980) indicated that based on length-frequency analysis, three layers may be deposited in dentine and mandibular bone in the first two or three years of life. If accumulation rates of corpora albicantia based on annual ovulation rate are correct, adult females may deposit one layer per year. The workshop did not resolve the question of annual deposit of one or two layers (Hay, 1980).

Finley and Miller (SC/33/SM10) found that males were about 390 cm long (with 100 cm tusks) and females about 340 cm long at sexual maturity. Hay (1980) reported similar values, with dentinal-layer counts of 17 for males and approximately 12 for females. Estimates of age at first reproduction will depend on the rate at which dentinal layers are actually accumulated.

Accurate estimates of pregnancy rate, birth rate, calving ratio and natural mortality were not available, and there are very few data on population structure. Seven of 18 mature females examined by Finley and Miller

Table 4

Available catch data for narwhals in Canada and Greenland 1976–80.
(From SC/33/ProgReps Canada, Denmark, SC/32/ProgRep Denmark, SC/30/ProgReps 29, 30, 32 and 33)

	Canada		Greenland		Totals
Year	Western Hudson Bay	N.E. Canadian Arctic	Reported catch	Estimated catch	(Canada and Greenland est.)
1976	8	297	106	110[1]	415
1977	8	200	232	350	558
1978	4	275	503	650	929
1979	30	289	289	350	669
1980	25+	325	185	350	700+
Totals	75+	1,386	1,315	1,810	3,271+

[1] Exclusive of Thule and East Greenland.

(SC/33/SM10) were pregnant, a similar ratio to that found by Hay. In a group of narwhals trapped in a *savssat*, there were 25 calves for 50 adult females (SC/32/ProgRep Canada). The representativeness of the sample is questioned because the group contained few adult males, and the degree to which females and calves segregate or concentrate is unknown. If it is assumed that adult males escaped from the *savssat* and that the original sex ratio was 1:1, then the proportion of calves would have been 19.2% of total.

3.3.5 Net reproductive rate and sustainable yield

As is the case for the white whale (discussed above), there were no data or analyses available to the sub-committee that would allow estimation of natural mortality rate. Therefore estimation of net reproductive rate and replacement and sustainable yields is not possible. The same problems and comments discussed above for the white whale apply here for the narwhal, including the inadvisability of using the 5% figure promulgated by Sergeant (1981) for use for the narwhal (by analogy with the white whale).

As discussed above, the very long history of substantial catches and the present estimates of abundance suggest that the narwhal population is not in a crisis situation such as are the three heavily depleted white whale stocks, and present takes may be smaller than replacement yields. However, in view of the fact that recent data indicate that narwhal takes on the coast of Greenland and those in the Canadian High Arctic are probably from the same stock (IWC, 1980, 1981), research should be continued to more accurately and completely document the take and to collect survey data and comprehensive biological data and specimens that will allow more precise estimation of the size and composition of the population than is possible with existing data. The sub-committee looks forward to the release of the results of the recent aerial survey of the narwhal wintering grounds in the Davis Strait carried out by Canada.

3.4 Killer whale

3.4.1 Review of report of workshop

The sub-committee reviewed and discussed the report of the Workshop on Identity, Structure and Vital Rates of Killer Whale Populations (SC/33/Rep 4). The workshop noted that while killer whales may be found in nearly every area of the world's oceans, concentrations are mainly near coasts and in high latitudes. Morphometrics and colouration may be useful tools in defining some types of geographical or ice-edge/open-water forms, but existing evidence of a high degree of isolation over a few hundred miles for coastal animals in coastal waters of the eastern North Pacific suggests that broader-scale stock areas as used for larger species may be inappropriate for killer whales. Given the extreme stability of local populations and the possibly low reproductive rates evidenced by the available data, any exploitation can be expected to have very long-term impacts on population size and structure.

Among the recommendations for research, the Workshop proposed that (1) reports be solicited from researchers to determine if social and breeding structure is similar to that in the eastern North Pacific; (2) osteological material in public museums and institutions useful for studies of age and of morphological variation be inventoried and their study encouraged and (3) studies be continued of animals in the wild to accurately determine life-history parameters.

3.4.2 The Northeast Atlantic Fishery

There is no new information on stock identification, abundance or migrations. SC/Jn81/KW1 reported year-round occurrence in Norwegian coastal waters, with 3 or 4 areas of particular concentration. Suggestions that the whales move in response to prey movements (Jonsgård and Lyshoel, 1970 and others) require further investigation.

Based on a long catch history, the killer whales in the eastern North Atlantic in 1980 were recommended to be provisionally classified as a Sustained Management Stock pending review this year of information necessary for identification of stocks and assessment of their status (*Rep. int. Whal. Commn* 31). In 1980, Norway voluntarily limited catch to 52 animals.

Christensen stated that mean lengths (SC/Jn81/KW1) have not changed appreciably from those previously reported (Jonsgård and Lyshoel, 1970).

The statement in SC/33/Rep4 that no new data have been received is incorrect (SC/Jn81/KW1). However, the available data are still inadequate for stock assessment.

3.4.3 The Southern Hemisphere fishery

3.4.3.1 Identity and status of stocks

Information available to the sub-committee from the workshop is still inadequate to define stocks for management. Data and analyses are inconclusive with respect to the six to eight longitudinally-defined stocks proposed by Mikhalev *et al.* (1981). There are data on other possible divisions. Description of a 'dwarf' form by Mikhalev *et al.* (1981) indicates that two species or subspecies may exist in the Southern Hemisphere. Ongoing work by Berzin and Vladimirov (SC/Jn81/KW11) may confirm existence of morphologically distinct forms in open waters and at the ice-edge. Colouration studies indicate a similar division (SC/Jn81/KW11). Analysis and stratification of the sample of killer whales taken by the USSR in 1979/80 may help to clarify the situation, but at the present no identification of separate stocks can be made.

3.4.3.2 Abundance

Data from 1978/79 and 1979/80 IDCR cruises were compared with Japanese sightings data by five-degree square, and an estimate of a Southern Hemisphere population of 144,900 killer whales was arrived at (SC/Jn81/KW10). A correction for differences in survey area produced a revised estimate of 254,000 (Appendix 4), but the methods are subject to several critical untested assumptions. Particularly, density within the five-degree-square strata is assumed to be homogeneous. Concern was expressed that effort directed along the ice edge and at minke whale concentrations may be biased towards areas of high killer whale density within some five-degree squares. If so, this could cause an overestimation of density within these strata. The effect of earlier Japanese sighting effort directed at sei whale concentrations before 1970 is unknown.

Hammond plans to re-examine available data on density of killer whales, taking into account 1980/81 IDCR data. The sub-committee requests of the Secretariat that data from the 1980/81, earlier and subsequent IDCR cruises be verified and made available for analysis before next year's meeting.

Lacking a basis for delineating stocks, there is no basis for catch limits. Pending more research of the type done elsewhere on population structure and stock identity, the sub-committee concluded that there should be no catches of killer whales in the Southern Hemisphere.

3.4.3.3 Catches

There were no catches of Antarctic killer whales in the 1980/81 season.

3.4.3.4 Sustainable yields

Sustainable yields cannot be estimated until vital rates are better known, stocks are delimited, and adequate population assessments are conducted.

3.5 Pilot whales

Small catches of long-finned pilot whales were noted for Greenland (SC/33/ProgRep Denmark) and Canada (SC/33/ProgRep Canada). SC/33/O 4 presents an abundance estimate from aerial survey data of populations of pilot whales in the Newfoundland – Labrador Area of 13,167 (± 3,155) whales. The take of 2,773 in the Faroe Islands (provisional issue LXXXVII of the International Whaling Statistics) represented a considerable increase over the 1979 catch of 1,725 (IWC, 1981: 153). The sub-committee is concerned that there is no population estimate for the Faroes and apparently no scientific programme documenting composition of the catches. Accordingly, the sub-committee urges that Denmark be requested to supplement current reports with improved accounting of catch composition.

Takes of short-finned pilot whales off Japan were also higher in 1980 (692—SC/33/ProgRep Japan) than in 1979 (104—IWC, 1981: 153). It was unclear whether the 1980 figure represents an increase in takes or simply a better reporting system. Balcomb reported that annual takes fluctuate but that in the 1975 drive fishery in Taiji alone 500–600 animals were havested. Fifty-three were reported taken that year in Japanese small-type whaling (Issue LXXXV of the International Whaling Statistics). Noting that there is fishing for pilot whales in Japan in small-type whaling and drive fisheries, the sub-committee encourages implementation of a by-village reporting system and a summary of historical fishing effort, abundance and composition of catches.

Short-finned pilot whales are also taken on the West Indian Islands of St Vincent, St Lucia and Dominica. In 1978 there were eight boats equipped to hunt for pilot whales (five in Castries, three in Vieux Fort). Walker reported that information from fishermen at that time indicated that catches were low, probably below 50 animals per year. He also reported that the fishery on St Vincent continues to decline; 1980 catches from two boats were probably around 11 animals.

3.6 Other Small Cetaceans

3.6.1 Bottlenose Dolphin

The reported Japanese take of 3,493 (SC/33/ProgRep Japan) represents a substantial increase over the 1979 take of 666 (IWC, 1981: 153). The sub-committee is concerned over the increased take, particularly since there is no estimate of population size and no data available on composition of the catch.

3.6.2 Striped Dolphin

The sub-committee noted with concern that the reported catch of striped dolphins in the drive-in fisheries in Shizuoka and Wakayama Prefectures, Japan, increased greatly in 1980. The total take for Japan was 16,344 (SC/33/ProgRep Japan); in 1979 it was only 2,193 (IWC, 1981: 153). Kasuya (1976) estimated total population size in 1974 at 186–202,000, less than 50% of the estimated original population of more than 404,000. He estimated MSY at 4,140–6,530 and replacement yield at slightly less. As pointed out in the 1980 report of the sub-committee, Kasuya's estimates were based on assumptions and models that need further examination. No new stock assessment has been carried out as recommended, even though available new estimates of life-history parameters could well strongly affect the outcome of a re-assessment. In any case, the take of over 16,000 is three to four times the estimated sustainable yield.

Ohsumi reported that the drive fisheries do not require a license and that the dolphin populations are not managed. He also reported that responsibility for local fisheries rests with the prefectural governments, not with the national government directly.

The sub-committee is extremely concerned about this severe over-exploitation of the striped dolphin population, which spends only part of the year in Japanese waters. There is a clear need for re-assessment of the populations of this and other species taken in the drive fisheries and for management of the stocks on a scientific basis.

3.6.3 Common Dolphin

Information presented in SC/33/SM11, supplemented by information provided by Duguy, documents a harpoon fishery for dolphins along the Atlantic coast of France which may take over 200 dolphins per year (*Delphinus delphis* and *Stenella coeruleoalba*).

3.6.4 Dall's Porpoise

Ohsumi reported that the figure of 1,000 Dall's porpoise captured incidentally in the salmon drift-net factory ship operation in the North Pacific (see Section 5) (SC/33/ProgRep Japan) is the *reported* catch, which is lower than the actual catch because of a misunderstanding of the reporting requirements by the fishermen. The USA (SC/33/ProgRep USA) estimated that 8,970 Dall's porpoise were taken within the US 200-mile limit off the Aleutian Islands during the summer of 1980. That figure is listed in Appendix 3.

3.6.5 Harbour Porpoise

Previous statements that records of strandings of harbour porpoise on the British Coast have declined (Evans, 1980; Sheldrick, 1976) have been taken to support contentions of population declines. New analysis of the same stranding data presented in SC/33/SM4 do not support those statements of strandings trends, noting instead significant fluctuations in reported strandings between 1936 and 1949.

A new programme has begun to monitor incidental kills of harbour porpoise in Pasamaquoddy Bay, between Maine and New Brunswick (SC/33/ProgRep USA).

4. STATISTICAL REPORTING FOR LIVE-CAPTURE FISHERIES

The sub-committee discussed live-capture fisheries, and members agreed that statistics for these removals from the populations should be reported to the Scientific Committee as are those for other types of directed take. Live capture of dusky dolphins is reported in SC/33/ProgRep South Africa, but known take by the USA of bottlenose dolphins and by Iceland of killer whales has not been reported to the Scientific Committee. Bryant (1981) listed live captures of 30 killer whales in Iceland during the period 1975–79. The sub-committee urges that members be requested to provide live-capture statistics.

5. INTERACTIONS BETWEEN SMALL CETACEANS AND FISHERIES

5.1 Incidental take

Incidental takes are listed in Appendix 4. Discussion was limited to new developments, summarised below by geographical region.

5.1.1 Europe

The sub-committee notes that incidental takes of small cetaceans have not been reported to the Scientific Committee by the United Kingdom, although contaminant analyses of incidentally-caught harbour porpoise have been reported in an ICES document (see 6 below).

Duguy (SC/33/SM11) reported that small cetaceans are taken incidentally in trawl and gillnet fisheries on the Atlantic coast of France, including long-finned pilot whales, striped dolphins, bottlenose dolphins, common dolphins, Risso's dolphins and harbour porpoises. He also reported that a system exists for mandatory reporting of incidental kills. Noting that France has not included such existing information in the Progress Report, the sub-committee believes that this should be done, for both the Atlantic and the Mediterranean coasts.

5.1.2 North America

The sub-committee reviewed information on progress of the joint US-Japan research programme on the problem of incidental kill of Dall's porpoise in the salmon gillnet fishery near the Aleutian Islands (SC/33/ProgRep USA). The estimated kill in 1980 was 8,970. Abundance has been estimated variously at 840,000 to 2,300,000 but it is thought that these may be overestimates because of several biases. Joint sighting cruises to collect more and better data on distribution and abundance continue. Stomach-contents analyses show that prey items taken by the porpoise are on the average larger and deeper-living than those utilised by salmon.

Balcomb reported that incidental mortality of harbour porpoise occurs in the US gillnet fishery in the Puget Sound area of the state of Washington. He collected 23 dead porpoise assumed to have been killed in gillnets in 1972. The sub-committee notes that the mortality in this fishery has not been reported in the US Progress Report.

A reported 254 dolphins and porpoise were killed in fishing gear on the southeastern coast of Newfoundland (SC/33/PS13: p. 22 and Table 5). Many of the entrapped animals were used as food. This count was extrapolated to an overall estimate for Newfoundland of 23,399. The estimate was based on a telephone poll of 100 fishermen asked to keep records of their incidental catch. It is pointed out in SC/33/PS13 that the estimate may not be accurate because the sample was from one part of the coast of Newfoundland but was used to extrapolate to the entire coast. Hay reported that the large majority of the 254 animals in the reported sample were taken by a few fishermen in one location and that most of the fishermen reported no catch. He stated that in his recollection the telephone survey was retrospective.

This information indicates that significant incidental catches of small cetaceans may be occurring off Newfoundland, and the sub-committee urges that Canada be requested to collect and report accurate and precise statistics.

5.1.3 South America

Perrin reported that he has learned of incidental takes of tucuxi (*Sotalia fluviatilis*) and boutu (*Inia geoffrensis*) in gillnet and seine fisheries for catfish (*Brachyplatostoma* spp.) in the Amazon River. Da Rocha has indicated that statistics for these incidental takes will be included in Brazil's Progress Report next year.

The sub-committee notes that Argentina, Chile and Peru have not reported takes for fisheries in which incidental kill of small cetaceans is known to occur (IWC, 1980).

5.1.4 Asia

Gong reported that small cetaceans of several species are taken incidentally in mackerel purse seines in southern waters of the Republic of Korea. Fishermen will be notified shortly of a new requirement that incidental capture be avoided and that live captured animals be released. Incidental take resulting in death of the animal must be reported to the fisheries agency. Statistics of incidental catch will be included in next year's Progress Report.

5.1.5 South Pacific

The sub-committee notes that SC/33/ProgRep New Zealand for this year includes information and statistics on incidental catch of small cetaceans in fishing gear. The species involved are dusky dolphin, common dolphin, Hector's dolphin and long-finned pilot whale.

5.1.6 Eastern Tropical Pacific

The UK reported incidental catch of spotted, spinner and other small cetaceans by tuna seiners registered in the Cayman Islands.

Hammond reported that several IWC members that are known to operate purse seine vessels fishing for tuna associated with dolphins in the eastern tropical Pacific are not at present participating in the international programme of research conducted by the IATTC on the problem. The programme includes placement of observers aboard purse seiners to collect incidental catch statistics and data and specimens for use in assessing status of the dolphin populations. The non-participating members include the Republic of Korea, Mexico, the Netherlands (Netherlands Antilles), Spain and the UK (Cayman Islands).

Fleischer reported that while Mexico is not participating in the international effort, a programme of research on the problem is being planned, including placement of observers on vessels and preparation of an identification guide for use by Mexican fishermen. It is not planned to collect sightings and effort, but no decision has been reached on collection of biological specimens. A report on the progress of the research programme will be included in next year's Progress Report.

Recent analyses have uncovered several potential biases in life-history data collected from dolphins killed in the fishery (SC/33/SM6), throwing earlier estimates of life-history parameters into doubt. Perrin reported that research to cope with these biases is underway.

The sub-committee notes that the estimated incidental kills in 1980 of both spotted and spinner dolphins increased about 100% over those in 1979 (SC/33/SM3). Kill of common dolphins decreased about a third. It was pointed out that the large changes in the extrapolated estimates may merely reflect the large variances caused by the small sample size of non-US vessels. The sub-committee wishes to emphasise that it is very important that more IWC members participate in the IATTC programme, so that better estimates can be obtained. The sub-committee also urges that the status of the dolphin stocks be assessed and that results of analyses and assessments be made available to the Scientific Committee.

5.1.7 Eastern Tropical Atlantic

A recent newsletter on West African marine mammal research (Maigret, 1981) contains information on dolphin mortality in tuna seines off West Africa. Seven French seiner captains (23% of those asked) made on the average less than 12 sets on dolphins annually, killing about 14 dolphins per set.

Maigret extrapolated from this sample to arrive at an estimate of 3,300 dolphins killed annually, based on the fleet of about 42 seiners from France, 12 from the USA and 14 from Spain that fished off West Africa in 1977/78. Incidental kill of dolphins in this fishery had not been reported to the Scientific Committee by these IWC members, and the sub-committee believes they should be requested to do so.

Maigret (1981) also reported incidental kill of common dolphins in a surface trawl fishery for sardines, mackerel and '*chinchards*'. In May, 1980, one trawler captured 6 to 22 common dolphins per haul during trawling at night. Twelve vessels from Romania and the USSR were fishing by this method in the area at this time. The sub-committee notes that incidental kill statistics for this fishery have not been reported to the Scientific Committee.

5.2 Direct conflicts

New information was available on interaction between killer whales and a drop-line fishery in waters off Tasmania (SC/33/ProgRep Australia). An initial estimate is that approximately 10% of the catch of blue-eyed trevalla (*Hyperoglyphe porosa*, Centrolophidae) may be lost to killer whales. Further work on the interaction is planned.

The report of the killer whale workshop (SC/33/Rep4) contains information on take of halibut off longlines by killer whales off Iceland.

5.3 Competition

Ohsumi and Kato reported on progress of research on the problem of perceived competition between fishermen and dolphins at Iki Island, Nagasaki Prefecture, Japan. A team of scientists was recently assembled to conduct ecological research. A programme of research lasting at least three years is planned. The research includes analysis of dolphin stomach contents. Research on methods to drive the dolphins away from fishery areas continues.

Ohsumi reported that present plans are to submit a preliminary report on the results of the research to next year's meeting of the Scientific Committee.

6. EFFECTS OF POLLUTION AND INDUSTRIAL DEVELOPMENT

6.1 New information on pollution

The sub-committee reviewed the IWC observer's report on a joint session of the ICES Marine Environmental Quality and Marine Mammals Committees (IWC/33/11A). Two papers related to small cetaceans were presented. Analysis for lead, cadmium, and mercury in 26 harbour porpoise from the northeast coast of Scotland revealed a trend towards increasing residues of mercury and cadmium with increasing body length in some tissues (ICES Paper E.41[1]). However, data points were sufficiently scattered that no statistical relationship could be shown. Concentrations of lead were below detection limit for all samples. Based on these results and the supposed migratory habits of harbour porpoise as they affect results of such studies, the authors suggested that the harbour porpoise may not be acceptable as an index species for monitoring metal concentrations in the marine environment.

In a second report, levels of mercury and organochlorine residues in two white whales from the St Lawrence estuary were compared with those from other areas. An adult female, found dead of an old injury, contained 36.9 ppm mercury in the liver (ICES Paper E.55[1]). High levels of both total DDT and PCB's were found in this whale and in a healthy calf killed by hunters, but the calf had five times as much total DDT and 25 to 35 times as much PCB as the adult. Unfortunately, neither paper reported any anatomical or histological information.

The sub-committee reiterates its support for the view expressed by ICES that studies of pollutants should not only deal with amounts but also with effects, and that anatomical and histological information should be included in reports so that possible confounding effects of infections, etc., may be made clear. The efforts of ICES to standardise assay techniques were noted.

No full reports relating to small cetaceans were available to the sub-committee. Two harbour porpoise were collected for heavy metal and organochloride analysis under Canadian government permit (SC/33/ProgRep Canada). A study of skin ulcerations in marine mammals (SC/33/ProgRep France) and the analysis of samples from stranded specimens for heavy metal and pesticide residues (SC/33/ProgRep New Zealand) were reported. The latter material includes that from a mass stranding of killer whales and from the bottlenose dolphin and common dolphin. Document SC/33/ProgRep Spain refers to a study of organochloride contamination in a Blainville's beaked whale. Duguy added that a study of 34 small cetaceans relating to organochloride residues will be presented at the next ICES meeting.

6.2 New information on industrial development

Document SC/33/ProgRep Canada lists a working paper on the reactions of whales to boat traffic in the area of the confluence of the Saguenay and St Lawrence rivers, an area where small cetaceans are found. Scientists of 2 nations contributed to and participated in a workshop on underwater noise generated by super tankers and its possible effects on marine mammal populations in Arctic waters (SC/33/ProgRep Denmark and ProgRep Canada). The question of noise effects on marine mammals was raised at the sub-committee meeting last year (IWC, 1980).

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[1] At authors' requests, these Publications presented to ICES were unavailable for release or complete citation.

The proceedings of the workshop will be submitted for public review. The US reports that environmental impact statements are in preparation relating to the occurrence of marine mammals in or near oil lease sites in the Gulf of Alaska (SC/33/ProgRep United States).

7. OTHER BUSINESS

7.1 Publication of documents

Documents intended for publication in the Report are so indicated in Appendix 2. Authors will obtain reviews by at least 2 peers and send revised versions for publication to the Scientific Editor by 1 October 1981.

7.2 Reproduction Conference

Note was taken of the Conference on Cetacean Reproduction, to be held 28 November to 7 December 1981 in La Jolla, California, USA. The symposium of the conference has a full programme of 52 papers; these and others submitted (for circulation only) before the conference will be considered for publication in a proceedings volume. A workshop that will follow the symposium is fully subscribed. The workshop is designed to bring biologists and quantitative workers together for interchange of ideas on the limits and possibilities of work on reproductive biology of cetaceans.

7.3 Conference on tropical Atlantic cetaceans

The sub-committee recognises and encourages current plans for a conference on the cetaceans of tropical West Africa and suggests that the scope of the meeting be expanded to include cetaceans of the tropical western Atlantic as well. The organiser of the conference is J. Maigret, Editor of GEMMATA (Newsletter of Groupe d'Etude des Mammifères Marins dans l'Atlantique Tropical Africain). Persons interested in the meeting should contact Dr J. Maigret at Centre National de Recherches Océanographiques et de Pêches, BP22, Nouadhibou, R. I. de Mauritanie.

7.4 Grant to IWC by the Netherlands

The Government of the Netherlands had contributed Df. 10,000 to the IWC Research Fund with the suggestion that it be spent 'on such activities as may be recommended by the Scientific Committee with regard to the conservation of small cetaceans'.

After discussion of possible uses of the grant, the sub-committee concluded that in light of problems of stock identification of killer whales in Norwegian waters, Norway should be invited to prepare a research plan for the utilisation of the grant for field studies to identify killer whale stocks on the Norwegian coast. Photographic and acoustic survey would seem to be the most promising methods for this work.

7.5 CITES

The sub-committee noted that the volume 'A World Review of the Cetacea' has been published. The volume was financed by the Nature Conservancy Council of the UK and authored by M. Klinowska. Klinowska and Rudge thanked the members of the sub-committee for their help in preparing the volume. The sub-committee hopes that this useful compilation will be updated by the authors at regular intervals.

7.6 Terminology

The sub-committee noted the recent re-description of the clymene dolphin, *Stenella clymene*, based on examination of extensive materials from widespread tropical Atlantic locations (Perrin *et al.*, 1981). The species is valid and should be added to the IWC list of cetacean names.

8. RECOMMENDATIONS TO THE SCIENTIFIC COMMITTEE

8.1 Northern bottlenose whale

The sub-committee again recommends that the research programme recommended for the northern bottlenose whale in 1977–78 be carried out and that the stock continue to be classified a Protection Stock with a zero catch.

8.2 White whales and narwhals

(1) The sub-committee notes that the status of most small cetaceans in the IWC remains unresolved and that a resolution adopted at the 1980 meeting of the Commission (*Rep. int. Whal. Commn* 31: Appendix 8) established an interim working arrangement for continuation of the work of the sub-committee and provision of scientific advice to the member governments. The resolution also calls for provision of data and analyses to the Scientific Committee by member governments. The sub-committee recognises that advice promulgated under the present working arrangement has resulted in expansion of national research programmes on some species and adoption of voluntary internal catch limits for some stocks. Nonetheless, the sub-committee believes that for scientific reasons the white whale and narwhal should be managed on the same basis as the other Arctic whales. Commonalities affecting scientific management are several, including long migrations, subsistence take of individual animals by indigenous peoples using light craft and harpoons (with various modifications from modern technology), relatively high loss rates that must be measured, and quantifiable fishery effort. For these reasons, most of the members of the sub-committee recommend that the white whale and narwhal be listed in the Schedule (Paragraph 1) and that stock classifications and catch limits be set in accordance with the Commission's management procedures. The two whales should be listed thus:

> 'white whale' (*Delphinapterus leucas*) means any whale known as white whale, beluga, belukha
>
> 'narwhal' (*Monodon monoceros*) means any whale known as narwhal, sea unicorn

Ivashin expressed the opinion that this recommendation is inappropriate in light of last year's resolution of the Commission.

(2) The sub-committee notes the responsive and considerable expansion of studies of populations of white whales and narwhals in Canadian and Greenland waters and recommends that Canada and Denmark be encouraged to continue this very important work, giving particular attention to stock identity (including identification of discrete summering populations), migration, abundance, calf production, collection of complete and accurate catch statistics, and full collection of age and reproductive samples from the catch.

(3) Noting the seriously depleted status of the stocks summering in Cumberland Sound (estimated to be at less than 14% of original size), Ungava Bay (less than 20% of original) and eastern Hudson Bay (less than 10% of

original) and the importance to the species of estuarine calf-rearing grounds, the sub-committee recommends that each of these separate stocks be classified as a Protected Stock with zero catch, and that critical habitat of the stocks be recommended for protection.

(4) Noting that the problems of unknown stock structure, abundance and status identified by this sub-committee in 1979 and 1980 for populations of white whales summering in US and Soviet Arctic waters remain for the most part unresolved, the sub-committee recommends that the US and the USSR be urged to initiate field studies needed for stock identification and assessment. Noting that the USA did not submit white whale catch statistics for 1980, it is recommended that it be asked to do so.

8.3 Killer whales

The sub-committee endorses the detailed recommendations of the Workshop on killer whale populations (SC/33/Rep 4) and includes the most important of them here.

8.3.1 Norway

(1) The Committee last year recommended that because of a long history of catches the killer whales in the northeastern Atlantic be classified provisionally as a Sustained Management Stock, pending review of identity and status of stock(s) at this year's meeting. Data necessary to establish identity and assess status of the stock(s) are still not available. In addition, the catch data and new information on the size and nature of stocks elsewhere indicate that the recent takes on the northern coast of Norway may have come from one or a few localized stocks rather than from an overall northeastern Atlantic stock. For these reasons, the sub-committee recommends that the killer whales on the coast of Norway be designated an Unclassified Stock with zero catch limit, pending identification of stocks and assessment of their status.

(2) Noting that data exist on sex and length of catches since 1938, the sub-committee recommends that catch data be analysed as planned by Norway with consideration of possible biases in capture, to determine whether changes in length frequency or sex composition have occurred.

(3) Because available effort data are inadequate for CPUE analyses, the sub-committee recommends that should the fishery continue, improved reporting of effort be requested from the fishermen. Such reports should include at least: time leaving port, time returning to port and estimated time searching.

(4) Noting that acoustic and photographic enumeration techniques have produced highly successful results in defining killer whale populations in other areas, the sub-committee recommends that such techniques be considered for use in delineating the Norwegian stock(s).

(5) Because of the perceived competition between fishermen and killer whales for herring, the sub-committee recommends that, should the fishery continue and whenever possible, stomach contents be examined by scientists and both species composition and volume determined.

(6) Noting the success of short-term censuses in inland marine waters of British Columbia and Washington, the sub-committee recommends that the planned whale count in coastal waters of Norway be carried out.

8.3.2 Antarctic

(1) Because of the continuing uncertainty over stock identities and consequently the abundance of any Southern Hemisphere stocks, the sub-committee recommends that the stock(s) be classified as an Initial Management Stock with a catch limit of zero.

(2) Noting the large amount of information on stock (or 'community') identity yielded by extended photographic and acoustic surveys in the northeastern Pacific, the sub-committee recommends that these and other methods be considered for use in expanded field studies to delineate Southern Hemisphere populations.

(3) Noting that a large sample (916) of killer whales was taken in 1979/80 by the USSR and has not yet been fully reported on, the sub-committee recommends that the USSR be requested to provide suitable report(s) to next year's meeting of the Scientific Committee. The report(s) should include analysis of reproductive data and specimens collected, analysis of morphometric, meristic and colour-pattern data, exact locations of catches, sightings-and-catch per effort data, and information on hunting strategy and tactics, especially as they may relate to possible sex, age or size bias in the samples from the catch and to possible biases in sighting effort. If possible, samples for morphological analyses should be stratified by age.

8.4 Statistics

As pointed out in previous years, catch statistics provided to the Scientific Committee or to BIWS by member nations are incomplete or inadequately detailed. The sub-committee again recommends that member nations be requested to collect and submit full statistics as detailed in *Rep. int. Whal. Commn* 30: 124. Member nations known to have taken small cetaceans but which did not report the takes or reported them incompletely include Argentina (Incidental), Australia (I), Brazil (I), Canada (Directed and I), Chile (I), France (D, I), Iceland (Live-capture), Republic of Korea (I), Mexico (I), Netherlands (I), Peru (I), Spain (I), UK (I), USA (D, I, L) and USSR (I).

9. LITERATURE CITED

Allen, R., 1981. Abundance estimates for killer whales in Antarctic Areas III and IV. *Rep. int. Whal. Commn* 31: 151–2.

Bada, J. L., Brown, S., and Masters, P. M., 1980 [1981]. Age determination of marine mammals based on aspartic acid racemization in the teeth and lens nucleus. *Rep. int. Whal. Commn* 31: 113–18.

Brodie, P. F., 1971. A reconsideration of aspects of growth, reproduction, and behaviour of the white whale (*Delphinapterus leucas*), with reference to the Cumberland Sound, Baffin Island, population. *J. Fish. Res. Bd. Can.* 28: 1,309–18.

Brodie, P. F., Parsons, J. L., and Sergeant, D. E., 1981. Present status of the white whale (*Delphinapterus leucas*), in Cumberland Sound, Baffin Island. *Rep. int. Whal. Commn* 31: 579–82.

Bryant, P., 1981. Are orcas dying to support oceanarium shows? *Whale News* 4: 1–5.

Evans, P. G. H., 1980. Cetaceans in British waters. *Mammal Review* 10: 1–52.

Hay, K. A., 1980 [1981]. Age determination in the narwhal *Monodon monoceros* L. *Rep. int. Whal. Commn* (special issue 3): 119–32.

International Whaling Commission, 1980. Report of the sub-committee on small cetaceans. *Rep. int. Whal. Commn* 30: 111–28.

International Whaling Commission, 1981. Report of the sub-committee on small cetaceans. *Rep. int. Whal. Commn* 31: 140–68.

Ivashin, M. V. and Mineev, V. M., 1981. Notes on the distribution and whaling for white whales (*Delphinapterus leucas*, Pallas, 1776). *Rep. int. Whal. Commn* 31: 589–90.

Jonsgård, A., and Lyshoel, P. B., 1970. A contribution to the knowledge of the biology of the killer whale *Orcinus orca (L).*, *Norw. J. Zool.* 18: 41–48.

Kasuya, T. 1976. Reconsideration of life-history parameters of the spotted and striped dolphins based on cemental layers. *Sci. Rep. Whales Res. Inst., Tokyo* 28: 73–106.

Maigret, J. 1981. Groupe d'étude des mammifères marins dans l'Atlantique tropical Africain. *Gemmata/N.I. No. 3, Jan. 1981.* 8 pp.

Mikhalev, Y., Ivashin, M., Savusin, V., and Zelenaya, F., 1981. The distribution and biology of killer whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 551–66.

Mitchell, E. D., and Reeves, R. R., 1981. Catch history and cumulative catch estimates of initial population size of cetaceans in the eastern Canadian Arctic. *Rep. int. Whal. Commn* 31: 645–82.

Ignetov, G. N., 1981. Studies on the ecology and the taxonomy of the white whale (*Delphinapterus leucas*, Pall., 1776) inhabiting the Soviet Arctic. *Rep. int. Whal. Commn* 31: 515–20.

Perrin, W. F., Mitchell, E. D., Mead, J. G., Caldwell, D. K., and van Bree, P. J. H., 1981. *Stenella clymene*, a rediscovered dolphin of the tropical Atlantic. *J. Mamm.* 62: 583–98.

Seaman, G. A. and Burns, J. J. 1981. Preliminary results of recent studies of belukhas in Alaskan waters. *Rep. int. Whal. Commn* 31: 567–74.

Sergeant, D. E. 1962. The biology of the pilot whale or pothead whale, *Globicephala melaena* (Traill), in Newfoundland waters. *Bull. Fish. Res. Bd Can.* 132: 84 pp.

Sergeant, D. E., 1973. Biology of white whales (*Delphinapterus leucas*) in western Hudson Bay. *J. Fish. Res. Bd Can.* 30: 1065–90.

Sergeant, D. E., 1981. On permissible exploitation rates of Monodontidae. *Rep. int. Whal. Commn* 31: 583–89.

Sergeant, D. E., and Brodie, P. F. 1969. Body size in white whales, (*Delphinapterus leucas*), *J. Fish. Res. Bd Can.* 26: 2561–80.

Sheldrick, M. C., 1976. Trends in the strandings of cetaceans on the British Coasts 1913–72. *Mammal Review* 6: 15–23.

Smith, T. D. (ed.) 1979. Report of the Status of Stocks Workshop (August 27–31, 1979, La Jolla, California) SWFC *Admin. Rep.* LJ-79-41, 120 pp. Southwest Fisheries Center, (US), Nat. Mar. Fish. Serv. NOAA., La Jolla, CA 92038.

Appendix 1

AGENDA

1. Participants, agenda and introductory remarks.
2. Documentation.
3. Review of new information on stocks, catches and status.
    - 3.1 Northern bottlenose whale.
    - 3.2 White whale.
        - 3.2.1 Distribution, migration, identity of stocks and abundance.
        - 3.2.2 Catches.
        - 3.2.3 Hunting loss rates.
        - 3.2.4 Status.
        - 3.2.5 Age determination and vital rates.
        - 3.2.6 Net reproductive rates and sustainable yields.
    - 3.3 Narwhal.
        - 3.3.1 Distribution, migration, identity of stocks, and abundance.
        - 3.3.2 Catches.
        - 3.3.3 Hunting loss rates.
        - 3.3.4 Status.
        - 3.3.5 Age determination and vital rates.
        - 3.3.6 Net reproductive rates and sustainable yields.
    - 3.4 Killer whale.
        - 3.4.1 Review of report of workshop.
        - 3.4.2 The Northeast Atlantic fishery.
        - 3.4.3 The Southern Hemisphere fishery.
    - 3.5 Pilot whales.
    - 3.6 Other small cetaceans.
        - 3.6.1 Bottlenose dolphin.
        - 3.6.2 Striped dolphin.
        - 3.6.3 Common dolphin.
        - 3.6.4 Dall's porpoise.
        - 3.6.5 Harbour porpoise.
4. Statistical reporting for live-capture fisheries.
5. Interactions between small cetaceans and fisheries.
    - 5.1 Incidental take.
        - 5.1.1 Europe.
        - 5.1.2 North America.
        - 5.1.3 South America.
        - 5.1.4 Asia.
        - 5.1.5 South Pacific.
        - 5.1.6 Eastern tropical Pacific.
        - 5.1.7 Eastern tropical Atlantic.
    - 5.2 Direct conflicts.
    - 5.3 Competition.
6. Effects of pollution and industrial development.
    - 6.1 New information on pollution.
    - 6.2 New information on industrial development.
7. Other business.
8. Recommendations to the Scientific Committee.
9. Compilation of references for report.
10. Adjournment.

Appendix 2

LIST OF DOCUMENTS SUBMITTED TO THE SMALL CETACEANS SUB-COMMITTEE

SC/33/SM

1 SMITH, T. Changes in size of three dolphin populations (*Stenella spp*) in the eastern tropical Pacific. [Withdrawn.]

2* OGNETOV, G. N. and POTELOV, V. A. The peculiarities of the white whale, *Delphinapterus leucas*, distribution and population dynamics in the White Sea.

3* ALLEN, R. and GOLDSMITH, M. D. Dolphin mortality in the eastern tropical Pacific incidental to purse seining for yellowfin tuna, 1980.

4* EASTON, D., KLINOWSKA, M. and SHELDRICK, M. C. A preliminary analysis of the British strandings records of the Harbour porpoise (*Phocoena phocoena*).

5 ABBOTT, R. M., KLINOWSKA, M. and EVANS, P. G. H. Analysis of the sightings records of the harbour porpoise (*Phocoena phocoena*) in British waters. [Withdrawn.]

6* PERRIN, W. F. and OLIVER, C. W. Time/area distribution and composition of the incidental kill of dolphins and small whales in the U.S. purse-seine fishery for tuna in the eastern tropical Pacific.

7* BRODIE, P. F. Growth and age determination of the beluga *Delphinapterus leucas* based on a captive specimen.

8 Anonymous. Canadian research and management proposals related to narwhal and beluga, 1981.

9 FINLEY, K. J., MILLER, G. W., ALLARD, H., DAVIS, R. A., and EVANS, C. R. The white whales (*Delphinapterus leucas*) of northern Quebec: distribution, abundance, stock, identity and catch history.

10* FINLEY, K. J. and MILLER, G. W. The 1979 hunt for narwhals (*Monodon monoceros*) and an examination of harpoon gun technology near Pond Inlet, Northern Baffin Island.

11* DUGUY, R. and HUSSENOT, E. Occasional captures of delphinids in the N.E. Atlantic.

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* Published in this volume.

Appendix 3

REPORTED OR PUBLISHED ESTIMATED CATCHES OF SMALL CETACEANS IN 1981 BY SPECIES AND COUNTRIES

				Denmark					(ETP)						
Species		Canada	Japan	Greenland	Faroes	Norway	USSR	South Africa	USA	Non-USA	Spain	France	New Zealand	Seychelles	Total
Baird's beaked whale	D	—	31	—	—	—	—	—	—	—	—	—	—	—	31
Narwhal	D	350	—	$350^{1,2}$	—	—	—	—	—	—	—	—	—	—	700
White whale	D	768	—	$550^{1,2}$	—	—	236	—	—	—	—	—	—	—	1,554
Indo.-Pac. hump-backed dolphin	I	—	—	—	—	—	—	8	—	—	—	—	—	—	8
False killer whale	D	—	356^{1}	—	—	—	—	—	—	—	—	—	—	—	356
	I	—	21^{1}	—	—	—	—	—	—	—	—	—	—	—	21
Killer whale	D	—	2	—	—	52	—	—	—	—	—	—	—	—	54
Long-finned pilot whale	D	—	—	$2^{1,2}$	2,773	—	—	—	—	—	—	—	—	—	2,775
	I	3	—	—	—	—	—	—	—	—	—	—	—	—	3
Short-finned pilot whale	D	—	686^{1}	—	—	—	—	—	—	—	—	—	—	—	686
	I	—	6^{1}	—	—	—	—	—	—	—	—	—	—	—	6
Dusky dolphin	I	—	—	—	—	—	—	—	—	—	—	—	—^{4}	—	—^{4}
	L	—	—	—	—	—	—	1	—	—	—	—	—	—	2
Pacific white-sided dolphin	D	—	69^{1}	—	—	—	—	—	—	—	—	—	—	—	69
	I	—	4^{1}	—	—	—	—	—	—	—	—	—	—	—	4
Bottlenose dolphin	D	—	$3,480^{1}$	—	—	—	—	13	—	—	—	—	—	—^{5}	3,493
	I	—	13^{1}	—	—	—	—	—	—	—	5	3	—	—	21
Risso's dolphin	I	—	3^{1}	—	—	—	—	—	—	—	—	1	—	—	4
[Pantropical] spotted dolphin	D	—	$1,440^{1}$	—	—	—	—	—	—	—	—	—	—	—	1,440
	I	—	20^{1}	—	—	—	—	—	$10,932^{2}$	$11,637^{2}$	—	—	—	—	22,589
Spinner dolphin	I	—	—	—	—	—	—	—	$4,334^{2}$	$10,884^{2}$	—	—	—	—	15,218
Striped dolphin	D	—	$16,247^{1}$	—	—	—	—	—	—	—	—	—	—	—	16,247
	I	—	97^{1}	—	—	—	—	—	75^{2}	342^{2}	—	4	—	—	518
Common dolphin	D	—	49^{1}	—	—	—	—	—	—	—	—	—	—	—	49
	I	—	75^{1}	—	—	—	—	89	400^{2}	$4,621^{2}$	—	7	5^{4}	—	5,197
Harbour porpoise	D	—	30^{1}	$850^{1,2}$	—	—	—	—	—	—	—	—	—	—	880
	I	—	10^{1}	—	—	—	—	—	—	—	—	1	—	—	11
Dall's porpoise	D	—	$6,718^{1}$	—	—	—	—	—	—	—	—	—	—	—	6,718
	I	—	$9,158^{7}$	—	—	—	—	—	—	—	—	—	—	—	9,158
Finless porpoise	D	—	153^{1}	—	—	—	—	—	—	—	—	—	—	—	153
Heaviside's dolphin	I	—	—	—	—	—	—	1	—	—	—	—	—	—	1
Hector's dolphin	I	—	—	—	—	—	—	—	—	—	—	—	1^{4}	—	1
Unidentified or mixed	I	$23,399^{6}$	9^{1}	6^{1}	—	—	—	61	314^{2}	—	—	—	$150^{1,2,4}$	≤ 100	24,039
Total		24,520	38,677	1,758	2,773	52	236	174	16,055	27,484	5	16	156	≤ 100	112,006

Legend: D = Direct
I = Incidental
L = Live capture

1 = Provisional.
2 = Estimated total.
3 = Non-USA kill in ETP.
4 = 1980/81—Catch listed under 'other' composed of dusky, common, and Hector's dolphins, unspecified proportions.
5 = Most of the estimated ≤100 reported are bottlenose dolphins.
6 = Actual takes of 254 animals, of mixed-species composition with unreported proportions, extrapolated to numbers of nets fishing off Newfoundland (SC/33/PS13). As noted in the text, the estimate is of questionable value, because data from a small sample of fishermen (100) in one area were extrapolated to the entire Newfoundland coast and because most of the fishermen queried reported no take (nearly all of the 254 reported were taken by a few fishermen in one location).
7 = Estimated by US (SC/33/ProgRep USA).

Appendix 4

ABUNDANCE ESTIMATES FOR KILLER WHALES IN THE ANTARCTIC

P. S. Hammond

Ohsumi (SC/Jn81/KW10) has calculated population estimates of killer whales in areas I–VI of the Antarctic. He used indices of abundance from Japanese scouting boat data collected from 1965–1980 calibrated to a population estimate made by Allen (*Rep. int. Whal. Commn* 31: 151–152) who employed line-transect methodology on data collected during the IWC/IDCR minke whale cruises in 1978/79 and 1979/80. The calibration involved calculating the ratio of the IDCR population estimate to the scouting boat index of abundance for data collected in Areas III and IV, zone B, in January in both cases. Population estimates for all areas were then calculated by multiplying the indices of abundance from the scouting boat data by this ratio.

One of the assumptions of this method is that the survey areas for the two data sets upon which the ratio depends are equal. This was not the case. The scouting boat index of abundance was calculated assuming a survey area of 1,560,000 sq. nm and the IDCR population estimate was calculated assuming a survey area of 960,500 sq. nm.

The sighting rates (number of whales seen/length of search track in nm) from the two data sets turn out to be very similar in the calibration area; 0.030 for the scouting boat data and 0.028 for the IDCR data. This indicates that given similar sighting conditions the two surveys were sampling the same population density. If it is assumed that sighting conditions were the same, an estimate of density of whales from the scouting boat sighting rate can be obtained by multiplying by the factor which converts sighting rate to density using the IDCR data. The number of whales in the area surveyed by the scouting boats can then be obtained by multiplying scouting boat density by the survey area. Since sighting rate can be obtained for the scouting boat data by dividing the index of abundance by the survey area, and the population estimate is obtained by multiplying by the survey area, the only calculation necessary to get from the scouting boat index of abundance to a population estimate is to multiply by the sighting rate: density estimate conversion factor from the IDCR data. This is given by

$$\frac{\text{Density of whales from IDCR cruises}}{\text{Sighting rate of whales from IDCR cruises}} = \frac{0.0637}{0.0278} = 2.29$$

This conversion factor can then be applied to the indices of abundance for Areas I–VI given in Table 4 in SC/Jn81/KW10 to produce revised population estimates. These are given at the foot of the page.

For these population estimates to be viewed as absolute numbers of whales, several assumptions need to be made: firstly, that the population estimate made by Allen is correct; secondly, that sighting conditions were the same for all surveys in all areas; thirdly, that any non-random searching with respect to killer whale density has been accounted for by the stratification schemes.

There is clear evidence that the density of minke whales in the Antarctic decreases very sharply from the ice edge to the north within 5° of the ice edge (*Rep. int. Whal. Commn* 30: 257–283; SC/Jn81/MiS15; SC/Jn81/MiS16). If killer whales are distributed similarly to minke whales, killer whale density will not be homogeneous within the 5° squares next to the ice edge. If searching effort has been directed towards regions of high minke whale density, estimates of sighting rates and densities of killer whales may be biased upwards.

Prior to 1970, the primary target of the Japanese scouting boats was the sei whale. Since 1970, the primary target has been the minke whale.

	Area						
	I	II	III	IV	V	VI	Total
Index of Abundance	11,565	17,082	37,290	30,921	6,953	7,503	111,314
Population estimate	26,500	39,141	85,445	70,851	15,932	17,192	255,061

Annex I

Meeting Procedures (see Agenda Item 4.1)

Item 26.2(d) of the Commission's 32nd Meeting Report (*Rep. int. Whal. Commn* 31: 27) endorses the Finance and Administration Committee's recommendation that:

> 'The Scientific Committee consider methods of reducing its work load, including, for example, a critical examination of only one third of the whale stocks each year with an overview of all stocks to ensure detection of unexpected changes in population estimate.'

The Committee believes that the framework for handling the problem of its excessive workload already exists, given the present system of sub-committees and special meetings. In addition the relatively small number of stocks currently exploited already results in a fairly high proportion of stocks only being 'overviewed' each year.

Given the above, however, the Committee recognises the need for clarification of the priorites to be given to particular stocks in its programme of work each year. It believes that priorities should be assigned as follows:

Priority 1. Those stocks exploited currently as primary targets of a fishery:
Detailed examination, and where necessary, assessment, should be conducted at least every other year;

Priority 2. All other exploited, or currently protected stocks:
Detailed examination should be undertaken every three to four years.

Additional points are:

(i) As a general rule major new assessments should not be undertaken during annual meetings, although 'reruns' may be possible using validated models, or revised parameter values, or new data sets, particularly where these have been developed by national groups between meetings and are available in checked form on the IWC system at the start of the meeting. Major reassessments involving validation of new models and/or refinement of new data sets should be reserved for Special Meetings or Workshops, although validation itself could be undertaken at annual meetings.

(ii) Major runs of programs not already 'up and running' on the computer, or that require major manipulation of data banks, should not be considered during the annual meeting.

(iii) During the annual meeting, sub-committees should identify priority stocks, and priorities for work to be done in relation to them during the following year. Such work should include assessments, using established programs and data banks, by the IWC computer centre as well as the accession of major quantities of data into the data bank.

RECOMMENDATION

In response to the Commission's request contained in their 26.2(d) of the 32nd Meeting Report the Committee recommends endorsement of the above by the Commission.

Annex J

Whale Marking—Progress Report 1981

S. G. Brown

Information on the progress of whale marking is available in the following Progress Reports: Denmark, Iceland, Japan, New Zealand, Norway, Peru, South Africa, USA, USSR. Recent marking is also referred to in SC/Jn81/KW1 SC/33/Ba6; Mi1, Mi5; PS1 and SC/Jn81/MiS10, 19, 21, 23, 28, 31 and 33. SC/Jn81/MiS19 is a report on the third IDCR Minke Whale Assessment Cruise 1980/81.

At the June 1980 meeting of the Scientific Committee, six proposed marking programmes were approved (*Rep. int. Whal. Commn* 31: 155) for the Antarctic season 1980/81 and for 1981. Marks and marking guns as required were to be supplied by the International Marking Scheme. The IDCR Minke Whale Assessment Programme and the Bryde's whale marking in the South Pacific were carried out in the 1980/81 season.

Details of the numbers of whales marked in the 1980/81 season programme and of marking in 1980 and early 1981, are given in Table 1. The total of 753 large whales marked in the Southern Hemisphere comprises 1 blue, 5 sei, 20 Bryde's, 608 minke and 119 sperm whales.

In the North Atlantic 57 whales were marked in 1980; 18 fin, 33 sei, 4 humpback, 1 minke and 1 sperm whale. In the North Pacific 194 whales were marked in 1980; 2 blue, 1 fin, 3 sei, 55 Bryde's, 29 bowhead, 88 gray and 16 sperm whales.

In addition to the above large whales, 6 killer whales were marked in the North Atlantic in 1980 and 1981 by Norway, and 2 killer whales in 1980 by Iceland. A single killer whale was marked in the North Pacific (Bering Sea) by USSR in 1980.

A fin whale was successfully tagged with a radio tag on the Icelandic whaling grounds in 1980 and tracked for approximately 1,500 km across Denmark Strait to the coast of East Greenland. The USA is conducting experiments in radio tagging bowhead whales, and is developing a tag for use with a Nimbus satellite in tracking dolphin movements. A technique for 'freeze-branding' bottlenose dolphins has also been developed.

One Southern right whale was marked with an experimental streamer mark of New Zealand design off the Auckland Islands in November 1980.

Recoveries of marks in 1980 are reported from 3 fin, 1 sei and 4 minke whales in the North Atlantic and 2 Bryde's whales in the North Pacific. In the Southern Hemisphere marks were returned from 13 minke whales in the 1980/81 whaling season, and from 1 Bryde's whale off Peru in 1981.

Proposed Marking Programmes

Marking programmes proposed for 1981/82 and 1982, including continuing programmes from earlier seasons are listed in Table 2, with estimated requirements of marks, guns, and estimated costs at current and 1982 prices of marks. Rough estimates of shipping costs are included.

Table 1

Large whales marked with Discovery-type marks during 1980 and 1981, and in the Antarctic Season 1980/81

	Blue	Fin	Sei	Bryde's	Humpback	Minke	Bowhead	Gray	Sperm	Total
Southern Hemisphere										
IDCR Minke Whale Cruise 1980/81	—	—	—	—	—	474	—	—	12	486
Japan (Scouting Boat 1980/81)	—	—	5	20	—	134	—	—	91	250
USSR Scheme 1980/81	1	—	—	—	—	—	—	—	8	9
Peru (March 1981)	—	—	—	—	—	—	—	—	8	8
Total	1	—	5	20	—	608	—	—	119	753
Northern Hemisphere—North Atlantic										
Denmark – Norway Joint Cruise 1980	—	8	—	—	4	1	—	—	—	13
Iceland 1980	—	10	33	—	—	—	—	—	1	44
Total	—	18	33	—	4	1	—	—	1	57
Northern Hemisphere—North Pacific										
Japan 1980	2	1	3	55	—	—	—	—	16	77
USSR 1980	—	—	—	—	—	—	29	88	—	117
Total	2	1	3	55	—	—	29	88	16	194

Table 2

Proposed whale marking programmes for 1981/82 and 1982

Programme	Estimated requirements and costs				
	12-bore standard	12-bore increased charge	.410	Guns	Shipment
Minke Whales					
1. Antarctic IDCR Cruise 1981/82	—	—	1,000 (£7,300)	—	£1,000
2. West Greenland Stock 1982	—	—	200 (£1,600)	—	£150
3. Central North Atlantic Stock 1982	--	—	300 (£2,400)	—	£200
Fin Whales					
4. West Greenland Stock 1982	200 (From stock)	—	—	—	£150
5. East Greenland/ Iceland Stock 1982	300 (From stock)	—	—	—	£200
6. British Isles/ Spain/Portugal Stock 1981	250 (From stock)	—	—	From stock	£100
Sperm Whales					
7. North Atlantic Stock 1981	—	150 (From stock)	—	From stock	£100

12-bore standard and increased charge marks for fin and sperm whales can be supplied from stock, together with a 12-bore gun. The .410 marks for the Antarctic IDCR 1981/82 Cruise are already on order. It will be necessary to order the 500 .410 marks for the two 1982 minke whale programmes.

Total costs of marks are estimated at	£11,300
Shipment costs for all programmes estimated at	1,900
	£13,200

Annex K

Report of the Working Group on the Proposal for North Atlantic IDCR Vessel Cruises

Harwood and Tillman jointly convened a working group to develop a proposal for IDCR vessel cruises in the North Atlantic.

Members: Sergeant, Mitchell, Leatherwood, Braham, Mizroch, Horwood, Brown, Lockyer, Martin, Øritsland, Christensen, Rørvik, Jónsson, Sigurjónsson, Kapel, Donovan, Aguilar.

The group reviewed the proposal of last year (Annex N, Scientific Committee Report, *Rep. int. Whal. Commn* 31: 162–5) and agreed that it constituted the basis for planning a multi-year IDCR programme in the North Atlantic, rather than just a one-year effort as originally intended. The group agreed that, within the limits of resources available, it was feasible to undertake each year only one or two segments of the cruise plan designed last year.

The group agreed that during 1981–82 the North Atlantic Programme should focus upon two areas: South Iceland – Denmark Strait (area 7 in Fig. 1 of last year's plan), Coast of Spain and Portugal (area 3 in Fig. 1). It was also agreed that the focus of future years' work would be reviewed by the working group at subsequent annual meetings.

SOUTH ICELAND – DENMARK STRAIT CRUISE

The group identified several major problems which could be addressed by an IDCR cruise in the South Iceland – Denmark Strait area during 1982:

1. Central Stock of Minke Whales

(a) An estimate of abundance is not available for this stock.

(b) The degree of isolation of this stock from the other North Atlantic stocks is unknown.

2. East Greenland – Iceland Stock of Fin Whales

(a) Uncertainties exist in the current assessments of this stock which are currently based upon CPUE data.

(b) The degree of isolation of this stock, if any, from the Spain – Portugal – British Isles stock is unknown.

3. North Atlantic Sperm Whales

(a) Whether the North Atlantic population is comprised of one or several stocks is unknown.

(b) Uncertainties exist in current estimates of abundance which are based upon CPUE data.

Systematic sightings undertaken during the cruise could provide estimates of density along the trackline for these three stocks. However, estimating abundance would require information about their spatial distributions, and the cruise would only start providing this needed information. Sightings might also provide information about the distribution of male and female sperm whales in the area. Marking with Discovery marks during the cruise could provide information about the movements and relations between the stocks of minke, fin and sperm whales if recoveries occurred in the various North Atlantic fisheries.

The working group proposed that a 130 ft small-whale catcher, or trawler with experienced whaling personnel aboard, undertake this sighting and marking cruise in the South Iceland – Denmark Strait area for six weeks during July–August 1982. Space should be provided for two to four scientists. Approximately two-thirds of the cruise should be devoted to sighting, the remaining third being dedicated to marking in areas of high relative abundance. Marking of sperm whales should only be done opportunistically. Marking and sighting activities should not be carried out simultaneously.

The group agreed that the cruise would take place in the area bounded by 60–68°N, and extending from the East Coast of Greenland to 14°E, north of Iceland, or 20°E, south of Iceland. Starting the first week in July, the vessel would survey the shelf areas of Iceland and Greenland and the waters in between. The groups believed that due to ice conditions it would be best to start the cruise in the southern part of the survey area.

It was agreed that the Institute of Marine Research, Bergen, would undertake to organize the cruise. Still needed, however, would be a cruise leader. Although it would be useful if the cruise leader were someone familiar with the analysis of sightings data, this would not be necessary if such expertise were made available afterwards.

The working group prepared the following budget to give an estimate of the expected level of costs. A detailed budget should be prepared during any subsequent planning sessions before July–August 1982. Wages of participating scientists are expected to be covered by national funds.

Ship charter, crew, fuel and other running costs for a 130 ft vessel, 42 days at £1,500 per day	£63,000
Marks:	
500 12-bore, standard charge at £7.00	3,500
200 12-bore, increased charge at £7.50	1,500
Packing and shipping	500
Airfare for two scientists	1,000
Lodging and meals for 5 days in Iceland	500
	£70,000

Scientists from Norway and Iceland believed that £20,000 might be forthcoming from each of their respective governments for support of this effort in 1982.

COAST OF SPAIN AND PORTUGAL

The group identified several major problems which could be addressed by an IDCR cruise off the coast of Spain and Portugal during 1981 and 1982:

1. Spain – Portugal – British Isles Stock of Fin Whales

(a) Uncertainties exist in current assessments of this stock which are based upon available CPUE data.

(b) The degree of isolation from and/or the relation of this stock, if any, to the East Greenland – Iceland stock is unknown.

2. North Atlantic Sperm Whales

Problems as previously noted.

3. Northeast Atlantic Stock of Sei Whales

(a) The number of stocks occurring within this area is unknown.

(b) No data are available with which to assess the status of this stock.

As previously noted, systematic sightings could provide a basis for estimating the abundance of these stocks if their spatial distributions were known. The group agreed it would be useful to undertake a vessel cruise in Area 3 during 1981 to begin obtaining distribution data, which in turn could help with detailed planning for a cruise in 1982.

The Spanish government indicated it would provide a suitable vessel for these cruises, with experienced whaling personnel aboard. Alex Aguilar will be the lead scientist and room will be available for up to two other scientists. The 1981 cruise will take place during September.

Marking of whales with Discovery marks will be undertaken opportunistically during 1981. No funds will be required for marks since this project has already been covered in Annex J.

RECOMMENDATIONS

The working group recommended that this proposal be endorsed by the Scientific Committee and forwarded to the Finance Committee for consideration of complete funding by the IWC.

The working group also agreed that it should consider meeting before the next annual meeting to undertake detailed planning for the cruises, if funded. It was noted that such a meeting would require 2–3 days to complete its work.

Annex L

Report of the Sub-Committee on Research on Cetaceans in the Indian Ocean Sanctuary

1. BACKGROUND

A sub-committee appointed by the Scientific Committee's Cambridge meeting, July 1980, consisting of Brownell (Convenor), Anderson, Best, Brown, Fraser, Pasqual, Saito and Wada met to consider a resolution passed at the 31st Meeting of the Commission (*Rep. int. Whal. Commn* 30: 34) requesting that the Scientific Committee investigate:

—the kind of research and the level of research effort which will be necessary to obtain adequate information on the abundance of whales, reproductive behaviour and related scientific problems relevant to assessment of stocks to which the sanctuary will give total or partial protection from whaling.

—whether it will be necessary to initiate additional research simultaneously in areas where exploitation of whales continues, in order to make comparison possible between stocks under the two different regimes.

—that the Scientific Committee reports on its progress in developing research proposals concerning the above mentioned problems at the 32nd Annual Meeting of the Commission.

The sub-committee noted the intention of the Government of the Seychelles to host a meeting of scientists early in 1981 for the development of a programme of monitoring and research in the Indian Ocean Sanctuary (SC/32/ProgRep Seychelles). IUCN and other organisations have been invited to support the meeting and the IWC has also been invited to send representatives.

The sub-committee agreed that its report would contain suggestions for research on all cetaceans in the Sanctuary and would form the IWC Scientific Committee's submission to be considered at that meeting when convened.

2. CONSIDERATIONS OF REQUIREMENTS OF RESEARCH PROGRAMME

The sub-committee noted that, in amending the Schedule at its 31st Annual Meeting, the Commission had established the Sanctuary for 10 years, with provision for review after five years, unless the Commission decides otherwise. The main features of an appropriate research programme were thus considered to be:

—that it should provide sufficient information within the five year period for assessments of stocks of both the large whales and small cetaceans, and

—that the programme should permit direct comparison of the status of species or population of species protected by the Sanctuary provision and exploited and unexploited stocks of the same species in other areas.

—that the opportunity should be taken to carry out relevant investigations of certain kinds which in areas where whaling continues would be impossible or would be more difficult to undertake.

The sub-committee recognised that the Seychelles Government had been instrumental in the development of the Indian Ocean Sanctuary proposal and considered that in deciding to establish the area, the Commission had accepted a responsibility to ensure that as much information as possible was derived from its establishment. The sub-committee recognised that some of the coastal states in the region had agreed to develop and co-ordinate plans for cetacean research in the Sanctuary, but recognised that the Commission has a broader responsibility for the proper conservation of whale stocks worldwide and thus a responsibility to ensure research was carried out in the Sanctuary which would be applicable in the long-term management of cetacean stocks, both in the Sanctuary and elsewhere.

3. RESEARCH UNDERWAY IN SANCTUARY AREA

The sub-committee reviewed the categories of work known to be underway in the Sanctuary area or on populations of cetaceans migrating to or passing through the area. It was noted that a more complete review of past and current research is in preparation.

3.1 IDCR Minke whale assessment cruises

The IDCR minke whale assessment cruises carried out in 1978/79 and 1979/80 represent an extremely important potential source of information on populations of cetaceans that may move into the Sanctuary area during part of the year. The group recognised the contribution made by Japan to this programme and the support provided by other countries.

3.2 Whaling operations in Southern Oceans

Japanese and USSR whaling operations which are carried out to the south of the current Sanctuary also provide considerable information on populations of cetaceans that occur in the Sanctuary area.

3.3 Known research by IWC Indian Ocean coastal states

3.3.1 Australia:

Southern right whales,	Area IV, aerial survey in coastal waters.
Humpback whales,	Area IV, aerial survey in coastal waters.
Sperm whales,	Division V, analysis of biological material collected during shore station operations.

3.2.2 France: Stranding information on cetaceans at Kerguelen

3.3.3 Seychelles: aerial survey—all species, with special attention to sperm whales

Studying proposal for an International Research Institute for the study of living whales.

Analysis of existing population data; compilation of review of whaling records.

3.3.4 South Africa

Sperm whales, Division III Minke whales, Area III	Analysis of biological material collected from commercial operations at Durban

Southern right whales Area III: Aerial survey in coastal waters.

Small cetaceans: Aerial survey in coastal waters; analysis of biological material from strandings on the South African Coast.

It was apparent that some research was being carried out which would allow assessments of some species found in coastal waters, which, if continued and complemented by research in the Southern Ocean section to the South, would be an important contribution in the Sanctuary. It was quite clear, however that a considerable effort would be required if assessments of species distributed in the offshore areas were be be similarly assessed.

4. OTHER SOURCES OF INFORMATION ON CETACEANS

The following categories of research and sources of information on cetaceans in the Sanctuary or adjacent areas were considered:

—incidental takes;
—strandings;
—sightings;
—historical records;
—platforms of opportunity;
—research catches; and
—captive animals.

4.1 Incidental take

Although more likely to occur in inshore waters of coastal states, incidental takes of small and large cetaceans provide a valuable source of distributional, biological and taxonomic information.

4.2 Strandings

Again occurring in areas under the direct control of coastal states, strandings may also be a valuable source of information.

The group considered that coastal states should be encouraged to develop reporting and recording programmes on biological research and collection of biological material for both incidental take and strandings. It considered that a manual or manuals giving details of identification and handling procedure would add considerably to the value of information derived from such sources.

4.3 Sightings

Aerial and particularly ship-based sightings programmes if properly planned and executed, constitute potentially the most useful approaches capable of yielding information of direct use in assessments of populations in the area. It was noted that the Seychelles, South Africa and Australia have current aerial survey programmes which were yielding information of the distribution and abundance of species necessary in inshore waters. However, many species occur in offshore waters and there is a need to develop sightings programmes for offshore areas.

Operations by Japanese scouting boats constitute the only current shipboard programme in the sanctuary. South Africa is considering a vessel-based survey using her Antarctic supply ship *S.A. Agulhas.*

4.4 Historical records and catch returns

Records of past catches in the Indian Ocean are a potentially useful source of information on past patterns of abundance and distribution. The group noted the report by Wray and Martin SC/32/O 8 and other work being carried out by Bannister and Dawbin on examination of whaling logbooks. Information was also being provided by an IUCN project involving analysis of historical records.

Catch returns from more recent whaling operations are of course available, and with recent estimates of stock, provide a very valuable source of data.

4.5 Platforms of opportunity

Other potential sources of information include commercial and other vessels working in the area. The group agreed, however, that these sources would provide primarily information on gross patterns or areas of seasonal abundance rather than some detailed information which would be dependant upon accurate species identifications unlikely to be achieved by untrained observers.

4.6 Research takes of cetaceans

The group also considered the possibility of research takes and marking and recapturing of cetaceans. While recognising that there are some categories of information that can only be derived from taking of cetaceans, most of the group considered that the initial programme of research in the Sanctuary should seek to carry out assessments using methods which did not require any catches. Some others emphasised the necessity of this kind of research.

4.7 Captive animals

Individuals of certain species which occurred in the Sanctuary which were maintained in captivity could provide useful information on age, growth, reproduction and behaviour.

5. POSSIBLE RESEARCH ON CETACEANS IN SANCTUARY AREAS

Possible research projects that could be undertaken in the Indian Ocean are given below under the following headings:

—Open ocean research on large whales
—Research on large whales by coastal states
—Other sources of information on cetaceans.

5.1 Open ocean research on large whales

5.1.1 Undertake large scale systematic sightings and visual 'marking' cruises throughout the Indian Ocean Sanctuary to—

> identify areas of abundance of baleen whales, especially during winter breeding season, which could constitute independent populations;
>
> establish and repeat small-scale sightings cruises on one or more of populations so identified to obtain accurate estimates of size, productivity and trends in numbers.

5.1.2 Assess alternative marking and tagging techniques, including individual recognition on basis of colour patterning, radio-tagging and satellite telemetry for use in behavioural and population assessment studies in the Sanctuary area.

5.1.3 Examine the possibility of further development of the Bryde's whale research initiated by Japan in 1976/77, 1977/78 and 1978/79. This could include the development of systematic sightings programmes for assessment purposes; stock identification; and biochemical differentiation of stocks.

Another possibility would be to consider assessments based on mark/recapture experiments. The sub-committee considered that any such experiment should be carefully planned and executed as a specific task rather than as an incidental component of other activities. Members also considered that mark/recapture methods required significant removals from stocks to achieve a reasonable level of reliability in estimates so derived. They considered that the implications of any proposal for such programmes would have to be carefully evaluated.

5.1.4 Assessments of whale stocks (Sperm, Bryde's and other baleen whales abundant in the Northwestern Indian Ocean).

5.1.5 Continuation of research on minke whales already initiated by Japan and the USSR in scouting programmes.

5.1.6 Investigation of distribution and possible local abundance of minke whales in lower latitudes in waters contiguous with Sanctuary.

5.1.7 Investigations on the social behaviour of sperm whales and baleen whales.

5.2 Research on large whales by Coastal States

5.2.1 Continuation of Australian aerial coastal surveys. There already exist data series for this region which would be important to continue to allow assessment of possible changes in numbers of sperm, humpback and southern right whales.

5.2.2 Continuation of aerial and shore based surveys in South African waters for southern right whales; resumption of aerial surveys on east coast for humpback whales.

5.2.3 Initiation of coastal surveys (aerial and ship surveys) in East African waters and around Madagascar to examine the distribution and numbers of humpback whales in these waters, compared with their past distribution in 19th century American and other whaling, and in-shore whaling and factory ship whaling in the 20th century.

5.2.4 Initiation of coastal surveys in the Gulf of Aden and Arabian Sea to examine distribution, identity and density of baleen whale species known to occur in the region.

5.2.5 Observations in the sub-Antarctic Island Groups (e.g. Iles de Kerguelen) for the possible occurrence of humpback and southern right whales.

5.2.6 Collation of all available stranding and other records of large whales in the coastal waters of the Indian sub-continent will provide information on the seasonal distribution of species in the Northern Indian Ocean and possibly provide indications of the relation of these animals to the populations in the Indian Ocean south of the equator.

5.2.7 Collection of biological data and materials from stranded cetaceans.

5.3 Other sources of information on cetaceans

The sub-committee recommends the following:

5.3.1 That statistics are maintained for—

All catches, incidental or direct, with particular attention to the completeness of the statistics, to ensure that the following minimum data are collected (as recommended in Scientific Committee Report. *Rep. int. Whal. Commn* 27: 31 and Resolution, Appendix 6, *Rep. int. Whal. Commn* 28: 30).

(i) Species name, and local vernacular name where available.
(ii) Numbers caught.
(iii) Location of catch.
(iv) Biological data, such as length, sex, weight, colouration etc. wherever it is possible to collect them.
(v) An appropriate indication of the intensity of catching effort and of the primary species caught; to which the sub-committee would add.
(vi) Day, month and year of capture.

5.3.2 That data and materials be collected whenever possible from cetaceans that strand in the area, such collections to be as systematic as possible.

5.3.3 That sightings be made when possible from research vessels operating in the area and specific sighting cruises be undertaken systematically and regularly.

5.3.4 That studies of historical records should be continued (such as the preliminary data from 19th century whaling in the western Indian Ocean presented in SC/32/O 8) and encouragement is given to reconstruct as far as possible the pattern of exploitation in the 19th century in the Indian Ocean and adjacent areas.

5.3.5 That platforms of opportunity be utilised to obtain sighting data from as wide an area as possible and to gather environmental data.

DISCUSSION AND RECOMMENDATIONS

The sub-committee had considered the kinds of research that could be undertaken in the Sanctuary, but was unable in the time available to give serious consideration to the level of research effort that will be necessary to obtain information adequate for the Commission's purposes. It noted however, the meeting/Workshop of Scientists proposed by the Seychelles and considered that proposals arising from that meeting should be considered by the Scientific Committee before its next meeting. (Some members oppose the IWC becoming a co-sponsor of the meeting.)

The sub-committee recommends that a small group of members be assigned the task of reviewing the report of the Seychelles Workshop, the review to be considered at the next meeting.

The sub-committee also briefly addressed the question of comparison of research in areas where exploitation was occurring and in the sanctuary area. It considered that in principle, directly comparable research would be extremely valuable. It noted that such research could include comparative observation on behaviour, colouration and feeding as well as research more directly related to estimation and assessment.

The sub-committee was unable to consider in detail priorities which could be assigned to either current research in the area or to categories of possible research, but draws the Commission's attention to the specific recommendation for research in the reports of the sub-committee of the Scientific Committee, many of which have direct bearing on research that may be carried out in the sanctuary area. Some members considered that a high priority should be given to research on those species most likely to be affected by exploitation of krill, such as blue and humpback whales.

Annex M

Statement on Minke Whale Assessments for the Southern Hemisphere and Advice to the Commission

D. G. Chapman, W. K. de la Mare, S. J. Holt, and J. G. Van Beek

Undoubtedly the Special Meeting has advanced our understanding of the many assessment problems encountered at the 1980 meeting of the sub-committee on minke whales, which led to that sub-committee's recommendation that a Special Meeting be held. The success of the meeting was in no small part due to the extraordinary efforts made by Horwood, as its Chairman, and Free, who ran the many analyses required using the BALEEN program. This paper is an attempt to step back from that intensive work and evaluate some aspects of it which have a particular bearing on our task to advise the Commission concerning catch limits for 1981/1982.

That task involves four major steps:

(1) the identification of stocks;
(2) the estimation of current stock size;
(3) the estimation of replacement yields;
(4) evaluation and expression of the confidence to be placed in the above results, especially where they may differ from those of previous years.

(1) Progress has been made in the first task to the extent of confirming a probable boundary roughly between Area IV and Area V. The other boundaries remain very uncertain. Analysis of marking experiments are inconclusive, as are the studies of longitudinal relative density estimates. The number of mark returns so far is extremely small. Marks tend to be returned from the vicinity of their placement, which gives an impression of immobility. The returns are confounded by the distribution of the catch effort. This matter has not yet been fully examined, and it must be, before conclusions can be drawn regarding directions and distances of longitudinal movement and mixing rates. Further, we still know next to nothing about the locations of breeding areas, and thus of the biological population distinctions which are a key to the decisions regarding management areas. The effect of the uncertainties on stock boundaries on analyses are as yet unevaluated. Nor do we know what are the effects on stock responses if management areas do not coincide with biological stocks.

For the benefit especially of those members of the Scientific Committee who did not participate in all of the discussions of the Special Meeting, we have summarised in Table 1, the situation as we understand it.

(2) Four methods of estimating stock sizes have been used. Only in Area IV and V do we have three independent estimates of stock sizes. In Area IV the BALEEN and sightings estimates are approaching consistency. This does represent a significant advance since last year. Last year the sub-committee had three wildly divergent estimates that it averaged to find a single value. At least this year the estimate from BALEEN and the sightings estimate are somewhat closer. The consistency is mostly due to revision of the sightings analysis estimate and a revised BALEEN estimate using a new value for M. Yet by an approximate statistical test they are significantly different.

For Area III there are two independent estimates of stock size based on sightings and mark-recapture but the latter has very wide confidence limits. BALEEN fails to produce a satisfactory estimate for this Area.

In Area I the only estimate available is based on a sightings cruise by one vessel and only a small number of whales were seen. The ratio of the estimated stock size to the number of animals seen is about 48 for this Area, compared with typical values of about 10 to 15 for the sightings estimates in other Areas.

In Area VI the only estimate available is from a BALEEN run. The procedure only converges using the higher value of M equal to 0.09.

Finally, no estimate by any of the above procedures was obtained for Area II and extrapolation using CPUE data to estimate relative densities and the length of the ice edge to measure relative areas, was used to obtain an estimate. This is both crude and untested.

(3) In arriving at estimates of RY last year, the minke whale sub-committee adopted a procedure of using the simulation feature of BALEEN to simulate a stock, with selected biological parameters, having a trajectory passing through the agreed best estimate of the current stock size. This was achieved by adjusting the value of the initial stock size alone. However, a closer examination of this procedure suggests that it has effects on the estimates of RY which were not anticipated. An examination of the BALEEN outputs suggest that the program has the following properties. First, the stock size estimate is very sensitive to the selected biological parameters. In Area IV, for example, when M is 0.09, the current exploitable stock size is estimated to be 27,659, however when M is set to 0.06 the exploitable stock size is 47,917. Second, the RY estimate seems to be relatively insensitive to the biological parameters. Again for Area IV, when M is 0.09, the replacement yield (three year average) is 1,193 compared with 1,251 animals for the M equals 0.06 case. This latter property of the program seems reasonable in that if the CPUE remains fairly constant then the catches must be approximately equal to the RY. Similarly, if the CPUE increases or decreases then the catches are less than or greater than the RY respectively. This tends to suggest that BALEEN has consistent properties for the RY estimation even when the stock size estimated is regarded with suspicion. However, there are two possible reasons why an estimate of the stock size from a BALEEN run may not have produced a correct result. First, the modelling of the stock via the biological parameters, input time series and the selected stock boundary is not adequate for the real stock. Second, the CPUE series do not accurately reflect the changes in relative abundance, particularly taking into account uncertainties in stock areas. Unfortunately the sub-committee in the last two years has not examined

Table 1

Stock size estimates and RY obtained with different methods in 1980 and 1981. Length of confidence interval shown in brackets

		BALEEN	Sightings	Markings	Index of abundance	Weighted average	RY	RY/ average	Catch limit*
Area I	1980	—	—	—	[4]	—	—	—	867[4]
	1981	—	28,000 (?)	—		28,000 (?)	1,179	4.2%	1,179
Area II	1980	—	—	—	[4]	—	—[4]	—	1,120[4]
	1981	—	—	—	56,358 (?)[3]	56,358 (?)[3]	1,593	2.8%	1,593
Area III	1980	—	74,200 (33,600)[1]	—		74,200 (33,600)[1]	1,178	1.6%	1,178
	1981	—	71,644 (63,064)[1]	257,790 (766,800)[1]		85,790 (?)	2,784	3.2%	2,784
Area IV	1980	29,300 (71,081)†	101,200 (44,520)†	95,000 (232,822)†		78,655 (?)[2]	2,272	2.9%	2,272
	1981	39,860 (5,200)[2]	57,951 (46,360)†	136,417 (139,020)†		44,767 (?)[2]	1,548	3.5%	1,548
Area V	1980	—	—	—	[4]	—	—[4]	—	1,190
	1981	14,409 (60,625)[2]	79,847 (76,652)[2]	94,109 (187,548)[2]		51,075 (?)[2]	1,504	2.9%	1,504
Area VI	1980	—	25,787 (?)	—		25,787 (?)	445	1.7%	445
	1981	52,928 (90,848)[2]	—	—		52,928 (?)	1,669	3.2%	1,669
							10,277		1980 7,072 1981 10,277

* Without allowance; set by the Commission.
† Refers to 1978/79.
[1] Refers to 1979/80.
[2] Refers to 1980/81.
[3] Refers to 1981/82.
[4] Dr Holt gave estimates, which in essence were used by the Commission.

separately the above reasons for discounting an estimate. The procedure of forcing a BALEEN simulation through a current stock size estimate not found by BALEEN's minimisation procedure is equivalent to ignoring the information about changes in relative abundance contained in the CPUE series. It seems that it would be a much better procedure to make feasible adjustments to the model until an estimated stock size can be obtained by minimisation which is consistent with good estimates of the stock size obtained by other methods. We can only have some confidence in RY estimates from BALEEN runs made with stock sizes close to those obtained by minimisation. This means that we have most confidence in the estimate of RY for Area IV.

(4) We need to examine the implications of our recommending reductions in catch limits in Areas where we think we have a fair knowledge now of the dynamics of the stock, such as Area IV, and large increases where we have no coherent estimates, or very poor ones, such as Area III. If anything one might have expected the reverse: more caution where we are ignorant, less where we feel we know with security the stock situation, unless we find it to be worse than previously thought.

The theory that minke whales have been increasing for many years as a consequence of reduction in their competitors is an attractive one. However, we are extremely unsure of the actual rates and pattern of expansion. The theory arose from an appreciation of the magnitude of the natural mortality rate in relation to observed age compositions. This year we have made drastic changes in the mortality rate and implicitly discarded all the evidence we accepted in 1979 and 1980 for higher rates. We did this to take advantage of the discovery of the possibility of minimising M on BALEEN estimation runs. The implications of this have not been examined, especially of using such estimates in different BALEEN simulation runs. We believe that the Committee should continue to make its recommendations on the basis of the southern minke stocks as being populations which have in the past expanded. But we do not know if any or all of these have continued to increase since exploitation started, how rapidly they had been increasing, and whether they had all been increasing at similar rates. The RY estimates we have depend critically on the assumption that M is *constant*, irrespective of its magnitude. It has again been pointed out that the assessments are radically altered if, for example, the adult M increases with age, and there is indirect empirical evidence that this is a possibility. The direction of error is such that estimates of RY assuming constant M may be far too high. We have not investigated the degree to which the RY estimates depend on the exact pattern in time of the decrease in age at maturity and on the presumed constancy of the pregnancy rate/juvenile mortality rate from the balance equation.

We have also applied the BALEEN model to small data sets, such as Area VI under conditions where it is attempting to adjust values as much in accordance with noise in the data as with real changes in the stock.

Even quite small changes in procedure of calculating RY can lead to surprisingly large differences. This applies to the exact formula for calculating RY from the simulated population series and, to the number of years used in the final average as a basis for catch limit recommendations. As to the formulae there appear to be several different ways and as yet no agreement on which is best. As to the length of the series averaged, in 1980, five years were used, and in 1981, four years, only because the computer run was not long enough. However, it makes, as far as we can see, a difference which is not negligible.

This year a great deal of attention has been given to the determination of measures of confidence in different estimates of stock sizes by various methods. The results have been used to derive 'best' estimates of stock size in each Area to which a simulation, the full implications of which have not been studied, applied to calculate RY. However, before proposing catch limits, it is necessary to make an appraisal of the relative confidences to be placed in the resulting 'best' estimates of stock size, and, further, in the replacement yield calculations in the various Areas. We believe that in most Areas these latter are so uncertain as to be unworthy bases for advice to the Commission. We propose that advice on specific catch limits should be given only where we believe we have reliable and consistent RY estimates. In other cases we should express our uncertainty in stock size estimates and our greater uncertainty in RY estimates, and advise that catch limits should be provisional. We are not likely to be able to quantify our uncertainty, but it could be expressed perhaps by classifying our results in, say, three grades of reliability. Such classification needs to be done separately for each stock size estimate and each RY estimate. We should also resist the tendency to use phrases in reporting to the Commission which carry particular value judgements; recent examples are 'the stock is in a robust condition' and 'the minke whales are in a healthy state'. We can only know the condition of the stocks if we have satisfactory analyses and the above discussion demonstrates that for most Areas we do not.

Annex N

Report of the Chairman of the Scientific Committee Working Group to Investigate the Most Suitable Method of Calculating Replacement Yield for Southern Hemisphere Minke Whales

This working group met under the Chairmanship of Horwood and Annex M and Appendix I were discussed.

It was noted that in 1980 replacement yield was calculated, for Areas III, IV and VI by finding the net recruitment in the years 1980 to 1985, from the BALEEN runs, and averaging this over the six years. (*Rep. int. Whal. Commn* 31: 120–21).

This year, due to lack of time, a shorter projection was considered (SC/33/Rep 3) and the formula used to calculate RY was:

$$RY = (N_{85} - N_{81} + C_{81})/4.$$

The period over which replacement yield was to be calculated was discussed. It was explained that a period of about 5 years was adopted after the Scientific Committee meeting in Canberra at which it was found that replacement yield calculated on a one year basis could give variable and erratic results depending greatly on the recent history of catches. It was not agreed what the best number of years might be nor was it agreed what the best time within a season (before whaling = December, or after whaling = April) might be to form a base date.

The meeting then considered the formula that should be used to calculate RY from outputs of the BALEEN programme. In addition to the methods noted above it was suggested than an improved approximation, which would produce results consistent with those obtained by the method used in 1980 is given by:

$$RY = (N_{85} - N_{81} + C_{81}e^{-4M})/4$$

However, some considered that equation 8 of Appendix 1 gave the best answer. Allen noted that the method adopted last year did not account for the fact that the catch was taken before natural mortality operated and that they should have been multiplied by exp(+M).

It was pointed out that often a weighted average estimate of stock size had been accepted for an Area that was, naturally, different from the BALEEN run. Replacement yield was then obtained by running the BALEEN model through the weighted estimate even though the same model had indicated a different result. It was noted that this method could be interpreted as rejecting, to some degree, the value of the indices of abundance. Another point was that values of M had been used that had been based on assuming the model and indices of abundance gave the best estimate. Some considered that, whereas the BALEEN model estimates were sensitive to the value of M chosen, the RY's calculated by BALEEN were more robust. Consequently it was not obvious what was the best method of obtaining a value for replacement yield.

Other suggestions were made as to how replacement yield might best be calculated. One suggestion was that estimates over the past few years might be more reliable than projections and that replacement yield could be based on past figures rather than future ones, but it was also noted that future recruitments were largely determined by estimated stock sizes over that same period. Harwood speculated that a procedure might be investigated wherein the best BALEEN fit is accepted and the value (replacement yield/recruited stock size) be applied to the weighted estimate of stock size.

It was considered that these discussions had been both important and useful and that the implications needed further study. It was evident these studies could not possibly be carried out at this meeting and it was agreed that, for this year, the technique used by the Special Meeting on Southern Hemisphere minke whales could be accepted.

Appendix 1

A METHOD OF EVALUATING RY TO STABILIZE THE POPULATIONS OF SOUTHERN MINKE WHALES

S. Tanaka and Y. Shimadzu

A procedure is developed to evaluate RY which stabilize population during 1981/82 to 1984/85 season. Fig. 1 illustrates the process of population trajectory relevant to those seasons.

With the model incorporated in BALEEN program,

$$\begin{aligned} N_{82} &= (N_{81} - C_{81})e^{-M} + R_{82} \\ N_{83} &= (N_{82} - C_{82})e^{-M} + R_{83} \\ N_{84} &= (N_{83} - C_{83})e^{-M} + R_{84} \\ N_{85} &= (N_{84} - C_{84})e^{-M} + R_{85} \end{aligned} \qquad (1)$$

where N_{82} denotes exploitable population at the beginning of 1981/82 season and R_{82} take place at the same time of this season. To stabilize population during 1982 to 1985 season N_{85} must be equal to N_{82}. $\bar{C}$, an average of catch during 1982 and 1984, then comes out to be

$$\bar{C} = C_{82} = C_{83} = C_{84} \qquad (2)$$

And thus $\bar{C}$ is so called RY to stabilize population. Yearly recruitment are easy to calculate with equation (1) since population trajectory of BALEEN assumes $C_{82} = C_{83} = C_{84} = 0$.

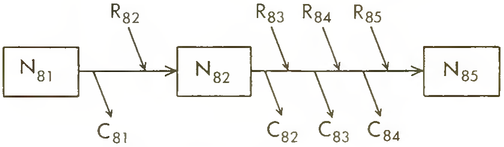

Fig. 1. Population trajectory diagram.

From equation 1 and equation 2.

$$N_{85} = N_{82}e^{-3M} - \bar{C}e^{-2M} - \bar{C}e^{-M} + R_{83}e^{-2M} + R_{83}e^{-2M} + R_{84}e^{-M} + R_{85} \tag{3}$$

$$\therefore \bar{C}(e^{-3M} + e^{-2M} + e^{-M}) = R_{83}e^{-2M} + R_{84}e^{-M} + R_{85} + N_{82}(e^{-3M} - 1) \tag{4}$$

$$\therefore \bar{C} = \frac{R_{83}e^{-0.1374} + R_{84}e^{-0.0687} + R_{85} - 0.1862N_{82}}{2.619} \tag{5}$$

$(\because M = 0.687)$

Given those recruitments and N_{82} from BALEEN output RY is estimated as in the following Tables 1 and 2.

Table 1

Estimates of RY for Area IV

	Female	Male
N_{82}	21,294	23,083
R_{83}	2,213	2,213
R_{84}	2,183	2,183
R_{85}	2,266	2,266
$\bar{C}$	866	739

Table 2

Estimates of RY to ensure $N_{85} = N_{82}$

	Female	Male	Total catch limit
Area I	623	648	1,271
II[1]	1,162	919	1,684
III	1,972	1,681	3,081
IV	866	739	1,604
V	1,140	1,041	1,701
VI	954	966	1,920

[1] Not including Brazilian catch in 1981.

Another set of calculation was done to estimate RY which stabilize population during 1982 and 1986 season; N_{86} is equal to N_{82}. Recruitment at the beginning of the 1986 season is given by equation 6.

$$\begin{aligned} R_{86} &= e^{-Mjtj}\, e^{-(tr-tj)M}(1/2)\, P\, N_{86-tr} \\ &= e^{0.439\times 2}\, e^{-(7-2)M}(1/2)\,(0.78)\, N_{86-7} \\ &= (0.1150)\, N_{79} \end{aligned} \tag{6}$$

Equivalent equations to equation 3 and equation 5 are now given as follows,

$$N_{86} = N_{82}e^{-4M} - \bar{C}e^{-4M} - \bar{C}e^{-3M} - \bar{C}e^{-2M} - \bar{C}e^{-M} + R_{83}e^{-3M} + R_{84}e^{-2M} + R_{85}e^{-M} + R_{86} \tag{7}$$

$$\bar{C} = \frac{R_{83}e^{-0.2061} + R_{84}e^{-0.1374} + R_{85}e^{-0.0687} + R_{86} - 0.2403\, N_{82}}{3.3787} \tag{8}$$

Results are given in Table 3.

Table 3

Estimates of RY to ensure $N_{86} = N_{82}$

	Female	Male	Total catch limit
Area I	619	645	1,264
II[1]	1,143	900	1,656
III	1,968	1,678	3,051
IV	910	783	1,679
V	1,153	1,054	1,711
VI	1,005	1,017	2,022

[1] Not including Brazilian catch in 1981.

Calculated recruitment by sex for 1985/86 season are 1,532, 2,779, 4,624, 2,374, 2,785 and 2,867 for Area I through VI, respectively.

Table 4

Estimates of recruitment from BALEEN output

ex. $R_{83} = N_{83} - (N_{82})e^{-M}$

	R by sex		Female	Male
Area I	N_{82}		14,495	14,132
	R_{83}	1,583		
	R_{84}	1,524		
	R_{85}	1,528		
	R_{86}	1,532		
Area II	N_{82}		26,464	29,883
	R_{83}	2,892		
	R_{84}	2,831		
	R_{85}	2,806		
	R_{86}	2,816		
Area III	N_{82}		42,066	46,153
	R_{83}	4,604		
	R_{84}	4,639		
	R_{85}	4,654		
	R_{86}	4,624		
Area IV	N_{82}		21,294	23,083
	R_{83}	2,213		
	R_{84}	2,183		
	R_{85}	2,266		
	R_{86}	2,374		
Area V	N_{82}		25,205	26,599
	R_{83}	2,713		
	R_{84}	2,723		
	R_{85}	2,771		
	R_{86}	2,785		
Area VI	N_{82}		27,155	26,987
	R_{83}	2,629		
	R_{84}	2,688		
	R_{85}	2,755		
	R_{86}	2,867		

Appendix 2

REPORT OF A SUB-GROUP CONVENED BY THE CHAIRMAN OF THE MINKE WHALE SPECIAL MEETING TO RECONSIDER THE CALCULATION OF RY FOR AREA II

Subsequent to the work of the Special Meeting it was noted that catch data had been incorrectly used in the Area II projections. The model was rerun with the correct catches but in 1980/81 only the Antarctic catches were included in the projection, i.e. the Brazilian catches in 1980/81 were not included.

A sub-group of Harrison, Shimadzu and Tillman was chaired by Horwood to address this problem.

It was agreed, that to use the procedure of the Special Meeting ($RY = (N_{85} - N_{81} + C_{81})/4$), the potential Brazilian catches in 1981 must be included.

The Area II allocation of catches in 1981 was 832. It was assumed that all this catch would be taken. The average sex ratio in the Brazilian catches over the past 5 years is 66:34::females:males (0.65♀ in 1980). The 1981 future catch was assumed to be 549♀ and 283♂.

The 1985 value was obtained from the recurrence relationship,

$N^{t+1} = (N^{t} - C^{t})e^{-M} + R^{t+1}$

C_{81} = Antarctic catch + expected Brazilian catch

$C_{82} - C_{85}$ were put = 0.0

$R_{82} - R_{85}$ (same for each sex) were calculated from the computer printout. These were

$R_{82} = 2{,}873$, $R_{83} = 2{,}892$, $R_{84} = 2{,}831$, $R_{85} = 2{,}806$

This gave N_{85}♂ = 32,073, N_{85}♀ = 29,088

The relation

$RY_{sex} = (N_{85,\ sex} - N_{85,\ sex} + \text{Expected } C_{81,\ sex})/4$

was used to give

RY♂ = 856 (Special Meeting = 865)

RY♀ = 1,092 (Special Meeting = 1,099)

Total = RY♀/0.69 = 1,583 (Special Meeting = 1,593)

Annex O

Report of the *Ad Hoc* Sperm Whale Group

Members: Kirkwood (Chairman), Beddington, Butterworth, Clark, Cooke, Harwood, Holt, Ikeda, de la Mare, Misaki, Ohsumi, Shimadzu, Shirakihara, Tanaka.

Before discussing the estimates of population size for the Western North Pacific stock of sperm whales obtained using the length-specific Cooke and Beddington (CB) technique of SC/33/Sp3 or the age-specific Shirakihara and Tanaka (ST) technique of SC/33/Sp5, the group discussed possible criteria that results obtained using either method should satisfy. The three criteria identified were:

(i) satisfactory performance on sensitivity tests recommended by the Sperm Whale sub-committee (Annex D, Section 5);
(ii) satisfactory attainment of a global minimum sum of squares (best fit to the data);
(iii) satisfactory agreement between observed and predicted pregnancy rates.

1. CB ESTIMATES, SENSITIVITY TESTS AND GLOBAL MINIMUM

Estimates for the Western North Pacific stock obtained using the CB method, and results of the requested sensitivity tests, are given in Appendix 1. Very similar estimates of population size were obtained when fitting coastal Japanese and pelagic catch at length data. Estimates obtained when fitting Soviet pelagic catch at length data were not considered reliable; the Soviet data failed to produce a proper convergence, with the estimates of the population size approaching an unlikely low value, and the observed data themselves were rather less reliable than the coastal and Japanese pelagic data, as outlined in Appendix 1.

Very similar estimates also were obtained when the two designated growth curve parameters were varied above and below their standard values. Also, a substantially worse fit to the data was obtained when the parameters were varied from the standard values, providing support for the standard values. A further sensitivity test involving fitting only to the later half of the coastal and Japanese pelagic data again produced results very similar to those obtained with the full data sets.

A further test recommended by the sperm whale sub-committee was examination of the results of a 100 year simulation with zero catches, in which an amendment to the computer programme had been incorporated. Cooke reported that there had been insufficient time to incorporate the amendment. However, the maximum discrepancy from the original length and age distribution in the unamended programme was less than 1% in any one age-length category after 100 years simulation.

Recognising that it is impossible to be absolutely certain, the group agreed that it was most unlikely that the results presented in Appendix 1 did not correspond to the best fit to the data.

Some members commented that a disadvantage of the use of the CB technique for the stock was that it depended on use of catch at length data, some pre-war subsets of which were not considered completely reliable as they were not available on NP3 forms. However, other members commented that this criticism applied to both techniques.

2. ST ESTIMATES, SENSITIVITY TESTS AND GLOBAL MINIMUM

Estimates obtained using the ST technique are given in Appendix 2. Shirakihara explained that in the time available, it had not been possible to determine accurately the estimate corresponding to the best fit to the data that could be obtained using the techniques of SC/33/Sp5. The plots of calculated sums of squares against initial male population size in Appendix 2 (the lowest point of this curve indicates the population size yielding best fit) indicated that this minimum was either poorly defined or it did not exist. Instead, the initial male population size estimate of 250,000 presented in Appendix 2 was selected visually as being a 'conservative' lower bound to the population size.

The sensitivity test requested for the technique involved a different weighting factor in calculating the average relative catchabilities. As a population estimate corresponding to the best fit that could be obtained using the ST technique had not been obtained, this sensitivity test could not be carried out.

3. PREGNANCY RATE COMPARISONS

The group noted the conclusions, reached by most members of the sperm whale sub-committee last year after extensive discussions, that the true pregnancy rate had declined between 1966 and 1979, but that there may have been an increase in the most recent years (*Rep. int. Whal. Commn* 31: 82, 697–701). It was agreed that this was qualitatively the same trend as shown in Table 7 of Appendix 1 of pregnancy rates predicted for the two estimates obtained using the CB technique.

The time series of pregnancy rates predicted using the initial ST estimate of 250,000 males 11+ years old (Appendix 2) does not show a decline in pregnancy rate. Ohsumi stated his view that the coastal pregnancy data shown on *Rep. int. Whal. Commn* 31: 802 do not indicate a decline in pregnancy rate, and that the ST results agree with this. However, it was noted that the sperm whale sub-committee had concluded that there was an apparent, but not statistically significant, decline shown by the coastal data (op. cit. p. 82). Shimadzu referred to his analysis which revealed no yearly trend in observed pregnancy rates (op. cit. p. 798).

While agreeing that there was good qualitative agreement between the CB predicted pregnancy rates and the trend in observed pregnancy rates, several members felt that the extent of the decline predicted was not supported by the observed data. It was noted that the fact that the decline was not predicted to occur until 1968 meant that the CB initial population estimate was little affected by this predicted decline, since only data to 1977 were used in the fitting process. It was noted that by 1981 the predicted decline would have only a relatively small effect, but that the effect on projections past 1981 would be more substantial. Several members recalled the doubts as to the form of the current sperm whale model raised in past discussions, due to the tendency for prediction of rather greater declines in pregnancy rates than shown in observed data.

CONCLUSIONS

Noting the steep increase in sums of square for initial male population estimates lower than 200,000, Shirakihara stated his view that the results obtained using the ST technique indicated that the CB population estimate was too low. Other members, noting the conclusion of Annex D, section 5 that the ST method may not find the best fit to the data, believed that such a conclusion could not be drawn. When the data handling error of last year had been corrected, the estimated population size was much greater than that originally calculated using the 'incorrect' selectivities, yet this latter lower estimate actually corresponded to a better fit to the data.

Shirakihara commented that when the initial male 11+ population was set to 150,000 (close to the CB estimate), negative values were obtained for certain age groups and simulations terminated. Cooke explained that in the CB method, observed catches by length are removed from the population in the simulation, and no age or length class became negative. As the ST method allocates the catch according to the predicted rather than observed catch by age, it is quite possible that this would lead to predictions of negative age classes, due to overallocation of the catch into a few age classes.

The group noted that it was not until very late in the meeting that the full data sets were available. Shimadzu commented that because of this there had been no alternative but to use the ST method on the full data set. On the other hand, separate estimates had been obtained for three subsets of the data when the length-specific technique was used. It was noted that the latter practice had been employed routinely when using CPUE data from different nations and areas to estimate Southern Hemisphere population sizes.

Some members felt that, even though strict comparison was not possible, a better fit had been obtained using the CB technique than had been obtained using the ST technique, as indicated by comparing the sum of the three entries in the SS (sum of squares) column of Table 1, Appendix 1 with the approximate minimum sum of squares indicated in Figs 1 and 2 of Appendix 2.

Believing that the estimates obtained using the CB technique satisfied each of the three criteria and that the ST technique had satisfied none of these criteria, they felt that the initial and 1981 population estimates obtained using this technique should be adopted.

Some members believed that it was not possible to compare the results any further or to determine the appropriateness of either model from sums of squares because no direct comparisons of results on the same data series were available. They believed that a further analysis of the two models should involve:

(i) execution of the two programmes employing the same data series, so that results were strictly comparable,
(ii) careful study of the available data sets and further refinement if possible, and
(iii) a check of the behaviour of each model relevant to the availability and validity of the data sets.

Appendix 1

WESTERN NORTH PACIFIC ESTIMATES USING THE REVISED BEDDINGTON AND COOKE TECHNIQUE

J. G. Cooke and J. R. Beddington

The analysis was performed using the computer program described in SC/33/Sp3 using the length selectivity technique of Cooke and Beddington CB. Data were fitted for the period 1946–77[1].

In Table 1 the results of the estimation procedure using the CB technique of SC/33/Sp3 are presented. The technique was applied to the Japanese pelagic data, the coastal data and the Soviet pelagic data. Minimisation was two dimensional with the maximum length and the 1910 male population size as free parameters. The Soviet data failed to produce a proper convergence, with estimates of the population size approaching an unlikely low value and the growth curve a high value. The Japanese pelagic and the coastal estimations produced rather similar results to each other, with estimates of population size and maximum length of the growth curve agreeing fairly closely. The results of utilising these latter estimates in extrapolation to 1982 stock sizes are given in Table 2.

Similar extrapolation using the approximate result of the fit to the Soviet data was not attempted. However, it can be readily seen that it would produce an extremely low estimate of current population size.

Table 1

	1910 Males >30′	1910 Females >10 years	Max. length	S S
Coastal	175,072	202,651	49.21	0.4049×10^4
Pelagic (Japanese)	171,008	197,513	50.03	0.98205×10^5
Pelagic (Soviet)[1]	106,115	—	53.94	0.3726×10^6

[1] Did not converge, best estimate after 60 iterations is tabulated.

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[1] The introduction of a maximum size limit in 1978 may have altered the selectivities so data post 1978 were omitted from the fitting procedure.

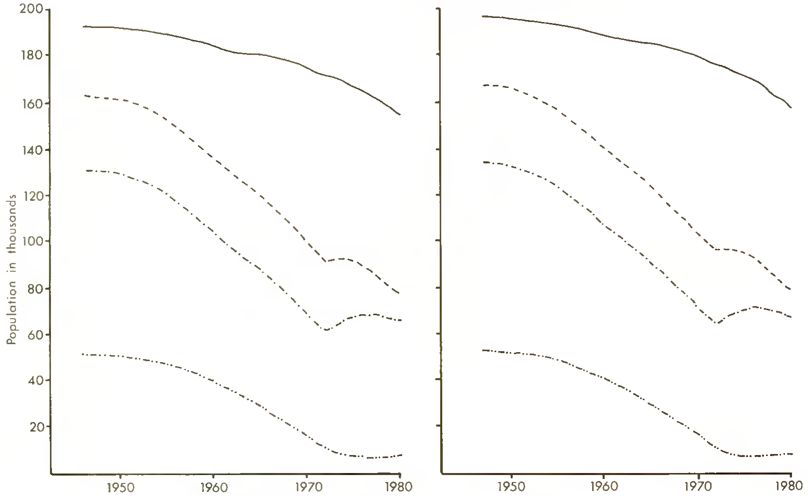

Fig. 1. Population trajectories for the pelagic (left) and coastal (right) estimates. —— females (10 years +); - - - males (30′+); - · - males (11 years +); - · · - males (socially mature).

DATA

Data on catch at length of male sperm whales are available in the IWC data files. These consisted of coded and corrected versions of the NP3 forms. Unfortunately this data set was not complete and had to be supplemented using the BIWS statistics. The main missing data consisted of the Soviet pelagic data prior to 1962. The BIWS statistics involve data which had been apparently allocated into one foot size classes from size classes larger than those originally recorded (to the nearest 10 cm). The classification appeared to be largely arbitrary. The unrealistic results of the analyses performed on the Soviet data is thus possibly a reflection of the rather arbitrary classification of these size groups into foot groups using metric measurements.

Table 2

Current and initial population sizes for the two estimates

	Males 30′+	Males 11 years +	Females 10 years +
Coastal estimate			
1910	175,072	143,970	202,651
1979	82,307	68,437	160,742
1982	74,782	65,034	148,798
% 1982/1910	42.7	45.2	73.4
Pelagic (Japanese) estimate			
1910	171,008	140,320	197,513
1979	80,062	66,320	156,975
1982	73,351	63,741	146,743
% 1982/1910	42.9	45.4	74.3

SENSITIVITY TESTS ON GROWTH CURVE ASSUMPTIONS

(1) Sensitivity tests on different variances around the growth curve

The data set from the Japanese pelagic fishery was used as the basis of the estimation technique using different variances. The results are presented in Table 3.

Table 3

Variance	Males > 30′	Females > 10 year	Max. length	S S
Standard 9	171,008	197,513	50.03	0.98205×10^5
16	175,096	202,372	52.68	0.1323×10^6
4	175,081	203,463	51.82	0.1316×10^6

(2) Sensitivity tests on different mean ages at 30′

The results on using a different age at recruitment are presented in the Table 4. Estimates were made for the Japanese pelagic data set.

Table 4

Age at Recruitment	Males > 30′	Females > 10 year	Max. length	S S
Standard 8	171,008	197,513	50.03	0.98205×10^5
11	167,444	237,307	51.70	0.1316×10^6
6[1]	180,054		52.75	0.1318×10^6

[1] Convergence almost complete.

(3) Sensitivity tests on half data set

In order to test the sensitivity of the results to changes in the data set, the estimation procedure was run on the last half of the data set only for the coastal and Japanese pelagic data set. The results are given in Table 5.

Table 5

	Males 30′	Females 10 years	Max. length	S S
Coastal	179,072	206,608	49.50	0.4256×10^4
Pelagic[1]	176,903	205,846	54.96	0.7660×10^5

[1] Did not converge completely, but evidence of convergence.

The results are encouraging indicating a degree of robustness to the details of the data set.

(4) Changes in length distribution under zero catch

As explained in the report of the sub-group on estimation, the use of the 'histogram' approximation to the distribution of length at age produced a slight drift of the length distribution. The improvement suggested by de la Mare to avoid this, using an approximation to the slope of the distribution, was attempted. Unfortunately a working tested version of this change in the program could not be completed in the time available.

Population Trajectories and Predicted Pregnancy Rates

The results of the population trajectories using the Japanese pelagic and coastal estimates are shown in Fig. 1. Predicted pregnancy rates are derived from the La Jolla model with the agreed parameters (Table 6).

Table 6

Predicted relative pregnancy rates for North-West Pacific sperm whales for the two estimates from the BC technique

	Pelagic estimate	Coastal estimate
1910	0.200	0.200
1947	0.203	0.203
1950	0.203	0.204
1960	0.208	0.208
1965	0.210	0.210
1966	0.210	0.210
1967	0.210	0.207
1968	0.187	0.180
1969	0.163	0.156
1970	0.150	0.143
1971	0.133	0.125
1972	0.108	0.101
1973	0.088	0.081
1974	0.080	0.074
1975	0.076	0.073
1976	0.074	0.072
1977	0.074	0.074
1978	0.078	0.080
1979	0.083	0.085
1980	0.089	0.092
1981	0.102	0.107

Appendix 2

POPULATION ESTIMATION OF THE NORTH-WEST PACIFIC STOCK OF SPERM WHALES

K. Shirakihara, S. Tanaka and J. Tedori

Table 1

Population estimates in 1979 and in the year of minimum population (1972 for male and 1978 for female), and their percentage to the initial value. Weight average of age-specific selectivity is done by the method described in SC/33/Sp5. (Unit: 1,000.)

Male 11+			
1910	250.0	400.0	500.0
1972	171.6	321.7	421.7
%	68.7	80.4	84.9
1979	181.6	331.7	431.8
%	72.6	82.9	86.4
Female 10+			
1910	351.9	563.0	703.8
1978	317.6	528.9	669.7
%	90.3	93.9	95.2
1979	318.3	529.6	670.4
%	90.5	94.1	95.3

1. Stock: the stock in the western area in the North Pacific divided by the line 160°W.
2. Subdivision of northwest Pacific: 11 subdivisions corresponding to Cooke's subdivisions and one subdivision of pre-war pelagic (subdivision number 12).

Table 2

Extrapolation of population change for 5 years up to 1984 for three different catch levels. (1) no catch, (2) male catch 1,077, female catch 115, (3) male catch 2,154, female catch 230. (Unit: 1,000.)

Initial population	Male 11+			Female 10+		
250.0	(1)	(2)	(3)	(1)	(2)	(3)
1979	181.6	181.6	181.6	318.3	318.3	318.3
1980	183.5	183.5	183.5	319.3	319.3	319.3
1981	187.2	186.2	185.2	320.4	320.3	320.2
1982	190.7	188.8	186.8	321.4	321.2	321.0
1983	193.9	191.1	188.3	322.4	322.1	321.8
1984	196.9	193.3	189.6	323.2	322.8	322.4
400.0						
1979	331.7	331.7	331.7	529.6	529.6	529.6
1980	333.7	333.7	333.7	530.6	530.6	530.6
1981	337.4	336.4	335.4	531.8	531.6	531.5
1982	340.9	338.9	337.0	532.8	532.6	532.4
1983	344.1	341.3	338.4	533.8	533.5	533.2
1984	347.1	343.5	339.8	534.7	534.3	533.9
500.0						
1979	431.8	431.8	431.8	670.4	670.4	670.4
1980	433.7	433.7	433.7	671.4	671.4	671.4
1981	437.4	436.4	435.4	672.6	672.5	672.4
1982	440.9	439.0	437.0	673.7	673.4	673.2
1983	444.2	441.3	438.5	674.6	674.3	674.0
1984	447.2	443.5	439.9	675.5	675.1	674.7

3. Data used: total catches by sex by subdivision by year 1910–79 prepared by Free, catches at length by subdivision by year 1910–79 prepared by Cooke and age-length key presented by Ohsumi (1977).
4. Model: ST model (SC/33/Sp5).
5. Parameters:

Mm	0.066	R	5
Mf	0.055	Tr	11
P	0.2	Tj	10
Q	0.05	Z	1.4

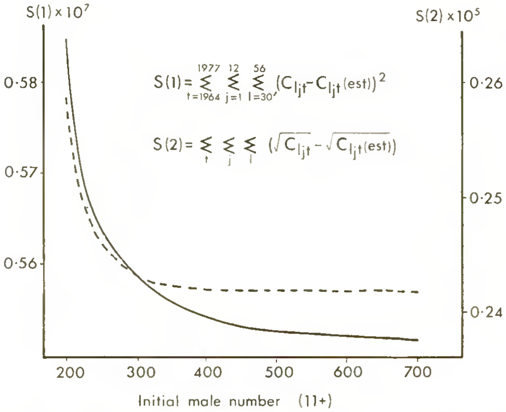

Fig. 1. Sum of squares against initial male (11+) number. The waiting average of age-specific selectivity follows the method given in SC/33/Sp5.

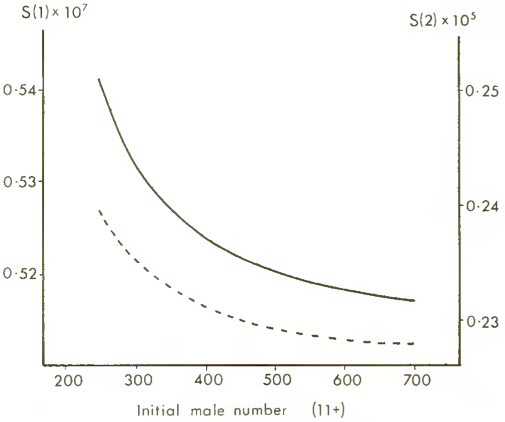

Fig. 2. Sum of squares against initial male (11+) number. The waiting average of age-specific selectivity is the inverse of the rooted catch.

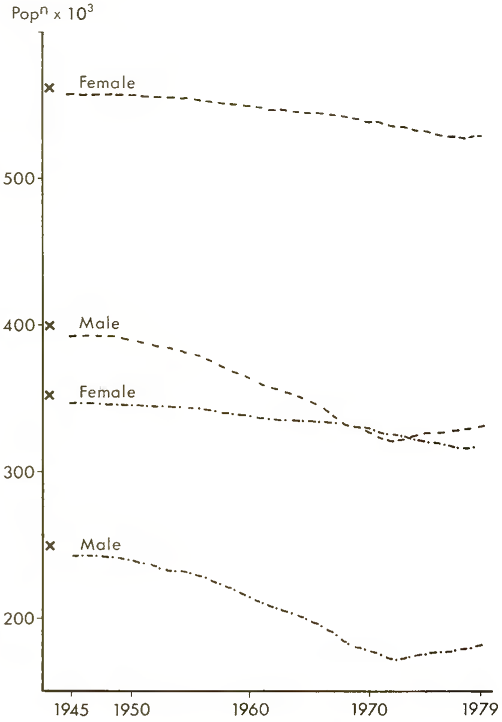

Fig. 3. Sperm whale population trajectories starting with two different levels of initial male (11+) populations: 250,000 (-·-·) and 400,000 (---). Females 10+, 1910 populations shown by crosses.

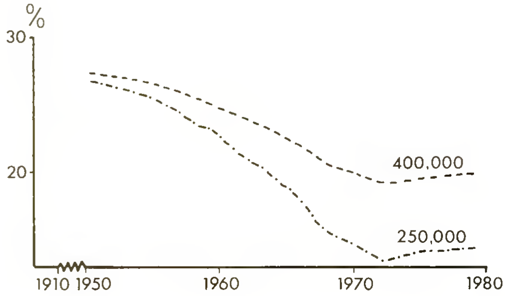

Fig. 4. Percentage of males (25+) to females (10+) in the population.

Annex P

North Atlantic sperm/British–Spanish fin whale

Comment on the interpretation of Spanish and Azores CPUE data and the implications for sperm whales

S. J. Holt

1. Interpretation of the Spanish data turns on the questions of changes in the composition of the Spanish whaling fleet and in species selection by whalers with respect to fin and sperm whales. Discussions in the Sperm and Other Baleen sub-committees have been incomplete because each species has been examined separately without looking at the implications with respect to the other.

2. The Spanish delegation have made available catch series by each vessel in the fleet, for the original purpose of evaluating various possible vessel efficiency factors. These data, which refer to a 'standard' part of the whaling season—July to October—during which the greater part of the catches of both species are taken, have been used in the preparation of catch and effort series 'A' which was the basis for a POPDYN sperm estimation. These data shed light on more general questions concerning North Atlantic fin and sperm whales. There has been no time for a detailed analysis, but the salient points regarding the data series can, I think, be demonstrated in a simple way.

3. Five vessels were involved in a series running from 1957 to 1976. From 1978 the operation changed with the advent of two new very powerful vessels. In 1977 only two of the five vessels operated so only one vessel-to-vessel comparison is possible. The present analysis is therefore confined to the 1957–76 data. The characteristics of the five vessels are as follows:

	G.W.T.	H.P.	Operated
A1	285	500	1957–76
A2	285	500	1957–76
B	299	844	1957–71, 73–76
C	287	1,000	1966–69, 71–76
D	250	702	1966–69, 71–76

These can be regarded as two subfleets: AB of three vessels, two of which are identical and the catch data for which are pooled, and CD of two vessels. Fleet AB operated mainly at the Canelinas station and, I understand, fleet CD at Moras. The species compositions of the two fleets, and the catch rates, are not the same. Relevant data are summarised in Table 1.

4. Subfleet AB

The smaller vessels, A1 and A2 together consistently caught more of each species than the larger vessel, B. This was true for the whole time series and also for two sub-sets 1957–66 (10 years) and 1967–76 (10 years for A, 9 years for B).

5. Subfleet CD

Again, the smaller vessel, D, caught more of each species than the larger one, C, in the whole period of operation 1966–76.

6. Comparison of subfleets

This comparison is crucial in the adjustment of the CPUE time series to allow for fleet changes, since there is one major change, in 1966, when the two new vessels begin operations. Note that the new vessels are, together, smaller in tonnage than the three older ones, but higher in horse-power.

Comparison between subfleets is possible directly for the years 1966–69, 1971 and 1973–76. For sperm whales the results are consistent: CD always catches more than AB, in a ratio averaging 1.37:1 over the entire period. For fin whales there is a change during the period, with Fleet CD initially catching very much less than AB then, later, catching very much more. Over the period it took slightly fewer, in the ratio 0.82:1.

Considering the two species together the newer fleet CD took, over the whole period, more than the older fleet AB, in the ratio 1.18:1. There was a change during the period CD initially taking a few less whales and later taking considerably more.

Considering the whole period it seems that it was not entirely inappropriate to make a crude adjustment to the catching power by applying a horse-power correction of approximately 1.38:1 when adjusting the sperm CPUE data, but this could be regarded as inappropriate with respect to the fin catches. The change in the apparent efficiency with respect to fins (which is, of course, really an expression of selectivity change in their favour) is so great during the period that application of any general factor is inappropriate.

7. Performance of fleet AB

The long time series during which this subfleet operated continuously provides an opportunity to review the trends in abundance of fin and sperm whales off the northwest coast of Spain. We examine the catches per boat per July–October season in two sub-sets: 1957–66 and 1967–76. The year 1972 must be omitted from the overall comparison because vessel B did not operate throughout the season that year.

It will be noted that the catch rate of each vessel declined from the early period to the later one. This decline is evident for the species separately and, naturally, together. This indicates that either or both species were declining during the period. The decline in fin catch rate is quite small. It is said that the relative interest of the industry in fin whales increased during this period, although not by so

Table 1

Vessel performance in Spanish operations. Catches per season, July–October.

Period	Fin			Sperm			Both Species		
Subfleet AB	A	B	A + B	A	B	A + B	A	B	A + B
1957–66	22.50	19.50	21.50	49.90	40.00	46.60	72.40	59.50	68.10
1967–76	23.11	17.00	21.07	41.78	37.22	40.26	64.89	54.22	61.33
1957–76	22.29	18.32	21.30	46.05	38.68	43.59	68.84	57.00	64.89
1967–76/57–66	0.87	1.03	0.98	0.84	0.93	0.87	0.90	0.91	0.90
Subfleet CD	C	D	C + D	C	D	C + D	C	D	C + D
1966–76, excl. 70	16.80	15.70	16.25	47.80	53.10	50.45	64.60	68.80	66.70
Comparison of sub-fleets	AB	CD	AB + CD	AB	CD	AB + CD	AB	CD	AB + CD
1967–69, 71	20.75	10.63	16.70	41.75	56.76	47.75	62.50	67.39	64.46
1973–76	16.92	24.50	19.95	31.00	48.50	38.00	47.92	73.00	57.95
1966–76	19.92	16.34	18.49	36.63	50.28	42.09	56.56	66.62	60.58

much as happened subsequently. This means that the fin stock could have declined by more than these figures indicate. If so then the decline in sperm catch rates is an exaggeration of the decline in the sperm stock. But it is not possible to conclude from these data that the sperm stock did not decline, for this would imply a very considerable concurrent decline in the fin stock.

8. At this point it is of interest to examine the apparent decline in the sperm whales off Spain in relation to the predictions of population analyses based on the CPUE data from the Azores.

The data presented in SC/33/O 13 show a decline in male and female sperm whales over the period 1949–67. Linear regressions, omitting for the sake of being 'optimistic' the two high values in 1949 and 1950, indicate a decline in the abundance of males by 1967 to 37% of their level in 1949. The corresponding reduction for females is also 37%.

The POPDYN run for the males in this data set did not model these changes well; the run shows a reduction in males to 43% as it should, but of females only 95% (exploited) or 92% (mature). However, looking only at the males the run predicts a continuing decline to 1972 and then a slow rise. The average predicted male stock number in the years 1957–66 is 1,813, and in 1967–76 it is 987. This is a decline to 0.54, to be compared with a corresponding decline in Spain to 0.78.

9. The sperm sub-committee agreed that the Azores POPDYN run was not acceptable because the pregnancy rate became unreasonably low in the 1960s. This was because the decline in the females was not modelled so the calculated sex ratio changed too much. So let us suppose the POPDYN run exaggerated the subsequent decline in males. The decline in the Spanish catches is, I think, nearer to reality. By combining the Azores and Spanish data series we can get a picture of the trajectories of both sexes through the period 1949 to 1976. The combination is made by scaling the Spanish CPUE (subfleet AB) to the Azores CPUE in the period of overlap 1957–67. The results are shown graphically in Fig. 1. Linear regressions, again omitting the high Azores data points for 1949 and 1950, indicate a decline by 1976 of males to 39% and of females to 49% of the 1949 level.

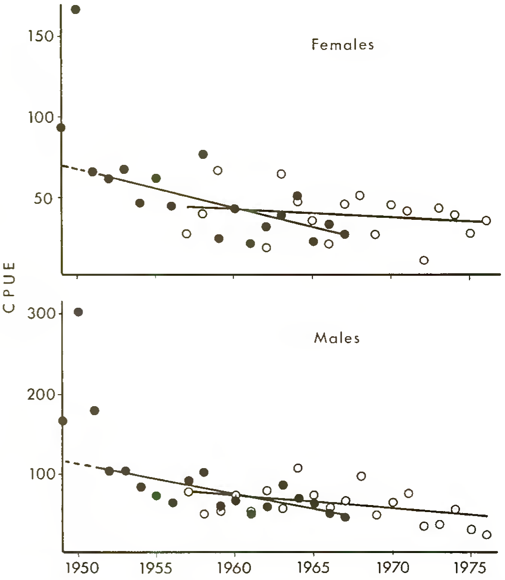

Fig. 1. Yearly trend in CPUE for the Azores (●) and Spain (○) by sex, in both cases the Azores slope is highly significant. The Spanish slope is significant for males.

10. These reductions alone are sufficient to justify the classification of both males and females in this stock as protected, since it is inconceivable that they could have increased in the last five years to be in the region of SMS for sperm whales. In any case the catch history of this stock is such that the males and females were both well below their initial levels in 1949. The Azores POPDYN run shows exploited males in 1949 at 80% of their 1940 level. (Females at 97%). The POPDYN runs on the Spanish data, Series A—not corrected for vessel efficiency—give very similar ratios (78% and 96%), and, in relation to initial stock, as follows:

1949/1905 Males—81%, females—90%

Combining these gives the ratios:

1976/1905 Males—32%, females—44%

Annex Q

Report of the Working Group on Computing Needs

Tillman convened a working group to establish priorities for projects to be undertaken by the IWC Computing facility during the ensuing year. The working group considered projects proposed by Free in IWC Technical Note No. 9 and by the convenors of sub-committees.

Members of the working group included : Allen, Beddington, Best, Chapman, Cooke, Free, Harrison and Ohsumi. Clark and Horwood also submitted written proposals.

The working group agreed that sperm whale projects should receive the highest priority during the coming year, both in terms of establishing or revising data bases and in validating existing computer programs. The projects recommended are listed as follows, according to priority within each category:

A. Data Bank Projects to be undertaken directly
  1. Encode and check North Pacific sperm whale data:
    (a) Remaining catch-at-length data.
    (b) Improve Soviet pelagic catch-at-length data.
    (c) Japanese age-length data by 10° square.
  2. Encode and check Southern Hemisphere sperm whale catch-at-length data.
  3. Encode and check North Atlantic fin whale catch data:
    (a) In cooperation with Brown obtain and enter historical data.
    (b) Obtain Icelandic data tape from Sea Mammal Research Unit (SMRU).

B. Computer Program Validation Projects to be undertaken directly
  1. Validate sperm whale models:
    (a) Cooke-Beddington.
    (b) Shirakihara-Tanaka.
  2. Validate 'non-standard' BALEEN.
  3. Validate BALEEN.
  4. Validate CHPOP.

C. Projects to be sub-contracted
  1. Encode and check marking data held by Brown at SMRU.
  2. Encode and check sperm whale school-size data.
  3. Encode and check extensions of the Japanese master tapes:
    (a) Southern Hemisphere.
    (b) North Pacific.

Free also reported that during the year he would cooperate with Butterworth in validating the Southern Hemisphere IDCR minke sighting data. The group endorsed this undertaking since Butterworth would be doing most of the work.

On considering projects for validating computer programs, the group briefly discussed the possibility of establishing a general policy for creating and using 'IWC standard programs' as suggested in IWC Technical Note No. 9. The group believed that a fuller discussion involving a larger number of members would be required to resolve this issue. However, it agreed that it would be useful for the IWC computing facility to validate the few computer programs proposed.

On considering the sub-contract project to encode data resulting from the international marking program, the group noted the problem of access to these data. It was believed that some governments may not wish their marking data to be entered generally into the IWC data bank. The group therefore recommends that the Secretary be asked to correspond with governments seeking permission for transferral of their international marking program data from SMRU to the IWC computing facility, as well as querying their desire to submit any other marking data which may have resulted from national programs.

SC/33/ProgRep Australia

Australia
Progress Report on Cetacean Research June 1980 to May 1981

This report refers to work carried out from the Western Australian Museum, Perth, Western Australia; the CSIRO Division of Fisheries and Oceanography, Cronulla, New South Wales; the University of Queensland, Brisbane, Queensland and the Australian National Parks and Wildlife Service, Canberra, Australian Capital Territory.

SPECIES AND STOCKS STUDIED

Work continued on biological material collected during earlier commercial operations on Division 5 sperm whale stocks off Albany, Western Australia, with particular emphasis on obtaining age readings from teeth in co-operation with the Sea Mammal Research Unit, Cambridge. Aerial surveys for southern right and humpback whales were continued on the west coast and for humpback whales on the east coast. Initial field investigations of an interaction between a dropline fishery on the edge of the continental shelf off Hobart, Tasmania and *Orcinus orca* were carried out and an initial economic assessment of the effects of the interaction on the fishery completed by the Tasmanian Fisheries Development Authority.

A pilot study for the development of an aerial survey programme for Division 5 sperm whale stocks was completed by CSIRO Division of Fisheries and Oceanography, Cronulla.

FIELD OBSERVATIONS AND COLLECTIONS

In the absence of commercial whaling operations, no routine work was undertaken in Australia.

Aerial sightings programmes were carried out for humpback whales off Carnarvon, Western Australia (in August 1980) and for southern right whales off the south coast of Western Australia (July–December 1980). Aerial and shore-based sightings programmes were carried out on the east coast from 27°S to 29°S, with a third shore-based observation post at 32°S. The aerial surveys were conducted from 25 June to 6 July 1980 and shore-based surveys at all three stations from 21 July to 5 July 1980, with an additional period of shore-based observations from 6 to 27 July at Stradbroke Island.

MARKING

Mr D. Hembree participated in the 1980/81 Southern Hemisphere IDCR Minke Whale Assessment Cruise from 17 December 1980 to 11 February 1981.

LABORATORY WORK

From November 1980, through an arrangement with the Sea Mammal Research Unit in Cambridge, a total of 1,276 sperm whale teeth collected by fisheries inspectors during the commercial operations in 1976, 1977 and 1978 at Albany, Western Australia, were sectioned and lamination counts obtained.

From existing aircraft sightings data from the commercial operations at Albany, data have been extracted on sperm whale school size and the numbers of whales captured from schools for 1968 and 1978, for 114 and 128 days respectively.

Information was also extracted from aircraft sightings on the ratio of socially mature males to females for the period 1963 to 1978. An initial analysis of testis weight against length indicated no obvious change from that for 1967–68 and 1977–78. A collection of 64 ovary pairs remaining from collections made during Albany sperm whaling operations were sectioned.

RESEARCH RESULTS

Aerial Survey, southern right whales, Western Australia
In five flights, one each month from July to October and in December, 74 individuals were seen, including 13 calves, along a standard flight pattern from Cape Leeuwin (34°22′S, 115°05′E) to Cape Arid (34°01′S, 123°09′E). The number of individuals seen was considerably higher than in any of the previous three years of surveys. For the comparable months in each year since 1978 (August–October), 1980 was still the highest, the comparable figures being: 1978, 34 (11 calves); 1979, 15 (2 calves); 1980, 59 (10 calves). The proportion of calves seen was, however, the same as in the previous year (18%) but lower than in 1978 (32%) or 1977 (22%). Mating was observed among a group of 9 right whales seen in September.

The 1980 survey details are given in Table 1. In 1980, as many individuals as possible were photographed to permit later matching, particularly of bonnet patterns.

Table 1

Summary of southern right whale sightings, aerial surveys, south coast of Western Australia, 1980

Month	Time flying (hours and minutes)	Whales seen
July	12.20	15 Right (including 3 calves)
August	11.15	25 Right (including 6 calves)
September	11.06	29 Right (including 3 calves)
October	10.27	5 Right (including 1 calf) 2 Humpback
December	10.13	Nil
	55.21	74 Right (including 13 calves) 2 Humpback

Aerial Survey, humpback whales, Western Australia

In eight flights during early August, 86 individuals were seen, including 4 calves. A standardised box search on a grid extending to some 50 miles offshore from Shark Bay off Carnarvon, Western Australia, was flown on each flight. Individuals seen were moving either north or south, with the latter predominating. The numbers seen were considerably higher than in the previous three surveys in recent years (1976, 1977 and 1978), both in absolute number and in number per flying hour. Details for the 1980 survey are given in Table 2 and a comparison with previous years in Table 3. Unfortunately, because of the high proportion (67%) travelling south in the 1980 survey, it is likely that a different proportion of the migration was observed. Direct comparison of the 1980 survey results with earlier years is thus not possible, as in those years, on the whole, a higher proportion were moving north. The general impression, however, from these and other observations from the west coast, is that there has been an increase in numbers seen since the cessation of humpback whaling.

Aerial Survey, humpback whales, Australian east coast

In 1979 an initial survey was carried out from Stradbroke Island, Queensland using simultaneous shore based and aerial surveys, further developing a triangulated survey pattern developed by W. H. Dawbin for a survey along the east coast further to the south during the 1978 northward migration. In 1980, aerial and shore based surveys were carried out by Dr M. M. Bryden through the University of Queensland in Brisbane and interested conservation groups. Three aerial survey patterns were flown—a box search intended to establish the distance offshore at which the northward-moving whales were travelling, an initial set of predetermined equilateral triangular legs along the coast, extending approximately 18 nm offshore (9 minutes at 120 knots) and a second series of smaller triangles of base 10 km and side 15 km (see Fig. 1).

Table 4 gives the total sightings of humpback whales during the two series of triangulated surveys. Table 5 gives a summary of sightings from the three shore-based observation posts: Point Lookout (27°25′S); Cape Byron (28°40′S), and Seal Rocks (31°55′S). Based on estimates of whales passing Point Lookout each week and the pattern of migration during the period in which catches were being taken by shore stations in the area during whaling operations up to 1962, Bryden has made an initial estimate of 506 individuals passing the east Australian coast in the northwards migration in 1980. Shore-based and aerial surveys are being carried out in 1981 to obtain more information.

Table 2

Humpback whale aerial survey, Carnarvon area, 1980

Flight No.	Date	Average weather conditions (%)	Humpback whales seen	Other marine mammals seen	Flying time hrs–mins	Searching time hrs–mins	Pilot/Observer	Aircraft	Average speed/ height
1	4.8.80	75	9 incl. 1 calf		3.55	3.19	J.N., D.H.	PN68	120 kt/ 1500 ft
2	5.8.80	100	9	5 Tursiops 10 'Dolphins' 13 Dugong	3.50	3.26	J.N., D.H., B.B., S.C.	"	"
3	6.8.80	50	4		3.15	2.32	J.N., D.H., G.F.	"	"
4	8.8.80	100	15 incl. 1 subadult	1 small baleen whale 1 Dolphin	4.05	3.29	J.N., D.H., R.B., B.F.	"	"
5	9.8.80	100	20 incl. 1 calf	28 Dolphins (incl. 5 'black') 8 Dugong	4.40	3.39	J.N., D.H., P.S., L.M.	"	"
6	13.8.80	75	7		3.45	3.24	J.N., D.H., F.L., J.C.	"	"
7	14.8.80	75	4		3.55	3.34	J.N., D.H.	"	"
8	15.8.80	100	18 incl. 2 calves	3 small baleen whales 5 Tursiops 11+ 'Dolphins'	4.20	3.37	J.N., D.H., P.G., R.F.	"	"

Table 3

Comparison of humpback aerial sighting records, Carnarvon area, for comparable months, 1963–80

Year	Humpback whales sighted	Comparable months flown	Flying days	Flying hours	Flying hours per day	Whales seen per flying day	Whales seen per flying hour	Proportion travelling north**
1963	119 (101)*	July/August	26	(143.53)	5.6	4.6	(0.69)	39/56 (70%)
1976	9	July/August	2	9.20	4.6	4.5	0.96	7/7 (100%)
1977	30	July	7	25.00	3.6	4.3	1.20	12/16 (75%)
1978	17	July	5	18.08	3.6	3.4	0.94	2/14 (14%)
1980	86	August	8	34.45	3.9	10.8	2.71	23/69 (33%)
1976–80 combined	142		22	83.73	3.8	6.5	1.70	21/37 (57%)

* Figures in brackets are those for which available 'flying hour' data exist for comparison with those of subsequent years.

** Of those whose direction of travel was readily apparent.

Table 5

Shore-based observations of humpback whales at Point Lookout, Cape Byron and Seal Rocks, 1980

	Whales observed	Hours of observation	Whales per 100 hours observation
Point Lookout			
Week ending			
25/6/80	5	46.5	10.75
2/7/80	17	73.5	23.13
9/7/80	9	42.0	21.43
16/7/80	16	48.0	33.33
23/7/80	17	44.5	38.20
30/7/80	4	19.5	20.51
Total	68	274.0	24.82
Seal Rocks			
21/6/80–25/6/80	0	25.3	0.0
26/6/80–2/7/80	12	59.4	20.2
3/7/80–6/7/80	0	24.8	0.0
Total	12	109.5	11.0
Cape Byron			
22/6/80–25/6/80	0	32.0	0
26/6/80–2/7/80	5	56.0	8.9
3/7/80–5/7/80	7	24.0	29.2
Total	12	112.0	10.7

species, blue-eyed trevalla, (*Hyperoglyphe porosa*, Centrolophidae), individuals of which may weigh up to 14 kg. Current landed values are between $1.90 and $2.50 kg to the fisherman. An initial assessment is that about 10% or less of the catch is lost through the activities of *Orcinus*. Interference from seals and seabirds is also reported and may occur more frequently than from whales. Log book collection of data on interference in the fishery, coupled with direct observation, will now provide more information on the incidence of interference. Young and mature animals are both reported to take fishes. It is not yet clear how many whales are involved, whether a single pod or group or a series of groups moving through the area during the August to December period in which most of the interference by whales is reported.

DEVELOPMENT OF TECHNIQUES

Under a consultancy agreement with the Australian National Parks and Wildlife Service, Dr Kirkwood (CSIRO Division of Fisheries and Oceanography) undertook a re-examination of the spotter aircraft logs from the commercial whaling operations at Albany, Western Australia. Data on the numbers of male sperm whales seen on the first of the two daily spotter flights were extracted for September, October and November for the period 1968 to 1978, when the operation closed. To obtain a probability distribution for the number seen, a number of possible distributions were fitted to the observed distribution, with a Polya-Aeppli distribution providing the best fit. Based on that probability distribution, estimates were derived of the numbers of survey flights needed to provide an estimate of abundance, comparable at acceptable levels of confidence with indices obtainable from the records of the commercial spotter flights. Table 6 gives estimates of the numbers of flights needed to detect, at a given probability level, an increase in abundance, given a true level of increase between 20 and 80%. The study has been completed and will form the basis of an assessment of the requirements and costs of a major aerial survey for Division 5 sperm whale stocks.

Table 6

Estimated numbers of flights needed to detect with probability θ an increase in abundance using a level 1–β test, given the true increase is α%

β	α(%)	0.80	0.90	0.95
0.05	20	575	797	1,006
	40	156	216	272
	60	74	103	130
	80	45	62	78
0.10	20	420	613	797
	40	114	166	216
	60	54	79	103
	80	33	48	62
0.20	20	264	420	575
	40	71	114	156
	60	34	54	74
	80	21	33	45

PUBLICATIONS

Allen, K. R. 1981. A note on catch limits for previously unexploited stocks. *Rep. int. Whal. Commn* 31: 593–6.

Allen, K. R. 1981. Further notes on the calculation of R_{II} recruitment rates. *Rep. int. Whal. Commn* 31: 597–600.

Allen, K. R. 1981. A modified DeLury method of estimating populations. *Rep. int. Whal. Commn* 31: 683–6.

Allen, K. R. 1981. Estimating of R_{II} recruitment rate and age at recruitment from Southern Hemisphere Division 5 catch data. *Rep. int. Whal. Commn* 31: 839–42.

Allen, K. R. 1981. Comparison of estimated R_{II} recruitment rates for Division 5 with values in POPDYN models. *Rep. int. Whal. Commn* 31: 94.

Bannister, J. L., Taylor, S. and Sutherland, H. 1981. Logbook records of 19th century sperm whaling: A report on the 12 month project 1978–79. *Rep. int. Whal. Commn* 31: 821–34.

De la Mare, W. K. 1981. A comparison of observed and predicted apparent pregnancy rates for North Pacific sperm whales. *Rep. int. Whal. Commn* 31: 96–8.

Kirkwood, G. P. 1981. Estimation of Stock size using relative abundance data—a simulation study. *Rep. int. Whal. Commn* 31: 729–36.

Kirkwood, G. P. 1981. Tests for validation techniques: Kirkwood technique sperm whales Southern Hemisphere Division 5. *Rep. int. Whal. Commn* 31: 91–2.

Van Beek, J. G., and De la Mare, W. K. 1981. A statistical review of the biochemical evidence for minke whale stock identity in the Antarctic. *Rep. int. Whal. Commn* 31: 114.

SC/33/ProgRep Brazil

Brazil

Progress Report on Cetacean Research June 1980 to May 1981

Jesuina Maria da Rocha and Nadia Maria Alves Braga

Fisheries Research and Development Institute—PDP Fisheries Development Superintendence—SUDEPE

SPECIES STUDIED

Research on the whale species off Brazil has been developed and aided by SUDEPE/PDP since 1974. The main species caught (96%) is the minke whale and studies are now directed towards this species.

This paper presents data analysed or collected in 1980. A detailed description of the 1979 time budget is given along with sightings on the whaling ground.

REPRODUCTION

Minke whales

The same methodology as described in previous works (e.g. da Rocha, 1981) has been used to determine sexual maturity. Females with at least one corpus luteum (C.L.) or albicans (C.A.) are considered sexually mature. It is assumed that males with testes of more than 400 g were mature.

The average number or ovulations per mature female was lower in 1980 than in previous years, although the frequency of mature females in the catch remained the same (Table 1, Fig. 1). This effect may be due to the earlier start to the whaling season compared to previous years.

The ovaries usually contained a large number of follicles, 50–100, and sometimes more, especially in immature animals. In fact follicles of 4 cm diameter were observed, although these are only useful as relative measurements as they are affected by the preservation methods. Ova were found in four of the analysed ovaries. The ova were compact structures, very different from the follicular mass. They were not damaged during cutting, probably due to the gelatinous consistency of the follicles. Information on the relevant females is contained below:

Catch date	Length (ft)	No. of C.A.s	C.L.
20 Sep. 1980	28	12	yes
23 Sep. 1980	28	—	—
6 Nov. 1980	33	8	yes
14 Nov. 1980	29	13	yes

Occasionally such ova have been seen when the ovaries were sectioned. Their position near the surface of the ovary indicates that ovulation is imminent.

The proportion of mature to immature (Table 1) males is greater than for females, probably due the inadequacy of the criterion used. In order to examine this, histological analysis of testis tissue has been started. Preliminary results are given in Table 2. Analysis of material from the 1980 and 1981 seasons is continuing.

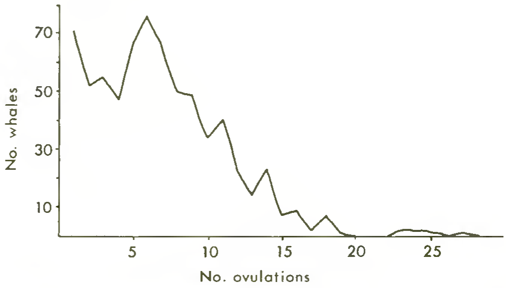

Fig. 1. Frequency distribution of ovulation number for minke whales, 1979–80.

Table 1

Percentage mature of the examined catch of minke whales, 1980 (total catch 902)

	Males			Females			Males + females		
Months	Total	Mature	%	Total	Mature	%	Total	Mature	%
Jun.	1	—		3	1	75.0	4	1	25.0
Jul.	30	24	80.0	54	26	48.0	84	50	59.5
Aug.	46	42	91.0	62	40	64.0	108	82	75.9
Sep.	68	65	95.0	120	84	70.0	188	149	79.3
Oct.	90	89	98.0	189	153	80.0	279	242	86.7
Nov.	62	62	100.0	119	112	94.0	181	174	96.1
Dec.	17	17	100.0	22	22	100.0	39	39	100.0
Total	314	299	95.0	569	438	76.0	883	737	83.4

Table 2

Histological analysis of minke whale testis tissue

Catch date	Length (ft)	Testis weight (g) Right	Left	Results
3 Jul.	29	1,950	2,050	mature—with spermatid
3 Jul.	27	2,000	1,900	mature—with spermatid
13 Jul.	27	2,200	2,000	immature—primary spermatocyte
13 Jul.	27	600	700	immature—primary spermatocyte
18 Jul.	28	1,500	1,400	immature—primary spermatocyte
30 Jul.	24	300	300	immature—primary spermatocyte
1 Aug.	28	1,600	1,900	immature—primary spermatocyte
2 Aug.	27	2,500	2,600	immature—primary spermatocyte
6 Aug.	28	2,100	2,100	immature—primary spermatocyte
8 Aug.	28	2,000	2,100	immature—primary spermatocyte
10 Aug.	28	1,900	2,000	mature—with spermatid
12 Aug.	25	600	500	mature—with spermatid
15 Aug.	27	2,500	2,500	mature—secondary spermatocyte
18 Aug.	28	1,100	1,100	mature—with spermatid
20 Aug.	26	800	700	mature—with spermatid
22 Aug.	30	1,500	1,700	mature—secondary spermatocyte
25 Aug.	25	1,500	1,600	immature—primary spermatocyte
26 Aug.	27	1,500	1,500	immature—primary spermatocyte
26 Aug.	24	100	100	immature—primary spermatocyte

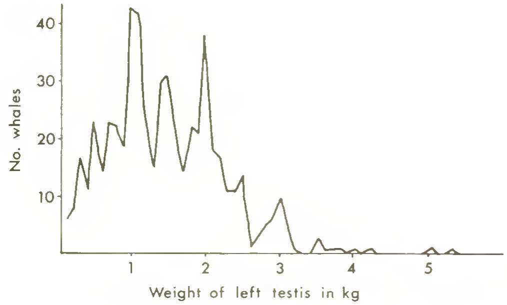

Fig. 2. Frequency distribution of left testis for minke whales, 1979–80.

Sperm whales

After examination of the ovaries of all captured females, only one (28 ft) was found to be immature. The mean length of the rest of the females was 31.7 ft (standard deviation 1.71).

The number of corpora varied between 1 and 11 but only 4 had a corpus luteum of less than 3.5 cm diameter; three whales were pregnant and a fourth had 2 corpora lutea. Information on the pregnant females is given below:

Catch date	Length (ft)	No. of ovulations	Foetus Sex	Foetus Length	Thickness of mammary gland
23 June	33	11	M	1.8 m	—
30 June	30	8	F	—	12 cm
30 June	31	2*	F	1.5 m	10 cm

* One ovary only.

Testes have been weighed and tissue samples for histological analysis have been collected. Although the number of samples available is not sufficient for a conclusive study on the sexual maturity of sperm whales, it is intended that all samples will be analysed.

GROWTH

Unfortunately our efforts to study the growth of whales captured along our coast have been as yet unsuccessful.

Although ear plugs have been collected many were damaged, and the few which were not were difficult to read, with great variation in the number of layers in the same size range animals. Ear plugs of young whales were particularly difficult to read. In spite of this SUDEPE is continuing to try and develop this research.

STOCK IDENTIFICATION

Of the 902 minke whales caught during the 1980 whaling season, three were visually distinct from the normal animals in this region.

The flippers of these animals had a white spot, in contrast to the all-black flippers normally found. However, other morphological characters such as number and position of ventral grooves were normal.

Although the animals were at the smaller end of length distribution of captured animals they were found to be mature, unusual for whales of this size taken off Brazil. The following data are available:

Catch date	Sex	Length (ft)	Testis weight (g)	No. of ovulations	No. of ventral grooves
13 Aug.	male	22.7	1,000 g	—	29
15 Aug.	male	23.4	1,000 g	—	23
27 Nov.	female	25.0	—	8	19

CATCH COMPOSITION

Table 3 shows the proportion of females in the catch for 1979 and 1980. This has not fallen, remaining at approximately two females to one male.

Table 3

Proportion of females in the minke whale catch, 1979 and 1980

Year	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1979	—	0.57	0.66	0.76	0.64	0.64	0.65	0.67
1980	0.75	0.64	0.59	0.64	0.68	0.66	0.57	0.65

TIME BUDGET AND SIGHTINGS DATA

Table 4 shows time budget data by month for 1979 and 1980.

It must be mentioned that the following information was not included:

—the period between the first hit and the death of each animal (about 5 min).

—the handling time (more or less constant at around 10 min);

—the time between delivering the catch at the land station and the beginning of resting in the port.

The towing time includes the time taken to collect the whales caught each day and return them to the land station. The time between port and fishing ground refers only to the outgoing journey, because the return is included in the towing time.

Table 4

Time budget (hours) for Brazilian minke whaling—1979 and 1980.

	From the port to the fishing ground		Searching		Chasing		Towing		Resting		Whales seen		Whales caught		Days of whaling	
Months	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
Jun.	—	9.33	—	97.67	—	8.97	—	25.95	—	91.11	—	5	—	4	—	10
Jul.	20.53	30.58	91.75	275.05	25.58	40.58	46.93	92.92	142.61	262.87	69	124	47	84	15	31
Aug.	29.67	30.67	223.20	263.27	50.63	46.92	91.82	110.42	291.23	241.22	175	168	124	113	31	31
Sep.	30.60	41.90	138.70	193.07	77.45	77.20	95.57	121.22	270.54	189.34	307	288	179	191	29	29
Oct.	31.42	47.58	177.68	153.58	84.83	123.18	121.28	146.58	242.12	178.26	339	460	213	284	31	31
Nov.	37.83	53.92	219.22	197.03	71.95	96.08	107.40	138.45	218.02	169.89	182	280	131	186	30	30
Dec.	30.17	59.13	271.97	187.93	20.98	26.12	86.00	84.83	179.77	103.87	51	45	44	40	26	20
Total	180.22	273.11	1,122.52	1,367.60	331.42	419.05	549.00	720.37	1,344.29	1,236.56	1,123	1,370	738	902	162	182

Table 5

Months	Whales seen/ searching 1979	1980	Whales caught/ chasing 1979	1980	Whales caught/ towing 1979	1980	Whales seen chasing 1979	1980
Jun.	—	0.05	—	0.45	—	0.15	—	0.56
Jul.	0.75	0.45	1.84	2.07	1.00	0.90	2.70	3.01
Aug.	0.78	0.63	2.45	2.40	1.35	1.02	3.46	3.58
Sep.	2.21	1.49	2.31	2.47	1.87	1.58	3.96	3.73
Oct.	1.91	2.99	2.51	2.31	1.76	1.94	4.00	3.73
Nov.	0.83	1.42	1.82	1.94	1.22	1.34	2.53	2.91
Dec.	0.19	0.23	2.10	1.53	0.51	0.47	2.43	1.72
Annual average	1.00	1.00	2.23	2.15	1.34	1.25	3.39	3.27

In 1980, from the 5–20 November, a tugboat was used (for 97.5 hours) to gather and tow part of the catch. This period is not included in the time budget shown in Table 4 because this procedure was only of an experimental nature.

Sighting and other data on the catch are reported in Table 5. Data were also collected on minke whale school size (Table 6).

Table 6

Frequency distribution of minke whale school sizes, 1980

Size of School	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1	1	16	38	30	30	37	22	174
2	2	24	37	34	40	27	4	168
3		10	10	25	24	17	3	89
4		2	4	12	11	6		35
5		2	2	5	9	6		24
6		2		1	7	3	1	14
7				2	8	3		13
8				1	4	1		6
9					2	1		3
10					3			3
11					1	1		2
12								
13								
14				1				1
15								
16								
17						1		1

Sightings data for other species are given in Table 7.

Table 7

Number of whales sighted (excluding minke whales)

Year	Sperm	Sei	Humpback	Blue
1979	165	3	6	1
1980	186	14	3	1

STOMACH CONTENTS

The stomachs of all examined whales were empty, with the exception of some algae and small worms.

MATERIAL WAITING FOR TREATMENT

Only testis samples from the 1980 catch have still to be analysed and it is hoped that this will be carried out in the coming year and the results presented in the next progress report.

DISTRIBUTION OF LENGTH FREQUENCY

Table 8 and Fig. 3 show the distribution of length frequency in the Brazilian minke whale catch for the years 1966–80. No overall decrease in length frequency during this period has been observed.

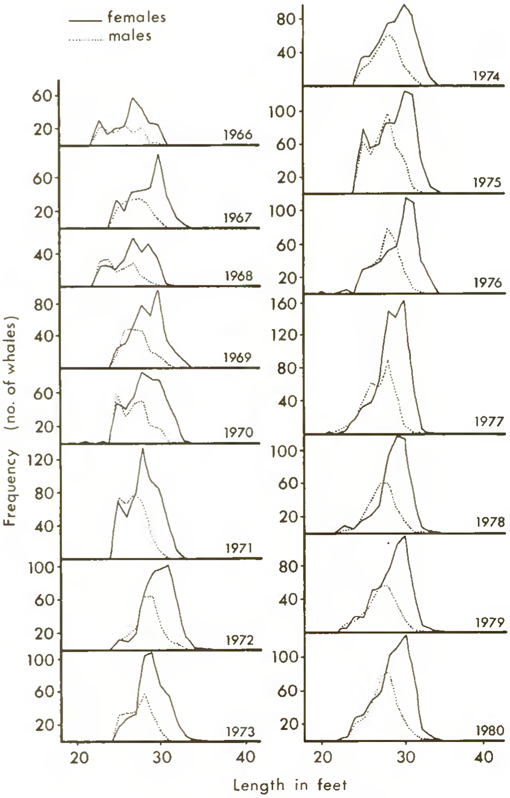

Fig. 3. Length distribution of minke whales, 1966–1980.

Table 8

Length distribution of minke whales captured in Brazil

Length (feet)	1966		1967		1968		1969		1970		1971		1972		1973		1974		1975		1976		1977		1978		1979		1980	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—
22	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	2	—	—	1	—	—	—	—
23	22	30	—	—	29	26	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	4	9	4	3	8	10	6	2	3
24	18	12	—	—	33	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	16	17	5	5	11	18	20	27
25	14	20	23	34	18	20	19	25	59	49	76	72	11	12	32	19	21	34	63	77	28	30	37	31	15	15	23	16	26	28
26	25	21	31	20	23	32	49	30	31	40	67	50	17	9	34	28	30	34	46	53	33	32	61	35	39	21	37	50	44	46
27	15	59	35	43	29	61	47	51	47	56	78	77	26	20	37	33	47	51	69	60	41	38	57	63	59	33	56	53	74	56
28	22	45	34	44	12	41	46	81	51	87	67	136	64	66	59	103	63	76	97	86	80	52	90	147	60	93	55	73	80	100
29	3	27	23	47	5	52	21	63	22	77	31	96	65	91	34	107	50	76	57	85	60	56	47	140	30	118	35	105	42	110
30	1	25	9	90	2	34	15	97	18	76	10	82	30	96	12	66	24	99	39	125	26	114	9	162	13	115	13	117	18	126
31	—	1	—	38	—	3	6	34	3	50	—	42	11	103	1	55	10	84	7	121	7	109	2	57	1	46	2	49	7	77
32	—	—	—	14	—	1	1	20	2	29	1	12	8	54	1	22	1	47	—	40	2	38	—	5	1	6	—	7	1	11
33	—	—	—	5	—	—	—	10	—	2	—	1	—	16	—	5	—	12	—	10	—	20	—	2	—	1	—	2	—	3
34	—	—	—	—	—	—	—	—	—	—	—	1	—	2	—	1	—	1	—	2	—	1	—	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—
36	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
37	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
38	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
39	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	120	240	155	335	151	296	204	413	233	468	330	570	232	470	210	441	246	515	379	659	279	497	330	664	226	462	242	496	314	587
$\bar{X}$	25.6	26.8	27.2	28.7	25.4	27.0	27.4	28.7	27.1	28.4	26.8	28.1	28.4	29.8	27.4	28.9	27.8	29.1	27.5	28.8	27.8	29.3	27.0	28.5	27.3	28.7	27.1	28.4	27.3	28.0
s	1.86	2.12	1.45	2.02	1.84	2.18	1.54	1.99	1.69	2.06	1.42	1.89	1.56	1.77	1.52	1.83	1.57	2.09	1.70	2.20	1.61	2.23	1.69	1.80	1.50	1.77	1.74	1.97	1.7	2.0

SC/33/ProgRep Canada

Canada
Progress Report on Cetacean Research
June 1980 to May 1981

Edward Mitchell

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1. SPECIES AND STOCKS STUDIED

Studies continued on the analysis of data and on previous biological collections from northwest Atlantic blue, fin, sei, minke, humpback and sperm whales. Related work on the history of exploitation of severely depleted species of cetaceans continued with emphasis on bowhead, humpback and right whales (E. Mitchell, M. Kozicki, R. Reeves). Research on Newfoundland whales emphasized aerial surveys (K. Hay) and studies of cetacean net-entanglements in fishing gear (J. Lien and staff).

Research on Arctic cetaceans included: surveys of beluga and bowhead (T. Smith and staff, P. Brodie, M. Fraker and K. Finley); behaviour studies of beluga in Cunningham Inlet (T. Smith and staff); compilation of catch-statistics (G. Horonowitsch, R. Peet and staff, Makivik Corp.); and work on the biology of narwhals (E. Mitchell and staff).

In the North Pacific, research continued on the population dynamics and pod-specific vocalization patterns of killer whales off British Columbia (M. Bigg and J. Ford).

2. FIELD OBSERVATIONS AND COLLECTIONS

No special permits were required. Some limited work continued on collections of biological materials from whales killed at Nova Scotia and Newfoundland during the last episode of Canadian whaling. A few stranded animals were examined. Censuses were carried out in Newfoundland and Labrador waters. K. Hay's summary of these censuses follows:

(a) From 1–22 August 1980, a large-scale aerial sampling survey in the eastern Newfoundland and S.E. Labrador marine areas was completed. Line-transect estimates of whale abundance were made in the survey area (47°48′N to 55°00′N and seaward to about 100 nautical miles).

(b) Two whale observers accompanied the research vessel *Gadus Atlantica* from 12 June to 7 July 1980 during a capelin survey in the Grand Banks region, where observations of humpbacks were made on the southeast shoal.

(c) Two observers accompanied the same vessel on a capelin survey off N.E. Newfoundland and S.E. Labrador from 18 October to 23 November 1980, but line-transect estimates of abundance were not attempted owing to a scarcity of sightings. High sea states were commonly encountered during this research cruise.

(d) John Parsons of MacLaren-Plansearch Ltd conducted aerial surveys and opportunistic vessel surveys of whales in the Grand Banks region from March 1980 to April 1981, as part of a contract with Mobil Oil Canada Ltd to undertake biological oceanographic studies of the Grand Banks region.

H. Whitehead of Cambridge University, England, completed a study of humpback whale feeding ecology and social behaviour in the Bay de Verde, Newfoundland area during June and July 1980.

J. Lien of Memorial University of Newfoundland completed the second field season of his research into the documentation, causation, and prevention of baleen whale collisions with inshore fishing gear in the Newfoundland–Labrador region (Tables 1 and 2). His staff also investigated strandings of whales where the cause of death was unknown (Table 3).

D. E. Gaskin's research programme included: (a) work on the biology and ecology of harbour porpoise in eastern Canadian waters and (b) work on the interrelationships of upper trophic level animals in the Bay of Fundy approaches (an ecological and energetics study of the pelagic food web of this region, with special attention to marine mammals and marine birds).

R. Peet reported that a Canadian government permit to capture three live beluga whales using the services of the Churchill Whales Cooperative was issued to the United States Navy, Naval Ocean Systems Center, San Diego, California. The following table summarizes data on the animals taken:

Animal number	Sex	Date collected	Length (cm)	Girth (cm)
1	F	15.7.80	271.0	145.2
2	F	16.7.80	260.9	156.0
3	F	16.7.80	270.4	147.3

Summer work on Arctic whales included aerial surveys in Lancaster Sound and behavioral observations and underwater recordings of beluga in Cunningham Inlet (T. Smith and staff).

P. Brodie and D. Sergeant, using aerial photography and visual counts, surveyed the Cumberland Sound belugas in August 1980. Poor conditions prevented collection of satisfactory data.

K. Finley and associates (LGL Ltd) studied the beluga of northern Quebec, addressing the problems of distribution, abundance, stock identity, catch history and management. M. Fraker (LGL Ltd) conducted a beluga and bowhead monitoring survey off the Mackenzie estuary.

In the Gulf of St Lawrence, A. Macfarlane monitored boat and whale activity in the mouth of the Saguenay River to document the impact of vessel traffic on the beluga population. He accompanied whale-watching excursions for the same reason. J. Martin Hughes is attempting to estimate the population size and net production of beluga in the St Lawrence by means of visual counts and observations.

Fifteen whale strandings were reported in the Gulf this year. These are summarized in Table 3.

M. Bigg continued studies of abundance, population dynamics and behaviour of killer whales off British Columbia. Acoustics of these pods is under study by J. Ford (University of British Columbia).

D. MacAlpine, Canadian IWC observer, facilitated the acquisition, by the New Brunswick Museum, of a sperm whale skull and a sei whale skeleton from Iceland.

3. TAGGING

No whales were tagged and no tags recovered from whales during this period of review.

4. LABORATORY WORK

Work continued on data from the 1965–72 eastern Canadian whale fishery. Analysis of computerized data has begun. Some computer work was carried out at the US National Marine Mammal Laboratory in Seattle, Washington, with J. Breiwick during M. Kozicki's visit (9–30 March 1980).

R. Reeves began a study to reconstruct catch history, to estimate initial population abundance and to assess the current status of the northwest Atlantic humpback whale.

A. Macfarlane is indexing data collected during the period 1973–75, from a land-based whale observations site on the St Lawrence River near Les Escoumins. A blue, fin and minke whale data base is being summarized preparatory to analysis.

5. DEVELOPMENT OF TECHNIQUES

K. Hay is developing a protocol for application of line transect theory to sightings of great whales, from aerial surveys at sea. J. Lien is continuing experiments on alarm systems designed to reduce mysticete collisions with fishing gear.

6. RESEARCH RESULTS

Results for the period of this review are given in publications and working documents cited below in Sections 9 and 10.

7. 1980 CATCHING OPERATIONS

Commercial whaling for large cetaceans was terminated in Canada in December 1972.

The accidental catch of whales in fishing gear in Newfoundland is summarized in J. Lien's tables (Tables 1 and 2).

No Canadian purse seiner was engaged in tuna fishing during the review period, with the exception of one small vessel that was active briefly on the Pacific coast. This vessel is not equipped to fish tuna from porpoise-associated schools (J. Beckett).

A female minke whale (*B. acutorostrata*) was shot and harpooned by local people in Pangnirtung Fjord on the 1st or 2nd of October 1980. The killed whale was one of 'many' of the same species seen in the area over a period of 3 to 4 weeks, feeding on schools of small fish, 'Ugaks'. The carcass, with buoy, floated to the surface on 4 October. It was towed ashore and left unutilized (G. Williams).

With government permits, D. Gaskin collected two harbour porpoises for heavy metals and organochlorine hydrocarbon analysis. The porpoises were taken near Barnes Island, N.B., on 8–9 August 1980 (135 cm male and 149 cm non-pregnancy female).

Catches of Arctic small cetaceans by Inuit have continued. Available catch statistics are given (Table 4) by species and by settlements for the Canadian Arctic. They are grouped by area, and compared with earlier catches, as previously reported to the Bureau of International Whaling statistics. There were no reported catches from Northern Ontario. Communities with a history of such catches are shown in Fig. 1.

Following is a brief description of how the Arctic harvest statistics were compiled:

Beluga: from all areas except Northern Quebec and eastern Hudson Bay—government officials visited settlements and received verbal accounts of numbers of whales landed. These figures were submitted as the official statistics (B. Wong, *pers. comm.* vi.81) from Northern Quebec and eastern Hudson Bay—Makivik Corporation undertook a study, in 1975, to determine sustainable levels of Inuit harvest of wildlife in this area. They began compiling beluga catch data by interviewing hunters and asking them to recall their catches for the 1973 and 1974 seasons. From 1975 to 1980 inclusively, hunters were asked to keep running written records of their landed catch. They were asked to note data and area of catch. Makivik workers visited the settlements every three or four months to insure that records were being kept. Using these records, best estimates of total landed catch were calculated for each community, resulting in the figures which were submitted as the official statistics. (See Anon., 1976; Anon., 1979; Boulva, 1980 MS; all cited in the last Canadian Progress Report (*Rep. int. Whal. Commn* 31: 171–9). The Makivik contract to generate these statistics ended in December 1980. [L. Brooks, *pers. comm.* 81.vi.81]).

Narwhals: all hunters apply for tags prior to hunting. Tags are limited according to settlement quotas. All narwhals, male and female, must be tagged when landed and the stub of the tag returned to the officer who issued the tag. The number of returned tag stubs constitutes the official landed catch statistics for narwhals (Narwhal Protection Regulations, 1980).

The Arctic harvest statistics represent reported landings, not total kills. The totals do not include lost or abandoned

Hay, K. 1981. Age determination of the narwhal, *Monodon monoceros* (L.). *Rep. int. Whal. Commn* (special issue 3): 119–32.

Mitchell, E. 1981. Canada. Progress Report on Cetacean Research June 1979 to May 1980. *Rep. int. Whal. Commn* 31: 171–9.

Mitchell, E. and Reeves, R. R. 1980. The Alaskan bowhead problem: a commentary. *Arctic* 33(4): 686–723.

Mitchell, E. and Reeves, R. R. 1981. Catch history and cumulative catch estimates of initial population size of cetaceans in the eastern Canadian Arctic. *Rep. int. Whal. Commn* 31: 645–82.

Sergeant, D. E. 1981. On permissible exploitation rates of Monodontidae. *Rep. int. Whal. Commn* 31: 583–8.

Sergeant, D. E., St. Aubin, D. J. and Geraci, J. R. 1980. Life history and northwest Atlantic status of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*. *Cetology* 37: 1–12.

Smith, T., Siniff, D. B., Reichle, R. and Stone, S. 1981. Coordinated behavior of killer whales, *Orcinus orca,* hunting a crab-eater seal, *Lobodon carcinophagus*. *Can. J. Zool.* 59(6): 1185–9.

10. WORKING DOCUMENTS

Not all documents listed will be formally published, and those that are may be substantially modified in the final form:

Davis, R. A. 1981. Report of a Workshop on Arctic Marine Mammals. Department of Fisheries and Oceans, Winnipeg, Manitoba R3T 2N6. Canadian Technical Report of Fisheries & Aquatic Sciences No. 1005, p. i–iv + 1–13.

Finley, K. J. and Miller, G. W. 1980. The 1979 hunt for narwhals (*Monodon monoceros*) and an examination of harpoon gun technology near Pond Inlet, Northern Baffin Island. [Prepared by] LGL Limited, Toronto. For Department of Economic Development and Tourism, Government of the Northwest Territories, Yellowknife, N.W.T. p. i–iii + 1–57.

Finley, K. J., Miller, G. W., Allard, M., Davis, R. A. and Evans, C. R. Ms 1981. The white whales (*Delphinapterus leucas*) of northern Quebec: distribution, abundance, stock identity and catch history. Paper SC/33/SM9 presented to the IWC Scientific Committee, June 1981. p. 1–23 + Figs 1–24 typescript.

Gaskin, D. E. and Smith, G. J. D. 1979. Observations on marine mammals, birds, and environmental conditions in the Head Harbour region of the Bay of Fundy. p. 69–86 *In:* D. J. Scarratt (ed.) Evaluation of Recent Data Relative to Potential Oil Spills in the Passamaquoddy Area. Department of Fisheries and Oceans, St. Andrews, N.B., EOG 2X0. Fisheries and Marine Service Technical Report No. 901. p. i–iv + 1–107.

Hay, K. Ms 1981. Aerial line-transect estimates of abundance of humpback, fin, and long-finned pilot whales in the Newfoundland–Labrador area. Paper SC/33/O 4 presented to the IWC Scientific Committee, June 1981. [Revised and published in this volume.]

Hay, K. Ms 1981. Line-transect estimates of whale abundance in the Newfoundland–Labrador Area, 1980. Paper presented to Canadian Atlantic Fisheries Scientific Advisory Committee, Halifax, April 14, 1981. CAFSAC Working Paper 81/9, p. 1–35 + Tables 1–17 + Figs 1–40 typescript.

Hay, K and McKinnon, D. Ms 1981. Inshore whale survey by helicopter in the Newfoundland–Labrador Area, 1980. Paper presented to Canadian Atlantic Fisheries Scientific Advisory Committee, Halifax, 14 April 1981. CAFSAC Working Paper 81/97, p. 1–4 + Table 1 + [i–ii] + Figs 1–11 typescript.

Hughes, J. M. Ms 1981. Estimates of production, birth rate and adult recruitment rate of white whales (*Delphinapterus leucas*) in the St. Lawrence Estuary. Preliminary Draft Contract Report for Department of Fisheries and Oceans, Quebec City. Contract No. FP401-0-3276, p. [i–ii] + 1–26 + Chart 1 + Tables 1–9 [12 unnumbered pages] + Appendix [i–vi] + Figs 1–4 + References [i–ii] typescript.

Lien, J. 1980. Final Report: whale entrapment in inshore fishing gear in Newfoundland. 31 December 1980. Memorial University of Newfoundland, St. John's, Newfoundland. p. 1–316 + Appendix.

Lien, J. Ms 1981. Humpback whale collisions with inshore fishing gear. Draft. Paper presented to Canadian Atlantic Fisheries Scientific Advisory Committee, Halifax, 14 April 1981. CAFSAC Working Paper 81/99, p. [i–iii] + 1–65 + Tables 1–7 + Figs 1–16 typescript.

Lien, J. Ms 1981. Whale collisions with inshore fishing gear in Newfoundland. Paper SC/33/PS13 presented to the IWC Scientific Committee, June 1981. p. [i–ii] + 1–98 typescript.

Macfarlane, J. A. F. Ms 1981. Reactions of whales to boat traffic in the area of the confluence of the Saguenay and St. Lawrence Rivers. Preliminary Draft Contract Report for Department of Fisheries and Oceans, Quebec City. Contract No. FP401-0-2323, p. 1–28 + Figs 1–3 + Tables 1–8 [19 unnumbered pages] typescript.

McLeod, P. F. Ms. Recent mass strandings of the long-finned pilot whale (*Globicephala melaena,* Traill) in Newfoundland. Paper presented to Canadian Atlantic Fisheries Scientific Advisory Committee, Halifax, 14 April 1981. CAFSAC Working Paper 81/100, p. 1–20 + Tables 1–4 + Figs 1–4 typescript.

Mitchell, E. and Reeves R. R. 1981. Catch history, abundance, and present status of northwest Atlantic humpback whales. Paper SC/33/PS14 presented to the IWC Scientific Committee, June 1981. [Revised and to be published in *Rep. int. Whal. Commn* (special issue 5).]

Parsons, J. Ms 1981. Grand Banks wildlife series 1980–81. Paper presented to Canadian Atlantic Fisheries Scientific Advisory Committee, Halifax, 14 April 1981. CAFSAC Working Paper 81/96, p. [1–6] + Figs 1–51 + Tables 1–3.

Whitehead, H. Ms 1981. The humpback whale at Bay de Verde. Final Report to Canadian Government, Department of Fisheries and Oceans, St. John's, Newfoundland, January, 1981.

Table 1

Whale and shark entrapment in fishing gear 1969–80. Data reported from 1969–77 are from Perkins and Beamish (1979); 1978 data collected from survey of fishermen by Lien *et al.* (1979). 1979 and 1980 data based on calls received from fishermen for help in releasing whales from fishing gear; 1979 was the first year comprehensive data were available; data for previous years are largely retrospective and may be incomplete (Lien *et al.*, 1979, 1980). (Taken from J. Lien, MS. 1981.)

	Minke			Humpback			Fin			Other large whales			Sharks
Year	Dead	Released alive	?	Dead	Released alive	?	Dead	Released alive	?	Dead	Released alive	?	
1969	—	—	—	1	—	—	—	—	—	—	—	—	—
1970	—	—	—	—	—	—	—	—	—	—	—	—	—
1971	—	—	—	—	—	—	—	—	—	—	—	—	—
1972	—	—	—	—	1	—	—	—	—	—	—	—	—
1973	2	—	1	1	—	1							
1974	2	—	1	1	—	1	—	—	—	—	—	—	—
1975	2	—	1	1	1	3	—	—	1	—	—	—	—
1976	3	—	—	1	2	—	—	—	—	—	—	—	—
1977	1	—	—	2	3	—	—	—	—	—	—	—	—
1978	2	—	—	6	3	2	—	—	—	1	—	—	—
1979	9	1	—	13	34	—	4	3	—	6	1	—	5
1980	9	3	—	17	44	—	1	2	—	8	1	—	65
	30	4	3	43	88	7	5	5	1	15	2	0	70

Table 2

Entrapments of whales in fishing gear in Newfoundland waters, 1980 (from J. Lien, MS 1981).
Abbreviations: H = humpback, P = pilot whale, F = fin, M = minke.

Date	Length	Species and number	Sex	Status	Gear	Location
15 May	?	1H	?	Alive	Gill	Dildo, T.B.
17 May	15.2–18.3	1F	?	Alive	Gill	Daniels Hbr.
30 May	9.1–12.2	2H	?	Dead	Gill	Daniels Hbr.
18 June	12.2	2H	?	Alive	Crab pots	Port de Grave
21 June	10.7–12.2	1H	?	Alive	Gill	Deadmans Cv., St Barbe
23 June	8.5	1H	m	Dead	Gill	Bay de Verde
23 June	?	1H	?	Alive	Gill	Greenspond, B.B.
24 June	10.7	1H	m	Dead	Trap	Blackhead, C.B.
25 June	10.7	1H	?	Alive	Trap	Bonavista
25 June	9.1	1H	m	Dead	Trap	St Vincents
26 June	7.6	1M	?	Dead	Trap	Portugal Cv. S.
27 June	9.4	1H	?	Alive	Trap mooring	St Vincents
29 June	6.1–6.7	1H	?	Alive	Trap	Torbay
29 June	?	1H	?	Alive	Trap	St Vincents
30 June	?	2H	?	Alive	—	Bar. Haven, P.B.
1 July	7.9	1H	?	Alive	Salmon net	Duntara
5 July	?	1H	?	Alive	Salmon net	Sibley's Cv.
5 July	?	1M	?	Dead	Salmon net	Newton, B.B.
6 July	13.7–7.6	2H	?	Alive	Gill	Conception B. near Bell Isle
6 July	7.3	1H	?	Alive	Trap	St Vincents
7 July	?	1H	?	Alive	Gill	Trepassey
8 July	?	1H	?	Alive	Trap	Port de Grave
9 July	10.7	1H	?	Alive	Trap mooring	Gaskiers, S.M.B.
9 July	?	1H	?	Alive	Trap	Pt. La Haye, S.M.B.
11 July	9.1	1H	?	Dead	Salmon net	Old Perlican
11 July	4.0	1P	?	Alive	Trap	Whiteway, T.B.
12–13 July	?	1H	?	Alive	Trap	Pouch Cove
14 July	9.1	1H	?	Dead	Trap	Grates Cv.
14 July	9.1–10.7	1H	?	Dead	Gill	Port Cove S.
14 July	10.7–12.2	2H	?	Dead	Trap mooring	Mal Bay, S.M.B.
15 July	7.3	1H	?	Alive	Gill-salmon net	Newtown, B.B.
16 July	9.1	1M	?	Dead	Salmon trap	Bonavista
17 July	8.2	1H	?	Alive	Trap	Cobbs Arm N.W.
18 July	9.1–12.2	1H	?	Dead	?	Eddies Cove near Gt. N.
20 July	7.3	1H	?	Alive	Gill	Trepassey/St Shotts
20 July	7.6–9.1	1H	f	Dead	Trap	Belle Island, N.D.B.
20 July	4.6–6.1	1M	?	Dead	Trap	Gooseberry Cv. T.
21 July	9.1	1M	?	Alive	Trap	St Vincents
23 July	9.1	1H	?	Alive	Gill	Riverhead, S.M.B.
23 July	12.2	1H	?	Dead	Salmon net	Salvage, B.B.
24 July	?	1H	?	Alive	Trap	St Vincents, S.M.B.
24 July	?	1H	?	Dead	Gill	Greenspond
24 July	9.1	1M	?	Dead	Gill	Ragged Isl., T.B.
25 July	16.8	1F	—	Alive	Gill	Little Hear Ease T.B.
25 July	6.7	1M	m	Dead	Trap	Port de Grave
26 July	9.1	1H	?	Dead	Salmon net	Bonavista
26 July	?	1H	?	Alive	?	Holyrood, C.B.
28 July	?	1H	?	Alive	Trap	Colliers Pt., C.B.
28 July	12.2	1H	?	Dead	Trap	Stag. Hbr. Fogo Isl.
29 July	4.6	1M	f	Dead	Salmon net	Porte de Grave
30 July	9.1–10.7	1H	?	Alive	?	Cape Spear near Petty Hbr.
31 July	6.1	1H	?	Dead	Trap	Red Head Cv.
31 July	1.8	1P	?	Alive	Gill	Old Perlican
1 Aug.	3.7	1P	?	Dead	Gill	Bay de Verde
3 Aug.	6.1	1M	m	Dead		Kelly's Isl., C.B.
4 Aug.	9.1	1F	?	Dead	Herring net	St John's Castor R.
7 Aug.	12.2	1H	?	Dead	Gill	Daniels Hbr.
7 Aug.	9.1	1H	?	Alive	Gill	Bay de Verde
11 Aug.	3.6–4.3	1M	?	Dead		Portugal Cv. S.
12 Aug.	10.7–12.2	1H	?	Alive	Gill	Horse Chops, T.B.
15 Aug.	?	1H	?	Alive	Herring/gill	St John's Bay, St Barbe
15–21 Aug.	8.2	1M	?	Alive	Gill	Trinity East
19 Aug.	9.1	1H	?	Dead	Gill	St Brides
20 Aug.	12.2	1H	?	Alive	Gill	Horse Chops, T.B.
21 Aug.	6.1–7.6	1P	?	Dead		Hillgrade, N.D.B.
25 Aug.	12.2–15.2	1H	?	Alive	Gill	Labrador
25–30 Aug.	7.6	1M	?	Alive	Gill	Old Bonaventure
3 Sept.	11.3–11.6	1H	?	Alive	Gill	Normans Cv.
3 Sept.	2.4–3.0	1P	?	Alive		Chapel Arm, T.B.
5 Sept.	?	1H	?	Alive	Trap	Dildo
10 Sept.	5.5–6.1	1P	m	Dead	Squid-trap	New Harbour
5 Oct.	?	1H	?	Alive	Gill	Conception Bay

Table 3

Reported strandings of cetaceans in eastern Canada, 1980–81. Newfoundland data supplied by J. Lien (*pers. comm.* 20.vi.80). Novia Scotia data supplied by B. Beck (*pers. comm.* 15.vi.80).

Record no.	Date of stranding	Number and species	Date of discovery/ examination	Locality and coordinates	Total length	Sex	Outcome	Evidence	Authority	Remarks
1	?	1 Sperm	16.iv.80	Carbonear, C.B. Nfld 47°43′N, 53°10′W	6.5 m	M	Left on beach	Examined by K. Hay	K. Hay, J. Lien	Teeth collected
2	May 1980	1 *P. phocoena*	26.v.80	Percé, Quebec 48°30′N, 64°10′W	115 cm	M	Dissected	Photos, measured by H. Powles	H. Powles	Skull saved
3	May 1980	1 Beluga	7.vi.80	Iles aux Lièvres, Quebec 47°50′N, 69°45′	~350 cm	?	?	Photos by D. Banville	J. Boulva	Advanced stage of decomposition
4	6.vi.80	1 Minke	8.vi.80	Roseville Shore P.E.I. 46°55′N, 64°13′W	~790 cm	F	Buried	Photos, measured by M. Ring	M. Ring	Wire cable around tail, scarred and slashed
5	9.vi.80	1 Minke	10.vi.80	Miminegash, P.E.I. 46°56′N, 64°12′W	670 cm	F	?	Photos, measured by M. Ring	M. Ring	Mackerel net around tail; dead about 1 week; relatively unscarred
6	Early June 1980	1 Sperm	18.vi.80	Long Beach, Vancouver Island, B.C. 49°00′N, 125°30′W	~1,165 cm	M	Left on shore	Examined by M. Bigg, tooth removed (a)	M. Bigg	Stranded alive, died shortly after
7	*c.* 20 June 1980	1 Minke	*c.* 25.vi.80	Harrington Harbour, Quebec 50°30′N, 59°30′	~800 cm	F	Left on shore	Examined by K. Blanchard-French. Photos, baleen and jaws collected	K. Blanchard-French	Whale entangled in leader of cod-trap. Drowned. Brought ashore by B. Cox
8	?	1 Pilot whale	7.vii.80	Holy Rood, S.M.B., Nfld 46°50′N, 53°40′W	~525 cm	F	Left on beach	Examined by J. Lien	J. Lien	K. Hay received teeth
9	?	1 Beluga (?)	28.vii.80	Pointe-aux-Outardes, Quebec 49°05′N, 68°20′W	~380 cm	?	?	Photos by M. Morin	J. Boulva	This was the second whale stranding in two weeks; no data on first
10	29.vii.80	1 *P. phocoena*	29.vii.80	Black Point, N.B. 47°55′N, 65°49′W	152 cm	M	Left on beach	Examined by Gildard Chaisson, DFO	B. Beck	Came ashore dead
11	Mid-Aug. 1980	1 Minke	Late Aug. 1980	Hopetown, Baie des Chaleurs, Quebec 48°02′N, 65°08′W	~700 cm	?	Washed away	Photos, examined by D. Attendue	D. Attendue	Late stage of decomposition; vertebrae and jaw collected
12	?	1 Beluga (?)	20.x.80	L'Anse au Marcadet St Pierre (France) 46°46′N, 56°13′W	~300 cm	?	?	Seen by D. Abraham and R. Etchevery	P. Richard	Flukes missing
13	18–19.x.80	*c.* 75 Pilot whales	23.x.80	Point Leamington, Nfld 49°20′N, 55°24′W	1.5 m to 5.0 m	M&F	Buried	Examined by P. J. McLeod and associates from Memorial University (b)	J. Lien, P. J. McLeod	Details in P. J. McLeod, 1981 MS
14	25.x.80	*c.* 18 Pilot whales	25.x.80	Grand Beach, F.B., Nfld 47°08′N, 55°30′W	1.9 m to 5.1 m	M&F	Buried	Examined by P. J. McLeod and associates from Memorial University (c)	J. Lien, P. J. McLeod	Details in P. J. McLeod, 1981 MS
15	Mid-Sept. 1980	1 Minke	October	L'Anse aux Fraises Anticosti, Quebec 49°47′N, 64°20′W	830 cm	?	Left on shore	Photos by R. Sears	R. Sears	Advanced stage of decomposition

Record no.	Date of stranding	Number and species	Date of discovery/ examination	Locality and coordinates	Total length	Sex	Outcome	Evidence	Authority	Remarks
16	Early Oct. 1980	1 Fin	Late Oct. 1980	Baie St Claire Anticosti, Quebec 49°47′N, 64°20′W	~1980 cm	F?	Left on shore	Photos by M. Morin	R. Sears	Advanced stage of decomposition
17	6.xi.80	1 Minke	10.xi.80	Tea Hill Beach Charlottetown, PEI 46°11′N, 63°00′W	724 cm	F	Buried	Photos, measured by F. Herring (d)	F. Herring	Excellent condition, two punctures under right flipper
18	9–18.xi.80	52 Pilot whales	9–18.xi.80	Bedeque Bay, PEI 46°23′N, 63°48′W	250 cm to 450 cm	M&F	Buried	Photos, examined by S. Katona (e)	F. Herring, S. Katona	Buried by P.E.I. Fish. Dept. 5 whales preserved for dissection
19	?	1 Pilot whale	30.xi.80	L'Anse aux Meadow, Nfld 51°40′N, 55°25′W	?	?	Left on beach	Examined by C. Strong (Nfld Dept of Env.)	J. Lien	
20	?	1 Pilot whale	5.xii.80	Chance Cove, T.B., Nfld 47°44′N, 53°50′W	?	?	Left on beach	Examined by C. Strong (Nfld Dept of Env.)	J. Lien	
21	?	1 Humpback	30.xii.80	Salvage, B.B., Nfld 48°45′N, 53°45′W	~1,067 cm	?	Left on beach	Examined by A. Barfett, photos taken	J. Lien	Advanced state of decomposition
22	13.v.81	1 Sperm	13.v.81	Martinique Beach, N.S. 44°40′N, 63°20′W	~915 cm	M	Buried		B. Beck	Buried (in consolidated dunes) prior to examination
23	13–14.v.81	1 Fin (?)	14.v.81	Newport, Baie des Chaleurs, Quebec 48°15′N, 64°45′W	~1,650 cm	?	Left on beach	Examined by Attendue and Greendale. Vert. and humerus collected	D. Greendale, D. Attendue	Extremely decomposed. Tail missing, carcass falling apart, bones lost, rope tied around flipper
24		1 *D. delphis*		Bay Head, Colchester Co., N.S. 45°45′N, 63°05′W	244 cm	M	Left on beach	Examined by E. Canfield, ID by Baker and Sinclair, DFO	B. Beck	Came ashore alive
25	*c.* 26.viii.79	1 Beluga	27.viii.79	G. Bergeronnes, Quebec 48°14′N, 69°36′W	340 cm	F	Dissected	Photos, measured by L. Pippard	L. Pippard	Whale first recognized in 1977; named 'Broken Tail' by Pippard. Last seen alive early Aug. 79
26	Early Nov. 1979	7 *L. acutus*	?	Miminegash, PEI 46°55′N, 65°45′W	—	—	Left on beach	Examined by H. Scarth	B. Beck	1 died, 1 disappeared and 5 freed themselves

Abbreviations: S.M.B. = St Mary's Bay, C.B. = Conception Bay, B.B. = Bonavista Bay, T.B. = Trinity Bay,
F.B. = Fortune Bay.
P.E.I. = Prince Edward Island, B.C. = British Columbia, Nfld = Newfoundland
N.B. = New Brunswick, N.S. =Nova Scotia

(a) Newspaper article: St John, N.B., *Evening Times Globe*, 5 June 1980.
(b) Newspaper article: St John, N.B., *Evening Times Globe*, 24 Oct. 1980. Boston, Mass., *Globe*, 26 Oct. 1980.
(c) Newspaper article: St John's, Nfld., *The Evening Telegram*, 1 Nov. 1980. St John's Nfld., *The Daily News*, 5 Nov. 1980.
(d) Newspaper article: Charlottetown, P.E.I., *The Evening Patriot*, 11 Nov. 1980 and 18 Nov. 1980.
(e) Newspaper article: Summerside, P.E.I., *The Journal Pioneer*, 10 Nov. 1980 and 11 Nov. 1980.

Table 4

Canadian Arctic catch statistics, 1980. See text, section '7. 1980 Catching Operations' for comments.
Abbreviations: K = killer whale, B = bowhead whale, M = minke whale.

		Narwhal						Beluga (c)						Other					
Area	Community	1975	1976	1977	1978	1979	1980	1975	1976	1977	1978	1979	1980	1975	1976	1977	1978	1979	1980
1. Eastern Arctic	Arctic Bay	167	115	40	65	33	100				0	31	0						
	Broughton Island	5	6	10	26		49				0		1						
	Cape Dorset			0	2	1	1	12	10	7	21	7	43						
	Clyde River	15	15	35	4	9	35				0	0	0						
	Frobisher Bay			0	0	0	0	10	10		5	2	18						
	Grise Fiord		11		0	12	0	10	15	11	15	12	16						
	Hall Beach			13	0	2	11		10	18	9	7	—						
	Igloolik				0	108	11	25	22	15	18	28	—						
	Lake Harbour				0	0	0	20	41	26	3	35	12						
	Pangnirtung		10	1	2	28	22	50	120	178	82	70	43(d)			14K			1M
	Pond Inlet	77	125	99	150	94	96				0	2	0						
	Resolute Bay			2	14	2	0	11	11	17	1	6	—						
	Sanikiluaq				0		0	2		14	6		—						
	Creswell Bay		15		12						1								
	Sub-total	264	297	200	275	289	325	140	239	286	161	200	133			14K			1M
2. Western Arctic	Herschel Island											4							
	Aklavik										40	32	24						
	Inuvik										35	45	36						
	Paulatuk												0						
	Sachs Harbour												0						
	Tuktoyatuk							45			52	63	25						
	Banks Island												0						
	Mackenzie Delta							139	154	148			0						
	Sub-total							184	154	148	127	144	85						
3. Western Hudson Bay	Churchill					0						21							
	Chesterfield				0	0			20	18	3	6	11						
	Repulse Bay		8	8	4	30	25+?		34	40	0	24	7?	1B					
	Coral Harbour				0	0	0	7	42	52	24	44	62						
	Rankin Inlet				0	0	0	21	25	12	30	0	14						
	Eskimo Point				0	0	0	41	20	39	18	10	22						
	Whale Cove				0	0	0	20	5	30	37	0	8						
	Bathurst				0	0	0				—	0	0						
	Cambridge Bay				0	0	0				—	0	0						
	Pelley Bay				0	0	0				4	0	0						
	Spence Bay				0	0	0				0	0	0						
	Baker Lake				0	0	0				0	0	0				1K		
	Gjoa Haven				0	0	0				—	0	0						
	Coppermine				0	0	0	5			0	0	0						
	Holman Island				0	0	0	7			2	0	0						
	Sub-total		8	8	4	30	25+	101	146	191	118	105	124	1B			1K		

		Narwhal						Beluga (c)						Other					
Area	Community	1975	1976	1977	1978	1979	1980	1975	1976	1977	1978	1979	1980	1975	1976	1977	1978	1979	1980
Eastern Hudson Bay, James Bay and Northern Quebec (a)	Poste de la Baleine (Great Whale)							24	60	55	53	46							
	Inukjuaq							106	79	124	64	90							
	Akulivik							7	4	2	5	20							
	Sugluk (b)							159	66	104	36	20							
	Maricourt (Wakeham Bay)							174	98	118	62	52							
	Koartac							36	55	85	39	26							
	Bellin (Payne Bay)							48	44	79	10	3							
	Aupaluk								6	31	4	0							
	Baie aux Feuilles							9	3	23									
	Fort Chimo							64	102	30	13	30							
	Port N-Quebec (George River)							27	20	15	11	29							
	Port Burwell (Killinik)							15	9	16									
	Lease Bay											3							
	Sub-total							668	546	*682	*297	319							
	Totals	271	305	208	279	*319	350+	1093	1085	1307	702	768		1B		14K	1K		1M

(a) Two villages in northern Quebec (Povungnituk and Ivujivik) did not submit data on harvests (Boulva, 1981). Roy (1971, La chasse des mammifères marins chez les Ivunivimmiut. Cahiers de Geographie de Quebec, vol. 15, p. 509–521) indicated Ivujivik annual catch varied between 10–300 beluga, averaging 50–60 in 1962–64.

(b) Only 56% of the hunters of Sugluk submitted catch data (Boulva, 1981).

*(c) 1977, 1978 and 1979 northern Quebec beluga catches are preliminary only (Boulva, 1981, Boulva, *in litt.*, 14.v.81).

(d) The quota was exceeded by 3 animals due to communication difficulties between hunting parties (D. Goodman, *pers. comm.*, 25.vi.81).

('0' indicates none were taken, '—' indicates no knowledge of any taken, ( ) indicates unconfirmed report.)

SC/33/ProgRep Chile

Chile

Progress Report on Cetacean Research June 1980 to June 1981

Rene Maturana

Servicio Nacional de Pesca

SPECIES AND STOCKS STUDIED

This report gives information on the Chilean sperm whale fishery from the land station Macaya Hermanos at Caleta Chome, Talcahuano (36°40′S, 73°10′W). The whaling grounds lie within the Chilean 200 mile economic zone between 32°00′S and 37°00′S.

CATCH AND EFFORT

Only one boat, the *Indus 19* (498 tons, 2,300HP, built 1949) operated in 1981. It was not active in April and part of May while repairs were being carried out. Information on the 1981 catch is given in Table 1.

Table 1

Information on the 1981 sperm whale fishery

	Catch			
Month	Males	Females	Total	Effort[1]
January	16	6	22	20
February	10	6	16	24
March	3	1	4	20
April	0	0	0	0
May	2	0	2	5
June	11	9	20	21
Total	42	22	64	90

[1] Gross working day.

Table 2

Catch and Effort data for sperm whales, June and July 1980.

Month	Catch	Effort[1]	No. of Boats
June	15	20	1
July	7	15	1
Total	22	35	1

[1] Gross working day.

The last report (Maturana, 1981) gave information on the 1980 catch up to May. Table 2 gives the 1980 data for June and July.

SIZE COMPOSITION IN 1981

The size composition of the 1981 catch by month is given in Table 3.

SIGHTINGS

Sightings data for 1979–81 by month are given in Table 4.

Table 4

Sightings data for 1979–81

Year	Month	Blue	Fin	Sei	Sperm
1979	Jan.	—	—	30	7
	Feb.	—	—	19	—
	Mar.	—	—	17	40
	Apr.	2	1	46	—
	May	3	1	37	24
	June	2	—	6	7
1980	Jan.	1	—	72	38
	Feb.	2	—	44	27
	Mar.	1	2	37	31
	Apr.	—	—	12	47
	May	4	3	7	17
	June	—	1	2	9
	July	1	—	1	3
1981	Jan.	—	—	55	88
	Feb.	12	4	50	65
	Mar.	28	5	34	41
	Apr.	—	—	—	—
	May	10	7	3	9
	June	18	14	19	37

PUBLICATION

Maturana, R. 1981. Chile. Progress Report on Cetacean Research, 1966–May 1980. *Rep. int. Whal. Commn* 31: 181–3.

Table 3

Size composition and mean length of sperm whales caught in 1981

Length	January	February	March	April	May	June	Total
12.0	0	1	2	0	0	12	15
12.5	3	0	0	0	0	4	7
13.0	1	4	1	0	0	4	10
13.5	1	1	0	0	0	0	2
14.0	8	2	0	0	1	0	11
14.5	5	2	1	0	0	0	8
15.0	4	3	0	0	1	0	8
15.5	0	2	0	0	0	0	2
16.0	0	1	0	0	0	0	1
Total	22	16	4	—	2	20	64
Mean	14.0	14.2	13.0	—	14.6	12.2	13.5

Denmark (Greenland) Progress Report on Whale Research June 1980 to May 1981

F. O. Kapel

SPECIES AND STOCKS STUDIED

Statistical information on the catch of whales and porpoises in Greenland was collected, but the reports received so far are exceptionally incomplete. Table 1 presents the available data of the 1980 catches compared with (preliminary) figures for 1979, but it must be stressed that the estimates for total catch are of a very preliminary nature.

For this reason it is not yet posible to comment on the hunting results in 1980 as compared with previous seasons.

FIELD OBSERVATIONS AND COLLECTIONS

Danish scientists participated 27 June–30 August 1980 in the operations of the Norwegian small-type whaling vessel operating off West Greenland. Observations on weather conditions, whale sightings, and catching were recorded, and biological material collected from 71 minke whales.

In March–April 1981 a Danish scientist participated in an aerial survey conducted by LGL Ltd, Toronto, for Arctic Pilot Project (Petro Canada, Calgary). The main purpose of the survey was to investigate distribution and densities of marine mammals in southern Baffin Bay and Davis Strait. Weather conditions were very favourable, and good coverage of the total area was obtained.

MARKING

Immediately after the whaling season the above mentioned Norwegian vessel began a marking cruise, jointly funded by Norway and Denmark. Unfortunately, the cruise had to be discontinued after five days due to technical difficulties (leakage). The result of the marking activity was (detailed data are given in Appendix I):

Minke whales:	1 hit, 2 missed.
Fin whales:	8 hit, 2 possible hits, 5 missed.
Humpback whales:	4 hit, 4 missed.

LABORATORY WORK

The data and samples collected on board the Norwegian whaling vessel have been examined and analysed by Greenland Fisheries Investigations. Tissue samples of minke whale collected during the same cruise have been analysed for electrophoretic variation at the Institute of Ecology and Genetics, University of Aarhus.

Danish scientists contributed to and participated in a workshop on underwater noise generated by ships (super-tankers), and its possible effects on marine mammal populations in Arctic waters. The workshop was sponsored by Arctic Pilot Project, and was held in Toronto, February

Table 1

Provisional figures for the catch of whales in Greenland, per district, 1979 and 1980, and estimated total catch[1]

	Minke whale		Fin whale		Humpback whale		Pilot whale		Narwhal		White whale		Harbour porpoise		Other Species	
District	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
Thule	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Upernavik	5	3	—	—	—	—	—	—	18	33	213	107	—	—	—	—
Umanak	29	12	—	—	—	—	—	—	132	107	22	63	—	1	—	—
Jakobshavn	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·
Christianshåb	6	·	—	3	—	·	—	·	18	·	87	·	34	·	—	·
Godhavn	10	8	—	2	—	—	—	2	7	2	98	39	18	12	—	3
Egedesminde	35	·	—	·	—	·	—	·	57	·	85	·	44	·	—	·
Kangaatsiaq	1	·	—	·	—	·	—	·	—	·	1	·	72	·	—	·
Holsteinsborg	·	5	·	—	·	—	47	—	·	—	·	9	·	16	·	—
Sukkertoppen	40	52	4	—	3	2	—	—	—	4	12	45	421	519	—	—
Godthåb	9	24	—	3	7	5	—	—	3	—	8	—	225	83	—	—
Frederikshåb	7	11	3	3	1	5	—	—	—	—	—	—	55	91	4	—
Narssaq	—	·	—	1	—	·	—	·	—	·	—	·	2	·	—	·
Julianehåb	18	—	—	—	—	1	—	—	—	—	—	—	2	18	1	—
Nanortalik	44	26	—	—	—	—	—	—	—	—	—	1	10	1	12	3
Angmagssalik	—	—	—	—	—	—	3	—	4	39	—	—	—	—	—	—
Scoresbysund	—	·	—	·	—	·	—	·	—	·	—	·	—	·	—	·
Sum	204	141	7	13	11	13	50	2	239	185	526	264	883	741	17	6
Estimated total	235	195	7	13	14	13	50	2	350	350	700	550	950	850	17	6

[1] • indicates no information, – no catch.

1981. The proceedings of the workshop will be submitted for public review.

RESEARCH RESULTS

The results of the field work in the summer of 1980, and of the following laboratory work were submitted to the 33rd Annual Meeting of IWC (SC/33/Mi5, SC/33/Mi6, and SC/33/O 12).

PUBLICATIONS

Larsen, F. 1981. Observations of Large Whales off West Greenland, 1979. *Rep. int. Whal. Commn* 31: 617–23.

Larsen, F. and Kapel, F. O. 1981. Collection of Biological Material of Minke Whales off West Greenland, 1979. *Rep. int. Whal. Commn* 31: 279–85.

Meldgaard, M. and Kapel, F. O. 1981. Observations of Narwhal in the Melville Bay, Northwest Greenland. *Rep. int. Whal. Commn* 31: 547–50.

Appendix I

WHALE MARKING OFF WEST GREENLAND, 1980

by m/s *Kato M* 192 SØ

Mark Number	Type	Date	Position	Species	Size	Result
39672	12-b	July 80		Fin		Miss
39673	12-b	24.07.80	68°06′N 57°30′W	Fin		Miss
39671	12-b	24.07.80	68°05′N 57°14′W	Fin		Hit
39674	12-b	04.08.80	63°36′N 52°25′W	Humpback		Miss
39675	12-b	04.08.80	63°36′N 52°25′W	Humpback		Hit
39676	12-b	17.08.80	66°50′N 55°35′W	Fin	65–70 ft	Hit
41761	.410	18.08.80	66°45′N 55°34′W	Minke	15–18 ft	Hit
39678	12-b	22.08.80	68°09′N 54°43°W	Fin	*c.* 50 ft	Miss
39679	12-b	25.08.80	68°44′N 55°59′W	Fin	55–60 ft	Hit (protruding?)
39677	12-b	25.08.80	68°44′N 55°59′W	Fin	*c.* 65 ft	Hit
39680	12-b	25.08.80	68°21′N 56°34′W	Fin		Hit
41762	.410	25.08.80	68°22′N 56°40′W	Minke		Miss
41763	.410	25.08.80	68°22′N 56°43′W	Minke		Miss
39681	12-b	28.08.80	64°00′N 52°39′W	Humpback	40–45 ft	Hit
39682	12-b	28.08.80	64°00′N 52°39′W	Humpback	40–45 ft	Hit
39683	12-b	28.08.80	63°58′N 52°38′W	Humpback		Miss
39684	12-b	28.08.80	63°58′N 52°38′W	Humpback		Miss
39685	12-b	28.08.80	63°56′N 52°36′W	Humpback		Hit
39686	12-b	28.08.80	63°53′N 52°26′W	Fin		Miss
39687	12-b	28.08.80	63°50′N 52°25′W	Fin		Hit
39688	12-b	28.08.80	63°50′N 52°25′W	Fin		Hit
39690	12-b	28.08.80	63°55′N 52°27′W	Fin		Hit
39689	12-b	28.08.80	63°55′N 52°27′W	Fin		Miss
39691	12-b	29.08.80	63°43′N 52°24′W	Fin	60–65 ft	Hit (possible hit?)
39692	12-b	29.08.80	63°44′N 52°22′W	Fin	*c.* 55 ft	Hit
39693	12-b	29.08.80	63°39′N 52°05′W	Humpback		Miss

SC/33/ProgRep France

France
Progress Report on Cetacean Research
June 1980 to May 1981

The yearly report of strandings of cetaceans on the French coasts was published in 1980 for the year 1979 and some data furnished on the sexual maturity of *Delphinus delphis* (Duguy, 1980).

The first results of a four year research programme on diseases and cutaneous ulcerations of fish and marine mammals were published in 1980 (Nounou, Orcel and Martoja).

Studies were carried out on the excretory function of the skin of some toothed and baleen whales (Viale, 1979).

An ecological research was made, noting the variations in the cetacean populations in the occidental Mediterranean, together with studies on ecological strategy among cetaceans (Viale).

In October 1980 in the Paris Museum, a meeting of the French Society of Mammalogy was held on the Behaviour and the Protection problems of Marine Mammals and papers were presented by Roux on large cetaceans and by Duguy on small cetaceans. At the same meeting, a study of *Tursiops truncatus* on the coasts of Brittany was presented by Hussenot.

A note on the Commerson's dolphin was published by Pascal in 1981. A research programme (commencing October 1981) has been established for the Kerguelen Islands area including sightings of cetaceans and a special study on the Commerson's dolphin.

PUBLICATIONS

Duguy, R. 1980. Rapport annuel sur les Cétacés et Pinnipèdes trouvés sur les côtes de France. *Ann. Soc. Sci. nat. Charente-Maritime* 6(7): 615–32.

Duguy, R. and Collet, A. 1979. Note sur la reproduction de *Delphinus delphis* dans le N. E. Atlantique, *Cons. Int. Expl. Mer*, 67e réunion, Varsovie.

Hussenot, E. 1980. Le Grand Dauphin *Tursiops truncatus* en Bretagne; types de fréquentation. *Penn ar Bed* 103(4): 355–80.

Nounou, P., Martoja, R. and Orcel, L. 1980. Ulcérations cutanées des poissons et des Mammifères marins, Pub. CNEXO, Rapport scientifique et technique No. 43. CNEXO, B.P. 337, 29273 Brest Cedex.

Pascal, M. 1981. Le Dauphin de Commerson aux Iles Kerguelen, *Revue d'Ecologie, Terre et Vie,* 35: 327–30.

Viale, D. 1979. Mise en évidence d'une fonction excrétrice de la peau chez certains Cétacés odontocètes et Mysticètes, *J. Exp. Mar. Biol. Ecol.* 40: 200–21.

Viale, D. 1980. Modifications du peuplement de Cétacés de Méditerranée occidentale; *C. R. Cons. Int. Expl. Sc. Médit.*, 27é congrés, Cagliari.

Viale, D. 1980. Stratégie écologique chez les Cétacés in Recherches d'Ecologie théorique—Les stratégies adaptatives, Actes du Colloque d'Ecologie théorique organisé à l'Ecole Normale Supérieure de Paris, pp. 209–16 Maloine éditeur, Paris.

SC/33/ProgRep Iceland

Iceland
Progress Report on Cetacean Research
June 1980 to May 1981

SPECIES AND STOCKS STUDIED

Studies of fin, sei and sperm whales caught west of Iceland and minke whales taken in all except the southern coastal waters of Iceland, continued in 1980. The distribution of large whales (including blue and humpback whales), minke whales and small odontocetes is also being studied.

FIELD OBSERVATIONS AND COLLECTIONS

A biologist from the Sea Mammal Research Unit (UK), the IWC Observer and a biologist from the Marine Research Institute (Reykjavík) collected various biological samples from the 236 fin, 100 sei and 101 sperm whales taken from the land station at Hvalfjördur between 1 June and 15 September, for age and reproduction studies. Samples were also collected at the request of certain foreign institutes and museums and by several foreign biologists who visited the station during the season. In accordance with the 1980 IWC resolution regarding an international whale research facility in Iceland, a new 60m^2 laboratory has been built for scientists visiting the station.

Time budget data were collected for all catcher boats operating from Hvalfjördur. As well as this information on searching, handling and chasing times etc., data on weather, sea state and visibility were recorded. Sightings records are kept for all species sighted by the Hvalfjördur catcher boats.

In co-operation with the minke whalers, ovaries, testes, earplugs (from only 15 animals) and *bulla tympanica* were collected. They also completed effort forms and recorded whales sighted.

A radio tagged fin whale was tracked for 226 hours (June 25–July 5) from the Icelandic vessel *Ljósfari*. The whales were marked from a catcher boat on the whaling grounds and followed for about 2,000 km, across the Denmark Strait to the eastern coast of Greenland. During the cruise (directed by W. A. Watkins, Woods Hole Oceanographic Institution, in co-operation with the Marine Research Institute and Hvalur H.F.) information on the behaviour of the animal was obtained in addition to the technical experience gained with respect to the tracking system.

MARKING AND RECOVERIES

1 sperm, 11 fin and 35 sei whales were marked from Hvalfjördur catchers and the *Ljósfari*.

Marking (Table 1) was conducted by the staff of the Marine Research Institute and the primary target was the sei whale as had been proposed by the IWC Scientific Committee (*Rep. int. Whal. Commn* 30: 134).

Six marks were recovered from five animals/(Table 2). Three from fin whales recovered 1, 45 and 52 weeks after marking and two from sei whales; one caught on the day of marking and another as part of a recovery experiment.

Table 1

Whale marking cruises and number of whales marked in Icelandic waters in 1980

Marking cruise	Duration of cruise	No. of whales			
		Fin	Sei	Sperm	Killer
Hvalur 9	25.5–30.5	7	0	0	0
Ljósfari *Hvalur 6*	23.6–7.7	2	0	0	0
Hvalur 9	11.8–15.8	2	0	0	0
Hvalur 7	28.8–31.8	0	16[1]	0	0
Hvalur 8	8.9–16.9	0	21[1]	0	0
Hvalur 9	23.10–30.10	0	0	1	0
Sólrún	18.8–24.8	0	0	0	2
Total		11	37[2]	1	2

[1] One possibly double-marked.

[2] Two possibly double-marked.

The Marine Research Institute had the minke whale catcher *Sólrún* at its disposal from 18–24 August but poor weather conditions resulted in only two killer whales being marked.

LABORATORY WORK

Minke whale ear plugs from the 1979 and 1980 seasons have been read. Work is in progress on the examination of *bulla tympanica* and reproductive organs.

DEVELOPMENT OF TECHNIQUES

Experiments with a new type of streamer mark are in progress. Work is being carried out to see if it is possible to determine pregnant animals using hormonal assay techniques.

RESEARCH

Analysis of catch per unit effort (CPUE) in the large whale fishery is continuing. Effort data have been extracted from logbooks for *Hvalur 3* (1954–60), *Hvalur 4* (1951–60), *Hvalur 5* (1956–60) and *Hvalur 6* (1962–80). Time budget data for 1979 and 1980 from this fishery have been collected and stored on computer.

A study of minke whaling in Iceland (SC/33/Mi9) has examined the past catches and estimated the CPUE in recent years. Age and reproductive material collected from the minke whale fishery in 1977–80 is being analysed and the results will be published in the near future.

Studies on the pregnancy rate in fin whales, the age structure of fin, sei and sperm whales and the distribution of sperm whale catches have been made by scientists from SMRU, UK (see SC/33/ProgRep UK).

Table 2

Whale marks recovered at Hvalfjördur whaling station (Iceland) in the 1980 season

Mark no.	Species	Date of marking	Position fired	Date of recapture	Approximate catch position[1]
36392	Fin	29.5.1980	63°19′N, 28°09′W	6.6.1980	63°08′N, 27°45′W
36310	,,	28.7.1979	62°39′N, 25°41′W	8.6.1980	64°22′N, 28°15′W
36282[2]	,,	26.7.1979	63°32′N, 26°52′W	25.7.1980	64°22′N, 29°15′W
36283[2]	,,	,,	,,	,,	,,
36400[3]	Sei	—	—	—	—
36240	,,	30.8.1980	64°59′N, 28°17′W	30.8.1980	65°08′N, 28°15′W

[1] Catch positions reported in stat. squares given here as (lat./long.) the centre of the respective square.

[2] 36282 and 36283 known to be the same animal at the time of firing.

[3] Recovery experiment.

Table 3

Minke whales caught by Iceland in 1980

	Number of whales			Average length (feet)			
Month	♂	♀	Total	♂	♀	Total	Per cent males
May	4	3	7	25.5	22.7	24.3	57.1
June	54	46	100	25.0	23.3	24.2	54.0
July	61	33	94	24.1	23.9	24.0	64.9
May–July	119	82	201	24.6	23.5	24.1	59.2

MINKE WHALES IN 1980

Eleven minke whaling licences were issued in 1980. The full quota was taken between 20 May and 17 July (Table 3).

PUBLICATIONS

Rørvik, C. J. and Sigurjónsson, J. 1981. A note on catch per unit effort in the Icelandic fin whale fishery. *Rep. int. Whal. Commn* 31: 379–83.

Sigurjónsson, J. 1980. Aldersstudier over vågehval (*Balaenoptera acutorostrata* Lacépède) i islandske farvann. Cand. real—thesis, Oslo University. 97 pp.

SC/33/ProgRep Japan

Japan

Progress Report on Cetacean Research June 1980 to May 1981

This summarises whale research conducted by the Far Seas Fisheries Research Laboratory, Fisheries Agency, with the co-operation of other related organisations.

1. SPECIES AND STOCKS STUDIED

Studies were conducted mainly on those species which are or were the objects of Japanese whaling in the North Pacific and the Southern Hemisphere. These include the sperm, Bryde's and minke whales, some smaller cetaceans and several protected species.

Dall's porpoise studies in the northern part of the North Pacific have been continued with the co-operation of US researchers since 1978.

2. FIELD OBSERVATION AND COLLECTION

Biological data and materials were collected from each whale caught by Antarctic pelagic whaling and large- and small-type coastal whaling. Detailed time budget data were obtained from these operations. Mr Miyashita of our laboratory was on board the factory ship *Nissin Maru No. 3* to engage in biological studies of whales in the Antarctic, and he also co-operated in a basic study of whale marking methods as part of the IDCR minke whale assessment project under the leadership of Dr Best.

No special permits to take whales for scientific purposes were issued by the Government.

Two scouting boats carried out sightings and marking in the North Pacific in the summer of 1980. They covered almost the same research area as in the previous season (Fig. 1). The distance covered was 13,222 n. miles, 1,085 miles further than in 1979 (Table 1).

During the 1980/81 season, three scouting boats engaged in whale sightings and whale marking in the Southern Hemisphere independently from the whaling fleet. They also carried out sightings in the lower latitudinal waters of the North Pacific on the way to and from the Southern Hemisphere (Table 2).

Most of the whales sighted and marked in the lower latitudes of the Southern Hemisphere were Bryde's whales. Two of the boats participated in the IDCR minke whale assessment cruise in Area V (which for the first time also included a Soviet scouting boat). Dr Miyazaki of the National Science Museum, Mr Kasamatsu of the Japan Whaling Association and Mr Kato of the Whales Research Institute joined in the IDCR cruise as international researchers from Japan. The other boat carried out sightings and marking in the higher latitudinal waters of Area I (mainly for minke whales). The total research distance of these three boats in the Southern Hemisphere (including the IDCR cruise) was 37,778 n. miles, 5,078 miles shorter than in 1979/80 (Fig. 2 and Table 3).

Data were obtained from the four catcher boats attached to the *Nissin Maru No. 3* fleet which were engaged in sightings in Area IV before whaling operations started. These data are also included in Table 3.

Sightings data were also recorded by the operating catcher boats of both coastal and pelagic whaling. Their sightings of protected species are shown in Tables 4 and 5.

Two research vesels, *Kaiyomaru* of the Fisheries Agency and *Umitakamaru* of the Tokyo University of Fisheries, joined in the FIBEX project of the BIOMASS programme. One sightings expert was present on each research vessel to collect data and to compare their results with those of the usual crew.

Table 1

Whale sightings by scouting boats in the North Pacific in summer, 1980

Sector	Distance (n. miles)	Blue	Fin	Humpback	Right	Sei	Bryde's	Minke	Sperm	Beaked*	Killer	Total
II N	161	—	—	—	—	—	—	—	1	—	5	6
III PNP	117	—	—	—	—	—	—	—	—	—	—	—
III N	1,667	—	1	—	—	5	—	—	22	—	9	37
IV N	2,087	12	—	—	—	4	1	1	7	—	5	30
IV M	140	—	—	—	—	—	8	—	—	—	—	8
V N	1,969	—	—	—	—	3	—	2	—	—	12	17
V M	944	1	—	—	—	—	6	1	—	—	10	18
VI N	479	—	—	—	—	—	—	—	—	—	—	—
VI M	2,675	—	—	—	—	—	24	1	15	4	6	50
VI L	2,746	—	—	—	—	—	105	—	72	—	7	184
VII M	237	—	—	—	—	—	—	—	—	—	—	—
Total	13,222	13	1	—	—	12	144	5	117	4	54	350

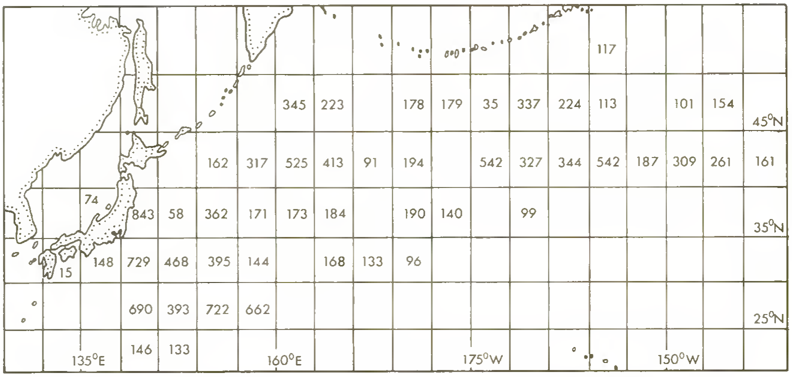

Fig. 1. Scouting distance (in miles) covered by Japanese scouting boats in the North Pacific in 1980.

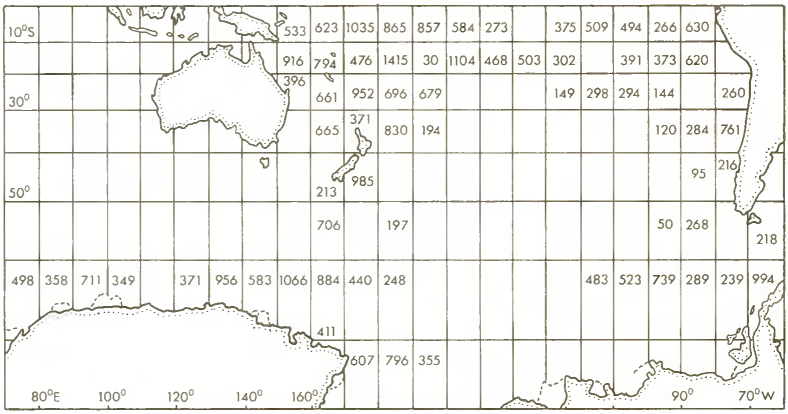

Fig. 2. Scouting distance (in miles) covered by Japanese scouting boats in the Southern Hemisphere in 1980/81, including the IDCR minke whale cruise.

Table 3

Whale sightings by Japanese scouting boats in the Southern Hemisphere in 1980/81 (including IDCR/minke whale assessment cruise)

Sector	Distance (n. miles)	Number of whales sighted							
		Blue	Fin	Humpback	Sei	Bryde's	Minke	Sperm	Total
IV A	747	—	3	2	—	—	12	6	23
IV B	2,287	—	—	2	—	—	126	47	175
V H	3,076	—	—	—	—	4	—	44	48
V G	3,601	—	—	—	—	2	6	57	65
V F	2,705	—	—	—	—	—	3	99	102
V E	1,866	—	—	—	—	5	—	178	183
V D	1,171	2	2	—	20	—	2	—	26
V A	903	—	1	—	—	—	3	1	5
V B	4,177	7	37	16	—	—	2,605	50	2,715
V C	1,814	—	—	—	—	—	1,445	30	1,475
VI H	2,089	—	—	—	—	13	—	26	39
VI G	2,407	—	—	—	—	4	1	1	6
VI F	828	—	—	—	—	1	—	10	11
VI E	194	—	—	—	—	—	—	20	20
VI C	355	—	—	—	—	—	1,133	—	1,133
I H	1,899	4	—	—	—	9	3	97	113
I G	1,384	—	—	—	—	6	7	23	35
I F	996	—	—	—	—	—	—	—	—
I E	1,165	—	4	—	—	—	1	12	17
I D	311	—	—	—	6	—	2	11	19
I A	536	—	4	—	17	—	1	6	28
I B	3,267	8	40	107	20	—	581	8	764
Total	37,778	21	91	127	63	44	5,931	726	7,003

Table 2

Whale sightings by scouting boats in the North Pacific in October and November 1980, and March 1981

Sector	Distance (n. miles)	Bryde's	Minke	Sperm	Total
IV K	300	—	—	—	—
IV J	1,118	8	—	15	23
V L	646	2	—	11	13
V K	1,204	4	1	—	5
V J	819	1	—	10	11
VI M	414	—	—	—	—
VI L	1,658	6	—	—	6
VI K	541	—	—	—	—
VI J	642	4	—	—	4
VII M	324	—	—	—	—
VII L	404	—	—	8	8
VII K	167	—	—	—	—
Total	8,237	25	1	44	70

3. WHALE MARKING

Two scouting boats marked 77 whales in the North Pacific in 1980. In the Southern Hemisphere, three Japanese scouting boats marked 466 whales (including the IDCR cruise results) in 1980/81 (Tables 6 and 7).

Two marked Bryde's whales were the only recoveries by Japanese coastal whaling in 1980 (Table 8). In the Antarctic, six marked minke whales were recovered in 1980/81 by Japanese whalers (Table 9). Mark No. 31466 was recovered during meat processing, and so the individual whale could not be identified. A marked minke whale (No. 31461) was also recovered on the same day as Mark No. 31466. The marking records show that the marks were fired into two different minke whales in the same school. If they are correct, then these two whales may have remained in the same school for almost two years.

An experiment to test the efficiency of .410 streamer marks was conducted by international researchers on board *Nissin Maru No. 3*. Mr Miyashita tested the recovery of .410 marks from the cookers, and also took movie pictures of the trajectory of .410 marks with the co-operations of an NHK camera man. These experiments were part of the IDCR assessment programme.

Table 6

Number of whales marked by scouting boats in the North Pacific in 1980

10° square	Blue	Fin	Sei	Bryde's	Sperm	Total
L21	—	—	—	24	1	25
L22	—	—	—	20	1	21
M21	—	—	—	3	—	3
M22	—	—	—	7	—	7
N25	—	—	—	—	4	4
N26	2	—	—	1	—	3
N27	—	—	3	—	10	13
N28	—	1	—	—	—	1
Total	2	1	3	55	16	77

4. LABORATORY WORK

All ovaries which had been collected from the Bryde's sperm and minke whales caught during pelagic and coastal whaling in the 1980/81 and 1980 seasons were examined in our laboratory. Earplugs of Bryde's and minke whales from coastal whaling in 1980 and earplugs of minke whales from the pelagic whaling in 1979/80 were prepared and read.

Sightings data from scouting boats in the North Pacific in 1980 and in the Southern Hemisphere in 1979/80 were put onto computer tape, as were biological data for minke whales caught in the Antarctic in 1979/80.

Mr Wada continued his laboratory work on the biochemical analysis of samples from Antarctic minke whales.

Table 4

Protected species observed by operating catcher boats in the coastal waters of Japan, 1980/81 (excluding data from one company)

10° square	Blue	Fin	Sei	Humpback	Right	Gray	Total	Effort (CDW)
N 21	—	—	—	—	—	—	—	6
M 20	—	—	—	1	—	—	1	171
M 21	—	1	—	1	—	—	2	511
L 20	—	—	—	—	—	—	—	4

Table 5

Protected species observed by operating catcher boats in the Antarctic, 1980/81

Sector	Blue	Fin	Sei	Humpback	Right	Sperm	Total	Effort (CDW)
III B	1	5	—	1	—	12	19	60
IV B	2	13	—	21	—	134	170	147
V B	12	135	—	2	—	27	176	72
V C	—	—	—	1	—	40	41	24
VI B	—	—	—	3	—	—	3	4
VI C	—	2	—	—	—	11	13	24
I B	—	3	—	60	—	2	65	52
I C	—	—	—	20	—	1	21	20
Total	15	158	—	108	—	227	508	403

5. STUDIES

Studies were made on the development of a revised management procedure for whale stocks with co-operation of other organisations, and these contributed to the Japanese proposal for a new management procedure at the IWC meeting in Tokyo in February–March 1981.

A research team carried out a simulation study on sightings theory which was developed by Dr T. Doi with the aid of a computer and sighting records collected during the 1980/81 IDCR minke whale cruise. The sightings efficiency of the crews of ocean research vessels was examined by comparing their data with that of experienced whalers on board the same research vessel and on board scouting boats.

Another research team closely examined the population models used in the Scientific Committee meeting in 1980 and attempted to develop the models further.

6. MANAGEMENT

Large- and small-type coastal whaling continued in the North Pacific in 1980 (Table 10).

Pelagic whaling was only carried out for minke whales in the Antarctic in 1980/81. Negotiations with the USSR concerning the areal allocation of quotas were unsuccessful and thus the fleet operated in all areas except Area II in 1980/81 (Table 10).

Smaller cetaceans were taken in local fisheries either by direct whaling or incidentally. Catch statistics collected by the Fisheries Agency from local governments are given in Table 11.

7. PUBLICATIONS

a. Papers published (other than IWC documents)

Ohsumi, S. 1980a. Is there prospect of whales as living resources? *Anima* 1980 (6): 89 (in Japanese).

Ohsumi, S. 1980b. Mammals in the Antarctic Region. *Animals and Nature* 10(14): 6–11 (in Japanese).

Ohsumi, S. 1981a. An account on late Dr C. L. Hubbs. *Geiken-tsushin* 337: 7–8 (in Japanese).

Ohsumi, S. 1981b. Marine mammals and fisheries. *Suisan Shryo Shikiho* 7(3,4): 3–13 (in Japanese).

b. Documents

F.S.F.R.L. 1980. Japan Progress report on cetacean research, June 1979–May 1980. *Rep. int. Whal. Commn* 31: 195–200.

Kasamatsu, E. and Ohsumi, S. 1980. Distribution pattern of minke whales in the Antarctic with special reference to the sex ratio in the catch. *Ibid:* 345–8.

Kato, M., Ohsumi, S. and Takagi, K. 1981. Report on abundance survey of marine mammals, mainly Dall porpoise, by Japanese salmon research vessels in the North Pacific Ocean in 1980. INPFC Doc. 2386.

Ohsumi, S. 1980a. Estimation of population size of minke whales in the Antarctic Area VI by means of whale sightings. *Rep. int. Whal. Commn* 31: 323–6.

Ohsumi, S. 1980b. Minke whales in the coastal waters of Japan, 1979. *Ibid.:* 333–5.

Ohsumi, S. 1980c. Estimation of population size of the fin whale in the Antarctic Area VI by whale sightings. *Ibid.:* 403–6.

Table 7

Number of whales marked by Japanese scouting boats in the Southern Hemisphere in 1980/81 (including the IDCR cruise)

10° square	Sei	Bryde's	Minke	Sperm	Total
H24	—	—	—	3	3
H25	—	4	—	11	15
H26	—	6	—	—	6
H30	—	—	—	4	4
H31	—	—	—	8	8
H32	—	2	—	3	5
H34	—	1	—	—	1
G22	—	1	—	7	8
G23	—	—	—	3	3
G25	—	—	3	4	7
G27	—	—	—	1	1
G33	—	4	—	—	4
G34	—	—	—	12	12
F23	—	—	—	2	2
F24	—	—	—	6	6
F25	—	—	—	5	5
E23	—	2	—	—	2
E25	—	—	—	16	16
E26	—	—	—	2	2
E33	—	—	—	1	1
E34	—	—	—	1	1
D24	—	—	1	—	1
D35	—	—	—	1	1
A23	—	—	—	1	1
A34	1	—	—	—	1
B20	—	—	14	—	14
B21	—	—	49	—	49
B22	—	—	14	—	14
B23	—	—	20	1	21
B24	—	—	35	—	35
B25	—	—	12	—	12
B31	—	—	25	—	25
B32	—	—	45	—	45
B33	—	—	23	—	23
B34	—	—	5	—	5
B35	—	—	8	—	8
B 0	4	—	28	—	32
C23	—	—	1	—	1
C24	—	—	12	1	13
C25	—	—	50	—	50
C26	—	—	3	—	3
Total	5	20	348	93	466

Table 8

Whale marks recovered by Japanese whalers in the North Pacific in 1980/81

Mark no.	Species	Sex	Body length at recovery (m)	Date marked	Date recovered	Position marked	Position recovered
Japanese marks							
13245 13246	Bryde's	Female	12.8	6 Feb. 1976	6 June 1980	01°15′S, 147°28′E	31°23′N, 143°17′E
Discovery marks							
33552	Bryde's	Female	13.4	28 June 1979	11 May 1980	27°55′N, 147°46′E	32°12′N, 137°21′E

Ohsumi, S. 1980d. Further estimation of population sizes of Bryde's whales in the South Pacific and Indian Oceans by means of whale sightings. *Ibid.*: 407–15.

Ohsumi, S. 1980e. Estimation of population size of the western North Pacific Bryde's whales by means of whale sightings. *Ibid.*: 417–24.

Ohsumi, S. 1980f. Reasons to oppose whale sanctuary in the Indian Ocean. Paper SC/32/O 18 presented to the IWC Scientific Committee, June 1980.

Ohsumi, S. 1980g. Pregnancy rate of the sperm whales caught by Japanese coastal whaling. *Rep. int. Whal. Commn* 31: 801–4.

Ohsumi, S. 1980h. Catches of sperm whales in the coastal waters of Japan. *Ibid.*: 873–920.

Ohsumi, S. 1981a. Biological criticism on management procedure for expanding whale stocks. IWC/TC/WG81/Tokyo 7.

Ohsumi, S. 1981b. Fixed exploitation rate and its practicality for management procedure of whale stocks. IWC/TC/WG81/Rome 2.

Ohsumi, S. and Shimadzu, Y. 1980. Catch and effort statistics of minke whaling by Japanese expeditions in the Antarctic. *Rep. int. Whal. Commn* 31: 363–6.

Ohsumi, S. and Yamamura, Y. 1982. A review on whale sightings system in Japan, Paper SS/17 (published in this volume).

Miyashita, T. and Ohsumi, S. 1980. Estimation of population size of the sperm whale in the Southern Hemisphere using sightings data. *Rep. int. Whal. Commn* 31: 805–12.

Wada, S. 1980. Japanese whaling and whale sighting in the North Pacific 1979 season. *Ibid.*: 783–92.

Yamamura, Y. and Ohsumi, S. 1980. Comparison of the yearly changes in CPUE for minke whales in the Antarctic based on Japanese and Soviet effort data. *Ibid.*: 327–32.

Table 9

Whale marks recovered by Japanese whalers in the Southern Hemisphere in 1980/81

Mark no.	Species	Sex	Body length at recovery (m)	Date marked	Date recovered	Position marked	Position recovered
Discovery .410 marks							
31461	Minke	Female	9.2	29 Jan. 1979	5 Jan. 1981	63°49′S, 116°40′E	63°22′S, 94°58′E
31466	Minke	—	—	29 Jan. 1979	5 Jan. 1981	63°49′S, 116°40′E	(63°10′S, 95°08′E)*
34102	Minke	Female	8.6	14 Jan. 1979	19 Dec. 1980	67°17′S, 70°55′E	63°57′S, 59°41′E
35170	Minke	Male	7.8	9 Jan. 1980	16 Dec. 1980	64°12′S, 60°21′E	63°16′S, 62°34′E
39069	Minke	Female	8.6	3 Jan. 1981	24 Jan. 1981	66°25′S, 141°28′E	66°55′S, 142°52′E
39176	Minke	Female	8.7	16 Jan. 1981	3 Feb. 1981	63°43′S, 161°10′E	65°48′S, 155°18′E

* Noon position of factory ship.

Table 10

Catch of whales by Japanese whaling in 1980/81

	Type of whaling	Bryde's	Sperm	Minke	Baird's	Killer	Pilot	Total
Pelagic	Antarctic	—	—	3,120	—	—	—	3,120
Coastal	Large-type	307	1,192	—	—	—	—	1,499
	Small-type	—	—	379	31	2	1	413
Total		307	1.192	3,499	31	2	1	5,032

Table 11

Catch of smaller cetaceans caught by Japanese local fisheries in 1980

Type of fishery	Prefecture	Fishing boats	Fishing season	Catch (individuals)
Hand harpoon	Iwate	93	10–3	Dall: 6,702, Common: 16, Striped: 10, White sided: 55, Harbor; 30, Finless: 153
	Miyagi	9	7–9	Dall: 16
	Ibaragi	1	4–5	Common: 11
	Nagasaki	—	—	Bottlenose: 15
	Okinawa	40	1–12	Common: 22, Pilot: 80, False killer: 5
Drive	Shizuoka	5	9–12	Striped: 5,220, Spotted: 1,440
	Wakayama	14	10–5	Striped: 11,017, White sided: 14, Bottlenose: 345, Pilot: 605
	Nagasaki	660	2–4	Bottlenose: 3,120, False killer 351
Fixed net	Hokkaido	3 set	3–11	Common: 15
	Aomori	1	5	Common: 1
	Iwate	4	1–6	Harbor: 6, Unknown: 8
	Ishikawa	1	1–12	Common: 10, Pilot: 1
	Fukui	1	4–12	Common: 5
	Kyoto	5	12–5	Common: 4, Bottlenose: 1, False killer: 1, Unknown: 1
	Yamaguchi	1	11	Minke: 1
	Kochi	1	9–7	Spotted: 20
	Nagasaki	3		Bottlenose: 3, Risso's: 3, Pilot: 5, False killer: 20
Purse seine	Ibaragi	4	5–	White sided: 4
Drift net	Hokkaido	10	3–11	Common: 20
	Miyagi	29	2–12	Common: 19, Bottlenose: 9, Dall: 49
	Ibaragi	2	12–4	Striped: 97, Minke: 2
	Niigata	1	4	Common: 1
	Salmon factory		6–7	Dall: 1,000, Harbor: 4
	Salmon landbased		5–7	Dall: 139

SC/33/ProgRep Korea

Republic of Korea
Progress Report on Cetacean Research
June 1980 to May 1981

This report refers to work at the Fisheries Research and Development Agency, Busan.

SPECIES AND STOCKS STUDIED

The research system to collect catch, effort and body size data from small type whaling was established in 1979. Data on the geographical distribution of the minke whale (*Balaenoptera acutorostrata*), the most important of the whales taken in Korean waters, are being collected.

FIELD OBSERVATIONS AND COLLECTIONS

Monthly minke whale catch, effort and body size data are being collected by sea block and by sector in Korean waters from log-books compiled by the fishermen themselves. No scientific research was carried out on board vessels in 1980.

LABORATORY WORK

Catch and effort data for minke whales are being analysed to examine their graphical distribution and abundance in Korean waters. The monthly whale catch by Korean whaling boats in 1980 is presented in Table 1.

FUTURE RESEARCH

Studies on the distribution, abundance and length composition of minke whales and the classification of the other cetaceans will be carried out.

Table 1

Monthly whale catch by coastal whaling boats in 1980

Month	Number of minke whale	Others
March	46	—
April	155	—
May	199	—
June	137	—
July	129	—
August	87	—
September	119	7
October	53	—
Total	925	7

SC/33/ProgRep Mexico

Mexico

Progress Report on Cetacean Research June 1980 to May 1981

The report summarizes cetacean research conducted by the National Marine Mammal Research and Conservation Program of the Fisheries Department (Departamento de Pesca), Mexico.

SPECIES AND STOCKS STUDIED

Gray whale, *Eschrichtius robustus*. Ojo de Liebre, San Ignacio Lagoons, Bahia Magdalena and the West Coast of Baja California, Mexico

The third consecutive research effort on gray whales in the lagoons Ojo de Liebre and San Ignacio, Baja California Sur, Mexico, was conducted between 1 January to 31 March 1981. The programme was developed in cooperation with US scientists and some logistical support from the National Marine Mammal Laboratory (NMML) NOAA, Seattle, as a part of the bilateral research programme.

The objectives of this Mexican research effort were directed towards obtaining demographic information on breeding gray whales including weekly counts of the number and distribution of female/calf pairs and other whales (singles) utilizing the lagoons.

Different sampling platforms, such as two observation towers and bi-weekly boat surveys were used through the entire season. In addition, and to estimate the gray whale population within the lagoons and adjacent waters, aerial censuses were conducted at the peak of the season in February 1981. This aerial effort also included surveys of the west coast of Baja and a helicopter survey of the Magdalena Bay complex.

Besides these estimation surveys, ground-truth experiments were performed between the different sampling platforms, especially boats and aircraft, to compare the accuracy of these census methods.

Other aspects of gray whale research included behavioural responses of the whales to boat traffic, especially tourist boats which visit the gray whales in their sanctuaries.

Planktonic communities were sampled in Ojo de Liebre lagoon as a preliminary investigation on the ecology of this coastal lagoon and its significance to gray whale survival.

The Mexican gray whale programme will be continued and expanded in 1982.

PUBLICATIONS

Departmento de Pesca. 1981. 'Mexicanas por Nacimiento'. Boletin de Divulgación Sobre la Ballena Gris de México. Oficina de Divulgación, Pesca, México.

Fleischer, L. 1981. La Migración de la Ballena Gris. Reunión nacional de la Ballena Gris. Centro de Estudios Ecónomicos y Sociales del Tercer Mundo, México, (in prep.).

Fleischer, L. 1981. Programa Nacional de la Ballena Gris en México. Seminario Proteccion de Cetáceos y sus Ecosistemas en el Hemisferio Occidental. Centro Tinker, University of Miami, (in press).

SC/33/ProgRep New Zealand

New Zealand
Progress Report on Cetacean Research
May 1980 to May 1981

This report summarises cetacean research conducted by the Fisheries Research Division of the Ministry of Agriculture and Fisheries (MAF) from May 1980 to May 1981.

1. SPECIES AND STOCKS STUDIED

During the past year studies have been continued in the south west Pacific, Tasman Sea, New Zealand coastal and sub-Antarctic waters on the following:

(a) Sperm whales (*Physeter macrocephalus*).
(b) Right whales (*Eubalaena australis*).
(c) Rorquals.
(d) Small cetaceans.

2. FIELD OBSERVATIONS AND COLLECTIONS

Sightings of all species continue to be collected from vessels at sea, shore-based observers and aircraft. Strandings of 52 cetaceans were recorded and complete data collected from 46 of these strandings by MAF personnel, primarily fishery officers or Research Division staff. Catches of small cetaceans incidental to normal fishing operations have been recorded and animals retrieved for examination wherever possible. Photographic records of identifiable marks on local groups of small cetaceans are being extended.

3. MARKING

The stock of Discovery marks and marking guns held in New Zealand and now surplus to requirements, have been returned to the Sea Mammal Research Unit, Cambridge, U.K. A southern right whale was tagged with an experimental streamer mark, as described in Cawthorn, 1979 (*Rep. int. Whal. Commn* 29: 123–5) at Enderby Island, Auckland Islands on 28 November 1980. Photographs of callosity patterns were taken at the time of tagging as an identification check.

4. LABORATORY WORK

Stomach contents, parasites, teeth and gonad samples collected from stranded cetaceans are being analysed for feeding, geographic marker, age and maturity studies. Tissues are being analysed for heavy metals and persistent pesticide residues. Material collected at a massed stranding of *Orcinus orca* is being processed and specimens of *Tursiops* and *Delphinus* are being held in cold storage.

5. DEVELOPMENT OF TECHNIQUES

A detailed recording system for selected merchant vessels travelling scheduled international routes is being developed in an effort to improve the quality of data received. Different propellant loads are to be tested for use with streamer marks to get greater muzzle velocities and flatter trajectories in flight. A photographic index of distinguishing body marks in local populations of *Delphinus* and *Lagenorynchus* is being extended.

6. RESEARCH RESULTS

Most sightings recorded by New Zealand are made in the area from 146°E to 170°W, and from 12°S to 54°S (Fig. 1). Of the 358 sighting forms returned by regular observers during the year ending May 1981, 30 (8%) recording 7 species of large whales were made outside this area (Appendix 1).

A total of 9,529 sightings of all species were recorded from all sources to May 1981. Whales are divided into three separate length classes: large whales, including minke (>10 m), medium whales (4–10 m), and small whales (<4 m), (Tables 1–3). As sighting returns are continuously received throughout the time of compilation those from April–May 1980 have been updated and included.

The percentage frequency of sightings by month (Fig. 2) presents a reasonably accurate indication of seasonal occurrence within the New Zealand sightings area. Effort in sightings of large whales has remained relatively constant; observations were collected from known sources, i.e., scheduled merchant vessels, or shore stations. Observations of small cetaceans, particularly coastal species, are subject to changes in sightings effort with seasonal shifts of human population to the coast and increased marine activity. However, the assumption is that this increase in effort does not introduce undue bias to the general trend. For example, the definite austral summer peak (Nov–Jan) shown by *Delphinus delphis* (Fig. 3) is due largely to an increase in sightings in the Bay of Plenty which coincides with the appearance of small 'baitfish', such as clupeids and *Trachurus* sp. (G. James, pers. comm.).

As a result of the incidental catches of cetaceans in the Bay of Plenty a systematic study of *D. delphis* distribution and feeding behaviour has been carried out for 12 months. Three identifiable groups have been separated into local, inshore and offshore populations. Each are readily identified using profound marks such as notched, cut, scarred, or amputated dorsal fins, or a combination of these marks. The behaviour of the offshore group is quite distinct from that of inshore groups.

Feeding behaviour and the utilisation of nets and warps by common dolphins feeding on clupeid and flatfish species has been observed at sea during studies of dolphin interactions with fishing gear. The movement of recognisable individuals from the south central Bay of Plenty to the Firth of Thames, approximately 155 nautical miles, has been observed.

Table 1

Large whales

	Month														
Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Σ
Sperm	58	25	3	12	3	1	19	24	11	33	32	48	11	8	288
Blue	1	—	—	—	—	—	—	—	2	—	—	—	—	—	3
Fin	—	—	2	—	2	—	—	7	—	—	—	1	—	—	12
Sei	7	—	—	16	2	—	4	—	13	3	1	2	—	—	48
Bryde	—	—	—	1	—	—	—	3	17	—	—	—	2	—	23
Minke	5	8	—	—	—	2	4	4	6	6	14	5	—	—	54
Humpback	—	3	18	5	19	1	8	22	1	11	2	29	6	1	126
Right	8	3	14	97	25	15	5	—	—	—	—	6	4	—	177
Unidentified	—	—	—	—	—	—	—	—	—	3	2	1	20	—	26
Monthly total all species	79	39	37	131	51	19	40	60	50	56	51	92	43	9	

Table 2

Medium whales

	Month														
Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Σ
Pigmy Right	5?	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Killer	13	—	4	11	23	23	—	23	9	31	2	6	—	—	145
Pilot	60	—	—	—	44	17	90	50	117	90	42	7	46	20	583
Beaked	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
Cuvier's	—	3	—	—	—	—	—	—	2	—	—	—	2	—	7
Bottlenose	5	2	—	—	—	—	—	—	—	8	—	—	—	—	15
False Killer	—	—	—	—	—	—	—	—	—	—	10	—	—	—	10
Risso's	—	—	85	—	—	—	—	—	—	—	—	—	—	—	85
Pigmy Sperm	—	—	—	—	4	—	—	—	—	—	—	—	—	—	4
Monthly total all species	83	5	89	11	71	41	90	73	128	126	24	13	48	20	

Table 3

Small whales

	Month														
Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Σ
Dusky Dolphin	—	242	46	—	—	—	2	60	15	—	62	90	240	—	757
Common Dolphin	1,238	420	341	323	205	162	254	290	271	655	149	204	1,430	5	5,947
Hector's Dolphin	36	3	3	—	5	—	5	—	—	—	—	8	—	4	64
Tursiops	100	41	16	—	—	—	25	80	159	41	170	80	140	33	885
Striped Dolphin	—	—	—	—	—	—	—	40	—	—	—	—	—	30	70
Right Whale Dolphin	—	—	—	15	—	—	—	—	—	—	—	—	—	—	15
Unidentified	32	—	—	—	—	—	—	—	—	—	—	—	—	—	32
Monthly total all species	1,406	706	406	338	210	162	286	470	445	696	381	382	1,810	72	

Table 4

Incidental catches of cetaceans

A. Reported catches

Date	Species	No.	Length (m)	Sex	Location	Fishing method
2 Jul 80	*Delphinus delphis*	1	1.25	F	Whale Island, Bay of Plenty	Fouled in rock lobster pot line
3 Jul 80	” ”	1	1.76	F	Cape Kidnappers	Single bottom trawl
28 Oct 80	*Cephalorynchus hectori*	1	1.50	F	Waiheke Island	Set gill net
9 Nov 80	*Delphinus delphis*	1	1.46	M	Raurima Reef, Whakatane	Fouled in rock lobster pot line
17 Dec 80	” ”	2	—	—	33°33.14′S 175°19.01′E	Purse seine
23 Jan 81	” ”	9	—	—	34°34′S 173°21′E	” ”
10 Mar 81	” ”	2	2.25 2.12	M M	40°0′S 173°–174°E ” ”	Set gill net ” ” ”
	Globicephala melaena	1	6.00	—	” ”	” ” ”

B. Observed unreported incidental catches

Date	Species	No.	Location	Fishing method
May 80–May 81	*Lagenorynchus obscurus* *Delphinus delphis* *Cephalorynchus hectori*	Estimated maximum 120–150	42°30′S 173°50′E	Deep set nets
May 80–May 81	*Cephalorynchus hectori*	Estimated 6	43°50′S 173°10′E	Set net fisheries

Incidental catches of Cetaceans

All fisheries in which incidental catches occur are being monitored by the Ministry of Agriculture and Fisheries and Fisheries Research Division.

Eighteen cetaceans were reported taken incidentally during normal fishing operations during 1980–81. Four catches including 1 pilot whale, were made in gill nets, 11 in purse seines, 2 were fouled in rock lobster pot buoy lines, and 1 dolphin drowned in a single bottom trawl (Table 4).

No relationship between *Delphinus delphis* and skipjack tuna (*Katsuwonis pelamis*)—the target species for seiners in the New Zealand tuna purse seine fishery—has been shown in New Zealand waters. Tuna seiners made approximately 800 sets during the 1980–81 season and incidental catches of Cetacea occurred in only 1.0% of these sets. *D. delphis* is most common in the Bay of Plenty during the austral summer. Dolphins feed on 'meatballing' clupeids beneath the hulls of trawlers and along the trawl warps during trawling on inshore fishing grounds.

Incidental catches have been observed, but not reported, in two South Island set gill net fisheries (Table 4B). The southernmost of these fisheries is confined to shallow coastal waters and involves Hector's dolphin (*Cephalorynchus hectori*) which is taken in small numbers around Banks Peninsula. Further north, at Kaikoura, gill nets are set at depths to 370 metres. The Dusky dolphin (*Lagenorynchus obscurus*) is the principal species taken in this seasonal fishery. *L. obscurus* is particularly abundant in this area and there is no evidence as yet that these incidental catches are having any effect on the stock.

The following information has been gained through observations at sea and from examination of Dusky dolphins taken from nets or stranded.

Mating takes place in the spring (September–November) and a pregnant female examined in December contained a foetus 7 cm long. Gestation probably lasts for about 11 months and parturition occurs in mid winter (June–August). Length at birth is 55 cm to 70 cm; a male calf of 98 cm collected in November weighed 22 kg. All females sampled through the summer months

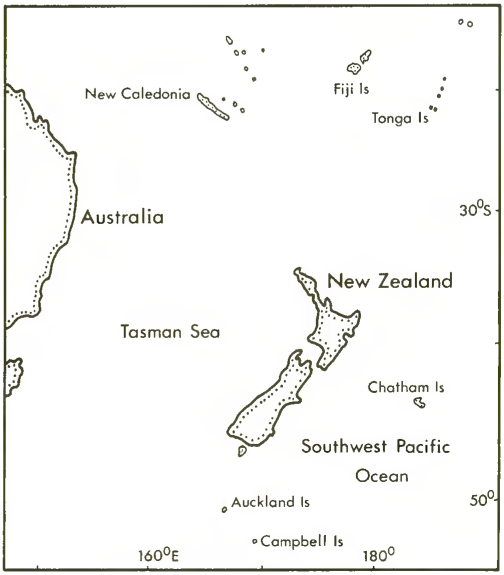

Fig. 1. New Zealand whale sighting area.

(November–January) were lactating; lactation is estimated to last 18 months. The mean length of sexually mature females sampled was 173 cm (range 165–182 cm). Adult *L. obscurus* in the Kaikoura area feed seasonally on squid, hoki (*Macruronus novaezealandiae*), and clupeids. They dive to a known depth of 150 m, and probably deeper. School sizes in the summer months range from tens to over 1000. The northern limit of the species in the New Zealand area is 35°S in June (sea surface temperature 18°C), from sightings data.

One New Zealand registered tuna purse seiner fished outside the NZ 200 mile EEZ in the Solomon Islands, New Caledonian and tropical eastern Pacific fisheries. The Solomon and New Caledonian fisheries are on schoolfish and thus did not involve porpoise. In the eastern tropical Pacific 14 sets were made on porpoise. The details of these sets are held by the Inter-American Tropical Tuna Commission.

Strandings

Strandings of 52 cetaceans were recorded from New Zealand and the offshore islands from May 1980 to May 1981 (Table 5) (Fig. 4). All strandings were attended by MAF personnel. Identifications were confirmed by direct observation or photographs. Wherever possible, samples of gonads, teeth, stomachs, internal organs and parasites have been collected for determination of sexual status, age, feeding, and possible cause of death. Tissues are analysed for persistent pesticide and heavy metal residues. Only two massed strandings have been recorded (ref. Nos 18 and 24, Table 5) (Fig. 4). For distribution of strandings refer to Fig. 4.

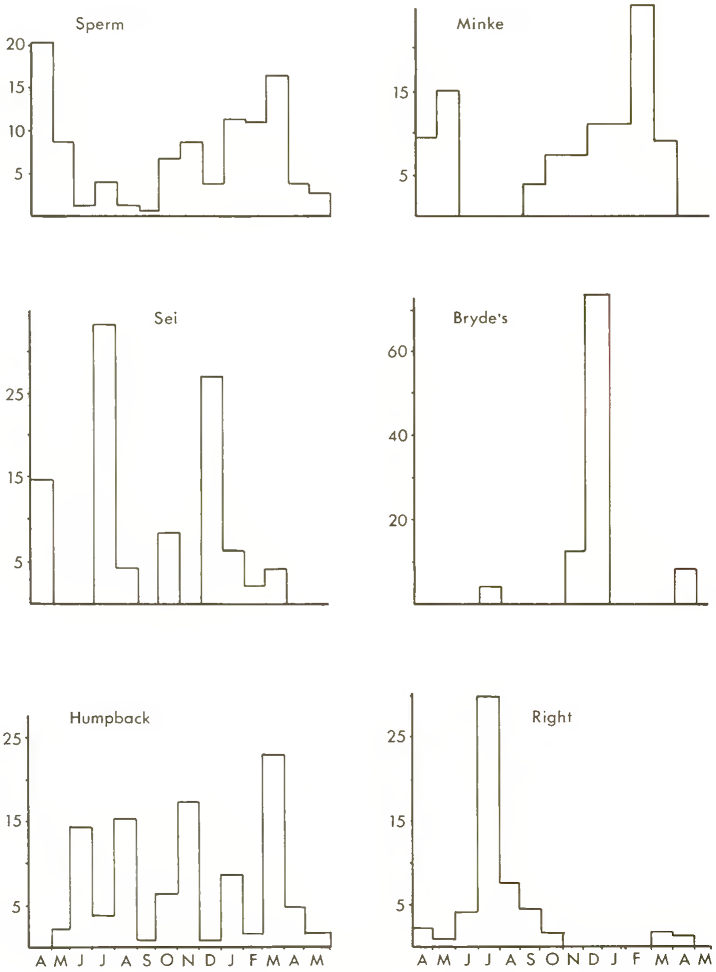

Fig. 2. Seasonal abundance of large whales in the New Zealand sightings area (percent frequency observations by month).

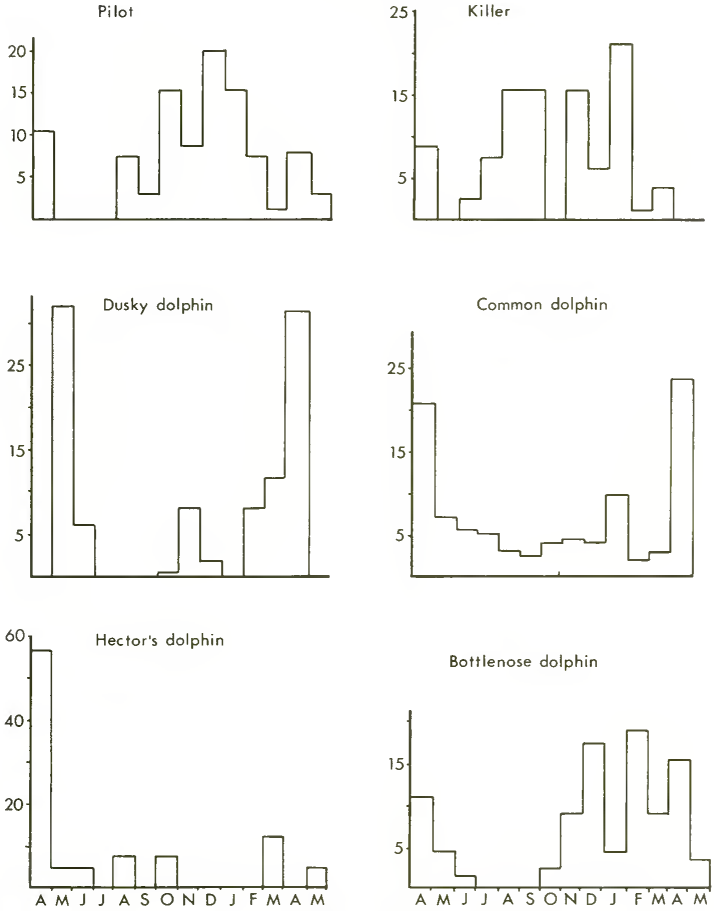

Fig. 3. Seasonal abundance of medium and small whales in the New Zealand sightings area (percent frequency observations by month).

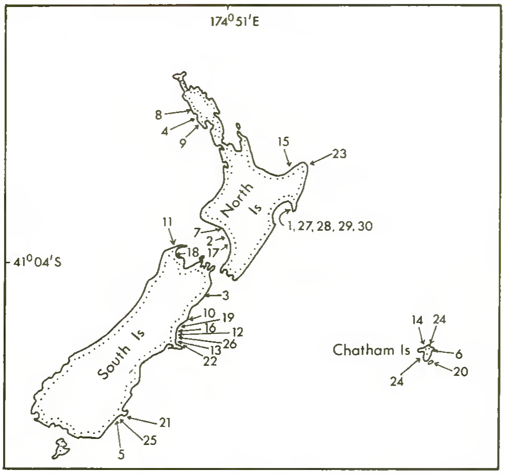

Fig. 4. Cetacean strandings distribution 1980–81. Reference Numbers—Table 5.

7. MANAGEMENT

As a condition of their fishing licences, trawlers now working in the trawl squid fishery south of Stewart Island are required to bring back to port, for examination by MAF Fisheries Research Division, all small cetaceans and pinnipeds taken incidentally during normal fishing operations.

PUBLICATION

Cawthorn, M. W. In press. New Zealand Cetaceans and Pinnipeds. *N.Z. Veterinary Journal*.

Table 5

New Zealand Cetacean strandings—Data summary

Date	Ref No.	Species	Number	Length	Sex	Location
1980						
19 May	1	*Kogia breviceps*	2	2.95 1.98	F M	Opoutama Beach, Mahia
19 May	2	*Ziphius cavirostris*	1	6.10	M	40°08′S 175°13′E
16 Aug	3	*Mesoplodon hectori*	1	3.73	M	Clarence River Mouth
17 Aug	4	*Balaenoptera acutorostrata*	1	3.85	M	Dargaville Beach
5 Sep	5	*Mesoplodon layardi*	1	4.85	M	Kakanui Beach, Sth Otago
Oct	6	*Mesoplodon*	2	6.00 6.15	M F	Pateriki Beach, Chatham Is. Lost at sea
12 Nov	7	*Stenella coeruleoalba*	1	2.34	M	Wanganui
6 Dec	8	*Cephalorynchus hectori*	1	0.85	?	Dargaville Beach
6 Dec	9	*Physeter macrocephalus*	1	7.20	M	Dargaville Beach
6 Dec	10	*Orcinus orca*	1	5.38	M	Motunau
13 Dec	11	*Lissodelphis peroni*	2	1.99 2.20	M F	Puponga, Farewell Spit Successfully refloated
1981						
19 Jan	12	*Lagenorynchus obscurus*	2	1.50 1.43	F F	Spencerville, Christchurch
20 Jan	13	*Lagenorynchus obscurus*	1	1.42	F	Shag Rock, Summer
28 Jan	14	*Caperea marginata*	1	6.46	?	Maunganui, Chatham Is.
26 Feb	15	*Mesoplodon grayi*	1	5.30	F	Kapiritotoro Stream, Bay of Plenty
2 Mar	16	*Mesoplodon layardi*	1	5.13	F	Leithfield Beach, Chch
5 Mar	17	*Kogia breviceps*	1	3.38	F^{P}	Hokio Beach, Levin
9 Mar	18	*Globicephala melaena*	5	6.00 5.00 4.00 2.00 5.00	M M M F F	Onekaka Beach, Golden Bay
31 Mar	19	*Globicephala melaena*	1	4.80	F	Amberley Beach, N. Chch
Apr	20	*Physeter macrocephalus*	1	—	?	Pitt Is., Chatham Is.
2 Apr	21	*Globicephala melaena*	1	1.87	F	Sonte Brighton, Dunedin
5 Apr	22	*Mesoplodon grayi*	1	6.00	?	Lyttleton Harbour
7 Apr	23	*Kogia breviceps*	2	2.80 1.69	F M	East Cape
10 Apr	24	*Orcinus orca*	12	6.25 5.45 8.05 6.15 1.40 5.85 6.70 6.35 5.55 4.90 2.00	M M M M M F F F F F F	Pt. Weeding, Chatham Is. Kaingaroa Chatham Is.
28 Apr	25	*Globicephala melaena*	1	—	?	Bruce Rocks, Taeri Mouth, Otago/Dunedin
8 May	26	*Ziphius cavirostris*	1	—	F	New Brighton
10 May	27	*Kogia breviceps*	2	2.40 ?	F^{L} ?	Opoutama Beach, Mahia
19 May	28	*Kogia breviceps*	1	3.01	F	Opoutama Beach, Mahia
27 May	29	*Kogia breviceps*	1	3.10	F	Opoutama Beach, Mahia
28 May	30	*Kogia breviceps*		2.90 calf successfully liberated.	F^{L}	Opoutama Beach, Mahia

P = Pregnant, L = Lactating

Appendix 1

Large Whales Sighted Outside New Zealand Sightings Area

Species	Month	Year	Position	Number	Heading
Sperm	June	1980	02°03′S 148°41′E	2	S
	July	1980	47°12′N 06°47′W	1	E
			25°42′S 168°51′W	3	NE
	August	1980	24°12′N 139°13′E	3	—
	October	1980	05°06′N 80°56′E	2	—
			36°56′S 130°20′E	8	N
	December	1980	05°01′N 82°06′W	2	—
			01°42′S 91°10′E	2	—
Sei	July	1980	02°50′S 92°40′W	3	E
	August	1980	12°09.9′N 50′15′E	1	NE
			13°04′S 174°20′W	1	W
	October	1980	18°16′S 116°10′E	2	—
	December	1980	18°40′S 171°20′E	1	N
Bryde's	December	1980	01°56′S 91°27′W	3	NW
			01°43′S 91°11′W	1	NE
	April	1981	11°00′N 53°00′E	2	NE
Humpback	June	1980	12°16′S 100°54′W	10	NE
	July	1980	09°09′S 159°42′E	4	SE
	August	1980	18°51′S 158°48′W	4	NE
			30°52′S 115°09′E	2	NW
	October	1980	19°00′S 169°50′W	1	—
			04°22′N 83° 27′W	1	SW
			31°36′N 13°50.2′W	1	—
	November	1980	32°15°S 115°40′E	2	SE
	April	1981	20°57′N 70°02′E	2	—
Minke	November	1980	20°12′S 154°07′W	2	W
	March	1981	03°12′N 91°32′W	5	NE
Fin	June	1980	28°30′S 122°34′W	1	S
	March	1981	01°46.3′N 168°41.9′W	1	SW

SC/33/ProgRep Norway

Norway
Progress Report on Cetacean Research June 1980 to May 1981

SPECIES AND STOCKS STUDIES

Four species of whales have been studied during the period June 1980 to May 1981: minke, humpback, bowhead, and killer whales. Revised assessments have been made for the northeast Atlantic stock of minke whales.

FIELD OBSERVATIONS AND COLLECTIONS

The field work carried out by the Sea Mammal Section of the Institute of Marine Research in Bergen has been continued in 1980. Institute personnel and whaling inspectors collected 40 sets of sexual organs and 33 *tympanic bullae* from minke whales in the Barents Sea. In addition 6 minke whales were examined in the North Sea and 21 off East Greenland. In cooperation with the whalers, teeth and sexual organs were collected from 50 killer whales caught on the coast of Norway.

Systematic sightings have not been carried out, but recorded observations in the 1980 whaling season include one blue whale near Iceland and 2 sperm, 8 humpback, 176 fin and more than 200 minke whales off East Greenland. Sightings recorded by one of the inspectors in the Barents Sea comprise one Greenland right whale, one humpback, one fin and more than 70 minke and 'many' (50–100) killer whales.

Killer whale sightings on the coast of Norway reported by fishermen and whalers include separate reports from Lofoten in Nordland county of 1,120 in October and 150, 180 and 400 in January. In March 200 killer whales were reported from Møre county.

Field observations of bowhead whales were made in Arctic northeast Atlantic waters in the summer of 1980 by biologists working on the *Ymer* and *Norvarg* expeditions.

WHALE MARKING

A Danish-Norwegian marking cruise in West Greenland waters was scheduled for 14 days after the end of the whaling season in 1980. Unfortunately the ship was damaged after five days when 10 fin whales, 4 humpbacks and 1 minke whale had been marked, and the work had to be stopped. Six killer whales were marked on the coast of Norway at Lofoten and off Møre during herring research cruises.

Four marks from previously marked minke whales were recovered in 1980. One of them was found when processing the whale onboard the ship. The other three marks appeared when the whale meat was cut after landing.

LABORATORY WORK

At the Sea Mammal Section in Bergen, *tympanic bullae* from 51 minke whales collected in 1980 and teeth from 121 killer whales collected in 1979 and 1980 have been processed for age studies. Testes from 45 male killer whales have been sectioned for microscopic studies and ovaries from 47 females sliced for macroscopic analysis. Ovaries from 43 female minke whales have also been analysed.

DEVELOPMENT OF TECHNIQUES

Christensen (1981) describes a technique developed for the age determination of minke whales from laminations in the *tympanic bulla*. Methods for age determination from tooth laminations have been adapted for use on killer whales.

RESEARCH RESULTS

Catch data for minke and killer whales were reviewed and collated by the Sea Mammal Section in Bergen. A total of 2,002 minke whales and 52 killer whales were taken by 89 Norwegian small type whalers in the 1980 whaling season.

Statistics of Norwegian catches of minke whales in 1976–79 have been reviewed and used to calculate revised indices of catch per ship-day (CPUE) and sex composition for these years and 1980. No obvious trend was found in CPUEs for any of the whaling areas used by Norwegian whalers in the North Atlantic. The overall sex composition in Norwegian catches shows a decrease from 67.2% females in 1976 to 56.3% females in 1980.

Recoveries in 1980 have been included in a revised marking-recapture stock estimate for northeast Atlantic minke whales. The total stock was estimated at 121,000 whales (95% confidence interval 79,000–190,000).

Material and data from recent killer whale catches on the Norwegian coast have been analysed for a study of the general biology of this species. Killer whales occur all along the coast and are most abundant in areas with concentrations of herring and other schooling fishes. The largest numbers are found in the Lofoten area of Nordland county and off the coast of Møre and Finnmark counties. Provisional age determinations have been used to study growth and maturity. Growth continues to an age of about 20 years in both sexes. Females reach sexual maturity at about 10 years and 50% of the mature females are pregnant, suggesting a reproductive cycle of two years. Data are available to indicate a carcass weight-composition of 40% meat, 29% blubber, 22% bones and 9% viscera.

At the Department of Marine Zoology and Marine Chemistry, Univerity of Oslo, studies of variations in surface structure of baleen plates in Antarctic humpback whales are nearly completed. A report has been produced on surveys for bowhead whales made on the *Ymer* and *Norvarg* expeditions in Arctic Northeast Atlantic waters in 1980, and another one on the food of minke whales in northern North Atlantic waters.

In January 1981 the Norwegian Ministry of Fisheries made funds available for a five-year project to improve killing methods in the Norwegian small-type whaling for minke and killer whales. Veterinarian Egil Ole Øen of the Norwegian Veterinary College, Oslo, was appointed principal investigator to plan and carry through the project.

The plans include an initial review of current killing methods and the anatomical, physiological and technological basis for improvement of present practice and the possible development of alternative methods for a more rapid and humane killing of whales.

An abundance of general literature on whaling is available. Killing methods which have been tested in commercial operations since the development of the explosive harpoon all seem to have been aimed at increasing the efficiency of the whaling operations. In most cases there is no apparent conflict between this purpose and the desirability of rapid and humane killing. Some alternative methods therefore may merit further attention upon the development of improved technology.

Anatomical studies of minke and killer whales are lacking in detail. There is also a lack of data on the reaction of whales and on killing time related to hits by harpoons or other missiles in different parts of the body.

A field study to provide data on killing times related to the point of entry of the harpoons, and corresponding type and extent of organ damage, is being carried out during the 1981 whaling season. Initial experiments will also be made in 1981 to evaluate the effects of high-velocity projectiles from rifles.

NEW RESEARCH PROJECTS

Funds have been made available by the Norwegian Ministry of Fisheries to transfer previous catch data and information on the whales caught from the compulsory report forms submitted by the whalers to magnetic tapes. A few administrative problems remain to be solved, but it is planned to start this two-year project at the Institute of Marine Research within 1981. Data on a total of 147,303 minke whales, 2,069 killer whales, 5,824 bottlenose whales and 2,041 pilot whales taken by Norwegian small type whalers in the North Atlantic from 1938 to 1975 will thus be made available for computer analysis. Eventually all data will also be submitted in an agreed format to the IWC data bank.

A conditional commitment has been made by Norwegian authorities for partial funding of the whale sighting and marking cruise to the waters of East Greenland, Iceland and Jan Mayen recommended by IWC in 1980. The intention is to carry through the cruise in the summer of 1982. Initial contacts have been made with the respective research institutes in Denmark and Iceland for cooperation in further planning.

Simultaneous observations of killer whales along the entire coast of Norway is planned for the autumn of 1981. Cooperation from fishermen in a one-week pilot project will be sought through local unions and representatives of the fishery authorities, and through trade journals and broadcasts to fishermen. If successful, the project will be repeated in early 1982.

PUBLICATIONS

Anon. 1980. Norway. Progress report on cetacean research—June 1978 to May 1979. *Rep. int. Whal. Commn* 30: 163.

Anon. 1980. Norway. Progress report on whale research—June 1979 to May 1980. *Rep. int. Whal. Commn* 31: 209–10.

Anon. 1980. Norwegian small whale hunting. Survey of Norway's activity in whaling in the period 1969–1979 and social and economic problems following a ban on whaling. Paper TC/32/B8 presented to the IWC, 1980.

Christensen, I. 1980. Observations of large whales (minke not included) in the North Atlantic 1976–1978 and markings of fin, sperm and humpback whales in 1978. *Rep. int. Whal. Commn* 30: 205–8.

Christensen, I. 1980. Catch and effort in the Norwegian minke whale fishery in the 1978 whaling season. *Rep. int. Whal. Commn* 30: 209–11.

Christensen, I. 1980. Miscellaneous data on killer whales caught in Norwegian coastal waters, 1978–79. Paper SC/32/SM14 presented to the IWC Scientific Committee, July 1980.

Christensen, I. 1980. Provisional data on catch and effort and data on the sex composition in the Norwegian minke whale fishery in 1979. Paper SC/32/Mi22 presented to the IWC Scientific Committee, July 1980.

Christensen, I. 1981. Age determination of minke whales, *Balaenoptera acutorostrata,* from laminated structures in the tympanic bullae. *Rep. int. Whal. Commn* 31: 245–53.

Christensen, I., Jonsgård, Å. and Rørvik, C. J. 1981. Catch statistics for minke whales (*B. acutorostrata*) and killer whales (*Orcinus orca*) caught by Norway in 1979. *Rep. int. Whal. Commn* 31: 635–7.

Christensen, I. and Rørvik, C. J. 1980. Results from markings of minke whales in the Northeast Atlantic. *Rep. int. Whal. Commn* 30: 201–3.

Christensen, I. and Rørvik, C. J. 1981. Analysis of markings and recaptures of minke whales in the Barents Sea 1974–1979. *Rep. int. Whal. Commn* 31: 255–7.

Christensen, I. and Rørvik, C. J. 1980. Availability of minke whales in the Barents Sea and adjacent waters. *Rep. int. Whal. Commn* 31: 259–62.

Christensen, I., Rørvik, C. J. and Jønsgård, Å. 1980. Preliminary catch statistics for minke whales (*B. acutorostrata*) caught by Norway in 1978. *Rep. int. Whal. Commn* 30: 219–22.

Haug, T. 1980. En grønlandshval observert på Tanasnaget (N71°00′, Ø28°51′) i mai 1980 [A bowhead whale *Balaena mysticetus* L. observed on Tanasnaget (N71°00′, E28°51′) in May 1980]. *Fauna, Oslo* 33: 158–9.

Haug, T. 1980. On some reproduction parameters in fin whales *Balaenoptera physalus* (L.) caught off Norway. *Rep. int. Whal. Commn* 31: 373–8.

Jonsgård, Å. 1981. Bowhead whales, *Balaena mysticetus*, observed in Arctic waters of the eastern North Atlantic after the Second World War. *Rep. int. Whal. Commn* 31: 511.

Øritsland, T. 1980. Preliminary report on actions taken by Norway to implement IWC resolutions on the humane killing of whales. Paper presented to the IWC, 1980.

Rørvik, C. J. 1980. Vitenskap og hval. *Norsk Natur* 16 (1): 24–5.

Rørvik, C. J. 1980. Catch per unit effort in the Icelandic fin whale fishery. *Rep. int. Whal. Commn* 30: 213–17.

Rørvik, C. J. 1980. Whales and whaling off Mozambique. *Rep. int. Whal. Commn* 30: 223–5.

Rørvik, C. J. 1981. Simulations of the Northeast Atlantic stock of minke whales. *Rep. int. Whal. Commn* 31: 263–9.

Rørvik, C. J. and Christensen, I. 1980. Considerations of factors affecting the use of catch per unit effort in the Norwegian minke whale fishery for stock estimates. *Rep. int. Whal. Commn* 31: 271–8.

Rørvik, C. J. and Sigurjónsson, J. 1981. A note on catch per unit effort in the Icelandic fin whale fishery. *Rep. int. Whal. Commn* 31: 379–83.

Sigurjónsson, J. 1980. *Aldersstudier over vågehval* (Balaenoptera acutorostrata *Laépede) i islandske farvann.* Cand. real. thesis, marine zoology, University of Oslo, spring 1980, 97 pp.

SC/33/ProgRep Peru

Peru
Progress Report on Cetacean Research May 1980 to March 1981

Julio Valdivia G., Antonio Landa, Pedro Ramirez and Humberto Tovar

Instituto Del Mar Del Peru

INTRODUCTION

This report covers whaling activities from May 1980 to March 1981: catches of sperm and Bryde's whales, effort and CPUE by month and season, commercial sightings by species, size composition by species. All these data were collected by IMARPE biologists stationed at Tierra Colorada. The results of a sighting cruise for sperm, Bryde's and blue whales and the marking of sperm whales conducted by IMARPE biologists during March 10–25 as well as the estimation of the abundance of Bryde's whales from a commercial trip with a biologist of IMARPE as observer from 24 February to 3 March are also described. Finally, CPUE data for Bryde's whales are presented which show the inadequacy of the DeLury method in this case and support a claim to modify the starting date of the 1982 season.

CATCH AND EFFORT

The taking of 264 Bryde's whales was authorised by the Peruvian Government, following the same pattern as in 1980, from 4 January to 5 July 1981; the authorisation for 225 sperm whales was effective from 4 January to 5 September 1981.

The annual catch and effort data from 1968 to 1980 are shown in Table 1; it is to be noted that for 1980 the total catch of Bryde's whales, 215, is only 81.4% of the total allowed and required only about 73% of the average effort of past years. Table 2 shows the monthly catch and effort data from May 1980 to March 1981 complementing Table 7 of the last Progress Report (Valdivia and Ramirez, 1981). The effort columns of Table 2 are based on the time budget analysis shown in Table 3, May 1980 to March 1981.

Table 1

Annual catch by species; total common effort (gross working day's and searching hours), 1968–80

	Catch					Effort	
Year	Sperm	Bryde's	Bryde's + Sei	Sei	Fin	GWD	SH
1968[1]	540		355		61	274.2	
1969	1,452		784		74	614.8	
1970	1,432		413		85	577.3	
1971	1,321		415		37	671.6	
1972	1,554		337		9	606.2	
1973	1,497	311		19	11	678.5	
1974	1,286	450		68	5	635.1	
1975	793	415		130	5	623.7	
1976	1,500	398		12	13	759.1	1,838.0[2]
1977[3]	799	386		5	2	622.2	4,724.0
1978	770	297		3	0	599.5	4,639.3
1979	742	300		0	0	638.6	5,050.4
1980	450	215		0	0	445.5	2,891.9

[1] Only from October to December.
[2] Only September to December.
[3] From here on, the catches are regulated by quotas.

Table 2

Monthly catch by species; total common effort (gross working days and searching hours) May 1980 to March 1981

		Catch		Effort	
Year	Months	Sperm	Bryde's	GWD	SH
1980	May	84	29	75.9	527.5
	June	141	22	74.0	582.3
1981	January	47	25	73.2	632.0
	February	61	22	72.8	444.3
	March	25	13	65.2	593.0

CATCH PER UNIT OF EFFORT (CPUE)

Since Peru joined the IWC in 1979, catches have not been allowed during October, November and December. In order to compare this year with past years back to 1973, we present in Table 4 the CPUE for Bryde's whales, in terms of gross working days and searching hour units, for the common months January, February and March; these data are also presented in Fig. 1. Neither effort indices show a decreasing trend, supporting our idea that (i) effort has not, so far, been intense enough to affect the stock and therefore, barring other causes than effort, the annual catch of the next year should be around the average for past years using about the same effort and (ii) that, in the absence of a downward trend, the DeLury method as modified by Chapman is not applicable to analysis of this Bryde's whale stock, although it is used for other Bryde's whale populations.

Fig. 1. Catch per unit effort of Bryde's whales, each point represents only January, February and March.

Table 3

Time budget by month in hours

Year	Month	Sailing	Searching	Chasing	Gathering	Resting	Towing
1980	May	276.1	527.5	59.4	69.4	401.5	475.4
	June	242.4	582.3	70.5	57.4	409.0	406.2
1981	January	210.0	632.0	55.0	50.4	494.6	310.3
	February	303.4	444.3	78.4	72.1	303.2	519.2
	March	215.3	593.0	30.4	39.2	472.0	201.5

Table 4

Catch, effort and CPUE of Bryde's whales for January, February and March of each year 1973–81

		Effort		CPUE	
Years	Catch	GWD	SD	C/GWD	C/SD
1973	77	237.3		0.32	
1974	174	225.0		0.77	
1975	154	233.8		0.65	
1976	178	228.2		0.78	
1977	150	231.0	80.2	0.64	1.8
1978	210	231.9	71.2	0.90	2.9
1979	132	225.9	77.9	0.58	1.7
1980	135	216.3	69.0	0.62	2.0
1981	106	211.4	69.5	0.50	1.5

Table 5 and Fig. 2 present a pooled weighted monthly average CPUE for Bryde's whales based on data from 1973 to 1981 to show that the distribution of the relative abundance and/or availability peaks around November, December and January; this could very well explain the fact that the catch in the IWC scheduled year of 1980 (i.e. January to July) did not reach the total allowed. This is a powerful argument, in our opinion, to allow the start of the season in November and its end in April.

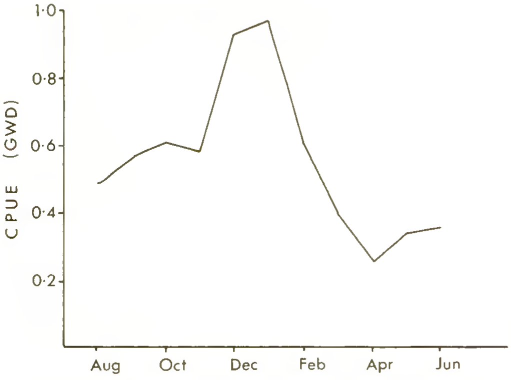

Fig. 2. Pooled monthly average CPUE 1973–80 Bryde's whale.

SIGHTINGS

These are given in Table 6 by month from October 1976 to March 1981. It is clear that the most abundant species are the sperm, Bryde's and blue whales. It is of interest to note that the sightings of Bryde's whales peak in November, December and January so that 50% of the total sightings occur in these months, 12 (30%) of the 39 months for which there are data; this result supports our appreciation of relative abundance by month deduced from actual catches.

Table 5

Average catch, effort and CPUE of Bryde's whales 1978–80

	Average catch	Average effort	CPUE C/GWD
January	75.3	623	0.97
February	42.9	549	0.62
March	33.1	657	0.40
April	17.8	425	0.25
May	27.0	398	0.34
June	24.6	338	0.36
July	—	—	—
August	12.8	104	0.49
September	32.5	341	0.57
October	38.0	436	0.61
November	38.0	399	0.58
December	69.7	450	0.93

ABUNDANCE EVALUATION

As requested in 1979 by the Bryde's whale sub-committee of the Scientific Committee, the Peruvian Government conducted a sighting and marking cruise in February 1980 (Valdivia *et al.*, 1981), and another in March 1981. Fig. 3 shows the track of the latter cruise together with the position of the only Bryde's whale sighting and of the three sperm whale schools in which a total of about 95 individuals were observed, about half the number observed in the previous year's cruise.

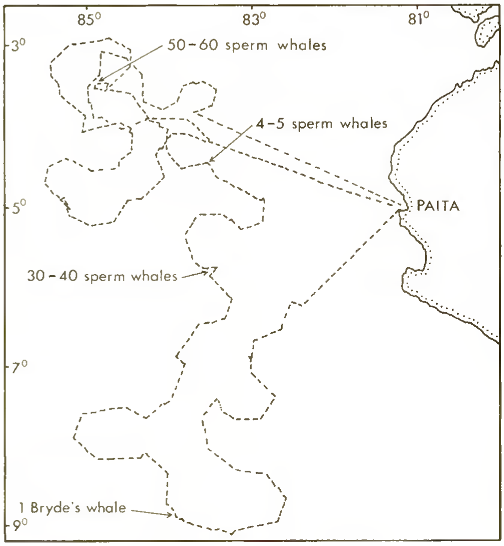

Fig. 3. Track line of IMARPE'S cruise, 10–25 March 1981 and positions of whales sighted.

However, during 24 February to 3 March 1981, the IMARPE whale biologist at Punta Colorada participated in a commercial catching trip (Fig. 4) and sighted a total of 22 Bryde's whales (see Table 7). The position of sightings, at least 20 nm apart, makes corrections to insure that no whale was counted more than once unnecessary and so the formula used in last year's cruise report can be applied directly:

$$P = N \times A/a \times b$$

where N = 22, the number of animals sighted.
A = 340 × 10^3 nm^2, the statistical area H-34.
a = 986 nm the length of the track while sighting (the actual track was 1,411 nm).
b = 4.0 the estimated track width (both sides) measured by actually approaching various sighted whales.

Table 6

Position and numbers of Bryde's whales sighted 24 February–3 March 1981

Date	Position		No. of Bryde's whales seen
24 February	03°34′S	83°41′W	11
25 February	03°40′S	84°01′W	1
2 March	03°27′S	83°23′W	20

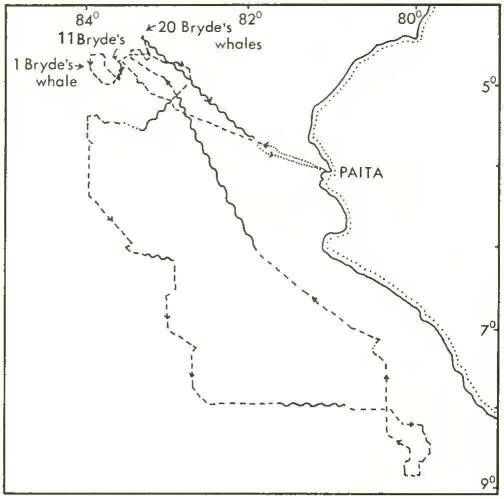

Fig. 4. Track line commercial trip, 24 February–3 March 1981. Sightings of Bryde's whales (Br).—Day's track; ~ Night track.

Table 7

Monthly distribution of whale sightings by species from the commercial fleet. October 1976 to March 1981

Year	Month	Fin	Sei	Humpback	Blue	Sperm	Bryde's	Total sightings
1976	October		13	10	8	185	80	296
	November			3	7	601	87	298
	December				32	873	208	1,113
1977	January	1	1		77	293	120	491
	February				132	62	73	267
	March				103	77	103	283
	April				58	448	52	558
	May	1	2	5	42	452	32	534
	June	2	6	8	42	341	67	466
	September			12	12	174	7	205
	October		7	9	27	94	154	291
	November			3	11	438	49	501
	December				7	346	308	661
1978	January		3		191	306	467	967
	February				324	177	114	615
	March				377	340	116	833
	April				114	276	61	451
	May				27	82	62	171
	June		1	8	33	271	73	386
	October			6		61	44	111
	November			31	15	149	116	311
	December				21	356	70	447
1979	January				301	54	213	568
	February				113	110	107	330
	March				115	275	56	446
	April				42	321	29	392
	May			2	90	538	92	722
	June			4	63	98	23	188
	September				7	30	21	58
	October	4	2	40	15	304	69	434
	November	1	3	1	19	464	34	522
	December	3		2	95	346	114	560
1980	January	7		2	297	63	111	480
	February				70	357	211	638
	March	1			108	462	50	621
	April				93	87	46	226
	May				32	465	51	548
	June	2	5	7	112	255	57	438
1981	January				45	826	59	930
	February				138	354	206	698
	March				170	164	53	487

The estimated number, P, is 1,989.5 which, multiplied by the six 10° squares adopted as the area of the Peruvian stock of Bryde's whales, gives a population of 11,370, quite comparable with the 11,651 estimated by us in 1980 and the 10,000 estimated by Rice in 1975. Although we appreciate that this is a relatively unsophisticated analysis, we believe that this result points again to the conclusion that the effort used (and the resultant catch) is not affecting the stock and that consequently an allowed total catch around the annual average catch is a sensible one which will not endanger the stock.

Oceanographic conditions during the IMARPE cruise

Figs 5 and 6, the surface temperature and salinity distributions, give an idea of the oceanographic conditions during the March cruise. Due to lack of below surface data it is not possible to make a close comparison with the conditions during last year's cruise. However, during the 1981 cruise the 25°C isotherm formed a clear wedge pushing NE from off Pta Falsa as part of a general movement of higher temperature isotherms in the same direction, whereas in 1980 the 25°C isotherm ran more or less parallel to the coast and instead of the single wedge of 1981 there was a small one off Talara with temperatures below 25°C and another at about 8°S of temperatures above 25°C, both running to the west.

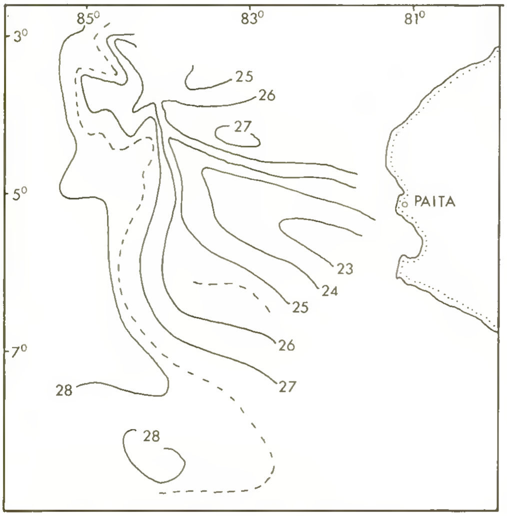

Fig. 5. Surface temperature (°C) chart, IMARPE'S cruise 10–25 March, 1981.

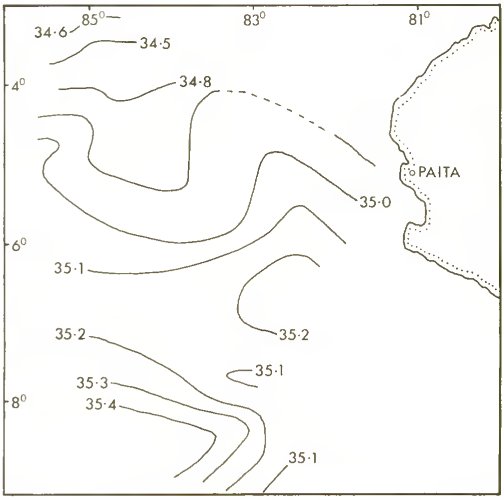

Fig. 6. Surface salinity (parts per 1000) chart, IMARPE'S cruise 10–25 March 1981.

Marking of sperm whales

Table 8 shows the results of the sperm whale marking cruise which took place from 10–25 March. Following IWC Scientific Committee recommendations, it was decided to mark only individuals larger than 9 m. The actual size of the whales marked was between 9.5 and 12.0 m. Although the cruise was intended for Bryde's whale marking also, no marks were used on the only individual seen.

Table 8

Marking results from the March 1981 cruise

Mark No.	Species	Result	Date	Position	Remarks
38456	Sperm	Hit	11.3.81	03°29′S 84°52′W	9.5–10.0 m
38453	Sperm	Possible hit	11.3.81	,,	9.5–10.0 m
38467	Sperm	Possible hit	11.3.81	,,	9.0–10.0 m
38468	Sperm	Hit	11.3.81	,,	9.5–10.0 m
38469	Sperm	Hit	11.3.81	,,	9.5–10.0 m
38470	Sperm	Hit	11.3.81	,,	9.5–10.0 m
38450	Sperm	Hit	21.3.81	85°46′S 83°26′W	11.0–12.0 m 38454
38452	Sperm	Hit, mark protruding	21.3.81	,,	10.0–11.0 m
38453	Sperm	Miss	21.3.81	,,	
38454	Sperm	Hit	21.3.81	,,	11.0–12.0 m 38450
38455	Sperm	Possible hit	21.3.81	,,	10.0–11.0 m
38457	Sperm	Hit, mark protruding	21.3.81	,,	10.0–11.0 m 38465
38458	Sperm	Hit	21.3.81	,,	10.0–11.0 m
38460	Sperm	Hit	21.3.81	,,	11.0–12.0 m
38461	Sperm	Hit, mark protruding	21.3.81	,,	1 inch 9.0–10.0 m
38463	Sperm	Hit	21.3.81	,,	11.0–12.0 m
38465	Sperm	Hit, mark protruding	21.3.81	,,	10.0–11.0 m 38457

Recapture of marks

One mark, number 37281, was recovered from a female 15.1 m Bryde's whale on 22 March 1981 at 08°16′S, 82°45′W; the individual was alone. The whale had been marked on 14 December 1980 at 09°32′S, 83°39′W by a Japanese research vessel.

CONCLUSIONS

1. The evaluation of this year is similar to that of last year and in 1978 indicating that current effort has not affected the stock.
2. There is no observable trend in CPUE since the onset of the Bryde's whale fishery, so that DeLury type methods cannot be used to ascertain stock size.
3. Throughout the years of the Bryde's whale fishery there has been a very conspicuous peak of relative abundance or availability during November, December and January. The catching season should include these months.

PUBLICATIONS

Valdivia, J. and Ramirez, P. 1981. Peru, Progress report on cetacean research, June 1979–May 1980. *Rep. int. Whal. Commn* 31: 211–14.

Valdivia, J., Franco, F. and Ramirez, P. 1981. The exploitation of Bryde's whales in the Peruvian Sea. *Rep. int. Whal. Commn* 31: 441–8.

Valdivia, J., Ramirez, P., Tovar, H. and Franco, F. 1981. Report of a cruise to mark and assess Bryde's whales of the 'Peruvian stock', February 1980. *Rep. int. Whal. Commn* 31: 435–40.

SC/33/ProgRep Seychelles

Seychelles
Progress Report on Cetacean Research 1981
June 1980–May 1981

1. Analysis of results of the 1980 aerial survey has been completed and publication is being arranged (Keller, Leatherwood and Holt). This work has involved assistance from scientists in the USA and elsewhere in species identification from photographs.

2. Co-operation has begun among countries in the Indian Ocean area for exchange and compilation of data from strandings. At present India, Oman and the Seychelles are co-operating in this matter; it is hoped that soon other coastal states will join in.

3. A project has been formulated for preparatory studies for a population study by sightings in the northwest Indian Ocean. The project is funded by World Wildlife Fund (Netherlands) and will be for three years, starting late in 1981.

4. Plans for a meeting to plan a programme of research in the Indian Ocean Sanctuary are at an advanced stage. It will now be held in the Netherlands, under joint sponsorship of the Governments of the Netherlands and Seychelles, with assistance from IUCN and WWF (Netherlands), starting 28 September 1981. It had been postponed from earlier this year because of problems in the arrangements, availability of documentation, and securing participation of key scientists in the meeting.

5. A manual for identification of cetaceans at sea, based on the recent available biological information is in press; it should be available late in 1981.

PUBLICATION

Watson, L. 1981. *Sea Guide to Whales of the World.* (Illustrated by Tom Ritchie), Hutchinson, London, 302 pp.

SC/33/ProgRep South Africa

South Africa
Progress Report on Cetacean Research June 1980 to May 1981

This report summarizes cetacean research conducted by the Sea Fisheries Institute of the Department of Agriculture and Fisheries.

1. SPECIES AND STOCKS STUDIED

During the past year field studies were conducted on the following:

(a) Right whales (*Eubalaena glacialis*)—coast of southern Africa.
(b) Minke whales (*Balaenoptera acutorostrata*)—Area V of the Antarctic.
(c) Small cetaceans—animals stranded on the South West African/Namibian coast and the South African coast west of Mossel Bay.

2. FIELD OBSERVATIONS AND COLLECTIONS

The annual aerial survey of right whales along the southern coast of South Africa was conducted from 25 to 26 September 1980 between Woody Cape (Algoa Bay) and Muizenberg (False Bay). On 21, 22 and 23 October 1980 aerial photographs were taken of 35 cow-calf pairs of right whales between Wilderness and Muizenberg, False Bay.

Dr Best participated in and was leader of the IDCR southern minke whale assessment cruise in Area V of the Antarctic, departing from Wellington on 17 December 1980 and returning there on 12 February 1981.

Sightings of cetaceans were carried out during two research cruises off the west coast, one 22-day cruise in August 1980 between Kleinsee and Ichaboe Island, and one 17-day cruise in April 1981 between the Orange River mouth and Cape Town.

Material was collected from 22 cetaceans that either stranded or were found as beach pick-ups or died during fishing operations.

3. MARKING

As part of the IDCR southern minke whale assessment programme, a total of 473 minke and 12 sperm whales was marked, mostly in Antarctic Area V. Two recoveries were reported from these minke whales in the 1980/81 season as well as a further 4 recoveries from minke whales marked in Area III in 1979/80 and 7 recoveries from minke whales marked in Area IV in 1977/78 or 1978/79. Details have been forwarded to the Sea Mammal Research Unit, UK.

4. LABORATORY WORK

Samples from the testes of 345 minke whales from Durban were examined histologically and the stage of maturation investigated. Ear plug sections from 543 minke whales were examined and the number of growth layers counted.

5. RESULTS

A total of 166 right whales (including 3 juveniles and 35 calves) was seen during the right whale survey. This total was the second highest since counts began in 1969.

As in 1979, callosity patterns on the heads of 35 cows and calves were photographed from a helicopter (using the same technique as previously). These patterns are being coded for eventual computer-assisted sorting and preliminary matching of individuals.

The results of the IDCR cruise will be presented elsewhere to this meeting, as will the results of the minke whale ear plug and testis examinations.

During two research cruises on the west coast (for the collection of seals at sea), 55 sightings of cetaceans were made.

Species	Number of sightings	Number of animals
August 1980		
Lagenorhynchus obscurus	18	155
Cephalorhynchus heavisidii	7	28
Unidentified dolphin	3	2*
Unidentified whale	1	1
April 1981		
Lagenorhynchus obscurus	7	297
Cephalorhynchus heavisidii	4	11
Grampus griseus	5	42
Balaenoptera edeni	1	2
Physeter macrocephalus	1	1
Orcinus orca	1	3
Unidentified whale	1	1
Unidentified dolphins	6	16

* No estimate for the size of one large school.

In addition, 3 female and 1 male *L. obscurus* and 1 female *C. heavisidii* were collected at sea for biological observations.

The following animals were stranded on the coast of South Africa (west of Mossel Bay) or South West Africa/Namibia and examined by staff of the Sea Fisheries Institute.

Balaenoptera acutorostrata	2	♂
Caperea marginata	1	♂
Physeter macrocephalus	1	♀
Kogia breviceps	1	♀
Kogia simus	1	♀
Pseudorca crassidens	1	♂
Grampus griseus	1	♂
Tursiops truncatus	3	♂
Tursiops sp	1	♂
Lagenorhynchus obscurus	1	♀, 2 sex unknown
Cephalorhynchus heavisidii	3 sex unknown	
Stenella coeruleoalba	1	♀
Mesoplodon layardi	1	♂
Mesoplodon mirus	1	♂

6. MANAGEMENT

No commercial whaling took place from South Africa in 1980.

On 5 December 1980 regulation 90 of the Sea Fisheries Act, 1973 (Act 58 of 1973) was substituted by the following:

'90.(1) No person shall—

(a) catch or kill any whale at any time; or

(b) disturb or harass any whale during the breeding season which stretches from 1 June to 30 November of any year.

(2) For the purpose of subregulation (1), 'disturb or harass' shall also include—

(a) the shooting at any whale;

(b) approaching any whale, whether in a boat or any other floating craft, aircraft or helicopter to within a distance of less than 300 metres;

(c) the stopping or lingering in a boat or any other floating craft within a distance of less than 300 metres from any whale;

(d) that in the event of a whale surfacing within a distance of less than 300 metres from a boat or other floating craft, the person in charge of such boat or other craft fails to proceed immediately to a distance of at least 300 metres from the whale.'

Dolphins caught under permit for public display during 1980/81 are given in the table at the foot of the page.

On 12.4.81 a *Cephalorhynchus heavisidii* (sex unknown) became entrapped by a purse-seine net during fishing operations off South West Africa/Namibia and was apparently killed by the fish pump. The frequency of such incidents is being investigated.

During 1980, 171 dolphins (one of which was released alive) were reported to have become entangled in shark nets off Natal. The seasonal and geographical separation was as follows:

	Number entangled (Number released alive)			
Month	Area A[1]	Area B[2]	Area C[3]	Total
January	0	1	0	1
February	0	4	0	4
March	3	0	1	4
April	0	0	0	0
May	0	0	1	1
June	3	2	4	9
July	20 (1)	50	7	77 (1)
August	31	0	0	31
September	25	0	0	25
October	14	2	0	16
November	2	0	0	2
December	1	0	0	1

[1] Richards Bay–Durban. [2] Amanzimtoti North–Mtwalume.
[3] Hibberdene–Port Edward.

This is the highest total recorded since regular collection of statistics started in 1972, the previous highest being 104 (4) in 1979. As in previous years, the majority of the animals were caught in mid-winter, in temporal association with the sardine (*Sardinops ocellata*) run, which was reputed to be even larger than that in 1979.

Sardines were netted between 26 June and 19 August, but sharks caught north of Durban between 13 and 27 October had been feeding on sardines, indicating that shoals were present after netting for them had finished (P. van der Byl, pers. comm., 9 June 1981).

One hundred and ten animals from the shark nets in 1980 have been positively identified from retained carcases as 89 *Delphinus delphis*, 13 *Tursiops aduncus* and 8 *Sousa plumbea* (G. J. B. Ross, pers. comm., 9 June 1981). In addition, 2 minke whale calves were caught in November.

Unlike previous years, the majority of entanglements occurred in Area A, or the northernmost section. The reasons for this difference are unknown.

7. PUBLICATIONS

(This refers to publications on Cetacea emanating from South African institutes).

Best, P. B. 1980. Pregnancy rates in sperm whales off Durban. *Rep. int. Whal. Commn* (special issue 2): 93–7.

Best, P. B. and Butterworth, D. S. 1980. Timing of oestrus within sperm whale schools. *Rep. int. Whal. Commn* (special issue 2): 137–40.

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Best, P. B. and Shaughnessy, P. D. 1981. First record of the melon-headed whale *Peponocephala electra* from South Africa. *Ann. S. Afr. Mus.* 83(3): 33–47.

Nemoto, T., Best, P. B., Ishimaru, K. and Takano, H. 1980. Diatom films on whales in South African waters. *Sci. Rep. Whales Res. Inst., Tokyo* 32: 97–103.

Schmitt, F. P., De Jong, C. and Winter, F. H. 1980. *Thomas Welcome Roys, America's pioneer of modern whaling.* University Press of Virginia, Charlottesville, 253 pp.

Date	Species	Length (m)	Sex	Locality	Status
9.2.81	*Lagenorhynchus obscurus*	1.75	M	Off Hout Bay	Released at capture
19.2.81	*Lagenorhynchus obscurus*	1.68	F	Off Hout Bay	In captivity 1.6.81

SC/33/ProgRep Spain

Spain
Progress Report on Cetacean Research June 1980 to May 1981

1980 WHALING SEASON

The 1980 whaling season was the first to be undertaken under IWC quota restrictions. Between 12 May and 2 October the total catch amounted to 220 fin whales, 13 sperm whales and 2 smaller, probably sei whales.

The 13 sperm whales were taken between the beginning of the season and the end of July, as by then Spain had decided upon a temporary halt to the capture of this species.

Due to the sinking of two whalers before the start of the season, only two boats took part in the operations, but they were aided by two tugs. This introduced important changes in the time spent on each segment of the operation, and as a result effort calculations have become more complex and CPUE data are not easily compared with those of other years.

Although Spain joined the IWC in July 1979, the ratification by Parliament and the publishing of the Convention in the Official Bulletin did not take place until the end of August 1980. As from that moment, the Spanish Fisheries Administration undertook exhaustive research into the records and books of both the presently operating company and those which had been operating in the past, in order to obtain complete and detailed statistics which would enable it to examine any trends in the capture of whales and the effort used.

At the same time, other measures were taken in order to solve certain difficulties which were detected during the 1980 season.

(a) *Inspection at cutting platforms.* The collection of standard data for each whale captured (species, length, sex, whether pregnant, etc.) will, from the start of the 1981 season, be controlled by the local Marine Authority at each whaling station, and these authorities are directly responsible for such data.

(b) *Exchange of observers.* Some months ago, Spain signed an agreement with Iceland on the exchange of observers. The Spanish observer will spend this year at the Spanish whaling stations to obtain the necessary experience and to undertake additional inspection. An Icelandic official will, however, be at the Spanish stations as an observer and will be free to move between the two stations as he sees fit. As of the 1982 season a normal exchange of observers is expected to take place.

(c) *Logbooks.* Starting with the present season, special logbooks have been distributed to the ships so as to obtain daily time budget information, which will enable us to establish more exact effort calculations, as well as extra data on captured and non-captured species. The logbook follows that recommended by the IWC in its 1980 report (*Rep. int. Whal. Commn* 30: 58).

(d) *Minimum size control.* The contracts with the harpooners on the boats and the workers at the land stations remained similar in 1980 to those of previous years. Also, two of the three vessels were sunk before the start of the season so that only one vessel had to furnish the whales needed for the work of both land stations for a certain period.

During the second half of the season, however, two old whalers which were to be broken up were put into service to aid the remaining one. Nevertheless, the total days of activity (346) was much lower than in any of the last ten seasons (average 771).

For these reasons it appears that the selectivity of the harpooners decreased greatly during the season, taking some animals below the minimum size permitted under IWC regulations.

In order to solve this problem, the fisheries administration has made the whaling industry prepare completely new contracts for the 1981 season with a minimum size of 16.8 m for fin whales, although a small compensation will be paid for a maximum of 11 fin whales between 16.8 and 15.2 m.

SPECIES AND STOCK STUDIES

Research has centered mainly on the fin and sperm whales brought to the land stations in northwest Spain.

Since the beginning of the whaling activities from which the present company has emerged (around 1951) it has been known that a certain species of smaller whale, called 'ballena de pintas' ('spotted whale') by the workers, has been taken as a secondary target. A few not too clear photographs as well as the measurements and description given by the workers, seems to indicate that they are sei or Bryde's whales, or perhaps both are caught and considered the same species. The statistics of captures of this species have been gathered by Aguilar and Sanpera (1982).

Data of cetaceans stranded on the shore or captured during fishing operations on the north Mediterranean coast of Spain have been collected as in previous years by the staff of the Museum of Zoology of Barcelona and the Department of Zoology (Vertebrates) of the University of Barcelona.

FIELD OBSERVATIONS AND COLLECTIONS

During the 1980 season, biologists of the Department of Zoology (Vertebrates) of the University of Barcelona took samples of ovaries, testes, ear plugs, stomach contents and parasites at the whaling stations. This research was financed by the fisheries administration and a total of 149 fin, 2 sei and 2 sperm whales were studied.

Samples of tissue to study contamination by organochlorides and heavy metals were taken during the season.

MARKING

No tags have been recaptured this year in the Spanish whaling stations, nor have tagging programmes been undertaken.

LABORATORY WORK AND RESEARCH RESULTS

The study of the ear plugs of 137 fin whales was undertaken by C. Lockyer (Sea Mammal Research Unit, Cambridge) and A. Aguilar (University of Barcelona). The results obtained are in Table 1.

The sampling did not start at the same time as the whaling season, but two months later. As it has been observed that the length of fin whales in a given season diminishes as the season advances, the samples taken cannot be considered as completely representative of the stock under study. This is the main reason why these data have not been used to calculate mortality rates, recruitment rates, etc. as they would certainly produce biassed results.

The evolution of average sizes and the sex ratios during each season from 1957 to 1980 are currently being studied. Fig. 1 shows the monthly change in length of fin whales during the 1980 season.

The samples of testes and ovaries taken during the season are being examined and the results should be ready by the next meeting of the Scientific Committee.

Catch and effort data for fin and sperm whales from 1957 to 1980 have been examined and the trends in mean lengths examined (Aguilar and Sanpera, 1982).

Seventy-seven fin whales have been sampled to obtain muscle tissue, krill and oil in order to determine

Table 1

Preliminary age-length key for the male fin whales (n = 54)

Length (metres)	Age																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Σ
13	1																					1
13.5																						0
14		1		1																		2
14.5			4				1															5
15			1	3	2																	6
15.5			1	1																		2
16				1		2																3
16.6				3		2																5
17				1			3															4
17.5						1	2	2	1													6
18						2						1						1				4
18.5									1				1	1					1		1	5
19											2	1	1	1	1		1	1		1	1	10
19.5										1												1
20																						
Σ	1	1	6	10	2	7	6	2	2	1	2	2	2	2	1	0	1	2	1	1	2	

Table 1b

Preliminary age-length key for the female fin whales (n = 59)

Length (metres)	Age																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	Σ
13.5		1	1																				2
14	1																						1
14.5		5			1																		6
15	1	2	1																				4
15.5		1	1																				2
16			1																				1
16.5		1		2																			3
17			1	1																			2
17.5			1	1	1		2																5
18					1		1	1															3
18.5			1	1			1	1	1														5
19				1	1	1	2	1		1				1			1			1			10
19.5												1	1										2
20								2				1	1							1			5
20.5												1		1						1			3
21										1		1							1		1		4
21.5																							0
22																							0
22.5																						1	1
Σ	2	10	7	6	4	1	6	5	1	2	0	4	2	2	0	0	1	0	1	2	2	1	

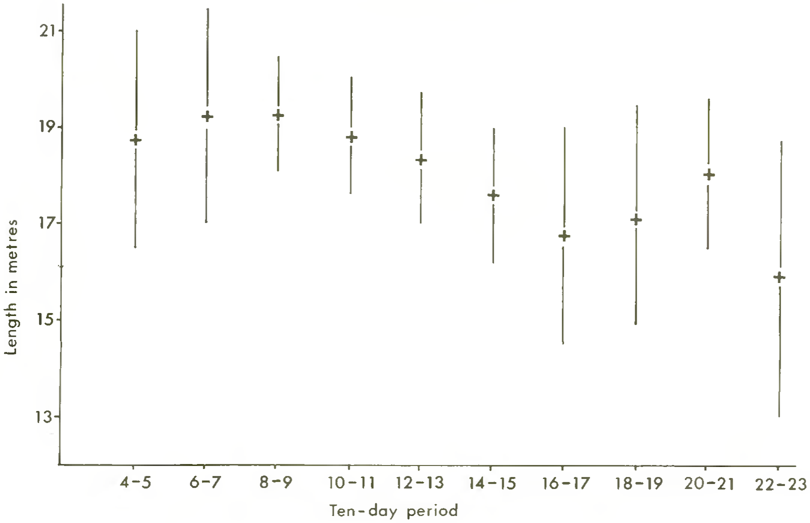

Fig. 1. The monthly change in length of fin whales during the 1980 season.

organochloride contaminants (Aguilar and Jover, 1981a). A similar study from a small sample of sperm whales is being completed by Aguilar. Samples of a beaked whale (*Mesoplodon densirostris*) stranded on the North Mediterranean coast of Spain have also been analysed in search of DDTs and PCBs (Aguilar and Jover, 1981b).

Data of whales recently stranded and of captures during non-whaling activities have been collected by Grau, Aguilar and Filella (1981) and by Casinos (1981). Only one species, the bottlenosed dolphin (*Tursiops truncatus*) is captured with any frequency by trawlers, and only five cases are known in the Spanish-Mediterranean waters from 1976 to 1980.

During the 1980 season the lamprey marks on the skin of fin whales were quantified by Grau, Jover, Aguilar and Sanpera in Spain and by Martin in Iceland in order to study possible stock differentiation. The presence of marks seemed to increase with the age of the animals, but the results did not permit any conclusions to be drawn on the identity of the population.

The samples of parasites and stomach contents have yet to be analyzed.

FINAL NOTE ON STATISTICS

Full research by the fisheries department into the accounting records of the present company and those original companies from which it derived became possible following the ratification of the Convention.

As a result we are now able to present the extensive and very exact statistics on which this year's research has been based and which go back to 1957. It must be pointed out that the new data now presented differs considerably from those presented to the administration by the whaling company and furnished to the IWC last year. The differences are specially notable in the case of sperm whales. It seems that the data presented had been worked out by means of an extrapolation of the captures of the factory in the Bay of Biscay, by then already closed down, and some extrapolations of captures between ships. The factory in the Bay of Biscay was the principle sperm whale factory, which explains why the differences in this species is greater than in fin whales.

Very considerable work was required to obtain the complete records and establish the new exact data.

PUBLICATIONS

Aguilar, A. 1981. The black right whale, *Eubalaena glacialis*, in the Cantabrian sea. *Rep. int. Whal. Commn* 31: 457–9.

Aguilar, A. and Lens, S. 1981. Preliminary report on the Spanish whaling activities. *Rep. int. Whal. Commn* 31: 639–43.

Aguilar, A. and Jover, L. 1981b. A note on the organochlorine contamination in a dense-beaked whale, *Mesoplodon densirostris* from the Mediterranean sea. *Pub. Dep. Zool.*, accepted.

Aguilar, A. and Jover, L. 1982. DDT and PCB residues in the fin whale, *Balaenoptera physalus*, of the North Atlantic. Paper SC/33/Bal (published in this volume).

Aguilar, A. and Sanpera, C. 1982. Reanalysis of Spanish sperm, fin and sei whale catch data. Paper SC/33/O 1 (published in this volume).

Casinos, A. 1981a. A record of *Orcinus orca* (Linnaeus, 1758) from the island of Minorca. *Säugetierkundliche Mitteilungen*:

Casinos, A. and Filella, S. 1981b. A specimen of *Mesoplodon densirostris* (*Cetacea*, Hyperoadontidae) stranded on the Spanish Mediterranean littoral. *Säugetierkundliche Mitteilungen*.

Duguy, R., Casinos, A. and Filella, S. 1980. Note sur la biologie de *Stenella coeruleoalba* dans le bassin occidental de la Mediterranée. *Rapp. Comm. int. Mer. Médit.* 25/26, 10: 137–9.

Duguy, R., Casinos, A., Di Natale, A., Filella, F., Ktari-Charroun, F., Lloge, R. and Marchessaux, D. 1981. Repartition et fréquence des mamifères marins en Mediterranée. *Rapp. Comm. int. Mer. Médit.* 27.

Grau, E., Aguilar, A. and Filella, S. 1981. Cetaceans stranded, captured or sighted in the Spanish coasts during 167–79. *Butll. Inst. Cat. Hist. Nat.* (Sec. Zool., 3): 167–79.

SC/33/ProgRep UK

United Kingdom
Progress Report on Cetacean Research
June 1980 to May 1981

(This refers to work at the Sea Mammal Research Unit of the Natural Environment Research Council, and the Ministry of Agriculture, Fisheries and Food Laboratory, Lowestoft).

SPECIES AND STOCKS STUDIED

Studies are continuing of fin, sei and sperm whales in the Southern Hemisphere and in Icelandic waters.

FIELD OBSERVATIONS AND COLLECTIONS

With the co-operation of the Icelandic whaling company, Hvalur H. F. and the Marine Research Institute, Reykjavik, a biologist made observations and collections from fin, sei and sperm whales at the Icelandic whaling station during the 1980 whaling season. Additional material was collected by an Icelandic biologist and by the station personnel. Ear plugs were collected from 241 fin and 75 sei whales, ovaries from 101 fin and 55 sei whales, and teeth from 86 sperm whales, together with other biological material.

WHALE MARKING

The SMRU continues to co-ordinate the International Whaling Marking Programme, and marks and guns were provided for a number of marking programmes carried out in the Antarctic season 1980/81 and 1980 whaling season elsewhere, or planned for the 1981 season.

LABORATORY WORK

Examination of the 1979 and 1980 collections of ovaries, ear plugs and sperm whale teeth from Iceland has been completed. Collections of sperm whale teeth from the 1976, 1977 and 1978 Australian catch have been processed and examined under contract for the Western Australian Museum, and age/length keys are being prepared.

Collections of ear plugs from the 1961 and 1963 seasons for North and West Norway, and from Iceland and Spain for 1980 have also been examined specifically for possible identification of stock differences.

Analysis is continuing of special collections made in Iceland for studies of energetics in baleen whales.

RESEARCH

Studies are continuing on stock assessments of the large whales and on the principles of management.

Pregnancy rates of fin whales in the Icelandic fishery have been examined and also changes in the mean length of the fin whale catch.

The use of eye-lens weight for age-determination in baleen whales is being evaluated.

A new approach to estimating population size from sightings data has been developed based on counting cues rather than counting whales. The approach is being evaluated in comparison with more conventional methods by using analytical techniques and simulation studies.

PUBLICATIONS

Brown, S. G. 1980. Whale marking-progress report 1979. *Rep. int. Whal. Commn* 30: 128–30.

Brown, S. G. 1981. Thirty-second annual meeting of the International Whaling Commission, 1980. *Polar Record 20* (127): 363–65.

Garrod, D. J. and Brown, S. G. 1980. Southern Hemisphere sei whales: a population estimate from marking data. *Rep. int. Whal. Commn* 30: 507–11.

Horwood, J. W. 1980. Competition in the Antarctic? *Rep. int. Whal. Commn* 30: 513–17.

Horwood, J. W. 1980. Population biology and stock assessment of Southern Hemisphere sei whales. *Rep. int. Whal. Commn* 30: 519–30.

Horwood, J. W. 1980. Comparative efficiency of catcher boats with and without Asdic in Japanese pelagic whaling fleets. *Rep. int. Whal. Commn* (special issue 2): 245–49.

Horwood, J. W. 1980. Relative increases in population pregnancy rate of sperm whales. *Rep. int. Whal. Commn* (special issue 2): 257–58.

Horwood, J. W., Donovan, G. P. and Gambell, R. 1980. Pregnancy rates of the Southern Hemisphere sei whale (*Balaenoptera borealis*). *Rep. int. Whal. Commn* 30: 531–35.

Horwood, J. W. and Garrod, D. J. 1980. The status of the North Pacific sperm whale. *Rep. int. Whal. Commn* 30: 187–92.

Martin, A. R. 1980. An examination of sperm whale age and length data from the 1949–78 Icelandic catch. *Rep. int. Whal. Commn* 30: 227–31.

Woolner, L. and Horwood, J. W. 1980. Length at capture of sei whales and areal associations. *Rep. int. Whal. Commn* 30: 537–44.

APPENDIX 1

SMALL CETACEANS—INCIDENTAL CATCHES BY BERMUDA REGISTERED VESSELS

The sub-committee on small cetaceans noted in 1980 (*Rep. int. Whal. Commn* 31: 147) that reports on tuna-fishery associated incidental takes of small cetaceans had not been submitted by several IWC members, including the United Kingdom for Bermuda and Cayman Islands tuna purse-seine activities.

The matter has been taken up with the respective governments by the Ministry of Agriculture, Fisheries and Food and the following information received.

Bermuda—Three vessels are employed. They do not purse-seine for tuna on porpoise but fish on schoolfish associated with floating logs and therefore have no incidental marine mammal mortality.

Cayman Islands—Nine purse-seine tuna fishing vessels are registered. Five of them are equipped with nets incorporating a medina porpoise safety panel and apron. Details are not yet available for two vessels and the remaining two vessels have not operated since June 1979. The incidental catch of small cetaceans in 1979 was 313 animals (146 off-shore spotted porpoise, 117 whitebelly spinner porpoise, 9 animals of other species, and 41 animals for which no information is available). 1980 catch figures are not yet available.

SC/33/ProgRep USA

United States
Progress Report on Cetacean Research
June 1980 to May 1981

This report briefly summarizes cetacean research conducted or supported from June 1980 to May 1981 by the US National Marine Fisheries Service at the National Marine Mammal Laboratory, Seattle, WA; the Northeast Fisheries Center, Woods Hole, MA; the Southeast Fisheries Center, Miami, FL; and the Southwest Fisheries Center, La Jolla, CA.

SPECIES AND STOCKS STUDIED

During the past year studies were conducted on the following species in the following areas:

Gray whale *Eschrichtius robustus*—Mexico; California; Bering Sea; Chukchi Sea.
Fin whale *Balaenoptera physalus*—Gulf of Alaska; western North Atlantic.
Blue whale *Balaenoptera musculus*—Gulf of St. Lawrence.
Humpback whale *Megaptera novaeangliae*—Gulf of Alaska; western North Atlantic.
Right whale *Balaena glacialis*—Western North Atlantic.
Bowhead whale *Balaena mysticetus*—Bering, Chukchi, and Beaufort Seas.
Sperm whale *Physeter macrocephalus*—Gulf of Alaska.
Dolphins (Delphinidae)—Eastern tropical Pacific.
Bottlenose dolphin *Tursiops truncatus*—Southeastern USA.
Harbor porpoise *Phocoena phocoena*—Maine.
Dall's porpoise *Phocoenoides dalli*—North Pacific.

FIELD OBSERVATIONS AND COLLECTIONS

National Marine Mammal Laboratory

An aerial census of gray whales throughout their winter range along the west coast of Baja California was conducted in February 1981. This census included line transects in the immediate offshore waters in Bahia Sebastian Vizcaino, Bahia de Ballenas, and the San Juanico bight. A vessel survey was also conducted in Bahia Sebastian Vizcaino in conjunction with the aerial survey. Ground truth experiments were performed, in addition to the census procedures, to compare the accuracy of these sampling platforms.

The fourth consecutive winter of research on gray whales in Laguna San Ignacio, Baja California Sur, Mexico, was conducted between 10 January and 15 April 1981. This program sought to obtain demographic information on breeding gray whales including weekly counts of the number and distribution of female/calf pairs and 'single' whales utilizing this lagoon. Whales with distinguishing markings were photographed and compared with whales photographed during previous winters and other areas to identify individual whales that return to San Ignacio each winter. Aerial surveys were conducted with a single-engine high-wing aircraft for comparison with simultaneous boat surveys to estimate the gray whale population within the lagoon and adjacent nearshore waters, and to compare these two survey techniques. The second aspect of this program was a preliminary examination and inventory of lagoon benthic invertebrate communities.

The distribution and abundance of potential gray whale prey species within the lagoon's benthic and mid-water communities will be utilized to evaluate the potential for significant foraging by gray whales. This program will continue through the winter of 1982, the fifth and final study season.

A preliminary investigation of the acoustical environment of Laguna San Ignacio, Baja California, Mexico, was conducted during March 1981. This work was undertaken to determine the feasibility of conducting research on the effects of non-biological underwater noise on gray whales.

Research on gray whales at Laguna Ojo de Liebre, Baja California Sur, carried out by the National Marine Mammal Laboratory in 1979 and 1980, was continued in 1981 by the Mexican Departamento de Pesca with partial logistic support from the NMML.

A shore census of northward-migrating gray whales was conducted at Point Piedras Blancas, California, in the spring of 1981, to obtain data on population size, timing of the spring migration, proportion of calves in the population, and proportion of whales migrating offshore.

Under contract to the NOAA Outer Continental Shelf Environmental Assessment Program, a study was conducted of the gray whale and its reliance on the food resources of the Bering Sea. The objectives were to (1) estimate the consumption of infauna by whales; (2) identify and describe preferred feeding area; and (3) evaluate the susceptibility of the benthic community to the physical disturbance imposed by the whales. The field research for 1980 consisted of three vessel cruises in the Chirikov Basin and area near St. Lawrence Island. Sidescan sonar and close-circuit TV were used to search the bottom for evidence of foraging whales. Bottom grabs were taken to analyze community structures. Scuba divers sampled specific benthic areas thought to be affected by feeding whales. Experimental sites were established to evaluate the colonization of areas cleared by whales. Whale densities were highest in the central Chirikov Basin, the region of highest amphipod density. Depressions in this area, possibly left by foraging whales, have a depauperate infauna compared to the adjacent sediment. The depleted patches are invaded first by scavenging amphipods and colonized later by tube-building species.

In the autumn of 1980, whalers from the villages of Kaktovik, Nuiqsut and Barrow hunted for bowhead whales, in spite of the fact that the US government had closed the 1980 whaling season on 29 May. Nuiqsut hunters joined those at Kaktovik, where five whaling crews landed one whale, killed but lost a second one, and struck but lost a third one. At Barrow, no whales were struck. Unfavorable weather and ice conditions contributed to the lack of success in taking whales during the autumn.

In the spring of 1981, 14 bowhead whales were landed, and 11 others struck but lost. Particulars for each village are as follows:

Village	Number of crews	Whales landed	Struck and lost	Total struck
Gambell	21	1	2	3
Savoonga	9	2	1	3
Wales	3	0	0	0
Kivalina	4	0	2	2
Point Hope	15	4	1	5
Wainwright	10	3	0	3
Barrow	31	4	5	9
Totals	93	14	11	25

The 1981 bowhead whale census effort was conducted 11 April—2 June 1981 near Point Barrow, Alaska, under contract to the Alaska Eskimo Whaling Commission (AEWC) in cooperation and under subcontract by the AEWC to Arctic Technical Research (ATR) from Fairbanks. NMFS scientists assisted in logistics and acted as scientific advisors to the AEWC and ATR.

The bowhead migration occurred in two major phases this year, one between 11 April and 3 May and the second 19 May to 2 June. On 2 June the watch was terminated because of unsafe ice. Between 4 and 18 May the lead was partially or completely closed, with fewer whales observed than in April. This is the earliest bowheads have migrated by in these concentrations since the beginning of our studies (i.e. 1976).

A total of 968 new, 190 conditional, 282 duplicate and 27 tentative sightings were logged. An estimate of percentage missed was 39.6%. Additional analyses of the data back to 1978, with emphasis on determining the number (or percentage) of missed whales which are within the observers' sample space and sighting distance estimation were conducted.

Preliminary reanalysis of our data base suggests that the 1978 estimate range is acceptable, and that the true population size (given the constraints on total sample space near the observers) lies within that range. Also, the earlier population estimate range (see Braham *et al.*, 1979) may be smaller than first thought.

Aerial surveys were conducted near the ice camp census teams from 6–21 May 1981 to determine the spatial frequency distribution of whales across the lead. The objective was to determine if a significant number of whales migrate in the lead beyond the sighting range of the camp observers.

Preliminary results support the hypothesis that most bowheads (up to 96%) migrate within the first 5 km from the edge of the shorefast ice lead, and that even when the lead is past the horizon (out to 36 km this spring at times) no bowheads were seen by the aerial crew beyond 7 km. Many belukha whales, however, were observed across the entire lead.

Calves were counted from the ice camp; a total of 14 were seen. An inverse correlation exists between distance away from the shorefast edge of the lead and proportion of calves to total whales seen. Two possible explanations are that (1) calves migrate closer to shore than larger animals, and/or (2) calves are more difficult to see beyond a specified distance than larger animals. A summary of estimates of recruitment, now totalling approximately 15 since 1976, ranges from a low of 1.4% (1980, spring ice camp) to a high of 4.0% (1980 autumn unpublished BLM data).

Data and specimens were collected from Dall's porpoises incidentally captured by the Japanese gillnet fishery for salmon within the United States 200-mile zone off the Aleutian Islands during the summer of 1980. Biological samples were collected from 929 Dall's porpoises (including 5 of the *truei* color phase and 1 black phase) and 4 harbor porpoises. From observations aboard salmon catcher boats, an incidental take rate of 0.94 per set and a total incidental take of 8,970 Dall's porpoises were estimated.

From June to August 1980, a line transect census of whales and other marine mammals was conducted in the Gulf of Alaska from Cape Fairweather (138°W) west to Chirikof Island (156°W).

A bilateral agreement to foster marine mammal research has been in effect since 1973 within the framework of the US–USSR Environmental Protection Agreement. Joint cruises to study bowhead whale distribution in the Chukchi Sea were conducted in October 1979 and September 1980. These studies were conducted in an effort to help determine if the bowheads observed in the western Chukchi Sea are animals that had migrated earlier to the Beaufort Sea and were returning, or are whales that have spent the entire summer feeding in the Chukchi Sea and consequently perhaps are not included in our spring bowhead census at Barrow, Alaska. Large numbers of bowheads (over 280) and gray whales (over 175) were sighted in 1980. Bowhead whales occurred along the north coast of the Chukchi Peninsula about 171°W longitude to 179°E longitude. Gray whales were seen along the north Chukchi Peninsula coast beginning at about 170°W, and continuing northwestward into the East Siberian Sea. Possibly responding to differences in food availability, gray and bowhead whales were never seen in the same areas; instead they alternated in occurrence along the coast. On 24 September, 3 gray whales were observed as far west as 174°08′E longitude, in the East Siberian Sea, apparently further west than they had ever been reported previously.

Since 1971 the National Marine Fisheries Service has been collecting marine mammal sightings from a number of sources under the auspices of the Platforms of Opportunity Program (POP). These sightings are made by members of NOAA and Coast Guard vessels, US Forest Service naturalists aboard Alaska State ferries, private fishing vessels, US observers aboard foreign fishing vessels, and numerous other biologists and boaters. NOAA's Outer Continental Shelf Environmental Assessment Program (OCSEAP) contracted the National Marine Mammal Laboratory to analyze backlogged 1978–80 POP sightings in an attempt to further describe the distribution of marine mammals in the Gulf of Alaska. Utilizing computer plots of these data and historical information, distributional limits for all species found in the Gulf of Alaska have been determined. Recent in-house use of POP data include the determination of a suitable research location for gray whale feeding studies in the northern Bering Sea and the determination of the extent of Dall's porpoise distribution in the North Pacific. BLM will utilize the data for both draft and final environmental impact statements in determining which marine mammal species are likely to occur in or near oil lease sites in the Gulf of Alaska.

Northeast Fisheries Center

The Northeast Fisheries Center has contracted a survey of the distribution and natural history of the bottlenosed dolphin off the Virginia Capes and lower Chesapeake Bay, and observations of blue whales along the Canadian north shore of the Gulf of St. Lawrence.

A joint US–Canadian study of harbor porpoises in the Passamaquoddy Bay area of Maine was undertaken through the New England Aquarium. Habitat use, subsistence take, and other human and environmental impacts on harbor porpoise are being examined in conjunction with the population and natural history studies begun earlier by D. Gaskin. Coupled with these studies, New England Aquarium investigators also surveyed the stocks of large whales that frequent the waters around Passamaquoddy Bay and the western Bay of Fundy. During the summer of 1980, significant numbers of humpback and fin whales were seen, and the counts of right whales were considerably higher than the researchers had anticipated.

Southeast Fisheries Center

Marine mammal research at the Southeast Fisheries Center is primarily directed toward population surveys, stock differentiation and local herd biodynamics of the bottlenosed dolphin. The objectives of the research are to refine and verify survey techniques, acquire site-specific density estimates, monitor seasonal site-specific density variation, evaluate state-of-the-art tagging, mark discrete herds and observe movement, collect and analyze blood serum to discern sub-populations, and compile a biological information data base. In addition, the research center has carried out work to enhance and expand the southeast regional marine mammal stranding and salvage network.

Southwest Fisheries Center

The Southwest Fisheries Center has continued an extensive program of studies on dolphins in relation to the eastern Tropical Pacific yellowfin tuna (*Thunnus albacares*) fishery.

MARKING

No whales were marked with Discovery tags, and no whales previously marked by the United States were reported recovered.

Two biologists from the National Marine Mammal Laboratory participated in the IDCR Minke Whale Marking Program's Antarctic cruise, December 1980 to February 1981.

There are now 272 individually recognizable North Pacific humpback whales in the PISAR data bank. Currently, there are three long-distance matches (Hawaii in 1978 to SE Alaska in 1979; Hawaii in 1975 to Prince William Sound, Alaska in 1978; and SE Alaska in 1978 to Mexico in 1980) as well as 50 matches within the same area (e.g. one animal in SE Alaska each year from 1977 to 1980).

A second edition of the Humpback Whale Fluke Catalog for the western North Alantic population was published through a contract to the College of the Atlantic, Bar Harbor, Maine. The catalog includes photographs of more than 1,000 humpbacks from Newfoundland to the Caribbean Sea. There are 13 long-distance matches between summer grounds in Labrador, Newfoundland, and the Gulf of Maine, and winter grounds in the Caribbean.

The Marine Mammal Tagging Office, National Marine Mammal Laboratory, conducted a study during the summer and autumn of 1980 to determine the feasibility of radio tagging and tracking bowhead whales. This research was undertaken in response to a Section 7, Endangered Species Act consultation which recommended studies to define the 'timing of movements and offshore distribution of bowhead and gray whales, *Eschrichtius robustus*, through the proposed (Beaufort Sea) lease sale area and adjacent waters'. Transmitter attachments, which were previously field tested on gray whales, were laboratory tested on bowhead blubber blankets prior to the field season. During the open water period in the eastern Beaufort Sea, in the area of Tuktoyaktuk Peninsula, Northwest Territories, Canada, radio tags with one-meter, colored streamers were placed on two bowheads. The first tag was low on the whale and transmission was lost shortly after tagging. The second transmitter was well placed and was tracked by aircraft for 1½ hours. Due to technical difficulties, the ship was unable to track either whale. During aerial surveys of the autumn migration in the vicinity of the Alaskan OCS lease sale areas, a brief radio transmission was received, but the presence of tagged bowhead whales was unconfirmed by either further transmissions or visual relocation.

A satellite-linked tag for tracking of dolphin movements with a Nimbus satellite is undergoing development at the Southwest Fisheries Center. A prototype tag has been developed and is receiving rigorous bench testing as well as field testing on captive and free-ranging dolphins. The tag weighs approximately 1 kg and is designed for attachment to the dorsal fin.

Studies contracted by the Southeast Fisheries Center have developed the 'freeze-branding' technique to mark bottlenosed dolphins. Twenty-five dolphins were marked in the Indian and Banana rivers, Florida, during 1980, and biological information was collected from each animal. During this program year: (1) all marked animals were resighted and their movements monitored throughout the year; (2) a systematic aerial survey technique was developed to estimate densities of *Tursiops;* (3) twelve seasonal surveys were conducted at six geographical locations for the purpose of estimating dolphin stocks; (4) a toll-free telephone service was established for reporting marine mammal strandings throughout the southeastern United States; and (5) public information posters were developed concerning the marine mammal and sea turtle stranding and salvage network.

LABORATORY WORK

Preparation and analysis of ovaries, testes, stomach contents, baleen, teeth, etc., from bowhead whales and Dall's porpoise are continuing at the National Marine Mammal Laboratory.

DEVELOPMENT OF TECHNIQUES

An area of research that is receiving attention at the Southwest Fisheries Center is development of aerial photographic techniques for counting and measuring length of animals in dolphin schools. Recent improvements in camera equipment and photographic techniques have allowed researchers to take high quality photographs of dolphin schools from aircraft. In November and December, 1980, a joint Inter-American Tropical Tuna Commission – National Marine Fisheries Service aerial survey was executed to test latest developments in photographic equipment and techniques. The objective of the survey was to obtain photographs of *Stenella* and *Delphinus* schools of high resolution and clarity so that the animals in the photograph can be counted and measured for length in the laboratory. The data collected on this survey are undergoing analyses and preliminary results indicate that the animals can be accurately counted and measured.

Gear research to reduce dolphin mortality in purse seining operations is continuing at the Southwest Fisheries Center with development of a computer model of the purse seining process. The model will be used to screen ideas on purse seine designs and fishing procedures for reducing dolphin mortality before further development of the ideas.

RESULTS

The data from the Baja California gray whale census have not been completely analyzed, but they have revealed that the vast majority of gray whales (other than cows with calves) spend the winter outside the lagoons in Bahia Sebastian Vizcaino and Bahia de Ballenas.

Data from 13 annual autumn shore censuses of gray whales near Monterey, California, were analyzed further to estimate the population level for each year. The width of the migratory corridor near the census station, possible observer counting biases, seasonal and daily migratory timing, the effects of visibility, and other census statistics were examined. A function to estimate population level was developed along with two procedures to approximate the variance of each estimate.

The 1980 level is estimated to be within the range 17,577 ± 4,364, with a 'best estimate' of 15,587. Within the 13-year time series there is a net annual increase of 2.5%. The documented annual increase, along with a re-evaluation of current estimates of gray whale vital parameters and information from comparative studies are combined to model the dynamics of the population. This model and documentation of the catch history were employed to estimate the probable range of the pre-exploitation equilibrium population size, and level of prehistoric aboriginal exploitation.

From studies on the life history of bowhead whales, the following preliminary conclusions have been made: (1) from 18 female whales ranging in size from 6.9–16.2 m, females mature at approximately 12 m; (2) the sex ratio in the population is 1.00 : 1.00; (3) the minimum proportion of calves, an index to annual recruitment, is 0.016–0.037 (from four spring counts, one summer counts, and four autumn counts); and (4) length estimates of 127 whales resulted in a ratio of 0.58 adults, 0.35 immatures, and 0.07 calves.

Stomach contents from landed bowhead whales indicate that copepods and euphausiids are the dominant prey in the Beaufort Sea. From a trophic study in the Beaufort Sea, ringed seals (*Phoca hispida*) and Arctic cod (*Boreogadus saida*) are the bowhead's most significant trophic competitors.

Analyses of biological samples from Dall's porpoises provide the following estimates of life history parameters (1) mean age of first birth approximately 4.5–5.0 years; (2) apparent pregnancy rate of 90% or more; and (3) a life span of less than 10–13 years generally. Biases in the sampling may have influenced these estimates.

Scientists in the Dall's porpoise research task at the National Marine Mammal Laboratory conducted sighting surveys in 1978, 1979, and 1980 on board research vessels of the Government of Japan and vessels cooperating in the US Platforms of Opportunity Program. Data collected during these cruises were used to make abundance estimates of Dall's porpoise in the North Pacific and Bering Sea portions of their range. Analysis of the 1978 and 1979 surveys by strip and line transect methodologies led to estimates of abundance that ranged from 8.4 to 23.0×10^5 porpoise. The problems with these analyses include inaccurate angle and distance measurement to each sighting, and the bias of animals moving towards the ship before being seen. These and other biases have resulted in overestimating the size of the population.

Stomach analyses were also undertaken to determine the food habits of Dall's porpoises taken in the fishery. Thus far the study has dealt primarily with the vertebrate species in the diet. Otoliths were used to identify and enumerate the prey. Preliminary results indicate that Dall's porpoise are feeding on a wide variety of epi- and mesopelagic fishes and squids. A total of 33 species of fishes have been identified, 19 of which have not previously been noted as Dall's porpoise prey. Generally these prey species are not associated with the near surface zones where most species of salmon are known to feed. Also, many of the species of fishes and squids consumed by Dall's porpoise are larger than those exploited by salmon. Generally, salmon exploit large zooplankton (i.e., copepods, amphipods, euphausiids, pteropods, and others). Those fishes and squids consumed by salmon are, in many cases, the same species but smaller-sized individuals than those in the diet of Dall's porpoise.

Continuing analyses of data collected from the International Whaling Statistics files, and from other research data bases (e.g. Canadian and Japanese governments) were made at the National Marine Mammal Laboratory. Special attention was given to the sei whale. Early results indicate that pregnancy rates have not shown any density dependent changes as a result of commercial exploitation for Southern Hemisphere baleen whales; nor any density dependent changes in fin whale ovulation rate and age at sexual maturity (1965–78 data). Other analyses on fin whales (North Atlantic) indicate that there were significant differences in lengths of whales landed (by sex) in the late 1940s but not during the more recent episode of whaling, while the percentage of females declined in the more recent years of the fishery.

PUBLICATIONS

Bouchet, G. C. 1981. Estimation of the abundance of Dall's porpoise (*Phocoenoides dalli*) in the North Pacific Ocean and Bering Sea. Northwest Alaska Fish. Cent., Proc. rep. 81-1, U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Natl. Mar. Mammal Lab., Seattle, Wash. 25 p.

Braham, H. W. 1980. Bowhead whale (*Balaena mysticetus*) I: Migration, distribution, and population enumeration. *Cetus* 2(1): 4–5.

Braham, H., Durham, F., Jarrell, G. and Leatherwood, S. 1980. *Ingutuk:* A morphological variant of the bowhead whale, *Balaena mysticetus. Mar. Fish. Rev.* 42(9–10): 70–3.

Braham, H., Fraker, M. and Krogman, B. 1980. Spring migration of the western Arctic population of bowhead whales. *Mar. Fish. Rev.* 42(9–10): 36–46.

Braham, H., Krogman, B., Johnson, J., Marquette, W., Rugh, D., Sonntag, R., Bray, T., Brueggeman, J., Dahlheim, M., Nerini, M. and Savage, S. 1980. Population studies of the bowhead whale (*Balaena mysticetus*): Preliminary results of the 1979 spring research season. *Rep. int. Whal. Commn* 30: 391–404.

Braham, H., Krogman, B., Nerini, M. Rugh, D., Marquette, W. and Johnson, J. 1980. Research in the western Arctic on bowhead whales, June–December 1978. *Rep. int. Whal. Commn* 30: 405–13.

Braham, H. W., Marquette, W. M., Bray, T. W. and Leatherwood, J. S. 1980. The Bowhead Whale: Whaling and Biological Research. *Mar. Fish. Rev.* 42(9–10): 1–96.

Breiwick, J. M. 1980. Determination of Antarctic baleen whale CPUE. *Rep. int. Whal. Commn* 30: 255–6.

Breiwick, J. M., Mitchell, E. D. and Chapman, D. G. 1980. Estimated initial population size of the Bering Sea stock of bowhead whale, *Balaena mysticetus:* an iterative method. *Fish. Bull.* 78(4): 843–53.

Carroll, G. M. and Smithhisler, J. R. 1980. Observations of bowhead whales during spring migration. *Mar. Fish. Rev.* 42(9–10): 80–5.

Dahlheim, M. 1980. Killer whales observed bowriding. *Murrelet* 61(2): 78.

Dahlheim, M., Bray, T. and Braham, H. 1980. Vessel survey for bowhead whales in the Bering and Chukchi Seas, June–July 1978. *Mar. Fish. Rev.* 42(9–10): 51–7.

Eberhardt, L. L. and Breiwick, J. M. 1980. Minimal historical size of the western Arctic population of bowhead whales. *Mar. Fish. Rev.* 42(9–10): 27–9.

Everitt, R. and Krogman, B. 1980. Sexual behavior of bowhead whales observed off the north coast of Alaska. *Arctic* 32(3). 277–80.

Johnson, J. H., Braham, H. W., Krogman, B. D., Marquette, W. M., Sonntag, R. M. and Rugh, D. J. 1981. Bowhead whale research: June 1979 to June 1980. *Rep. int. Whal. Commn* 31: 461–75.

Jones, L. L. 1980. Cooperative U.S.–Japan research program on Dall's porpoise. *Cetus* 2(4): 3.

Katona, S. K., Harcourt, P., Perkins, J. S. and Kraus, S. D. 1980. Humpback whales: a catalogue of individuals identified by fluke photographs. College of the Atlantic, Bar Harbor, Maine. 169 pp.

Krogman, B. D. 1980. Sampling strategy for enumerating the western Arctic population of the bowhead whale. *Mar. Fish. Rev.* 42(9–10): 30–6.

Marquette, W. and Bockstoce, J. 1980. Historical shore-based catch of bowhead whales in the Bering, Chukchi, and Beaufort seas. *Mar. Fish. Rev.* 42(9–10): 5–19.

Mizroch, S. A. 1980. Some notes on Southern Hemisphere baleen whale pregnancy rate trends. *Rep. int. Whal. Commn* 30: 561–74.

Reilly, S. B. 1981. Population assessment and dynamics of the California gray whale (*Eschrichtius robustus*). Ph.D. dissertation, University of Washington.

Reilly, S., Rice, D. and Wolman, A. 1980. A preliminary population estimate for the California gray whale based upon Monterey shore censuses. *Rep. int. Whal. Commn* 30: 359–68.

Rice, D. and Kinman, K. 1980. *Mesoplodon* Gervais, (1850) (Mammalia: Cetacea): Proposed conservation. Z.N. (s)2081. *Bull. Zool. Nomenclature* 37(1): 30–33.

Rice, D. W., Wolman, A. A., Withrow, D. E. and Fleischer, L. A. 1981. Gray whales on the winter grounds in Baja California. *Rep. int. Whal. Commn* 31: 477–93.

Rugh, D. J. 1980. Gray whale census in Alaska. *Whalewatcher* 14(4): 7–8.

Rugh, D. J. and Cubbage, J. 1980. Migration of bowhead whales past Cape Lisburne, Alaska. *Mar. Fish. Rev.* 42(9–10): 46–51.

Stroud, R. K., Fiscus, C. H. and Kajimura, H. 1980. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington. *Fish. Bull.* 78(4): 951–59.

Swartz, S. L. and Jones, M. L. 1980. Gray whales, *Eschrichtius robustus*, during the 1977–78 and 1978–79 winter seasons in Laguna San Ignacio, Baja California Sur, Mexico. U.S. Department of Commerce, N.T.I.S. Publ., PB 80-202989.

Tillman, M. F. 1980. Soviet time budget data for sperm whale operations. Annex K to Report of Special Meeting on Sperm Whale Assessments 27 November to 8 December 1978. *Rep. int. Whal. Commn* (special issue 2): 129.

Tillman, M. F. 1980. Introduction: A scientific perspective of the bowhead whale problem. *Mar. Fish. Rev.* 42(9–10): 2–5.

Tillman, M. F. and Grenfell, B. 1980. Estimates of abundance for the western North Pacific stock of Bryde's whales. *Rep. int. Whal. Commn* 30: 369–73.

Withrow, D. 1980. Gray whales in Scammon's Lagoon. *Whalewatcher* 14(4): 11–12.

Withrow, D. 1980. Leviathans in Scammon's Lagoon. *NOAA Magazine* 10(4): 30–3.

SC/33/ProgRep USSR

USSR
Progress Report on Cetacean Research June 1980 to May 1981

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1. SPECIES AND STOCKS STUDIED

Pelagic whaling was undertaken by the floating factory *Sovietskaya Ukraina* and four catcher boats in the Antarctic in 1980/81; 3,120 minke whales (1,229 males and 1,891 females) were taken. The catcher boat *Vdumchivy 34* participated in the IWC/IDCR minke whale cruise in Area V. The catcher boat *Zvezdny* took 178 gray whales (52 males and 126 females) in the North Pacific on behalf of the native people of Chukotka; one flagged whale near one of the villages was lost in stormy weather.

Scientists with the whaling fleet examined and took biological samples from the minke whales. Similar work was carried out with respect to gray whales.

2. FIELD OBSERVATIONS AND COLLECTIONS

In accordance with recommendations made by the IWC Scientific Committee, sightings data continued to be collected by Soviet vessels (Tables 1 and 2).

Samples taken from minke whales included 2,819 ear plugs, 1,154 testes and 1,797 ovaries. Ninety-nine gray whales were examined: genetic samples were taken from each whale; 23 testes samples, 52 ovaries and 34 ear plugs were collected as well as 123 samples of whale lice from 60 animals; 90 stomachs were examined and the standard series of measurements were taken for 80 whales.

3. WHALE MARKING

3.1 Soviet marking programme

As in previous years, marking was carried out by catcher boats and research vessels. In 1980, 88 gray whales (Ivashin and Votrogov, 1982), 29 bowhead whales and 1 killer whale (marked in square Q25) were marked in the Bering Sea. During the 1980/81 season, 8 sperm whales (square E-23) and one blue whale (square E-24) were marked in the Southern Hemisphere.

3.2 International marking scheme

The Soviet research vessel *Razyaschy 34* marked 268 minke whales and 10 sperm whales during the 1980/81 pelagic season. *Vdumchivy 34* engaged in marking during its participation in the 1980/81 IWC/IDCR minke whale assessment cruise.

3.3 Mark recoveries

Seven .410 Discovery marks were recovered during the 1980/81 season in the Southern Hemisphere (Table 4). No marks were recovered from the North Pacific.

4. LABORATORY STUDIES

The processing of samples collected in recent years continues.

5. DEVELOPMENT OF TECHNIQUES

It was determined that in a number of processes the definite (critical) values of parameters may lead to the loss of stability of a system and the spasmodic transition to a new stable condition is characterised by the fundamentally different nature of the development (Kuz'min and Zhirmunsky, 1980). A hypothesis of the existence of critical boundaries in the development of populations and

Table 1

Sightings by the catcher boat *Zvezdny* off Chukotka, 1980

Month	Square	Observations of whales				Miles covered	CDW	No. of gray whales per day work	No. of gray whales per 100 miles
		Gray	Humpback	Fin	Minke				
June	Q 25	57	—	—	—	450	2	28.5	12.7
July	Q 25	515	—	—	4	5,012	20	25.8	10.3
	Q 26	30	—	—	—	631	3	10.0	4.8
August	Q 25	542	1	—	5	4,719	25	21.7	11.5
September	Q 25	524	1	—	2	3,480	20	26.2	15.1
October	Q 25	512	2	—	—	3,230	20	25.6	15.9
Total		2,180	4	—	11	17,522	90	24.2	12.4
1979		1,183	14	5	18	15,345	92	12.9	7.7

Note: 1. The season was characterized by favourable weather and ice conditions.
2. The column 'CDW' does not include the days spent loading, making repairs or other unproductive time when neither whaling or searching were carried out.
3. 43 gray whales were observed in square Q 24 in June 1980 during transition.

Table 2

Sightings in the Southern Hemisphere by the Soviet whaling fleet *Sovetskaya Ukraina*, 1980/81

Sector	Zone	Blue	Fin	Sei	Humpback	Right	Minke	Sperm	Killer	CDW
I	B	—	1	1	32	—	6,231	27	77	115
I	C	—	—	—	—	—	97	—	10	10
II	B	—	—	—	—	—	2,128	—	—	48
III	B	5	—	—	4	—	2,627	25	—	104
IV	B	26	1	—	73	—	7,727	150	814	172
V	B	5	—	—	5	5	1,198	—	961	48
V	C	—	—	—	—	—	2,806	—	480	50
VI	C	—	—	—	13	—	1,172	—	25	50
Total		36	2	1	127	5	23,986	202	2,367	597
Catcher boat 34 from 18 December 1980 to 12 February 1981										
IV	B	—	—	—	—	—	27	5	4	4
V	D	—	—	2	—	—	—	—	—	1
V	A	—	6	1	—	—	9	—	25	2
V	B	—	12	—	9	—	2,310	56	329	30
V	C	—	—	—	—	—	912	—	242	18
VI	C	—	—	—	—	—	497	—	30	1
Total		—	18	3	9	—	3,752	61	630	56
Grand total		36	20	4	132	5	27,738	263	2,997	653
1979/80		5	151	233	189	4	38,805	261	9,211	915

intrapopulation groupings determined on this basis was found also to be applicable to whales (Zhirmunsky, Kuz'min and Yablokov, 1981).

Methods of taking thin sections of mineralised structures of fish and mammals were developed (e.g. *Delphinus delphis* Kochkin, 1980). Studies relating to the development of reading cut surfaces of sperm whale teeth were continued (see SC/33Spl).

6. RESULTS OF INVESTIGATIONS*

Yablokov (1981) showed the necessity of further development of phenetic studies using cetaceans as an example. He believed that the constant observation of a considerable number of individually recognisable animals may reveal valuable information on recruitment and mortality rates as well as behaviour and the dynamics of small groupings.

R. G. Borodin (1980a) noted that the criterion of maximum sustainable yield (MSY) adopted by the IWC did not completely meet the regulation purposes put forward by whaling operations. He believed that in the absence of reliable assessments of a stock, the recommended catch limit should be lower than 0.9 MSY so as not to deplete the abundance of the stock.

The generalised model developed by Borodin (1980b) took into consideration variable parameters such as natural mortality and recruitment, catchability coefficient, etc. and defined the size of whaling, the abundance of the breeding stock, maximum sustainable yield etc.

According to the agreement between the USSR and the US for cooperation in the field of environmental conservation, an American research vessel examined the coastal zone between 27° and 41°N in June–July 1980 (Berzin, 1981). Blue, fin, humpback, Bryde's, minke, gray and sperm whales were observed. Blue whales occurred in groups of up to 36–40 in the area up to 35°N. Single whales and groups of up to six individuals were found to be pygmy blue whales. This has increased our knowledge of the distribution of this sub-species. They were also observed in the Eastern Pacific Ocean in 1975. Some people believe that pygmy blue whales were distributed from 20°S to 35°N where two populations probably existed. The common dolphin (*Delphinus delphis*) and Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) were most commonly seen in schools of up to 500–1,300 and 300–500 whales respectively. The abundance of the eastern dolphin population was thought to have decreased from 15–19 million to three million between 1960 and 1975, mainly due to the American fishery for yellowfin tuna. The abundance is not thought to have stabilised.

Ivashin (1980) discussed the distribution of Bryde's whales in the World Ocean and results of whaling in the North Pacific Ocean in detail.

Problems of the state of modern whaling were dealt with by Ivashin and Nikonorov (1980). The contribution of the IWC to rational exploitation based mainly on recommendations from the IWC Scientific Committee was stressed.

Krupnik (1980) gave statistics of whaling operations for a number of Eskimo villages for 1932–37 (predominantly bowhead whales) and information of the commercial importance of white whales.

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* According to publications in Russian.

Table 3

Marking of whales from the Soviet research vessel under the International Programme

Whale species	Square	B20	B21	B22	B23	B24	C23	C24	C25	C26	Total
Minke whale		25	92	16	5	8	15	59	46	2	268
Sperm whale[1]		—	—	3	3	1	—	—	3	—	10
Total		25	92	19	8	9	15	59	49	2	278

[1] 12 calibre Soviet marks used.

Table 4

Information on mark recoveries of whales taken by the *Sovetskaya Ukraina* in 1980/81

Mark number	Date of marking	Coordinates of marking		Date of recovery	Coordinates of recovery		Length of whale at marking (feet)	Area of mark recovery	Time after marking (years)
		latitude southern	longitude		latitude southern	longitude			
35722	6.2.80	68–52	11–17 E	9.12.80	62	56 E	27	meat	1
33975	22.1.79	62–43	104–52 E	4.1.81	64	81 E	—	,,	2
38820	13.1.80	67–07	66–51 E	12.1.81	67	73 E	27	,,	1
34766	24.1.79	64–43	106–49 E	14.1.81	67	74 E	—	,,	2
38822	13.1.80	67–07	66–51 E	19.1.81	68	77 E	28	,,	1
34216	12.1.79	68–04	73–56 E	19.1.81	68	77 E	—	,,	1
32985	?	?	?	26.1.81	68	73 E	—	,,	?

Bogoslovskaya and Votrogov (1981) were of the opinion that the constant wintering area of a small stock of bowhead whales was ‘the window’ of ice-free water near Ostrov Arakamchechen Island and Mys Kriguigun and Mys Chaplino, but the largest polynya was found from the entrance to Kresta Zaliv up to Mys Staletiya (Sireniki). Whales appeared in the first decade of November; in April calves occurred. In spring whales moved to the north in the first half of June. The first gray whales were observed by the tenth of May and stayed to the end of the May.

In August 1980 during geographical investigations of the coastal zones of the Eastern Yamal (area of Se-Yakha village), 400 km from the open part of the Kara Sea and 60 km from the shore, remnants of the tail, skull and spinal cord of a 12 m bowhead whale were found (Vasil’chuk and Yablokov, 1981). The whale may have died several or even 20 years ago. This was thought to show the existence of a probably increasing Spitsbergen population.

Borisov (1981a) studied haemoglobins and myoglobins of Southern Hemisphere sperm, fin, sei and minke whales using electrophoresis. Haemoglobins from foetuses did not differ from those of adults. Intraspecific differentiation was confined mainly to the existence or the absence of certain fractions in the spectra. He also discussed (1981b) the possibility of using data on lactate dehydrogenase for a deeper investigation of some aspects of their biology, viz the biochemical mechanism of the adaptation of mammals to an aquatic environment.

Kochkin (1980) developed a device for obtaining thin (up to 0.04 mm) sections of mineralised structures. The examination of such sections from *Delphinus delphis* previously injected with tetracyclin in ultraviolet light (under the microscope if necessary) gave good results.

Tomilin (1980) reviewed marking data from commercial whale species and small cetaceans up to the end of 1973. Marking data (first of all for fin and humpback whales) showed regular migrations of whales from wintering to feeding grounds extending for several thousand kilometers. Fin whales of the Northern and the Southern Hemisphere migrated only within their Hemispheres. Results of marking showed that several separate local stocks of whales existed on feeding grounds and that there was a close relationship between some individuals for several decades.

To investigate ancestral forms of current cetaceans, the types of cytoarchitectural organisation of the dorsal nucleus of the lateral geniculate body was examined in relation to the eyeball location and the brain (Zvorykin, 1980). The analysis of neuromorphological data showed that the widely held theory of cetaceans originating from primary predators was unsound. Analysis of the structure of the caudal brain hemispheres of cetaceans also contradicted this theory. The brain of predators had to enlarge in size, intricacy and number of convolutions and furrows in the process of the transformation in cetaceans while the diameter of its neocortex had to narrow by two times, in order to return from this complex mode of organisation to the simple one.

7. PUBLICATIONS

Atlas of Marine Mammals of the USSR. 1980. Pischevaya promyshlennost, Moscow, 184pp.

Berzin, A. A. 1981. Soviet-American investigations of Cetacea in the Pacific Ocean. *Priroda* (2): 116–7.

Bogoslovskaya, L. S. and Votrogov, L. M. 1981. Mass winterings of birds and whales in polynyas of the Bering Sea. *Priroda* (1): 42–3.

Borisov, V. M. 1981a. Comparative analysis of electrophoretic spectra of whale albumin. 1. Haemoglobins and myoglobins of three species of baleen whales and sperm whales. *Zool. Zh.* 10(3): 438–42.

Borisov, V. M. 1981b. Comparative analysis of electrophoretic spectra of albumin of whales from the Antarctic. 2. Lactate dehydrogenase of three species of baleens and sperm whales. *Zool. Zh.* 10(4): 595–600.

Kochkin, R. N. 1980. Techniques for making thin sections of mineralised structures of fish and marine mammals. *Zool. Zh.* 9(2): 289–93.

Kuz’min, V. I. and Zhirmunsky, A. V. 1980. Critical levels in the models of stable allometric development of biological systems. 1. Critical level modelling. *Ontogenesis* 11(6): 563–70.

Morosova, N. N. 1981. The current status of the Black Sea dolphin population. *J. Rybn. Khoz.* (4): 44–5.

Studenetskaya, I. S. 1981. Development of marine mammal investigations. pp. 111–9. *In: Biological resources of the hydrosphere and their utilisation. The history of investigations of biological resources of the hydrosphere and their utilisation.* Nauka, Moscow.

Sukhovskaya, L. I. and Yablokov, A. V. 1979. Morpho-functional characteristics of the larynx of Balaenoptera. *Investigations of Cetacea* 10: 205–14.

Tomilin, A. G. 1980. Cetaceans. pp. 272–81. *In: Results of Mammal Marking. Problems of teriology.* Nauka, Moscow.

Vasul’chuk, Yu. K. and Yablokov, A. V. 1981. Bowhead whale in Obskaya Bay. *Priroda* (3): 116.

Yablokov, A. V. 1981. On the benefit of the ‘superficial’ view. *Nauka i zhizn* (3): 76–81.

Zhirmunsky, A. V., Kuz’min, V. I. and Yablokov, A. V. 1981. Critical levels in the development of population systems. *J. Gen. Biol.* 10(1): 19–37.

Zvorykin, V. P. 1980. New criteria for the approach to the problem of the origin of cetaceans and pinnipeds. *Zool. Zh.* 9(4): 598–608.

BOOKS

Agarkov, G. B., Khomenko, B. G., Manger, A. P., Khadzhinsky, V. G., Vronsky, A. A. 1979. *Functional Morphology of Cetaceans.* Naukova dumka. Kiev, 223pp.

Marine Mammals. 1980. VNIRO. Proceedings.

Borodin, R. G. On criteria used for regulation of whaling: 9–10.

Borodin, R. G. A generalised model of the analysis of marine mammals and its application: 10–18.

Ivashin, M. V. Distribution and fishery for Bryde's whale: 18–31.

Ivashin, M. V. and Nikonorov, I. V. The state of modern whaling: 31–40.

Krupnik, I. I. Asiatic Eskimo marine mammal hunting in the 1920–1937: 40–79.

Problems of marine biogeography. All-Union Conference. Abstracts. Vladivostok:

Latogursky, V. I. To the precision of the south boundary of *E. recurva* and *E. spinifers* distribution in the Indian Ocean: 63–4.

Medvedev, L. P., Morosova, N. N. Seasonal migrations of the Black Sea dolphins: 69–70.

Sazhinov, E. G. Fraser's dolphin from the Atlantic: 94–5.

SC/33/Sp1

Subjective and Objective Assessments of the Laminations in Sperm Whale Teeth

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The ability to determine the age of whales is essential if true assessments of the numbers and status of whale stocks are to be obtained and rational quotas established. The importance of this was recognised at a special meeting of scientists on the age determination of toothed whales and sirenians (IWC, 1980), held in September 1978. In spite of the progress made, problems still remain and are discussed at the annual meetings of the IWC Scientific Committee.

In response to a request by the Scientific Committee, Donovan, Breiwick and Best (1982) presented a note on a preliminary study to investigate individual differences between readers. Dr M. V. Ivashin provided 50 etched sperm whale teeth which were cross-read by Soviet, Japanese, South African and three English specialists.

The results revealed that the readings differed between all six specialists, although the differences were not significant between the three English and one South African reader. In general the readings of the Soviet expert tended to be higher and for the Japanese expert, lower, than the average readings of the other four. Without suggesting that any of the readings were 'better' than the other, the authors concluded that the problem should be further investigated by increasing the sample size and the number of readers. If consistent variation between readers from different nationalities did in fact exist then this may significantly affect the results of models using age-length data. In particular they suggested that the process by which Japanese and Soviet experts had arrived at age-length keys in earlier years, be duplicated, but for a common sample of teeth.

In order to examine the problem further (I was the Soviet expert in the initial work), I have re-examined the initial readings of the six experts and added the results from two Soviet experts, A. A. Berzin (TINRO) and G. A. Klevezal (Institute of the Biology of the Animals Development, Academy of Sciences of the USSR). The results are shown in Table 1.

DISCUSSION

It is initially important to thoroughly examine the reasons why variation in reading may occur.

Sperm whale teeth as a 'registering structure'

Tissues, organs or parts of animals and plants, in which laminations are accumulated during life as the reflection of their activity and the conditions experienced were termed as 'registering structures' by Mina and Klevezal (1970). Ear bones, teeth, ear plugs, the periosteal zones of bones and certain other structures have been considered as such in marine mammals. However, it remains difficult to read the information from these structures even where they are available.

Ear plugs (baleen whales) and teeth (toothed whales) appear to be the best registering structures in cetaceans (within the latter group, sperm whale teeth in particular are very good). We consider the teeth from the lower jaw to be the most useful structures: neither too small nor too large, easily handled and stored, while after treatment the laminations are quite distinctive.

The length of a sperm whale's life and the resultant number of laminations open up possibilities for a deeper analysis of an individual's life history. The number and character of the layers are similar in all the teeth of an individual. The front teeth of some individuals do not erupt during the animal's life and thus do not get worn, so that it is thought that they retain all the growth layer groups ('GLGs', IWC, 1980), i.e. the deposited layers do not undergo significant changes with time.

It must be remembered that this is as yet an assumption and has not been proven. For example, Nishiwaki, Ohsumi and Kasuya (1961) found that resorption took place in the periosteal zone of the lower jaw of the sperm whale and there is no theoretical reason why this could not happen in sperm whale teeth as well. In addition, analyses of profilographs of cut decalcified teeth show that the laminations are quite distinct in young animals, but not so clear at the top (corresponding to the early years) from old individuals (Mikhalev, 1975). However, if there is lamination resorption, it appears to be only very minor and the information to be obtained from the teeth does not disappear completely.

The character of the dentine lamination in sperm whale teeth

Annual laminations can be clearly distinguished in registering structures in animals, especially in poikilotherms and plants inhabiting areas where there are sharp seasonal fluctuations in environmental conditions (e.g. temperature, food supply). In such cases the reasons for the laminations and their significance are not too difficult to determine. The significance of laminations in animals (especially homeotherms) and plants from apparently unchanging environments is much more difficult to determine.

Sperm whales occur in this latter category, being warm-blooded and finding enough food in both the Antarctic and in temperate and warm waters. In addition the water temperature at great depths appears to be almost the same. Although food species differ in different areas almost all are squid species (Mikhalev *et al.*, 1981), and the nutritional value of each species will be much the same. The above factors may be the reason why the laminations are only just visible in untreated teeth. The different methods used to enhance these laminations are discussed in IWC (1980).

One of the major questions concerning the use of teeth was how many GLGs are deposited annually. There is now

Table 1

Number of GLGs in 50 sperm whales teeth read by eight experts

No.	Tooth no.	Length (m)	Sex	Number of laminations according to experts data							
				1	2	3	4	5	6	7	8
1	655	10.0	♀	18+1	19	16	6	14	16	18	15
2	4,520	10.6	♀	32+3	32+	30+	29+5	30+	32	29+	
3	3,863	10.7	♀	27	24	26	25	23	27	27	26
4	4,125	10.7	♀	30	30+	31+	31+	30	33	34	30
5	3,810	10.8	♀	17+1	18+	17	17	16	17	17	17
6	4,132	10.8	♀	30+3	26	28+	26	24	27	30	27+
7	3,683	10.9	♀	21+4	22+1	21+	22+	20	18	22	19+
8	3,944	10.9	♀	34	34+1	31+	34	26	35	34	29+
9	3,885	11.0	♀	31+6	28+	29+	29+	29	32	31+2	28
10	3,645	11.0	♀	26+2	23+	22+	22	18+1	23	24+1	21+
11	4,905	11.1	♀	33+2	30	31+	31+	33+	30+	33	30
12	3,884	11.5	♂	18	16	16+	16	11+	17+	18	16
13	3,284	12.0	♂	18+4	20	19+	20+	17	20	20+1	18
14	682	12.3	♂	21+2	28	24+	25+	23+3	23	22	23+
15	3,902	12.3	♂	20+2	19	18+	18+	17	21	20	18
16	3,259	12.4	♂	26+1	24	23	25	23	24	26	23
17	4,009	12.4	♂	25+2	29+	25+	25+	22	30	25+2	22+
18	4,083	12.4	♂	25	22	23+	22+	18	23	25	20+
19	3,301	12.5	♂	22+3	27+	24+	25+	18	23	21+2	20+
20	3,883	12.5	♂	20+4	18	21+	21+	19	20	20+2	19+
21	4,622	12.6	♂	25+2	23	23+	23+	22	25	25	22
22	3,885	12.6	♂	25+2	22	22+	22+	18+1	22	23	22
23	678	12.7	♂	23	28	23	26	22	26	23	22
24	3,771	12.7	♂	27	25	25	25	14+1	24	27	23
25	4,528	12.8	♂	28	29+	29	29	29	28	28	28
26	3,758	12.8	♂	28	25	25	25	21+	25	28	24
27	3,772	12.9	♂	22+4	24+	22+	22+	22	21	23+1	21
28	4,127	12.9	♂	30+2	32+	30+	31	28	32	31	29+
29	4,526	12.9	♂	29+2	23	25+	25	23	24	26	24
30	4,403	13.0	♂	23+3	24+	22+	22+	25	21	23	21
31	4,052	13.0	♂	25+3	24+	21+	24+	24+1	25	25	24
32	4,028	13.1	♂	30	26+	23+	24+	25	27	26	24
33	3,928	13.2	♂	24+3	25+	24+	25+	19	24+	24+2	22+
34	4,036	13.3	♂	27+3	25+	26+	25+	26	26	27	26
35	4,048	13.3	♂	22	22	20	22	20	23	23	20
36	3,485	13.4	♂	22	20	22+	22+	19	22	22	22
37	3,856	13.4	♂	32+3	27+	27+	27+	27	27	31	27+
38	3,926	13.4	♂	30	25	27+	25	26	26	28	25
39	4,140	13.4	♂	27	20	23+	21	20	20	21	21
40	3,515	13.5	♂	32+5	30	33+	30+	29	33	32	23+
41	3,472	13.6	♂	30+3	32	26+	26+	27	26+	28	26+
42	3,984	13.6	♂	31+5	33+	27+	31+	26	26+	32+2	29+
43	805	13.9	♂	40	40+	39+	40+	40	38+	38	37+
44	5,178	14.0	♂	33+6	33+	32+	32+	35+2	37	33+2	32+
45	3,529	14.0	♂	30	33	32+	32+	31	32	34	30
46	802	14.1	♂	41+3	37	38+	39+	44+1	34+	40	34+
47	2,641	14.2	♂	40+6	36+	35+	35+	34+	38+	35+5	35
48	1,734	14.3	♂	45	41+	39+	40+	37	37	43	37
49	4,891	14.4	♂	31+2	27+	29+	28+	21	28	29	27
50	4,004	14.7	♂	29+5	21	22+	21+	23+2	27	—	—

substantial evidence to suggest that one GLG is deposited annually (IWC, 1969; 1981; Best, 1970; Gambell, 1977). One of the problems concerned interpretation of the structures present; in particular whether fine translucent bands constituted GLGs or merely 'accessory layers'. Some authors consider that the problem in distinguishing some accessory layers from main layers is the main reason for divergences in readings between readers. Klevezal and Tormosov (1971) observed that certain very prominent layers were observed in the teeth of females (63% of females investigated), which divided the teeth into groups of GLGs of varying numbers up to 8. These more clear layers were termed as 'marks'. 'Marks' were also noticed in 10% of the males investigated, although they were not as regular as in females. However they found no relationship between 'marks' and number of GLGs in a tooth or between the number of 'marks' and number of pregnancies in females.

Investigations using profilographs and microphotometers (Mikhalev, 1975; 1975a) further illustrated the complex character of laminations. In several cases areas in a tooth gradually changed from having clear to not-so-clear GLGs from the top of the tooth to the pulp cavity. Even in the inner part of these areas though, more distinctive layers could be seen (analogous to 'marks').

The information described above serves to illustrate the complexity of laminations which sometimes makes the counting of annual layers difficult or almost impossible. A deeper study of the significance and nature of the laminations in sperm whale teeth is required.

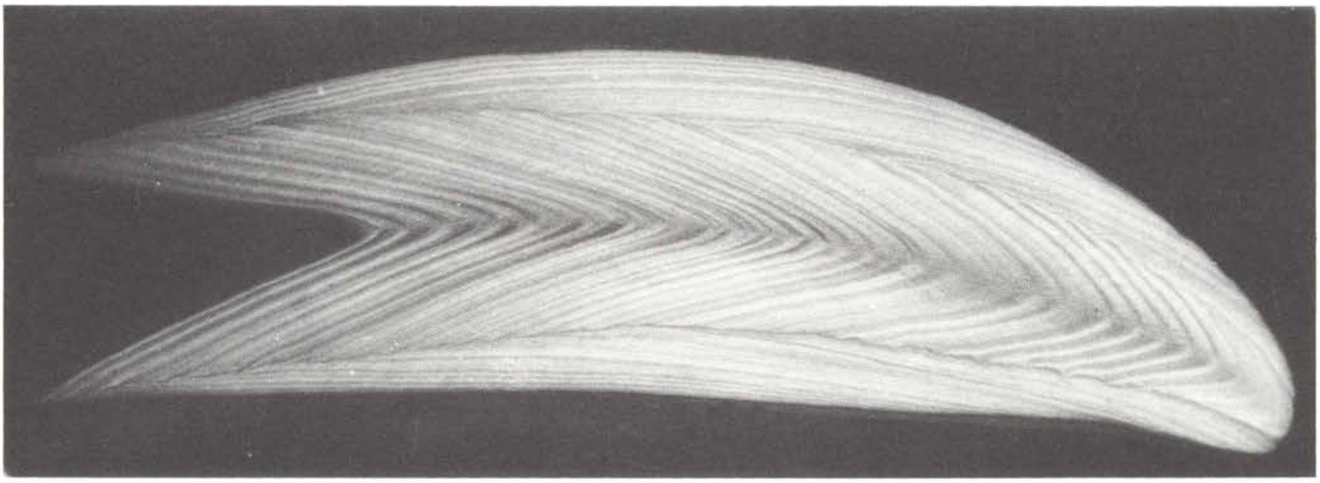

Fig. 1. Decalcified cut surface of a male sperm-whale tooth.

Expert or subjective assessment of laminations

The age of sperm whales is arrived at by the estimation of the number of main layers or GLGs. This approach has enabled general conclusions to be drawn on the life-span of sperm whales, the growth curves of males and females, the ages at sexual and physical maturity, and to allow determination of the correlation between different age groups etc.

However, at the same time, the complex nature of the laminations and the problems associated with determining additional from main layers does not always allow us to estimate the number of annual layers with 'absolute' accuracy as it is now understood. For these reasons, the age determination of sperm whales is often 'erroneous' and is to some extent subjective. It often happens that investigators in the same laboratory using the same methods and with the same scientific opinions arrive at different assessments of the GLG number; the differences are not great but do exist. Indeed the very fact that 'experts' are used emphasises the subjective nature of aging teeth: there is no need for 'experts' when the investigated characteristics are obvious and discrete, e.g. when determining the number of ventral grooves. Strictly speaking, expert assessments are qualitative and not therefore an 'assessment'. Although numbers may be used in expert assessments they are only rough, approximate and subjective. For example, in assessing mastery in certain sports (e.g. figure skating, gymnastics etc.) the experts can arrange the sportsmen in order of merit easily enough but cannot give a true quantitative assessment of the degree of mastery of one sportsman over another. Although this is an extreme example, an increase in the number of experts cannot practically alter this and the essence of the assessment will remain qualitative and subjective. One question which may well be asked is whether an expert assessment can in general be a scientific one?

Turin (1978), in examining certain nonparametric statistical methods wrote: 'expert assessment has been popular in certain circles. Some specialists are ready to use experts in any difficult case. Others consider the value of using experts to be fictional and believe that such methods will soon be out of fashion'. I believe that such an approach is valid only up until quantitative and objective assessment methods have been developed. One of the peculiarities of expert assessment is that increasing the number of experts serves only to increase the variation and that therefore there is no reason their number should exceed 5–6 persons. It should also be remembered that both the mean and extreme values have a similar probability of coinciding with (or indeed differing from) the true value. The results of each expert may be more 'truthful' than the total averaged solution. This was confirmed in the results of Donovan *et al.* (1982) where there was clear variation in the readings.

I do not believe that it is correct to average the results obtained by different experts as there are no grounds to suppose that average values are closer to the 'true' values. Averaging also tends to hide the divergences in the results of the experts. Fig. 2 shows that the divergences seen in the GLG counts between the first and second experts are practically the same as those between the second and third experts, i.e. between two English experts. In the first case, the readings coincide in 5 cases, and are higher for the first reader on 29 occasions and lower on 16 occasions. In the second case, readings coincide 7 times, and are higher for the second expert on 27 occasions and lower on 16.

To assess the significance of these divergences I have used a range Willcockson method used for the variants conjugated by two (Urbah, 1963), as possessing a great effect. The 'U-criterion' appeared to be 2.17 in the first case and 2.16 in the second one. That is the truthfulness of the assessment divergences between the first and second experts and the second and third ones is almost the same, within the ranges of 0.05 and 0.01 levels of significance.

It is clear that averaging could be applied not only for the four experts, but also with all six, and that the results would be very close (although not necessarily closer to the truth).

To illustrate the subjectivity in GLG counts, the results of the second, third, fourth and sixth experts coincided on only three out of 50 comparisons performed and on only 11 occasions did the values obtained by three out of four readers coincide. In all other cases the readings, although close, were different.

I have noted that increasing the number of experts only increases the variation. To obtain the base material for this paper, the same 50 teeth were sent to Dr A. A. Berzin (TINRO, Vladivostok) and Dr G. A. Klevezal (Institute of the Biology of Animal Development, USSR Academy of Sciences, Moscow). Their results are given in Table 1.

The readings given by Dr Berzin (the seventh expert) are between those given by the first and second experts, and those of Dr Klevezal (the eighth expert) are between the

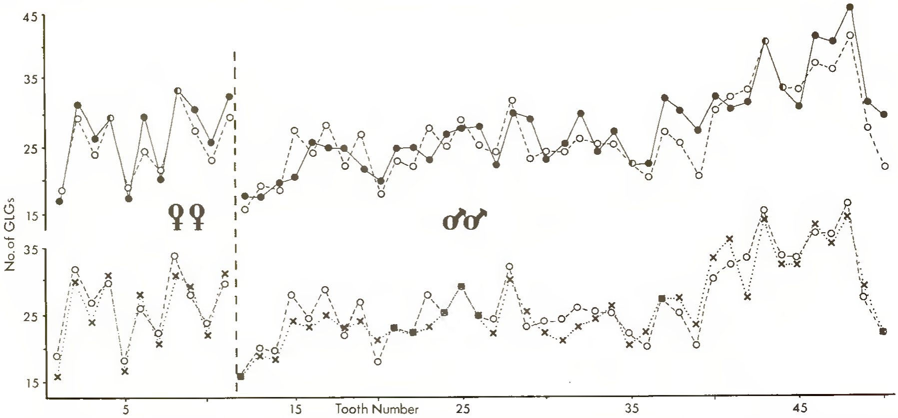

Fig. 2. Comparison of readers 1 and 2 (above), and 2 and 3 (below) in pairs. ●——● the first expert; o----o the second expert; x-----x the third expert; number of layers arranged according to the length of the animals.

fifth and third experts. These values do not help to solve the problem and testify to the fact that this problem can only be solved by finding methods of objectively assessing the number of GLGs. Although the present method of aging sperm whales does not yet give an 'absolute' solution I would stress that it gives quite satisfactory results for general problems as the divergences are not usually very great. For example, the divergence between the readings of the first and fourth expert was on average only 1.4 layers and that between the readings of the first and fifth experts (extreme values) was 3.2 layers. Thus, if the mean age of the animals was 26–27 years, the divergence was only about 3 years. I do not believe that this would greatly affect the results of models using age-length data. Having said this it does not mean that the method of aging sperm whales should not be perfected.

Objective assessment of the laminations

In this section I examine some ways in which we may improve the current aging method and discuss the development of a more objective assessment of the number of laminations.

One simple way of obtaining more precise results is to reject those teeth where annual laminations are not clear, i.e. where the readings from experts significantly differ[1], even if this results in a large number of rejected teeth.

Divergences often arise when assessing the layers adjacent to the pulp cavity. It is not yet clear whether the last layer should be considered as complete or not. One approach would be to arrange that the last 'layer' is designated as '+', and only to consider it as complete when the line of a new layer is apparent. In disputed cases, one would try to analyse a profilogram or to reject the tooth.

Another difficulty is the determination of the neonatal line, from which the calculation of the annual layers begins. To do this, only those teeth which have either not yet been cut, or, which have a full cement layer at the top should be used although the neonatal line is still difficult to determine visually.

It must be remembered that prenatal dentine is homogeneous, i.e. has no laminations and that their development takes place after birth; lamellar dentine appears after the line has been formed. It should also be noted that early laminations are difficult to notice for some time after birth, and the first or even the second annual layer may be mistaken as the neonatal line. This is well illustrated by the photograph and profilogram of a young sperm whale tooth (Fig. 3).

The examination of undecalcified cut surfaces of teeth (not thinly sectioned and investigated under a microscope) with the unaided eye can lead to the misidentification of the neonatal line. Even experienced investigators may identify the neonatal line more than 5 mm from the top of a tooth whereas the width of prenatal dentine is less than half this: not more than 1.5–2.5 mm in near term embryos. A new born whale caught with a net from the research scouting catcher boat *Bodryi-25* had about 2 mm of prenatal dentine on its first teeth. The same width of prenatal dentine was found in a sperm whale aged approximately 16 years (Fig. 3). I consider that results incorporating a neonatal line found at a greater distance from the top of a tooth should be considered doubtful and the teeth investigated more thoroughly.

While trying to decide where to begin counting GLGs, it should be taken into account that a cut may not pass exactly along the whole tooth axis, since all teeth are curved to a greater or lesser extent. This may result in the loss of one or even two GLGs. An acute angle lying at the fold of a layer serves as a criterion that a cut was made along the tooth axis. If the angle is rounded, it means that the cut was made at the side of the axis.

The aging of teeth with a worn tip by 'reconstructing' the effaced laminations (Berzin, 1971) is quite unacceptable in any objective assessment of GLG numbers, as it can result in errors of up to five or even more layers.

Counting annual laminations (even on selected teeth) is hampered by the fact that the character of the laminations changes periodically. This periodicity is observed more clearly in some teeth (Fig. 4) than others (Fig. 1). As a rule, areas with a clear alternation of layers are periodically replaced by unclear areas. In such cases it is difficult to distinguish between main and accessory layers (Fig. 4). The layers are less distinctive towards the edge of the teeth and better towards the centre in the more clear areas. It has also been observed that two and sometimes three to four layers are often grouped into blocks within these areas with one of these layers being more distinctive. Such layers are also to be seen on the undecalcified cut surfaces of teeth (as

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[1] Such an approach is followed by the Sea Mammal Research Unit, UK.

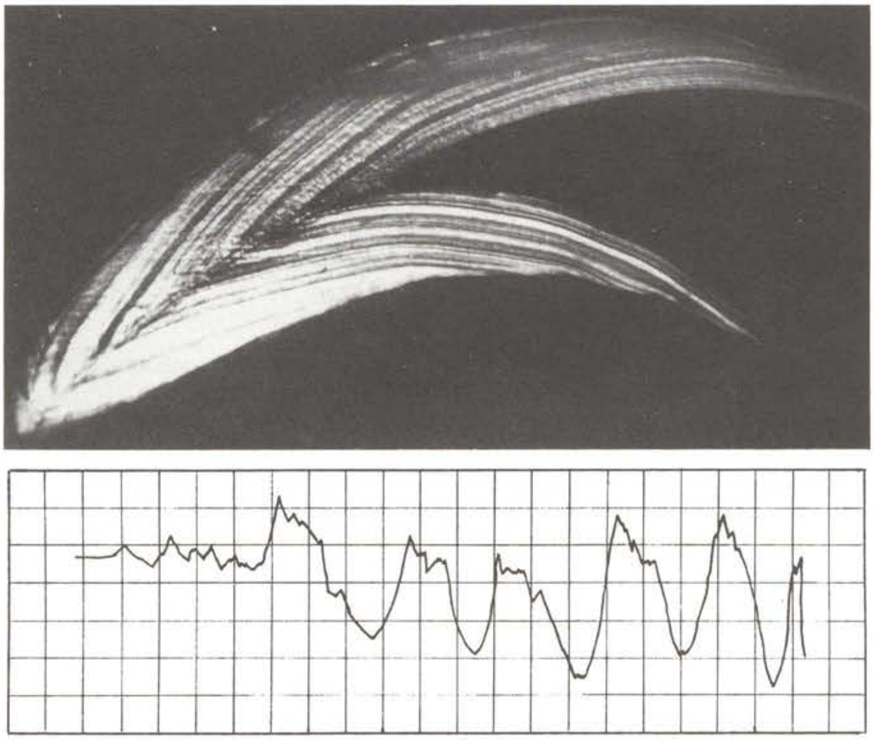

Fig. 3. Decalcified cut surface of a tooth of a young female sperm whale (above) and a profilogram of this tooth (below).

we have seen earlier, these layers were termed 'marks' by Klevezal and Tormosov (1971). The distances between layers are not always constant which does not allow accurate estimation of GLGs in difficult areas.

However, if the layering is not clear to the naked eye, it may become more clear if a profilogram of the surface relief of the tooth is made (Fig. 5). Methods for obtaining profilograms and microphotograms were described some years ago (Mikhalev, 1975a and b; 1977). They are almost the same as the methods used to obtain profilograms (Utrecht-Cock, van, 1965) and photograms (Ichihara, 1963) for the 'registering structures' (baleen plates, ear plugs) of baleen whales. Profilograms reveal the undulating character of the laminations even when the layers are distinctively observed. (Fig. 3).

This undulating nature is interesting and may lead to a further line of investigation. Mikhalev (1975a) postulated the possibility of a relationship between the character of the laminations and solar activity, as has been observed in trees. This possibility can and should be further examined by considering photographs and profilograms of cut teeth (Figs 1, 4 and 5). If such a connection is confirmed, this will help to answer the problem of how many and what kind of layers are formed throughout a year.

Although obtaining profilograms and microphotograms is very time consuming it does open the possibility of

Fig. 4. The varying character of the clear laminations in a male sperm whale tooth.

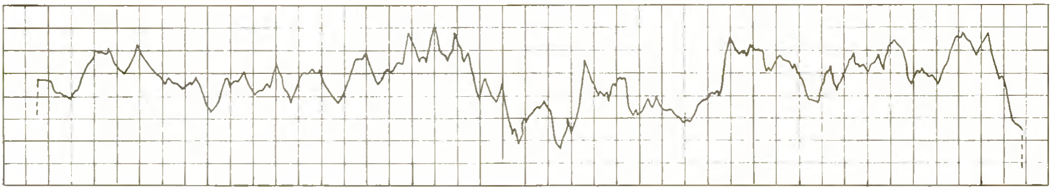

Fig. 5. Profilogram of the decalcified tooth surface of a male sperm whale with unclear laminations.

obtaining new methods for the objective assessment of laminations and the determination of their significance. Profilograms or microphotograms made for different sections of the same tooth may help often to resolve doubts concerning certain layers, e.g. if they are main or accessory. In addition a graphical record of the tooth laminations both after its decalcification (profilograms) and without treatment of its cut surface with acids (microphotograms) would allow us to quantify the characteristics (width, height, distance between layers) of each lamination, which opens up new possibilities of obtaining objective assessments. This is convincingly confirmed by Gonchorov and Smetanina (1974), who made profilograms and used spectro-correlation and periodical gram analysis in the age determination of fish. An analogous analysis was tried for baleen whales by van Utrecht-Cock (1965).

Assessing the significance of laminations is also somewhat easier with paper copies. If a sheet of paper is placed on a decalcified cut surface of a tooth an image can be obtained by rubbing over it with the side of a graphite or wax pencil, the strongest layers appearing with the least pressure.

Of course, many other more objective methods may be subsequently suggested and it is important that research into such methods is continued. For example, there is no doubt that valuable information can be obtained from tagged sperm whales, if the abiotic and biotic conditions of the tagging season are compated with the peculiarities of layer development during the season. Such work will be difficult but should be investigated. Only quantitative, objective methods will allow us to fully interpret such a complex 'registering structure' as the sperm whale tooth which not only encodes age but also many other characteristics of the biology of the species.

CONCLUSION

Fluctuations in the sperm whale's growth rate and, apparently, different bio-physiological changes taking place in the animal's life, are reflected in the laminations in the sperm whale's teeth. Therefore, the interpretation of this 'registering structure' may give answers to many problems of sperm whale biology. First of all, it is necessary to determine the age of the harvested animals to help in estimating the optimal quota for their exploitation.

The present age determination method allows us to solve particular general problems. It is considered to be satisfactory, as no obvious contradictions exist between ages determined and other factors in a full biological analysis. Thus, the growth curves of male and female sperm whales have been drawn, the ages at sexual and physical maturity determined, the reproductive capacity of the species calculated and so on. The fact that the difference in the assessment of the number of annual laminations is only about 3 layers even with a sample of 50 teeth when determined by six experts testifies to the satisfactory nature of the method.

Simultaneously, this method does not yet allow us to determine the absolute age of every animal. The expert assessment method used may result in differences of GLG counts for the same tooth of 5 or even 10 layers.

These divergences are explained by the complex nature of the laminations, and our present state of knowledge does not allow us to precisely decide which are main and which are accessory layers. The averaging of the results of several experts does not necessarily improve the precision of the estimate.

To obtain truly objective assessment a fuller interpretation of the whale tooth as a 'registering structure' is needed. Some ways of approaching this are suggested by choosing only those teeth which are not worn and which have clear laminations, although examination should not be limited to a visual examination but should incorporate the use of microscopes, and an analysis of profilograms and microphotograms. Special attention should be paid to obtaining quantitative characteristics of the laminations and examining the cause and significance of the layers seen.

Although tooth rejection will decrease the sample size, it will greatly increase the 'truthfulness' of age determination. This will result in more accurate 'age-length' keys with which will allow more precise determination of the age composition of the sperm whales taken and thus more accurate estimates of the size and status of the stocks.

REFERENCES

Berzin, A. A. 1961. Data on tooth development and age determination of sperm whales. *Tr. Sov. Ikhtiol. Komissyi AN SSSR* 12: 94–103. (In Russian).

Berzin, A. A. 1971. *The Sperm Whale.* Izdatelstvo Pischevaya Promyshlennlost Moscow. (In Russian).

Best, P. B. 1970. The sperm whale (*Physeter catodon*) off the west coast of South Africa. 5. Age, growth and mortality. *Investl. Rep. Div. Sea Fish. S. Afr.* 79: 1–27.

Bow, J. M. and Purday, C. 1966. A method of preparing sperm whale teeth for age determination. *Nature* 210(5034): 437–8.

Donovan, G. P., Breiwick, J. and Best, P. 1982. A note on comparative readings of sperm whale teeth. Paper SC/32/Sp4 (published in this volume).

Gambell, R. 1977. Dentinal layer formation in sperm whale teeth. pp. 583–90. *In:* M. Angel (ed.), *A Voyage of Discovery*, Pergammon Press, Oxford, xii + 696pp.

Ichihara, T. 1963. Photometric method for counting laminae in ear plug of baleen whale. *Sci. Rep. Whales Res. Inst., Tokyo* 17: 37–48.

International Whaling Commission. 1969. Report of the meeting on age determination in whales. *Rep. int. Whal. Commn* 19: 131–7.

International Whaling Commission. 1980. Report of the workshop on determining age of odontocete cetaceans [and sirenians]. *Rep. int. Whal. Commn* (special issue 3): 1–50.

Klevezal, G. A. 1963. *On the Causes of Dentine Lamination in the Teeth of Marine Mammals.* Vtoroye Vsesoyuznoye soveshanye po izuchenyu morskih mlekopitayushih. Tezisy docl. L., Ins. AN SSR.

Klevezal, G. A. 1966. Age-dependent changes in the structure of dentine and cement and the periosteal zone of mammalian bones. Kandidatskaya dissertatsiya, Moscow. (In Russian).

Klevezal, G. A. and Kleinenberg, C. E. 1967. *Determination of the Age of Mammals.* Izdatelstvo Nauka, Moscow. (In Russian).

Klevezal, G. A. and Tormosov, D. D. 1971. On the separation of local sperm whale groupings according to the layers character in the teeth dentine. *Tr. AtlantNIRO* 39: 35–43.

Mikhalev, Yu. A. 1975. A method of quantifying characteristics of marine mammal teeth and registering structures of the vertebrae. pp. 7–9 *In: Sbornik Morskye Mlekopitayuschye, Chast 2, Materialy VI Vsesoyuznogo Soveschanya,* Kiev. (In Russian).

Mikhalev, Yu. A. 1975a. The analysis of profilograms of decalcified cut surfaces of sperm whale teeth. pp. 10–12. In: *Sbornik Morkye Mlekopitayuschye. Chast 2. Materialy VI Vsesoyuznogo Soveschanya,* Kiev. (In Russian).

Mikhalev, Yu. A. 1977. Method for graphical record of surface relief of decalcinated sections of sperm whale teeth with the aim to determine their age. *Rep. int. Whal. Commn* 27: 356–60.

Mikhalev, Yu. A., Savusin, V. P., Kishlan, N. A. and Ivashin, M. V. 1981. To the problem of the feeding of sperm whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 737–45.

Mina, M. V. and Klevezal, G. A. 1970. Principles of investigations of registering structures. *Uspekhy sovremennoy biol.* 70: 341–52. (In Russian).

Nishiwaki, M., Hibiya, T. and Ohsumi, S. 1958. Age study of sperm whale based on reading of tooth laminations. *Sci. Rep. Whales Res. Inst., Tokyo* 13: 135–53.

Nishiwaki, M., Ohsumi, S. and Kasuya, T. 1961. Age characteristics in the sperm whale mandible. *Norsk Hvalfangsttid.* 50: 99–506.

Smetanin, M. M. 1974. The method of an objective age determination and studies of fish growth with use of scales. *Inf. bul. Inst. biol. vnutren. vod AN SSSR* 22: (In Russian).

Tormosov, D. D. 1969. Treatment of teeth cut surfaces of sperm whales. *Rybn. Khoz.* 7: 14–15.

Turin, Yu. N. 1978. *Non-parametric Methods of Statistics.* Izdatelstvo Znanye Moscow.

Urbakh, V. Yu. 1963. *Mathematical Statistics for Biologists and Medicine Workers.* Izdatelstvo AN SSSR, Moscow. 324pp.

Utrecht-Cock, C. N. van. 1965. Age determination and reproduction of female fin whales, with special regard to baleen plates and ovaries. *Bijdr. dierkunde* 35: 39–75.

SC/33/Sp2

Comment on the Beddington and Cooke Age-Specific Assessment Model for the Sperm Whale Population

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ABSTRACT

The expected value of the estimate of the selectivity function of the Beddington and Cooke age-specific sperm whale assessment model is computed. It is shown that the Beddington and Cooke estimate does not estimate the true selectivity function. An alternative estimate is proposed which is unbiased provided the selectivity function is polynomial (or, more generally, linear parametric) in form and the range of catch lengths exceeds the degree of this polynomial.

INTRODUCTION

Beddington and Cooke (1980) (hereafter referred to as BC) have presented two interesting assessment models for certain whale populations, in particular sperm whales, based on a comparison of observed catch length distributions with expected length distributions. Part of the first model given involves estimating a postulated age-specific selectivity function, also called an availability function by Doi (1979), and which is a generalization of the well-known catch coefficient. It is the purpose of this paper to show that the BC estimate of the age-specific selectivity function does not estimate the true selectivity function but does estimate what could be called an average length-specific selectivity function. An alternative estimate of the selectivity function is given provided that this function is assumed to be of polynomial form, more generally of linear parametric form, and the range of catch lengths (27 in the present case) exceeds the degree or the number of parameters of this function.

The BC models are basically deterministic although at various points the authors must assume that certain variables, which are not stated, are random, because confidence regions and expected values are computed. The method used in this paper to examine the utility of the estimate of the age-specific selectivity function is to compute its expected value. For this purpose it is necessary to postulate a stochastic model. The changes required are mainly some additional notation in order to distinguish between parameters and random variables.

NOTATION

The notation follows BC except that K_{al}, the conditional probability of length l given age a, in the population, is sometimes written in standard mathematical form, $P(l|a)$, for the sake of clarity. $P_t(a|l)$, $P_t(a)$, and $P_t(l)$, respectively the conditional probability of age a given length l, and the absolute probabilities of a and l, are also introduced. BC assume, as will be done here, that $P(l|a)$, as given in the Ohsumi (1977) age-length key is invariant with respect to time. Then the other probabilities cannot be except if the population is in equilibrium. The subscript t is meant to indicate the dependence on time. The above four probabilities are related by the well-known Bayes formula,

$$P_t(a|l)P_t(l) = P(l|a)P_t(a)\ . \qquad (1)$$

Below, random variables are starred " * " and it is stated whether or not they are observed directly. All other quantities are parameters or constants. The interpretation of the expected value of a random variable such as N_{at}, which is the population size of age a at time t, is hypothetical: it is the average value of N_{at} if the sequence of years involved could be repeated infinitely often. The conditional expected value of C_{ajt}, the catch of age a, from area j, at time t, given the population N_{at}, a = 1,2,. . ., is the average value of C_{ajt} if the whaling expedition were rerun infinitely often, each time restoring the population to its original form. The notation used for this conditional expectation is $E(C_{ajt}|\{N_{at}\})$. E( ) in general refers to expectation and P( ) to probability.

$*\ C_{a}l_{tj}$ = catch of males of age a, length l[2], area of fleet j, time t, (not observed).
$*\ C_{ajt}$ = $\Sigma_l C_{aljt} = CL_{ljt}$ (not observed).
$*\ C_{ljt}$ = $\Sigma_a C_{aljt} = CL_{ljt}$ (observed).
$*\ C_{jt}$ = $\Sigma_a C_{ajt}$ (observed). This could also be a constant if set by quota.
$*\ CF_t$ = female catch, year t (observed). This could also be a constant if set by quota.
$*\ CL_{ljt}$ = male catch of length l, $l < 55$ ft., area j, time t (observed).
$*\ CL_{56,jt}$ = same as above except length is 56 ft or greater.
$*\ B_t$ = births in year t (not observed).
F_0 = number of mature females in population in initial year, a parameter.
$*\ F_t$ = number of mature females in population, year t (not observed).
$P(l|a)$ = K_{al} = conditional probability of male of length l, given age a, under random selection from the population = proportion of males of length l in the subpopulation of males of age a. Note $\Sigma_l K_{al} = 1.0$, and the numbers in the age-length key are assumed to be standardized to have this property (Ohsumi (1977) does not give the age-length key in standardized form).

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[2] Written as *l* in the equations to avoid confusion with the number 1.

* $P_t(a|l)$ = conditional probability of male of age a given its length l at time t (not observed).

* N_{at} = number of males, age a, year t, in population (not observed).

N_{a0} = number of males, age a, in initial year 1910 (from equilibrium distribution). Sometimes the actual year will be substituted, thus: $N_{a,1910}$.

S_{aj} = relative likelihood of capture of male of age a, area j. This is called a selectivity constant, or function, as a function of a.

All other quantities are parameters or constants and are the same as in BC. In general, a parameter or random variable below with fewer subscripts than given above indicates a sum over the missing subscripts, thus: $CL_{jt} = \Sigma_l CL_{ljt}$.

KEY ASSUMPTION

BC give as the key assumption of the age-specific model

$$C_{ajt} = KS_{aj}N_{at} \quad \text{(BC equation 9)} \qquad (2)$$

where the proportionality constant K, which depends on j and t, satisfies

$$\Sigma_a C_{ajt} = CL_{jt} \text{ or } K = CL_{jt}/\Sigma_a S_{aj}N_{at}.$$

The important point in (2) is that S_{aj} does not depend on t and hence on the changing length and age distributions with time. Multiplying (2) by $P(l|a)$ we obtain

$$C_{ajt}P(l|a) = KS_{aj}N_{at}P(l|a).$$

BC state that the left side equals C_{aljt}. This is correct if we define $P(l|a) = C_{aljt}/C_{ajt}$ for all j, t. While this is the basis for estimating the age-length key, I have followed the usual statistical practice of defining $P(l|a)$ in terms of population ratios (see section on notation). Therefore, it is necessary to assume $C_{aljt} = C_{ajt}P(l|a)$. Then we take as the key assumption,

$$E(C_{aljt}|\{N_{at}\}) = KS_{aj}N_{at}P(l|a), \qquad (3)$$

where K satisfies

$$\Sigma_a \Sigma_l E(C_{aljt}|\{N_{at}\}) = E(CL_{jt}) \text{ or } K = E(CL_{jt})/\Sigma_a S_{aj}N_{at}. \quad (4)$$

In use, estimates CL_{jt}, $\hat{S}_{aj}$ replace $E(CL_{jt})$, S_{aj}, respectively. Summing (3) over l we obtain

$$E(C_{ajt}|\{N_{at}\}) = E(CL_{jt})S_{aj}N_{at}/\Sigma_a S_{aj}N_{at}, \qquad (5)$$

which is the random variable analogue of (2). Therefore (2) or, in random variable form, (5), is a consequence rather than an assumption. The difference is not particularly important except that it enables us to compute an expected value of the estimate of S_{aj}. The remaining assumptions are as in BC.

EXPECTED VALUE OF THE BC ESTIMATE OF S_{aj}

The BC estimate of S_{aj} is next derived. Equation (5) with CL_{jt} replacing $E(CL_{jt})$ and S_{aj} and N_{at} the current estimates, gives one estimate of C_{ajt},

$$\hat{C}_{ajt} = CL_{jt}S_{aj}N_{at}/\Sigma_a S_{aj}N_{at},$$

which is used to obtain $N_{a,t+1}$, a = 4, . . .,40. To obtain S_{aj}, a = 4, . . .,40, for the next iteration solve (5) for S_{aj}, replacing $E(CL_{jt})$ by CL_{jt}:

$$S_{aj} = E(C_{ajt}|\{N_{at}\})(\sum_{a=4}^{40} S_{aj}N_{at})/CL_{jt}N_{at}, \qquad (6)$$

(BC equation 13)

Where the N_{at}'s are the current values. $\hat{C}_{ajt}$ cannot be substituted for $E(C_{ajt}|\{N_{at}\})$ since this would lead to a circular definition. Therefore, it is replaced by a new estimate as follows. The factor $\Sigma_a S_{aj}N_{at}$, common to all S_{aj}'s in group j, may be dropped since these are relative numbers. By Bayes' formula (1),

$$P_t(a|l) = \frac{P(l|a)P_t(a)}{\Sigma_a P(l|a)P_t(a)} = \frac{K_{al}(N_{at}/\Sigma_a N_{at})}{\Sigma_a K_{al}(N_{at}/\Sigma_a N_{at})} = \frac{K_{al}N_{at}}{\Sigma_a K_{al}N_{at}},$$

for l = 30,. . .,56. Take as the new estimate

$$\tilde{C}_{ajt} = \Sigma_{l=30}^{56} CL_{ljt}P_t(a|l) = \Sigma_l \frac{CL_{ljt}K_{al}N_{at}}{\Sigma_a K_{al}N_{at}}$$

(BC equation 15)

BC make this an additional assumption. But it can be shown that, if this is done, a conflict with assumption (3) arises unless $S_{4j} = \ldots = S_{40,j}$ for all j. Therefore, $\tilde{C}_{ajt}$ is called an estimate.

From the middle equal term it can be seen that this is the familiar method of distributing the catch of length l (for each j and t) according to the conditional probability of age given the length. Substituting in (6),

$$\hat{S}_{aj} = \Sigma_{l=30}^{56} \frac{CL_{ljt}K_{al}N_{at}}{\Sigma_a K_{al}N_{at}} \; \frac{1}{CL_{jt}N_{at}}$$

where $\hat{S}_{aj}$ also depends on t though this is suppressed in the notation. Next average over the years t = 1946 to 1977, for which data are available (up to the time of the BC paper), with respect to the weights CL_{jt} obtaining

$$\hat{S}_{aj} = \Sigma_{t=1946}^{1977} \Sigma_{l=30}^{56} \frac{CL_{ljt}K_{al}}{\Sigma_{a=4}^{40} K_{al}N_{at}} \qquad (7)$$

the new estimate of S_{aj}, which now does not depend on t. Except for the factor $(\Sigma_a S_{aj}N_{at})$ which was dropped this is BC equation 17. It should be noted that it generally does not make sense to average relative numbers without prior standardization, say by making each vector $(\hat{S}_{4j}, \ldots, \hat{S}_{40,j})$ have length 1, i.e. dividing $\hat{S}_{aj}$ by $(\Sigma_a \hat{S}_{aj})^{1/2}$. BC have not done this.

The expected value of $\hat{S}_{aj}$ is now computed. By definition, $CL_{ljt} = \Sigma_i C_{iljt}$, where i is the age index. Hence, by (3) and (4),

$$\begin{aligned} E(CL_{ljt}|\{N_{at}\}) &= \Sigma_i E(C_{iljt}|\{N_{it}\}) \qquad (8) \\ &= \frac{\Sigma_i E(CL_{jt})S_{ij}N_{it}P(l|i)}{\Sigma_i S_{ij}N_{it}}. \end{aligned}$$

Substituting into (7),

$$\begin{aligned} E(\hat{S}_{aj}|\{N_{at}\}) &= \Sigma_t \Sigma_l \frac{E(CL_{ljt}|\{N_{at}\})K_{al}}{\Sigma_i K_{il}N_{it}} \\ &= \Sigma_t \Sigma_l E(CL_{jt}) \frac{(\Sigma_i S_{ij}N_{it}K_{il})K_{al}}{(\Sigma_i S_{ij}N_{it})(\Sigma_i K_{il}N_{it})}, \end{aligned}$$

where the S_{ij}'s are the true parameter values. This is a highly smoothed function of all of the S_{aj}'s depending on the population values N_{at} as well. An interpretation of this function can be given. Recall that $E(CL_{jt})/\Sigma_i S_{ij}N_{it} = K$ of equation (3), where the dependence of K on j and t is suppressed. Substituting, the right side of the last equation becomes

$$\Sigma_t \Sigma_l \frac{(\Sigma_i K S_{ij} N_{it} K_{il}) K_{al}}{\Sigma_i K_{il} N_{it}} \tag{9}$$

Look at this piece by piece. For year t we have

$KS_{ij}N_{it}K_{il}$ = expected catch of length l age i,
$\Sigma_i KS_{ij}N_{it}K_{il}$ = expected catch of length l,
$\Sigma_i K_{il}N_{it}$ = number in population of length l.

Hence for each t the sum to the right of Σ_t in equation (9) is

$$\Sigma_l \frac{\text{E (catch of length } l)}{\text{no. in population of length } l} P(l|a).$$

It is reasonable to define as the relative length-specific selectivity coefficient, neglecting for the moment that this is an age-specific model, S_{ljt}, where

$$S_{ljt} = \frac{\text{E (catch of length } l)}{\text{no. in pop. of length } l}, l = 30, \ldots, 56, .$$

and for each j and t. Then summing over t we obtain

$$E(\hat{S}_{aj} | \{N_{at}\}) = \Sigma_l (\Sigma_t S_{ljt}) P(l|a)$$

which can be interpreted as an average length-specific selectivity with weights $P(l|a)$, $l = 30, \ldots, 56$. It is clearly the wrong parameter for an age-specific model. The relationship, if any, with S_{aj} is not defined since length-specific selectivities are not defined for this model. We next give an artificial, simple example to illustrate how far off the mark the expected values can be.

EXAMPLE OF EXPECTED VALUES

The age-length key, the selectivity coefficients, and the age distribution are given below.

Table of $P(l|a) = K_{al}$

		age	
		1	2
length	1	0.6	0.3
	2	0.4	0.7
P(a) :		0.8	0.2
S_a :		1	5

Only a single area and time period are assumed. For this case, the expected values of the selectivities become

$$E(\hat{S}_a | \{N_a\}) = \Sigma_l \frac{(\Sigma_i S_i P(i) K_{il}) K_{al}}{\Sigma_i K_{il} P(i)} \tag{10}$$

Substituting, we obtain

$$E(\hat{S}_1 | \{N_a\}) : E(\hat{S}_2 | \{N_a\}) = 1:1.13$$

while $S_1 : S_2 = 1:5$. The considerable distortion is not due to any special choice of numbers but is due, as stated above, to the averaging which takes place in the formula.

ALTERNATIVE ESTIMATE OF THE SELECTIVITY FUNCTION

In this section an alternative estimate of the selectivities is given which is unbiased provided a polynomial or other linear parametric representation of the selectivity function S_{aj}, $a = 4, \ldots, 40$, is acceptable. With no additional assumptions, linear equations for the S_{aj}'s can be obtained, one set for each year and area. However, for each area, j, there are 37 selectivities, S_{aj}, $a = 4, \ldots, 40$, so that at least 37 years of data are required to estimate them and this is not available in the present case. By substituting a linear parametric function with fewer parameters than equations available to estimate them, it becomes possible to find unbiased estimates of the S_{aj}'s. There are other reasons for approximating the S_{aj}'s.The selectivities, as BC state, do depend on length. Therefore, no increase in reality results by estimating precisely imprecise numbers. Moreover, it seems reasonable to assume that the selectivities vary smoothly with age. For these reasons, and lacking compelling reasons for any other choice, the class of polynomial functions seems a good choice to provide a sufficient degree of reality. Accordingly, the following assumption is made.

Assumption: The points S_{aj}, $a = 4, \ldots, 40$, lie on a polynomial of degree $r \leqslant 26$, for each j, namely,

$$S_{aj} = q_j(a) = q_{0j} + q_{1j}a + \ldots + q_{rj}a^r, 4 \leqslant a \leqslant 40. \tag{11}$$

If the above assumption is accepted, then in (8) replace the proportionality constant, $E(CL_{jt})/\Sigma_i S_{ij} N_{it}$, by the constant K. Then, for fixed j and t, upon replacing $E(CL_{ljt} | \{N_{at}\})$ by its sample estimate, we obtain

$$K\,CL_{ljt} = \Sigma_a S_{aj} N_{at} K_{al}, \; l = 30, \ldots, 56.$$

Since the S_{aj}'s are relative numbers there is no loss of generality in making K = 1. Now substituting from (11), we obtain a system of linear equations in the coefficients $q_{0j}, \ldots, q_{rj}$:

$$CL_{ljt} = \Sigma_{i=0}^{r} X_{ilt} q_{ij}, \quad l = 30, \ldots, 56, \tag{12}$$

where

$$X_{ilt} = \Sigma_{a=4}^{40} N_{at} K_{al} a^i$$

The least-squares solution to these equations has the form

$$Q = (X'X)^{-1} X'Y_{jt} \tag{13}$$

where

$$Q = \begin{bmatrix} q_{0j} \\ \vdots \\ q_{rj} \end{bmatrix} X = \begin{bmatrix} X_{1,30,t} & \ldots & X_{r,30,t} \\ & \ldots & \\ X_{1,56,t} & \ldots & X_{r,56,t} \end{bmatrix} Y_{jt} = \begin{bmatrix} CL_{30,j,t} \\ \vdots \\ CL_{56,j,t} \end{bmatrix}$$

There is a separate solution to these equations for each j and t. Substituting in (11) gives the solution for S_{aj}, $a = 4, \ldots, 40$. Following BC these are averaged with respect to t over all years for which data are available, in the present case from 1946 to 1977. If there is a suspicion that the selectivities are changing with time, then the solutions can be averaged over fewer years, e.g. the most recent 10. Bearing in mind the comment above about averaging relative numbers, the vectors $(S_{4j}, \ldots, S_{40,j})$, $j = 1, 2, \ldots$, are first standardized to have length 1 each.

Almost all the computation effort is in setting up the matrix X. Some saving results because it does not depend on j. Some care must be exercised in inverting (X′X) as the range of entries in X is large. Use of a standard method of 'well-conditioning' this matrix may be helpful. Some computing time can be saved by initially assuming r is small, say 4 or 5, and then increasing r at a later stage.

A well-known property of linear least-squares estimates of the parameters of a linear submodel such as the one used here is that the estimates are unbiased. Since the S_{aj}'s in (11) are then linear combinations of unbiased estimates, they are also unbiased.

It is possible to impose certain a priori restrictions on the polynomial $q_j(a)$. Doi (1979) assumes that his availability function, analogous to the polynomial $q_j(a)$, is 0 for all sufficiently small a. The same effect can be achieved by having the polynomial become 0 at some point below age 4, say 3.5, for example. Then we obtain

$$q_{0j} + 3.5q_{1j} + \ldots + 3.5^r q_{rj} = 0,$$

which is added to the system of equations (12).

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REFERENCES

Beddington, J. R. and Cooke, J. G. 1980. Development of an assessment technique for male sperm whales based on the use of length data from the catches, with special reference to the north-west Pacific stock. *Rep. int. Whal. Commn* 31: 747–60.

Doi, T. 1979. Theoretical aspects analyzed by introducing age-specific maturity and age-specific availability into population analysis of Minke Whales in the Antarctic. *Rep. int. Whal. Commn* 29: 439–46.

Ohsumi, S. 1977. Age-length key of the male sperm whale in the North Pacific and comparison of growth curves. *Rep. int. Whal. Commn* 26: 295–300.

SC/33/Sp3

Further Development of an Assessment Technique for Male Sperm Whales Based on Length Data from the Catches

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ABSTRACT

Some weaknesses in the statistical properties and the application of the age- and length-specific assessment technique developed by Beddington and Cooke (1981) for male sperm whales stocks are highlighted, and a new technique is derived to overcome these problems. This is achieved only at the price of far more stringent requirements on the completeness of the data base.

1. INTRODUCTION

In a previous paper (Beddington and Cooke, 1981) we outlined a procedure for obtaining stock size estimates for male sperm whales using length data from the catches without any external index of abundance such as Catch Per Unit Effort (CPUE). The main reason why the development of this technique was considered necessary was due to the lack of success encountered in the estimation of sperm whale populations from CPUE data. For example, in its last major review of the Southern Hemisphere sperm whale stocks, the Scientific Committee of the International Whaling Commission (IWC) attempted assessments from 87 different CPUE series, of which only 16 produced an estimate at all (IWC, 1980). In the case of the North Pacific, the rising CPUE trend in the coastal operations coupled with the declining CPUE trend in the pelagic operations has similarly led to doubts on the validity of the use of CPUE as an index of abundance, and at its last review of North Pacific sperm whales the Scientific Committee was unable to carry out an assessment using the CPUE data (IWC, 1981a).

As there has been little experience with length-distribution-based stock assessments for whales, a fuller analysis of the behaviour and reliability of such estimates is needed. This we attempt in this paper.

2. WEAKNESSES IN THE PREVIOUS ANALYSIS

At the 1980 meeting of the Scientific Committee, stock estimates were obtained for sperm whales in the North-West Pacific and the Southern Hemisphere Divisions 3, 5 and 9, using the age-length technique described by Beddington and Cooke (1981), which used both age-specific and length-specific relative catchability functions (called selectivity functions in Beddington and Cooke, 1981).

Some serious statistical problems associated with the technique have been identified, some associated with the method itself and some related to the particular data sets it was applied to.

The main difficulties arose from the fact that it was applied to incomplete data sets where the catch at length was only available for a few years: this meant that in the population simulations the observed catches at length could not be incorporated directly, and expected catches at age and length had to be incorporated based on the selectivity functions which were estimated in an ad hoc way from the data. Thus although the technique provided a way of fitting series of catch and length data to a model in order to estimate population size, it could not guarantee to provide the best fit to the data. A quick check on the North Pacific assessment showed that a substantially better fit to the length data could be obtained by calculating the selectivity (relative catchability) functions in a different way.

The need was clearly revealed for an objective criterion for finding the best possible fit to the data.

3. AN IMPROVED TECHNIQUE

The major improvement in the technique is to use the observed catches at length in the stock simulations. To do this, complete or nearly complete length data are needed for the whole catch for all years. For most sperm whale stocks, except the North Atlantic and the South-East Pacific, virtually complete length data exist for nearly all twentieth century (or at least post-war) catches, though much has not yet been compiled into a usable form. Especially for the North Pacific reference to original sources is still necessary to compile a complete set.

As a complete series of catches at age is of course not available for any stock we do not attempt to pursue the age-specific techniques (IWC, 1981b) developed in Beddington and Cooke (1981), but only the length-specific technique. The growth model and the methods of generating populations by length in the simulations are the same as those in Beddington and Cooke (1981) although the methods of computation have been made more efficient. A full description of the modelling of the growth process and suggestions for modifications will be presented in a subsequent paper. As before, only males are considered as the variations in length of the females are too small to provide much information on the changes in population size.

The aim of the exercise is to estimate from the catch-by-length-by-year matrix a small vector of parameters x which are applied to a population model and a growth function to generate a unique series of populations by length by year from the catches. The components of x are typically the initial population size and parameters of the growth curve.

The central assumption of the technique is that for a given whaling operation in a given place, the catch rate of whales from each length class is proportional to the abundance of that length class in the total population weighted by a relative catchability function (length-specific) which reflects both operational characteristics (e.g. size limits, preferences for larger animals) and natural characteristics (e.g. geographical distribution of the different size classes, seasonal factors, relative ability of whales of different sizes at avoiding capture, etc.) In symbols:

$$CR_{jt} \propto N_{jt}q_j \tag{1}$$

where CR_{jt} is the catch rate from length class j at time t, N_{jt} is the number of whales of length j in the population at time t, and q_j is the relative catchability of length class j. q_j is assumed not to vary with time, though as will be explained later in certain applications of the technique q_j can be allowed to vary with time to a limited extent.

The constant of proportionality in (1) will depend on the overall level of catching, and thus will vary with time: let us denote it F_t. Thus we have:

$$CR_{jt} = N_{jt}q_jF_t \tag{2}$$

If N_{jt} is the population at the beginning of the year t, then the expected total catch in the year from length class j, EC_{jt}, is given by:

$$EC_{jt} = N_{jt}(1 - e^{-F_tq_j}) \tag{3}$$

if we suppose for simplicity that natural mortality is not occurring during the whaling season. Provided that N_{jt} does not change substantially during the course of a single season or time period, (3) can be simplified to:

$$EC_{jt} = N_{jt}F_tq_j \tag{4}$$

where the values of F_t and q_j are adjusted accordingly. This approximation does not affect the validity of the arguments that follow (as the time periods could be taken arbitrarily small) but makes the algebra substantially easier to read.

According to an idealised model of catching individuals, one would expect the actual catches by length by year—which we shall denote C_{jt}—to follow a Poisson distribution, that is, each individual being caught randomly independent of the others. Examination of the actual catches in real cases shows that the variability of the catches by length is probably more than one would expect from such an idealised model, that is there is a degree of non-independence or clumping, in that following the catch of a whale of a certain length, the next whale caught is more likely to be of a similar length to the previous one.

Kirkwood (1981) reported a similar problem of over-dispersion in his analysis of catch-effort data, in that the variance of catches for known effort appeared to be substantially larger than the mean. It is probable that in this case most of the overdispersion is due to the fact that CPUE is not a perfect index of abundance or availability, though there may well remain some intrinsic over-dispersion. In his treatment of the CPUE case, Kirkwood supposes that the variance of the catches is proportional to their means, i.e.:

$$EC_t = qN_tE_t;\ \mathrm{var}(C_t) = qN_tE_t\sigma^2 \tag{5}$$

where q is the overall absolute catchability, N_t is the abundance in year t, and E_t is the measured effort in year t. σ^2 is unknown and assumed to be constant. He then carries out a square-root transformation yielding the asymptotic result:

$$E(C_t^{1/2}) = (qN_tE_t)^{1/2};\ \mathrm{var}(C_t^{1/2}) = \sigma^2/4 \tag{6}$$

yielding approximately homoscedastic residuals enabling an efficient estimation, though the distribution of the residuals will be only approximately normal. This asymptotic result is valid provided the individual catches are more than about 10 or 20 times σ^2. It is therefore not useable in our case, as although a typical assessment (such as the North Pacific sperm whale stock) will have several thousand year-length-division cells, the individual catches by length in each operation are mainly rather small in each year, and the equations (6) will not hold even approximately. We therefore use the untransformed catches: the lack of statistical efficiency is not serious considering the large quantity of data. The main thing is that the expected catch equation (4) holds exactly and that we use an estimation statistic that is consistent not only in the usual sense as each sample size increases but also as the number of different samples increases, and this condition is satisfied by the simple least squares statistic defined as follows:

Provided we have the complete series of catch at length data, C_{jt}, then the population by length and year, N_{jt}, is a function only of the original vector of parameters we want to estimate, *x*, and the observed catches, C_{jt}. We can obtain ordinary least squares estimates of *x*, q_j, and F_t by minimising the residual function:

$$S = \sum_t\sum_j(C_{jt} - N_{jt}q_jF_t)^2 \tag{7}$$

over *x*, *q*, and *F*.

In practical applications, we usually have further to divide up the data into separate whaling operations and/or geographical areas, as the relative catchabilities of each length class often depend on these factors. The statistic to minimise then becomes:

$$S = \sum_i\sum_t\sum_j(C_{ijt} - N_{jt}q_{ij}F_{it})^2 \tag{8}$$

over *x*, *q*, and F where the subscript i denotes the data divisions. Even if the only *x* parameter we wish to estimate is the initial population size, we still have a large number of non-linear regression parameters to estimate: if there are 30 years of data and 30 length classes and 10 data divisions, then we have 600 F and q parameters to estimate. Fortunately, provided the entire series of catch by length is available, the parameters q and F feature only in the evaluation of S and not in the population simulation generating the values of the N_{jt}, and they can therefore be found analytically. It is even not necessary to calculate the q and F parameters explicitly, but only to find for each value of *x* the value of S at the minimum over the other parameters.

Given a certain *x* value, and hence a series of N_{jt} values, we find the minimum value of S by differentiation: setting

$$\left.\begin{aligned}\delta S/\delta F_{it} &= 0 \text{ for each i and t}\\ \delta S/\delta q_{ij} &= 0 \text{ for each i and j}\end{aligned}\right. \tag{9}$$

yields the equations:

$$\text{and:}\quad \left.\begin{aligned}\sum_t EC_{ijt}^2 &= \sum_t C_{ijt}EC_{ijt} \text{ for each i and j}\\ \sum_j EC_{ijt}^2 &= \sum_j C_{ijt}EC_{ijt} \text{ for each i and t}\end{aligned}\right. \tag{10}$$

where EC denotes the expected catches defined by:

$$EC_{ijt} = N_{jt}q_{ij}F_{it} \tag{11}$$

These equations are solved computationally very quickly by the following algorithm:

(1) Set each EC_{ijt} initially equal to N_{jt}

(2) multiply each EC_{ijt} by the factor

$$f_{ij} = \sum_t C_{ijt}EC_{ijt}/\sum_t EC_{ijt}^2$$

(3) multiply each EC_{ijt} by the factor

$$g_{it} = \sum_j C_{ijt} EC_{ijt} / \sum_j EC_{ijt}^2$$

(4) if equations (10) are still not satisfied to the required degree of accuracy, return to (2).

When these equations have been solved in this way, S can be evaluated directly from formula (8). The minimisation over the x parameters has to be done numerically, but as this would rarely involve more than 3 different parameters, the computation is relatively tractable.

A computer programme in standard FORTRAN language to carry out an assessment of a sperm whale population using the techniques outlined in this paper is available from the authors or the International Whaling Commission on request. In a subsequent paper, the authors plan to present the results of a full Monte Carlo simulation study of the technique to assess the behaviour and reliability of the estimates so obtained.

REFERENCES

Beddington, J. R. and Cooke, J. G. 1981. Development of an assessment technique for male sperm whales based on length data in the catches, with special reference to the North-West Pacific Stock. *Rep. int. Whal. Commn* 31: 747–60.

International Whaling Commission. 1980. Report of the sub-committee on Sperm Whales. *Rep. int. Whal. Commn* 30: 79–96.

International Whaling Commission. 1981a. Report of the sub-committee on Sperm Whales. *Rep. int. Whal. Commn* 31: 78–102.

International Whaling Commission. 1981b. Report of the Sperm Whale Workshop. *Rep. int. Whal. Commn* 31: 687–705.

Kirkwood, G. P. 1981. Estimating Population Sizes from Relative Abundance Data: a simulation study. *Rep. int. Whal. Commn* 31: 729–35.

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Reconstruction of the Beddington and Cooke Age-specific Model and Some Comments on Their Models for Sperm Whales

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INTRODUCTION

Two interesting models for the stock assessment of sperm whales have been proposed by Beddington and Cooke (1981) (hereafter referred to as BC). One is the age-specific model and the other is the length-specific model. We obtained the computer program and input data of the former model and examined it in detail. It was found that the BC age-specific model did not hold the age-specific assumption.

In the present paper, we try to reconstruct the age-specific model, and propose some corrections to the BC models and outline some remaining problems.

NOTATION

The notation follows BC in principle, but several terms are modified for clarification.

a: age
f_{jt}: rate of exploitation for males in area j, year t
j: area
l: length
t: year
A: number of age classes of males
C: catch of males. For example, C_{aljt} means the catch of age a and length l in area j, year t
CF_t: catch of females in year t
J: number of areas
K_{al}: component at a-th column and l-th row in the age-length key matrix
M_f: instantaneous natural mortality coefficient of females equal to or older than 1 year old
M_j: instantaneous natural mortality coefficient of juveniles younger than 1 year old
M_m: instantaneous natural mortality coefficient of males equal to or older than 1 year old
N: number of males
NA: number of males available for capture
P: initial pregnancy rate
S_{ajt}: age-specific selectivity of males of age a in area j, year t
S_{ajt}': alternative age-specific selectivity expressed as $f_{jt}S_{ajt}$
S_{aj}, S_{aj}': age-specific selectivity of males of age a in area j. Equivalent to S_{ajt} and S_{ajt}' respectively, under the assumption that the age-specific selectivity is invariant with respect to year t
S_{ij}: length-specific selectivity of males of length l in area j
SS: coefficient of goodness of fit
T_f: mature age of females

1. RECONSTRUCTION OF THE AGE-SPECIFIC MODEL

According to BC, the fundamental assumption of the age-specific model is that the geographical distribution of whales and the probability of capture in any given year is a function of their age and not of their length. The assumption can be reinterpreted as follows.

(i) Availability for capture, or selectivity, is dependent on age groups but is not dependent on length classes within an age group. The age-specific availability (Doi, 1979) or, in our definition, the age-specific selectivity, is expressed as:

$$S_{ajt} = NA_{ajt}/N_{at} \tag{1}$$

Moreover, the age-specific selectivity is a function of age a.

$$S_{ajt} = g_{jt}(a) \tag{2}$$

where, g_{jt} is some function specified by area j and year t. Under the additional assumption that the age-specific selectivity is invariant with respect to year t, which is the essential assumption in the BC model, equations (1) and (2) are replaced by the following equations:

$$S_{aj} = NA_{ajt}/N_{at} \tag{1'}$$

$$S_{aj} = g_j(a) \tag{2'}$$

(ii) The likelihood of capture of the available whales is independent of their age and length.
By definition,

$$f_{jt} = C_{jt}/NA_{jt} \tag{3}$$

Under the assumption (ii), the following expressions hold good.

$$f_{jt} = C_{ajt}/NA_{ajt} = C_{ljt}/NA_{ljt} = C_{aljt}/NA_{aljt} \tag{4}$$

1.1 Estimation of the age-specific selectivity

We follow the BC estimation method of S_{aj}. From equations (1′), (3) and (4),

(3) and (4),

$$C_{ajt} = f_{jt}NA_{ajt} = \frac{C_{jt}}{NA_{jt}} S_{aj}N_{at} = C_{jt}\frac{S_{aj}N_{at}}{\sum_{a=1}^{A} NA_{ajt}}$$

$$= C_{jt}\frac{S_{aj}N_{at}}{\sum_{a=1}^{A} S_{aj}N_{at}} \quad \text{(equation (9) in BC)} \tag{5}$$

---

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The catch C_{ajt} is also estimated from the recorded data C_{ljt} and K_{al}, where K_{al} is expressed as follows under the age-specific assumption.

$$(6)\quad K_{al} = C_{aljt}/C_{ajt} = NA_{aljt}/NA_{ajt} = N_{aljt}/N_{ajt} = N_{alt}/N_{at}$$

Note $\sum_{l=1}^{L} K_{al} = 1.0$. And from equations (1′), (4) and (6),

$$\begin{aligned} C_{ajt} &= \sum_{l=1}^{L} C_{aljt} = \sum_{l=1}^{L} f_{jt}NA_{aljt} \\ &= \sum_{l=1}^{L} \frac{C_{ljt}}{NA_{ljt}} NA_{aljt} = \sum_{l=1}^{L} \frac{C_{ljt}}{\sum_{a=1}^{A} K_{al}NA_{ajt}} K_{al}NA_{ajt} \\ &= \sum_{l=1}^{L} C_{ljt} \frac{K_{al}S_{aj}N_{at}}{\sum_{a=1}^{A} K_{al}S_{aj}N_{at}} \end{aligned}$$

(corresponding to equation (16) in BC)

Equation (7) is not equivalent to equation (15) in BC. This will be discussed later in the section 2.1.

Then the following estimation equation for S_{aj} is obtained by combining equations (5) and (7):

$$(8)\qquad S_{aj} = \frac{\sum_{a=1}^{A} S_{aj}N_{at}}{C_{jt}} \sum_{l=1}^{L} C_{ljt} \frac{K_{al}S_{aj}}{\sum_{a=1}^{A} K_{al}S_{aj}N_{at}}$$

(corresponding to equation (15) in BC)

This equation should hold for any year for which catch at length data are available. Therefore the age-specific selectivity in equation (8) can be expressed as $S_{aj(t)}$ instead of S_{aj}, as shown in the following equation.

$$(8')\qquad S_{aj(t)} = \frac{\sum_{a=1}^{A} S_{aj(t)}N_{at}}{C_{jt}} \sum_{l=1}^{L} C_{ljt} \frac{K_{al}S_{aj(t)}}{\sum_{a=1}^{A} K_{al}S_{aj(t)}N_{at}}$$

(corresponding to equation (16) in BC)

As the unknown value of $S_{aj(t)}$ is included in both sides in equation (8′), $S_{aj(t)}$ must be estimated by successive approximation, according to BC.

We will now examine whether the successive approximation technique is valid or not. Denote the k-th estimate as $S_{aj(t)}$ (k), and

$$(9)\qquad \frac{S_{aj(t)}(k)}{S_{aj(t)}(k-1)} = \frac{\sum_{a=1}^{A} S_{aj(t)}(k-1)N_{at}}{C_{jt}} \sum_{l=1}^{L} \frac{C_{ljt}K_{al}}{\sum_{a=1}^{A} K_{al}S_{aj(t)}(k-1)N_{at}}$$

Under the age-specific assumption, if the catch at length includes several age classes,

$$C_{jt}/\sum_{a=1}^{A} S_{aj(t)}\,(k-1)N_{at}$$

may not be much different from

$$C_{ljt}/\sum_{a=1}^{A} K_{al}S_{aj(t)}\,(k-1)N_{at}.$$

Hence, $S_{aj(t)}(k)/S_{aj(t)}(k-1)$ may be close to unity. In other words, the difference between $S_{aj(t)}$ (k) and $S_{aj(t)}$ (k) − 1) is small. The convergence of $S_{aj(t)}$ to the solution is considered to be very slow, even if estimation is possible by this method. A test executed by an artificial simple example supports this. In conclusion, the estimation of $S_{aj(t)}$ by successive approximation is not pragmatic.

The inappropriateness of this method can also be seen from a purely mathematical point of view. In the case of the Northwest Pacific sperm whales, A is less than L (A = 37 and L = 22 in BC). In equation (8′), the terms

$$\sum_{a=2}^{A} S_{aj(t)}N_{at}$$

and

$$\sum_{a=2}^{A} K_{al}S_{aj(t)}N_{at}$$

are common to all $S_{aj(t)}$ in a group of j, and are considered to be constants specific to j and t. If j and t are fixed, the number of unknown values on the right is 22, whereas, the total number of unknown values is 37. Thus the solution cannot be obtained.

We estimate the age-specific selectivity by an alternative method which is based on the idea proposed by Zahl (1982). The estimate of the recorded catch C_{ljt} is obtained as:

$$\begin{aligned} C_{ljt}(\text{estimated}) &= \sum_{a=1}^{A} C_{aljt}\,(\text{estimated}) = \sum_{a=1}^{A} f_{jt}NA_{aljt} \\ &= \sum_{a=1}^{A} f_{jt}K_{al}NA_{ajt} \\ &= \sum_{a=1}^{A} (f_{jt}S_{ajt})\,K_{al}N_{at} \\ (10)\qquad &= \sum_{a=1}^{A} S_{ajt}{}'K_{al}N_{at} \end{aligned}$$

where,

$$(11)\qquad S_{ajt}{}' = f_{jt}S_{ajt}$$

Moreover,

$$\begin{aligned} S_{ajt}{}' &= f_{jt}S_{ajt} = f_{jt}g_{jt}(a) \\ (12)\qquad &= q_{jt}(a) \end{aligned}$$

where, q_{jt} is some function specified by j and t.
From equation (11) and (12), $S_{ajt}{}'$ can be considered to be also a kind of the age-specific selectivity. But the selectivity $S_{ajt}{}'$ is not the age-specific availability in our original definition, but the age-specific selectivity defined as the following equation (13).

$$\begin{aligned} S_{ajt}{}' &= f_{jt}S_{ajt} \\ &= \frac{C_{ajt}}{NA_{ajt}}\,\frac{NA_{ajt}}{N_{at}} \\ (13)\qquad &= \frac{C_{ajt}}{N_{at}} \end{aligned}$$

Furthermore, if the age-specific selectivity $S_{ajt}{}'$ is assumed to be invariant with respect to year t,

$$\begin{aligned} (13')\qquad S_{aj}{}' &= \frac{C_{ajt}}{N_{at}} \\ &= q_j(a) \end{aligned}$$

Here the selectivity $S_{aj}{}'$ can be approximated by the following polynomial function of age a with (R − 1)th order:

$$(14)\qquad S_{aj(t)}{}' = q_{1jt}a^0 + q_{2jt}a^1 + \ldots + q_{Rjt}a^{R-1}$$

where, q_{rjt} (r = 1, 2, . . . , R) is a constant specific to j and t. In the above equation, $S_{aj}{}'$ is replaced by $S_{aj(t)}{}'$, because

S_{aj}' can be estimated by the following least-squares method in any year for which catch at length data are available. Then let us denote I_{jt} as:

$$
\begin{aligned}
I_{jt} &= \sum_{l=1}^{L} (C_{ljt} - C_{ljt}(\text{estimated}))^2 \\
&= \sum_{l=1}^{L} (C_{ljt} - \sum_{a=1}^{A} K_{al} S_{aj(t)}' N_{at})^2 \\
&= \sum_{l=1}^{L} (C_{ljt} - \sum_{a=1}^{A} K_{al} (\sum_{r=1}^{R} q_{rjt} a^{r-1}) N_{at})^2 \\
(15) \qquad &= \sum_{l=1}^{L} (C_{ljt} - \sum_{r=1}^{R} X_{lrt} q_{rjt})^2
\end{aligned}
$$

where,

$$(16) \qquad X_{lrt} = \sum_{a=1}^{A} a^{r-1} K_{al} N_{at}$$

Let $\partial I_{jt}/\partial q_{rjt}$ be equal to zero and the following equation is obtained.

$$(17) \qquad \sum_{l=1}^{L} (X_{lrt} C_{ljt}) = \sum_{l=1}^{L} (X_{lrt} (\sum_{r=1}^{R} X_{lrt} q_{rjt}))$$

Equation (17) is rewritten in the following matrix form.

$$(18) \quad \begin{bmatrix} X_{11t} & \dots & X_{L1t} \\ \multicolumn{3}{c}{\dots\dots\dots\dots} \\ X_{1Rt} & \dots & X_{LRt} \end{bmatrix} \cdot \begin{bmatrix} C_{ljt} \\ \vdots \\ C_{Ljt} \end{bmatrix} = $$

$$\begin{bmatrix} X_{11t} & \dots & X_{L1t} \\ \multicolumn{3}{c}{\dots\dots\dots\dots} \\ X_{1Rt} & \dots & X_{LRt} \end{bmatrix} \cdot \begin{bmatrix} X_{11t} & \dots & X_{1Rt} \\ \multicolumn{3}{c}{\dots\dots\dots\dots} \\ X_{L1t} & \dots & X_{LRt} \end{bmatrix} \cdot \begin{bmatrix} q_{ljt} \\ \vdots \\ q_{Rjt} \end{bmatrix}$$

The above equation is rearranged as:

$$(19) \qquad {}^tX \cdot Y = {}^tX \cdot X \cdot QQ$$

Where,

$$X = \begin{bmatrix} X_{11t} & \dots & X_{1Rt} \\ \multicolumn{3}{c}{\dots\dots\dots\dots} \\ X_{L1t} & \dots & X_{LRt} \end{bmatrix}, Y = \begin{bmatrix} C_{1jt} \\ \vdots \\ C_{Ljt} \end{bmatrix}, QQ = \begin{bmatrix} q_{ljt} \\ \vdots \\ q_{Rjt} \end{bmatrix}$$

Therefore the least-squares solution matrix QQ is expressed in the following form:

$$(20) \qquad QQ = ({}^tXX)^{-1} \cdot {}^tX \cdot Y$$

Then the estimate of $S_{aj(t)}'$ is obtained by substituting the value of q_{rjt} ($r = 1, 2, \dots, R$) into equation (14). Next, the estimate of S_{aj}' is calculated by the following weighted average of $S_{aj(t)}$:

$$(21) \qquad S_{aj}' = \frac{\sum_t S_{aj(t)}'/C_{jt}}{\sum_t 1/C_{jt}}$$

such that the average with the weight of the recorded catch C_{jt} is executed in order to eliminate the sampling variability of the catch.

1.2 Population assessment method based on the reconstructed age-specific model for the Northwest Pacific sperm whales

The assessment method in the reconstructed age-specific model follows the BC age-specific model in principle except for the estimation method of S_{aj}'. We briefly explain our method below, using the flowchart in Fig. 1.

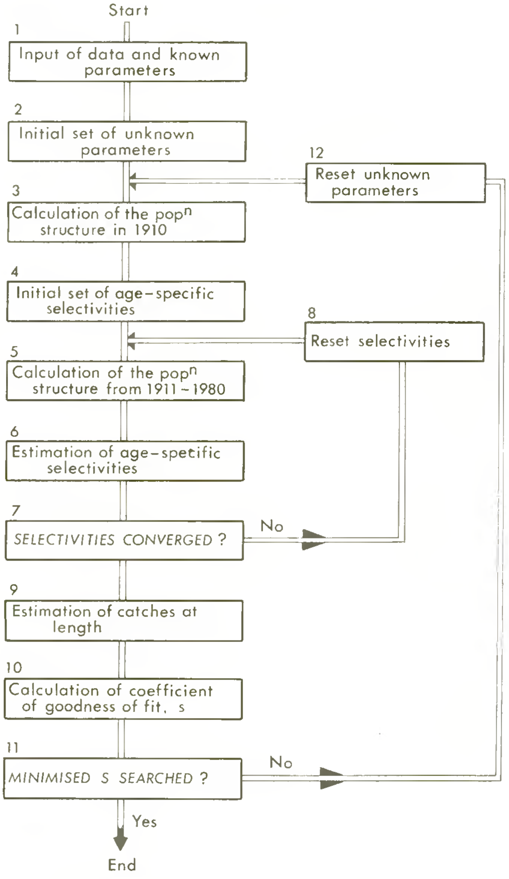

Fig. 1. Flowchart of the reconstructed age-specific model.

Procedure 1: The input data necessary for the assessment are catches by sex by area by year from 1910 to the present, catches of males by length by area by year from 1946 to the present and the age-length key presented by Ohsumi (1977). Of the above input data, K_{al} and C_{ljt} are modified whenever the minimum size limit of the catch was changed in the past, as explained later in section 1.2.1.

Procedure 2: In the case of one-dimensional search, the number NA_{1910} is selected as the unknown parameter.

Procedure 3: In the flowchart, the term of the population structure in year t means both the age distribution of males ($N_{1t}, N_{2t}, \dots, N_{At}$) and total number of mature females in year t.

Procedure 4: The initial value of S_{aj}' is set to be non-negative and equal to or less than 1.0.

Procedure 5: The estimate of C_{at} is necessary to calculate the population structure in year (t + 1) from that in year t.

The estimation equation for C_{at} is obtained by the following formula:

$$C_{at} = \sum_{j=1}^{J} C_{ajt} = \sum_{j=1}^{J} C_{jt} \frac{S_{aj}N_{at}}{\sum_{a=1}^{A} S_{aj}N_{at}}$$

$$(22) \qquad = \sum_{j=1}^{J} C_{jt} \frac{S_{aj}'N_{at}}{\sum_{a=1}^{A} S_{aj}'N_{at}}$$

Procedure 6: When age-specific selectivities are estimated by the polynomial approximation of age, it is an important problem to decide the order of the polynomial equation, $R - 1$. If R is set to be a small number, for example $R = 3$, it seems inappropriate to approximate the complicated age-specific selectivity function by the second order equation. On the other hand, if R is set to be a large number, the error in the numerical calculation will come to be a serious problem. In the case of north-west Pacific sperm whales, R was set at 5 after several trials.

Procedure 7 and 8: The convergence of selectivities is judged by the following method. Let us denote K as:

$$(23) \qquad K = \sum_{j=1}^{J} \sum_{a=1}^{A} (S_{aj}'(k) - S_{aj}'(k-1))^2$$

where, $S_{aj}'(k)$ is the estimate of S_{aj}' in the k-th iteration. If the value of K becomes lower than a limiting value after several iterations, then convergence is judged to have been obtained. If the convergence of selectivities is not obtained, selectivities are reset to be the estimates obtained in Procedure 6 and the calculation is started again from Procedure 5.

Procedure 9: The estimation equation for C_{ljt} is as follows:

$$(24) \qquad C_{ljt}(\text{estimated}) = \sum_{a=1}^{A} K_{al}S_{aj}'N_{at} \frac{\sum_{l=1}^{L} C_{ljt}(\text{observed})}{\sum_{l=1}^{L} \sum_{a=1}^{A} K_{al}S_{aj}'N_{at}}$$

Procedure 10: The following expressions for SS are presented by BC, and Cooke and Beddington (1982), respectively:

$$(25) \qquad SS(1) = \sum_{t} \sum_{j} \sum_{l} (C_{ljt}(\text{observed}) - C_{ljt}(\text{estimated}))^2$$

(equation (20) in BC)

$$(26) \qquad SS(2) = \sum_{t} \sum_{j} \sum_{l} (C_{ljt}(\text{observed})^{1/2} - C_{ljt}(\text{estimated})^{1/22}$$

Procedure 11 and 12: The values of unknown parameters in Procedure 2 are changed step by step or automatically by the optimization method. And the coefficient SS is calculated at each reset of unknown parameters. Their estimated values are judged to have been obtained when the search for the minimized value of SS has been completed.

1.2.1 Treatment of the size limit in the reconstructed age-specific model

The legal minimum size limit for the North Pacific sperm whales has been frequently changed since 1937 (Ohsumi, 1980). If the harvest of the whales has been obedient to the size (length) limit, the available whales may have the capture probability dependent on their length. This is contrary to the age-specific assumption (ii) that the likelihood of capture of the available whales is independent of their age and length. But we find our way out of the present difficulty by adding the assumption that the whales with the length less than the minimum size limit are not available for capture. Under this assumption, the recorded data K_{al} and C_{ljt} are modified as follows:

$$(2bA) \qquad \left.\begin{array}{l} K_{al} \rightarrow 0 \\ C_{ljt} \rightarrow 0 \end{array}\right\} \text{if } l < ll_{jt}$$

where, ll_{jt} is the minimum size limit in area j, year t. It can be seen in the International Whaling Statistics and the NP forms that catches of whales below the minimum size limit were small. It can therefore be considered that the assumption above does not seriously bias the result of the population assessment.

2. COMMENTS ON THE BC MODELS

2.1 On the estimation of the age-specific selectivity

BC's estimate of the age-specific selectivity is not the age-specific selectivity in a true sense, but an average length-specific selectivity (Zahl, 1981). Moreover, it is noted that the formula for the estimation of selectivities in BC is modified in their computer program omitting some factor, otherwise they cannot obtain a solution.

We show below how to estimate S_{aj} in BC. First, BC derived two expressions for C_{ajt}. One is equation (5) (equation (9) in BC). The other is:

$$(27) \qquad C_{ajt} = \sum_{l=30}^{56} C_{ljt} \frac{K_{al}N_{at}}{\sum_{a=4}^{40} K_{al}N_{at}} \quad \text{(equation (15) in BC)}$$

Our equation (7), corresponding to above equation, is rearranged as follows:

$$(28) \qquad C_{ajt} = \sum_{l=30}^{56} C_{ljt} \frac{K_{al}S_{aj}N_{at}}{\sum_{a=4}^{40} K_{al}S_{aj}N_{at}}$$

It should be noticed that the term S_{aj} drops out in equation (27). Next, BC obtained the following equation by combining equations (5) and (27):

$$(29) \qquad S_{aj(t)} = \frac{\sum_{a=4}^{40} S_{aj(t)}N_{at}}{C_{jt}} \sum_{l=30}^{56} C_{ljt} \frac{K_{al}}{\sum_{a=4}^{40} K_{al}N_{at}}$$

(equation (16) in BC)

We will now consider what the selectivity $S_{aj(t)}$ in the above equation means. Equation (29) is rearranged as follows by the age-specific expression of equations (1′), (3), (4) and (6):

$$S_{aj(t)} = \frac{NA_{jt}}{C_{jt}} \sum_{l=30}^{56} C_{ljt} \frac{K_{al}}{N_{lt}} = \frac{NA_{jt}}{C_{jt}} \sum_{l=30}^{56} \frac{C_{ljt}}{NA_{ljt}} \frac{NA_{ljt}}{N_{lt}} K_{al}$$

Here, the length-specific selectivity is defined as:

$$(30) \qquad S_{lj} = NA_{ljt}/N_{lt}$$

Hence,

$$S_{aj(t)} = \frac{NA_{jt}}{C_{jt}} \sum_{l=30}^{56} \frac{C_{ljt}}{NA_{ljt}} S_{lj}K_{al} = \frac{1}{f_{jt}} \sum_{l=30}^{56} f_{jt}S_{lj}K_{al}$$

$$(31) \qquad = \sum_{l=30}^{56} S_{lj}K_{al}$$

Table 1

Check of the two requirements shown in equations (36) and (37). Symbols *, ** are put on the value of e^{-M_j} when the requirements (i), (ii) are not satisfied, respectively. Constant parameters T_f and P are set to 10, 0.2, respectively.

M_m	0.04	0.05	0.06	0.068	0.069	0.072	0.073
e^{-M_m}	0.9608	0.9512	0.9418	0.9343	0.9333	0.9305	0.9296
e^{-M_f}	0.9671	0.9591	0.9512	0.9449	0.9441	0.9418	0.9410
e^{-M_j}	0.4438	0.5949	0.7654	0.9172	0.9372**	0.9986**	1.0195*,**

Table 2

Comparison between the estimates of initial male population size obtained from the trials in Japan of the BC age-specific model and the corresponding estimate in Table 3 in BC. Used data of catches at length are pooled data 1962–1977 (Japan Coastal and Pelagic, Soviet Pelagic).

Q	M_m	Results from trials in Japan Males 13+	SS	Results from BC Males 13+	SS
0.05	0.066	179,922	2.272×10^6	108,794	2.009×10^6
0.05	0.060	184,766	2.346×10^6	—	—
0.06	0.066	181,016	2.271×10^6	—	—
0.05	0.075	—	—	113,403	1.903×10^6
0.025	0.066	—	—	109,390	2.017×10^6

It is clear from equation (31) that the selectivity $S_{aj(t)}$ is indeed an average length-specific selectivity with the weight K_{al}.

We now comment on the modification of the estimation method of the BC age-specific selectivity in the computer programming. The equation to estimate S_{aj} in the program is:

$$(32) \qquad S_{aj} = \sum_t ((\sum_{a=13}^{40} N_{at}) \sum_{l=30}^{56} \frac{C_{ljt}K_{al}}{\sum_{a=4}^{40} K_{al}N_{at}}$$

The corresponding equation in BC is:

$$(33) \qquad S_{aj} = \sum_t ((\sum_{a=4}^{40} S_{aj}N_{at}) \sum_{l=30}^{56} \frac{C_{ljt}K_{al}}{\sum_{a=4}^{40} K_{al}N_{at}}$$

(equation (17) in BC)

It is noticed that the term $\sum_{a=4}^{40} S_{aj}N_{at}$ was replaced by the term $\sum_{a=13}^{40} N_{at}$ in equation (32). The convergence of S_{aj} after only few iterations, as BC mentioned, is due to the modification of equation (33) into equation (32).

2.2 On the juvenile mortality

BC derived the following equations under the assumption that the stock remained in equilibrium in 1910:

$$(34) \qquad Pe^{-M_j} = 2((1 - e^{-M_f})e^{-(1-T_f)M_f}$$

(equation (5) in BC)

$$(35) \qquad e^{-M_f} = 0.1621 + 0.8379e^{-M_m}$$

These equations have the following two requirements, which BC did not take into account.

(i) Juvenile annual mortality rate, $1 - e^{-M_j}$, must be positive. Therefore

$$(36) \qquad e^{-M_j} < 1.0$$

(ii) On biological grounds, the mortality of juveniles younger than 1 year old, M_j, is likely to be higher than that of whales older than or equal to 1 year old, M_m and M_f. Therefore

$$(37) \qquad e^{-M_j} < e^{-M_m} \text{ and } e^{-M_j} < e^{-M_f}$$

Of the four parameters in equations (34) and (35), only M_m is independent. The values concerning the two requirements are calculated in the case of changing the value of M_m. The results shown in Table 1 indicates that M_m is likely to be equal to or less than 0.068 and that M_m must be equal to or less than 0.072. Whereas the BC estimate of M_m by 3-dimensional search in the length-specific model was 0.0748 (p. 758 in BC). This value does not meet both requirements.

2.3 On the BC estimate of the population size

We ran the digital computer, HITAC M-170 at Fuyo Data Processing and System Development, Ltd, Japan, using the computer program and input data of the BC age-specific model. The results of our trials are summarized in Table 2. The estimates of the initial male population size in Table 2 are quite different from those in Table 3 in BC. Regrettably, we have no information and materials to consider why such differences were caused. Furthermore, we note that males 13+ (equal to or older than 13 years old) and females, 10+, have begun to increase in numbers since 1972, 1978, respectively, in our trials.

REFERENCES

Beddington, J. R. and Cooke, J. G. 1981. Development of an assessment technique for male sperm whales based on the use of length data from catches, with special reference to the north-west Pacific stock. *Rep. int. Whal. Commn* 31: 747–60.

Cooke, J. G. and Beddington, J. R. 1982. Further development of an assessment technique for male sperm whales based on length data from the catches. Paper SC/33/Sp3 (published in this volume).

Doi, T. 1979. Theoretical aspects analyzed by introducing age-specific maturity and age-specific availability into population analysis of minke whales in the Antarctic. *Rep. int. Whal. Commn* 29: 439–45.

Ohsumi, S. 1977. Age-length key of the male sperm whale in the North Pacific and comparison of growth curves. *Rep. int. Whal. Commn* 26: 295–300.

Ohsumi, S. 1980. Catches of sperm whales by modern whaling in the North Pacific. *Rep. int. Whal. Commn* (special issue 2): 11–18.

Zahl, S. 1982. Comment on the Beddington and Cooke age-specific assessment model for the sperm whale population. Paper SC/33/Sp2 (published in this volume).

SC/33/Sp6

Population Estimation of the Northwest Pacific Stock of Sperm Whales

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Applying the reconstructed age-specific method (Shirakihara and Tanaka, 1981), the population size of the northwest Pacific stock of sperm whales is estimated. The data source for catches and length distributions, and the subdivision of the northwest Pacific follows Beddington and Cooke (1981). Parameters used in the model are:

M_f	(instanteous natural mortality coefficient of females)	0.055
M_m	(instanteous natural mortality coefficient of males)	0.066
P	(initial pregnancy rate)	0.2
Q	(range of the density-dependent exponent in the pregnancy rate model)	0.05
Z	(density-dependent exponent in the pregnancy rate model)	1.4
R	(number of terms in the polynomial equation of age-specific selectivity function)	5

The goodness of fit of estimated length distributions to observed ones is calculated assuming various values of the initial male population of 13 years old and older in 1910. The results are shown in Fig. 1. The goodness of fit is calculated by either of two formulae:

$$SS(1) = \sum_t \sum_j \sum_l (C_{ljt}\ (\text{observed}) - C_{ljt}\ (\text{estimated}))^2$$

$$SS(2) = \sum_t \sum_j \sum_l (C_{ljt}\ (\text{observed})^{1/2} - C_{ljt}\ (\text{estimated})^{1/2})^2$$

SS(1) gives a minimum value at an initial population of about 340,000 and SS(2), at about 380,000. It may be concluded that the best estimate is about 350,000.

As the degrees of freedom of the sum of squares is very large, the confidence region calculated theoretically by Bard's (1974) method is considerably narrow and the lower limit of the initial value is more than 300,000 for both SS(1) and SS(2). Fig. 1 indicates that when the initial value becomes smaller than 200,000, the goodness of fit drops sharply. Hence, the possibility that the initial male population of 13 years old and older is less than 200,000 can be neglected.

Changes of the male and female populations are illustrated in Fig. 2 for two different initial values of 350,000 and 200,000. The male population begins to increase in 1972 and the female population in 1978.

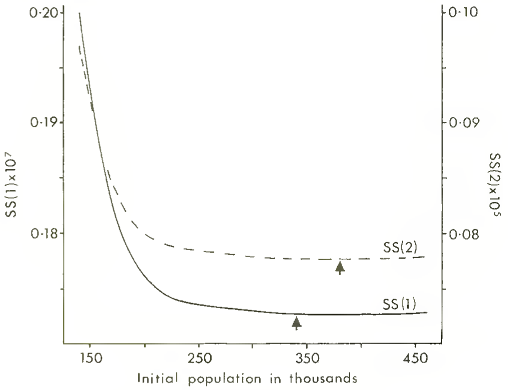

Fig. 1. Coefficient of goodness of fit against initial population level. Arrows indicate approximate minimum points.

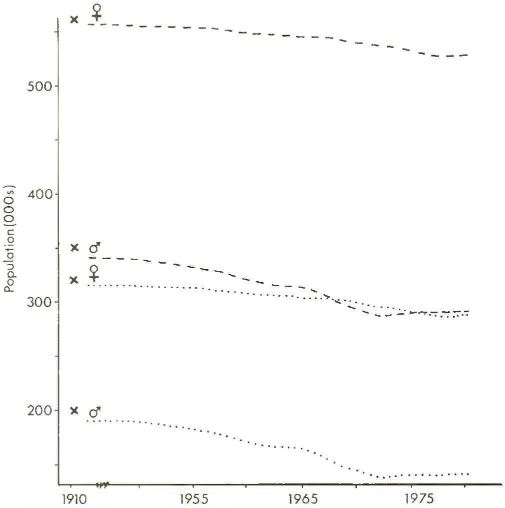

Fig. 2. Trajectory of populations starting from two initial population sizes of 13+ males: 200,000 and 350,000 (females, 10+).

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Table 1

Population estimates (in thousands) in 1980 and in the year of minimum population (1972 for male and 1978 for female), and their percentage to the initial value.

Male 13+			
1910	200.0	300.0	350.0
1972	138.3	237.8	287.7
%	69.2	79.3	82.2
1980	142.1	241.9	291.9
%	71.1	80.6	83.4
Female 10+			
1910	321.2	481.8	562.2
1978	286.8	447.6	527.9
%	89.3	92.9	93.9
1980	288.5	449.3	529.7
%	89.8	93.3	94.2

Table 2

Extrapolation of population changes (in thousand) for 5 years up to 1985 for three different catch levels. (1) no catch, (2) male catch 1,077, female catch 115, (3) male catch 2,154, female catch 230.

Initial popu-lation	Male 13+			Female 10+		
	(1)	(2)	(3)	(1)	(2)	(3)
350.0						
1980	291.9	291.9	291.9	529.7	529.7	529.7
1981	294.1	294.1	294.1	530.7	530.7	530.7
1982	296.9	296.1	295.2	531.8	531.7	531.6
1983	299.7	298.0	296.3	532.8	532.6	532.3
1984	302.4	299.8	297.2	533.7	533.3	533.0
1985	304.9	301.5	298.1	534.4	534.0	533.6
200.0						
1980	142.1	142.1	142.1	288.5	288.5	288.5
1981	144.1	144.1	144.1	289.5	289.5	289.5
1982	146.9	146.1	145.2	290.6	290.5	290.4
1983	149.7	147.9	146.2	291.5	291.3	291.1
1984	152.3	149.7	147.1	292.4	292.1	291.7
1985	154.7	151.3	147.9	293.1	292.7	292.3
150.0						
1980	92.7	92.7	92.7	208.0	208.0	208.0
1981	94.6	94.6	94.6	209.0	209.0	209.0
1982	97.2	96.4	95.5	210.0	209.9	209.8
1983	99.8	98.1	96.4	211.0	210.8	210.5
1984	102.3	99.7	97.1	211.8	211.5	211.2
1985	104.7	101.2	97.8	212.5	212.1	211.7

Population levels in 1910, 1980 and 1972 for males and 1978 for females are given in Table 1. The present population level relative to the initial value is 83% for males and 94% for females when the initial male population is 350,000.

The change in the ratio of the number of socially mature males (25+) to that of mature females (10+) is shown in Fig. 3. The ratio is kept higher than 13% throughout the period for initial values of 200,000 or larger. It drops below the 13% level for a short period only when the initial value is set at an extremely small value of 150,000.

Predicted future population trends on the basis of three different levels of catches are presented in Table 2. This table indicates that the possibility of population decrease can be neglected even if the male catch of 2,154 and female catch of 230 are continued hereafter.

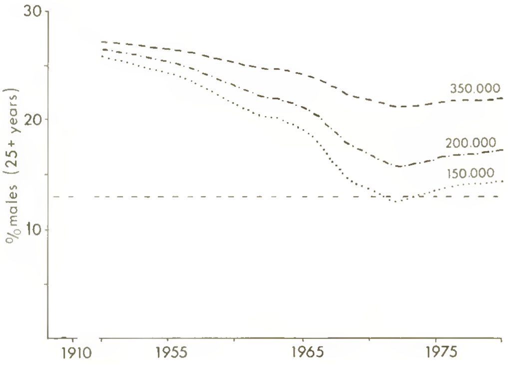

Fig. 3. Ratio of the number of socially mature males (25+) to mature females (10+). Initial number of 13+ males is shown on the figure.

REFERENCES

Beddington, J. R. and Cooke, J. G. 1981. Development of an assessment technique for male sperm whales based on the use of length data from the catches, with special reference to the northwest Pacific stock. *Rep. int. Whal. Commn* 31: 747–60.

Shirakihara, K. and Tanaka, S. 1981. Reconstruction of the Beddington and Cooke age-specific model and some comments on their models for sperm whales. Paper SC/33/Sp5 (published in this volume).

A Note on Comparative Readings of Sperm Whale Teeth

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INTRODUCTION

In response to a request from the Scientific Committee (IWC, 1980a), Dr M. V. Ivashin supplied 50 etched sperm whale teeth, which had been read by a Soviet scientist, for cross-checking. The teeth were then read by one Japanese, one South African and three British readers.

RESULTS

The readings are given in Appendix Table 1. In order to determine if there was any significant difference between the readers, a non-parametric analogue of a randomised block analysis (Friedman's test) was performed. The sums of the ranks of the six readers are given below (the means of tied observations were used):

Reader no.	1	2	3	4	5	6
Sum of ranks	228	186	167.5	175.6	107	186

The χ^2 statistic with 5 degrees of freedom was 44.18 ($p < 0.001$). The same analysis was performed for readers 2, 3, 4 and 6 resulting in a χ^2 value of 1.35 (3 df, $p > 0.70$).

Table 1

Comparison of readers 1 and 5 ([a] Mean deviation from mean of readers 2, 3, 4 and 6. [b] Standard deviation of deviations).

Reader 1			Reader 5		
>mean	<mean	=	>mean	<mean	=
35	12	3	10	37	3
$\bar{X}$[a]	1.42			−1.76	
S[b]	2·41			2·61	

Table 2

Results from the age determination meeting. La Jolla (from IWC, 1980b, p. 10)

Reg. no.	Sex	Length (m)	Reader		
			A	3	5
PA91	♂	15.6	37	45	43
PA602	♂	10.3	11	12	11
PA956	♂	16.1	19	24.5	23
P19	♂	14.0	17	20	16
PI370	♂	13.4	19	22	19
T20	♂	11.6	12	14	13
T25	♂	9.7	11	13	11
PA168	♀	9.7	18	24	27
PA170	♀	9.1	13	15	16
PI18	♀	9.1	9	10	12
PI62	♀	9.1	19	23	20
Sum of ranks			13.5	30	22.5

DISCUSSION

Fig. 1 shows a plot of the mean readings of readers 2, 3, 4 and 6 in ascending order, and the readings of readers 1 and 5. Reader 1 (Soviet) is frequently higher than the mean value whereas reader 5 (Japanese) exhibits the opposite tendency (Table 1). This does not infer that readers 2, 3, 4 and 6 are 'correct', but shows that in this sample there are differences between readers.

Table 2 examines readings from 3 readers at the Age Determination Workshop held in La Jolla in 1978 (IWC, 1980b). Reader A is a different Soviet scientist, readers 3 and 5 are the same as above. In this case the sample size

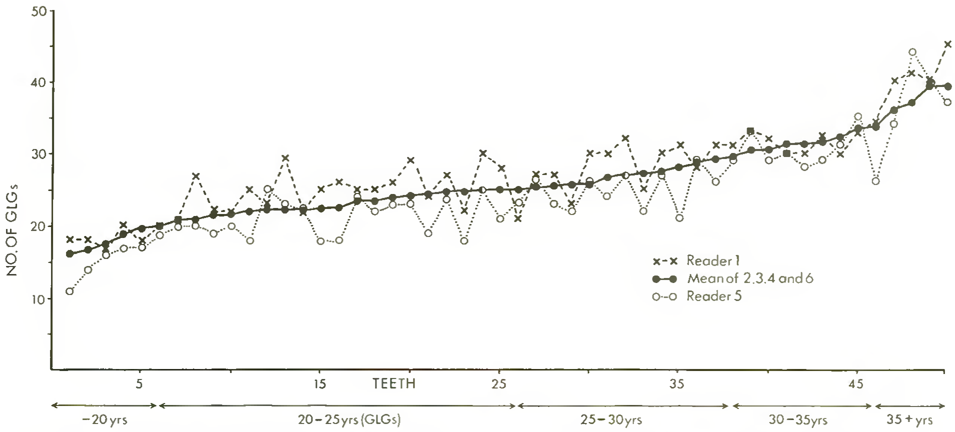

Fig. 1. A plot of the mean readings (growth layer groups) of readers 2, 3, 4 and 6 in ascending order, and the readings 1 and 5.

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[3] Sea Fisheries Institute, Cape Town, South Africa.

was rather small—11 readings. Using Friedman's test, a significant difference ($p < 0.01$) was observed between the readers. In this case however the Soviet reader was frequently the 'lowest' while reader 3 was the 'highest'.

These analyses suggest that there are significant differences between readers. If so this would have some bearing on the use of age-length keys. However, it is important to realise that these results are from a single reading of a limited sample of teeth by a limited number of readers. For example in Japan there are at least 5 people reading teeth and in the Soviet Union there are at least 4 people reading teeth.

In order to look more carefully into the problem we suggest that a sample of teeth is read by all the Soviet, Japanese and other readers, in the same manner as used when constructing age length keys, and a similar analysis to that described above then performed.

REFERENCES

International Whaling Commission, 1980a. Annex M, Appendix 1. Sperm whale teeth and age-length key material. *Rep. int. Whal. Commn* 30: 136.

International Whaling Commission, 1980b. Report of the Workshop *Rep. int. Whal. Commn* (special issue 3): 1–50.

Appendix Table 1

Readings of 50 sperm whale teeth by 6 readers

Reg. no.	Sex	Length (m)	1[a]	2	3	4	5[a]	6	Mean of 2, 3, 4+6
655	♀	10.0	18+1	19	16	16	14	16	16.75
678	♂	12.7	23	28	23	26	23	26	25.75
682	♂	12.3	21+2	28	24+	+	23+3	23	25.00
802	♂	14.1	41+3	37	38+	39+	44+1–2	34+	37.00
805	♂	13.9	40	40+	39+	40+	40	38+	39.25
2641	♂	14.2	40+6	36+	35+	35+	34+	38+	36.00
3248	♂	12.0	18+4	20	19+	20+	17	20	19.75
3259	♂	12.4	26+1	24	23	25	23	24	24.00
3301	♂	12.5	22+3	27+	24+	25+	18	23	24.75
3485	♂	13.4	22	20	22+	22+	19	22	21.50
3683	♀	10.9	21+4	22+1	21+	22+	20	18	20.75
3771	♂	12.7	27	25	25	25	24+1	24	24.75
3772	♂	12.9	22+4	24+	22+	22+	22	21	22.25
3810	♀	10.8	17+1	18+	17	17	16	17	17.25
3856	♂	13.4	32+3	27+	27+	27+	27	27	27.00
3868	♀	10.7	27	24	26	25	23	27	25.50
3885	♀	11.0	31+6	28+	29+	29+	29	32	29.50
3926	♂	13.4	30	25	27+	25	26	26	25.75
3928	♂	13.2	24+3	25+	24+	25+	19	24+	24.50
3944	♀	10.9	34	34+1	31+	34	26	35	33.50
4004	♂	14.7	29+5	21	22+	21+	23+2	27	22.75
4125	♀	10.7	30	30+	31+	31+	30	33	31.25
4129	♂	12.9	30+2	32+	30+	31	28	32	31.25
4132	♀	10.8	30+3	26	28+	26	24	27	20.75
4140	♂	13.4	27	20	23+	21	20	20	21.00
4403	♂	13.0	23+3	24+	22+	22+	25	21	22.25
4520	♀	10.6	32+3	30+	32+	30+	29+5	30+	30.50
4526	♂	12.9	29+2	23	25+	25+	23	24	24.25
4528	♂	12.8	28	29+	29	29	29	28	28.75
4622	♂	12.6	25+2	23	23+	23+	22	25	23.50
4891	♂	14.4	31+2	27+	29+	28+	21	28	28.00
4905	♀	11.1	33+2	30	31+	31+	31+	30+	30.50
5178	♂	14.0	33+6	33+	32+	32+	35+2	37	33.50
1734	♂	14.3	45	41+	39+	40+	37	37	39.25
3472	♂	13.6	30+3	32	26+	26+	27	26*	27.50
3515	♂	13.5	32+3	30	33+	30+	29	33	31.50
3529	♂	14.0	30	33	32+	32+	31	32	32.25
3645	♀	11.0	26+2	23+	22+	22	18+1–2	23	22.50
3758	♂	12.8	28	25	25	25	21+	25	25.00
3884	♂	11.5	18	16	16+	16+	11+	17+	16.25
3883	♂	12.5	20+4	18	21+	21+	19	20	20.00
3885	♂	12.6	25+2	22	22+	22+	18+1–2	22	22.00
3902	♂	12.3	20+2	19	18+	18+	17	21	19.00
3984	♂	13.6	31+5	33+	27+	31+	26	26+	29.25
4009	♂	12.4	25+2	29+	25+	25+	22	30	27.25
4028	♂	13.1	30	26+	23+	24+	25	27	25.00
4036	♂	13.3	27+3	25+	26+	25+	26	26	25.50
4048	♂	13.3	22	22	20	22	20	23	21.75
4052	♂	13.0	25+3	24+	21+	24+	24+1	25	23.50
4083	♂	12.4	25	22	23+	22+	18	23	22.50

[a] Readers 1 and 5 estimated how many extra layers they thought there would have been in teeth with a worn tip. These were ignored for the analyses in order to make them comparable with Readers 2, 3, 4 and 6.

+ = tip worn, broken or unclear—neonatal line not counted if present.

SC/33/Mi2

Catch and Effort and the Sex Composition in the Norwegian Minke Whale Fishery 1976–80

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ABSTRACT

A revision and re-evaluation of the catch and effort and sex composition data for the minke whale fishery in the period 1976–80 is presented. The number of participating vessels has varied between 82 and 89, and total annual catches have been from 1,592 to 2,002 whales, while the effort has varied between 2,520 and 3,362 ship-days. The CPUE data show no trend over the period. Variations can be explained by weather conditions (efficiency of ships) or regulatory measures. High percentages of females in the catch are discussed. A delayed opening date for whaling in the Northeast Atlantic has lowered the percentage of females in catches from this area from 65.8% in 1978 to 56.3% in 1980.

INTRODUCTION

The reporting system introduced into the Norwegian small whale fishery in 1976 (Christensen, 1979), has now been in force for five whaling seasons. The discovery of a minor error in our computer program has made it necessary to revise the statistics for all the seasons since 1976. The error did not influence the calculated sex distributions, but had some effect on the calculated CPUE for some areas. This revision also offered an opportunity to re-evaluate the statistics for Norwegian catches of minke whales in the last five seasons. The present report gives the revised data for the seasons 1976–79, as well as data for the 1980 whaling season.

CATCH AND EFFORT

Table 1 gives the number of whaling licences issued, the actual participation and the distribution of ships on catch areas by season. It also shows the total number of minke whales caught and Norway's total quotas in the North Atlantic.

The number of licences issued by the Norwegian Government has varied between 91 and 93 and the participation between 82 and 89 ships. The seasonal distribution by area shows that the number of ships has varied between 81 and 88 in the eastern North Atlantic, between 7 and 11 in the central North Atlantic and between 1 and 6 off West Greenland.

Table 2 gives the number of vessels participating in the fishery in the period 1976–80, the total number of ship-days, ie. the pooled number of days the ships have been on the whaling grounds, and the catch per ship-day (CPUE).

Table 2

Total catch and effort in the Norwegian minke whale fishery in the North Atlantic in the period 1976–80

Season	No. ships	No. ship-days	CPUE
1976	82	2,963	0.71
1977	87	2,855	0.61
1978	87	2,520	0.63
1979	83	2,833	0.69
1980	89	3,362	0.60

The catches have varied between 0.60 and 0.71 whales per ship-day. CPUE data for the different catch areas in the North Atlantic are shown in Fig. 1. There is no trend in the CPUE over these five years. The figure shows that the catch per ship-day in the Barents Sea is high and relatively constant. The CPUEs are more variable at Svalbard and off the Finnmark coast, but a high CPUE in the Svalbard area is compensated by a low CPUE off Finnmark in the same season. There is an obvious connection between the Barents Sea, the Svalbard and the Finnmark areas and therefore these are compiled as 'Northeast Atlantic north

Table 1

The number of Norwegian whaling licences issued and used per season, their distribution on whaling areas, and total Norwegian catches and quotas of minke whales in the North Atlantic, 1976–80

	Number of licences						
Season	Issued	Used	NE Atlantic	CN Atlantic	West Greenland	Catch no. of whales	Quota
1976	93	82	81	11	6	2,145	2,550
1977	93	87	86	0	1	1,772	1,985
1978	91	87	86	9	1	1,592	1,985
1979	91	83	82	9	1	1,980	1,985
1980	92	89	88	7	1	2,002	1,985

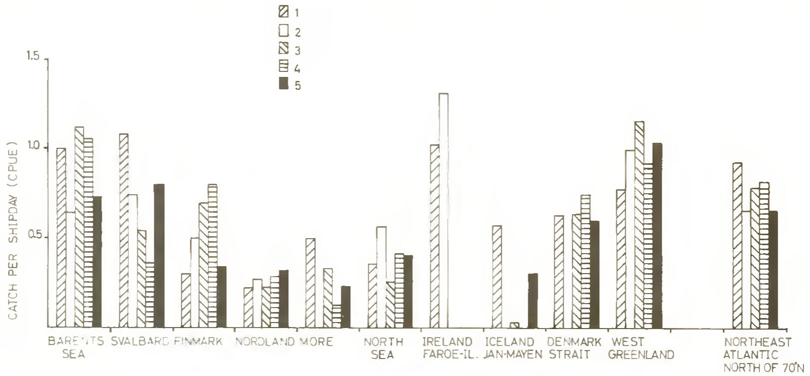

Fig. 1. Norwegian catches of Minke Whales per ship day (CPUE), by area in the North Atlantic, 1976–1980: 1–1976; 2–1977; 3–1978; 4–1979; 5–1980.

of 70°N' in Fig. 1. The seasonal variation is low and the CPUEs are high in these compiled data.

The catches per ship-day for Nordland county are low but constant. This is an inshore fishery where the smallest whaling vessels participate. Catches in the Møre county area are more erratic, as reflected by the variation in CPUE and minke whales are mostly caught when ships are passing through to other fishing grounds. The North Sea is a consistently good catch area considering that the ships which operate there are also small. The high CPUEs off Ireland and the Faroe Islands in 1976 and 1977 are due to the submission of incomplete effort data by the whalers. This area was closed to Norwegian whalers in 1978.

The catches in the Iceland – Jan Mayen area, where whales are generally taken by whalers on their way to the Western grounds, are sporadic. The CPUE data for the Denmark Strait show a constant yield per season. Because of marketing problems in Norway no whaling was undertaken in this area in 1977. The catch per ship-day at West Greenland is the highest of all areas. The output also is constant year by year. Catches per ship-day in the three main areas are compared in Table 3.

Table 3

Catches of minke whale per ship-day in the main whaling areas

	Catch per ship-day		
Season	NE Atlantic N. of 70°N	Denmark Strait	West Greenland
1976	0.92	0.62	0.73
1977	0.65	—	0.99
1978	0.78	0.63	1.15
1979	0.81	0.74	0.92
1980	0.65	0.59	1.03
Mean	0.75	0.65	0.89

The table suggests that West Greenland is the best catch area, followed by the Northeast Atlantic north of 70°N and then the Denmark Strait.

SEX COMPOSITION

Table 4 shows that the catches of females are very high in the Northeast Atlantic and West Greenland stocks, while the males dominate in catches from the Central North Atlantic stock.

DISCUSSION

Quotas were introduced into the North Atlantic minke whale fishery in 1975. However, measures previously in force including a strict licensing system and time limits by area (Jonsgård, 1977) are maintained by the Norwegian Government as additional regulations. Since 1977 only one licence per season has been issued for whaling off West Greenland (Table 1). Whaling off East Greenland has been open for Norwegian whalers from 21 July to 1 September. Ships operating in this area (Table 1) have first been whaling in the Northeast Atlantic. If a licensee has taken less than 70 tonnes of meat in the Northeast Atlantic, he can apply for permission to fulfill his quota of 70 tonnes at East Greenland. The number of licences issued and used has been about the same each year and the same ships have been used with very few replacements. Therefore the changes in effort are small over the period discussed here and in fact the greatest influence on hunting efficiency is the weather. Christensen (1979) showed that both wind and visibility influence the catch, the wind having the strongest effect. The small variations in catch per ship-day over the last five seasons are caused by weather conditions, CPUE otherwise remaining nearly constant (Fig. 1, Table 2).

A comparison of catch per ship-day in the three main hunting areas in the North Atlantic (Table 3), indicates that West Greenland is the richest whaling area, however, weather conditions in any single season are not the same in all areas, and the efficiencies of individual ships are different, with less efficient ships bringing the average CPUE down. This is clearly demonstrated by the catch at West Greenland in 1976 (Table 3), when six ships participated as compared to one ship in 1977–80.

Christensen (1979) showed that the percentage of females in the Northeast Atlantic catches have tended to increase after 1972. He also showed that the fishing areas

Table 4

The number of male (M) and female (F) minke whales, and percentage of females (%F) caught by Norwegian whalers from three minke whale stocks in the North Atlantic

	NE Atlantic			CN Atlantic			West Greenland		
Season	M	F	%F	M	F	%F	M	F	%F
1976	599	1,230	67.2	63	27	30.0	31	135	81.3
1977	743	934	55.7	—	—	—	21	54	72.0
1978	473	910	65.8	73	58	44.3	10	65	86.7
1979	752	996	57.0	76	43	36.1	31	44	58.7
1980	781	1,006	56.3	78	41	34.5	14	61	81.3

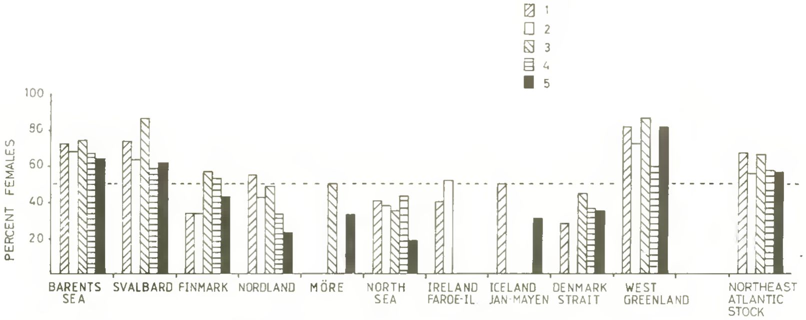

Fig. 2. The percentage of females in Norwegian catches of Minke Whales by area in the North Atlantic, 1976–77; 1–1976: 2–1977: 3–1978: 4–1979: 5–1980.

had changed, and that females dominated in the northern and northeastern areas early in the whaling season. Jonsgård's (1980) examination gave the same result. The Government therefore in 1979 delayed the opening date for whaling in the Northeast Atlantic from 1 May to 16 May and in 1980 closed those areas east of 33°E until 28 May. The proportion of females in Northeast Atlantic catches subsequently dropped from 65.8% in 1978 to 57.0% in 1979 and to 56.3% in 1980. The decrease was less than expected, mainly because the allocated quotas were taken in early July, before the dominance of females had changed. In 1980 a larger part of the catch was also taken in the northern Svalbard area where the female dominance is greatest (Fig. 2).

For evaluation of the sex composition in catches from the Central North Atlantic and West Greenland stocks, the Icelandic and Greenlandic catches should be added to the Norwegian catches. In the 1978 whaling season the catch of minke whales in Iceland was 86 males and 109 females (Anon., 1980), and 112 males and 86 females in 1979, (Anon., 1981). When these are added to the Norwegian catches from the same stock, the resulting sex compositions are 51.2% females and 48.8% males in 1978, and 40.7% females and 59.3% males in 1979.

The Greenlandic as well as the Norwegian catches of minke whales off West Greenland comprise a high percentage of females. Kapel (1980), referring to other migrating species (cod and redfish) which show a connection between East Greenland–Iceland and West Greenland, assumed from the sex distribution of minke whales in the two areas that they belong to the same stock. The data are few, but a comparison of the sex composition in catches from the central North Atlantic stock with the composition in catches from the West Greenland stock (Table 4; Anon., 1980 and 1981; IWC, 1981, p. 108) shows that a change in one area does not affect the sex composition in the other area. These data therefore suggest that the connection between the Central North Atlantic and the West Greenland minke whales is weak.

To date, no minke whale marked in the Northeast Atlantic area has been recaptured in any of the other areas. The assumption of a separate minke whale stock in the Northeast Atlantic is thus to some extent supported (and certainly not refuted) by the markings data.

REFERENCES

Anon. 1980. Iceland. Progress report on cetacean research. June 1978–May 1979. *Rep. int. Whal. Commn* 30: 153–4.

Anon. 1981. Iceland. Progress report on cetacean research. June 1979–May 1980. *Rep. int. Whal. Commn* 31: 189–91.

Christensen, I. 1979. Norwegian minke whales fisheries in 1976 and 1977. *Rep. int. Whal. Commn* 29: 467–72.

International Whaling Commission. 1981. Report of the Scientific Committee. *Rep. int. Whal. Commn* 31: 51–165.

Jonsgård, Å. 1977. Norwegian and international regulations in the Norwegian whaling for minke whales, *Balaenoptera acutorostrata* and small whales. *Rep. int. Whal. Commn* 27: 400–1.

Jonsgård, Å. 1980. On the sex proportion in Norwegian minke whaling. *Rep. int. Whal. Commn* 30: 389.

Kapel, F. O. 1980. Sex ratio and seasonal distribution of catches of minke whales in West Greenland. *Rep. int. Whal. Commn* 30: 195–203.

SC/33/Mi3

The Food of Minke Whales (*Balaenoptera acutorostrata*) in Northern North Atlantic Waters

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ABSTRACT

A total of 237 minke whale (*Balaenoptera acutorostrata*) stomachs was examined, from animals caught in 1943, 1944, 1945, 1950 in northern Norway (Lofoten and Vesterålen), in 1950 (Barents Sea, Spitsbergen and Bear Island), and in 1968 (East and West Greenland). Fish only was found in 104 stomachs (43.9%). The species of fish identified were: cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), coal-fish (*Pollachius virens*), herring (*Clupea harengus*), capelin (*Mallotus villosus*) and sand-eel (*Ammodytes* sp.). Pelagic crustaceans only (euphausiids and *Calanus finmarchicus*) were recorded in 74 stomachs (31.2%). A mixture of fish and pelagic crustaceans was found in 15 stomachs (6.3%). Empty stomachs were found almost exclusively in Lofoten where 34 of 98 (34.7%) stomachs contained no food.

The composition of the stomach contents seems to depend on both the time of examination and where the whales were caught. It is concluded that economically important species of fish and also euphausiids are the basic food sources for minke whales in northern North Atlantic waters, and that large quantities of fish are consumed.

INTRODUCTION

The minke whale (*Balaenoptera acutorostrata*) is known to feed on some economically important fish species in addition to the crustaceans usually consumed by baleen whales (Jonsgård, 1951). The amount of fish eaten might influence the recruitment and size of fish stocks, especially if the fish stocks are being overfished. Knowledge of the food consumption of minke whales in different fishing areas is therefore very important.

Jonsgård (1951) briefly discussed the stomach contents of minke whales caught in certain northern North Atlantic waters. Since then stomachs have been examined in other North Atlantic areas. In the present paper the food of minke whales in northern North Atlantic waters is discussed on the basis of all the material available at the University of Oslo.

MATERIAL

Table 1 shows the number of male and female minke whales examined for stomach contents in different waters and seasons in the North Atlantic. A total of 237 stomachs have been examined. In 1943, 1944 and 1945 the investigations were restricted to the northern coast of Norway and the author examined 96 stomachs in Lofoten (Vestfjorden) and nine off Vesterålen in these three seasons. Two more minke whales were examined by two biologists in Lofoten in 1950. In 1950 a group of biologists also carried out work on the minke whale in the eastern North Atlantic. Altogether 94 stomachs were examined in the Barents Sea, off Spitsbergen and at Bear Island. In 1968 two biologists examined 31 minke whale stomachs off the southeast coast and five stomachs off the southwest coast of Greenland.

Table 1 shows that in most areas there is a great difference between the number of males and females examined. This is because the sex groups of minke whales are segregated by area at certain times of the year (Jonsgård, 1951).

RESULTS

Table 2 shows the main types of stomach contents recorded in male and female minke whales in different areas and seasons. *Fish only* were found in 104 stomachs or 43.9% of all whales examined in all areas. The whales examined off East Greenland (31) and off Vesterålen (9) had fed exclusively upon fish. Altogether 38 males and 66 females had eaten fish only.

Pelagic crustaceans only were found in the stomachs of 74 whales or 31.2% of all examined. Of these 18 were

Table 1

Minke whale stomachs examined in the northern North Atlantic in different areas and seasons

	1943		1944		1945		1950		1968		Sum	
Area	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Barents Sea							6	7			6	7
Spitsbergen							7	19			7	19
Bear Island							9	46			9	46
East Greenland									11	20	11	20
West Greenland									2	3	2	3
Coast of Norway:												
Lofoten	8	19	14	43	3	9	1	1			26	72
Vesterålen	7	1		1							7	2
Total	15	20	14	44	3	9	23	73	13	23	68	169

Table 2

Types of stomach contents found in male and female minke whales by area and season

		Fish		Pelagic crustaceans		Fish and pelagic crustaceans		Milk		Not identified		Empty stomachs		Sum	
Area	Season	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Barents Sea	1950	1	3	4	3							1	1	6	7
Spitsbergen	1950	1	1	4	11		2			2	5			7	19
Bear Island	1950	1	8	6	28	2	10							9	46
East Greenland	1968	11	20											11	20
West Greenland	1968	1	1	1	2									2	3
Lofoten	1943	3	5	1	5				1			4	8	8	19
	1944	11	19	1	7		1					2	16	14	43
	1945	2	7									1	2	3	9
	1950			1									1	1	1
Vesterålen	1943	7	1											7	1
	1944		1												1
Total		38	66	18	56	2	13		1	2	5	8	28	68	169

males and 56 females. Krill (*Thysanoessa inermis*) was found in seven out of 13 whales examined in the Barents Sea, five stomachs being full of krill. In the Spitsbergen area crustaceans were found in 15 out of 26 stomachs: 13 whales had eaten *T. inermis* and two stomachs contained a mixture of *T. inermis* and *Calanus finmarchicus*. In the Bear Island area crustaceans were found in 34 out of 55 stomachs: 23 stomachs contained *T. inermis* and 11 a mixture of *T. inermis* and *C. finmarchicus*.

A mixture of *fish and pelagic crustaceans* was found in 15 stomachs or 6.3% of all animals examined. Twelve of these whales were caught in the Bear Island area, and they had eaten large quantities of *T. inermis* and some capelin.

The stomachs of seven animals caught off Spitsbergen contained a 'green-coloured substance' which could not be identified.

Empty stomachs were rarely recorded except for the Lofoten area where 34 stomachs out of 98 (34.7%) contained no food.

As mentioned above fish were recorded in minke whale stomachs in all areas, and fish also constitute the largest group of stomach contents. Table 3 shows the number of stomachs which contained just one single species of fish, in different areas, seasons and months. As seen from the table, 100 animals or 42.2% of all minke whales examined belonged to this category. The identified fish species are cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), herring (*Clupea harengus*), capelin (*Mallotus villosus*) and sand-eel (*Ammodytes* sp.).

Cod had been fed upon by one animal caught off Spitsbergen and 14 taken in Lofoten. The Spitsbergen whale was a 25 feet long female caught on 18 June, with her stomach half full of the remains of small fish—in all probability cod.

The stomachs of the 14 animals from Lofoten, on the other hand, contained large Norwegian-Arctic cod. All these whales were mature females taken in April and early May. Seven stomachs were completely filled with cod, one stomach contained as many as 40 large fresh cod.

Haddock had been eaten by three whales taken in the Barents Sea and four in Lofoten. The Barents Sea whales were females, 22, 23 and 25 feet long, all taken on 22 May. The stomachs were ½, ¾ and full of haddock, the largest fish weighing nearly 4 kg. The four whales taken in Lofoten also were females. Two of them—20 and 26 feet long—were caught on 29 April, and their stomachs contained a considerable quantity of haddock remains. The other two—16 and 22 feet long—were taken on 13 and 17 May. Their stomachs were 1/3 full of haddock remains (and a longline fishing hook) and full of haddock respectively.

Herring was found in the stomachs of minke whales taken in the Barents Sea, off Spitsbergen, in Lofoten and

Table 3

Minke whale stomachs containing one single species of fish related to area, season and month

		Cod			Haddock		Herring						Capelin				Sand-eel	Unspecified fish remains			
Area	Season	IV	V	VI	IV	V	V	VI	VII	VIII	IX	X	V	VI	VII	VIII	VIII	IV	V	VI	Sum
Barents Sea	1950					3		1													4
Spitsbergen	1950			1					1												2
Bear Island	1950												4	3	2						9
East Greenland	1968														16	15					31
West Greenland	1968																2				2
Lofoten	1943					1		3												1	5
	1944	9			2	1	3		12									1	1		30
	1945	1	4				4														9
	1950																				
Vesterålen	1943										4	4									8
	1944											1									1
Total		10	4	1	2	5	7	4	13		4	5	4	3	18	15	2	1	1	1	100

off Vesterålen. The stomach of a 19 feet long male taken on 12 June in the Barents Sea was full of small herring and a 22 feet long male taken on 5 July off Spitsbergen contained bones of large herring. In the Lofoten area 22 whales had eaten herring. Almost all these whales were taken in the outermost part of Vestfjorden (the Vaerøy and Skomvaer area). In May two males and five females 17–28 feet in length had eaten small herring (ca. 10 cm long). In June two males and one female 26, 27 and 28 feet long had fed upon large 'fat herring' and small herring (*c.* 10 cm long) respectively. In July ten males and two females 16–27 feet in length taken near Skomvaer all had eaten small herring (5–6 cm long). The quantities of herring recorded varied from 3 litres of herring bones to full stomachs.

Nine whales examined off Vesterålen in September and October had all eaten small herring. The stomachs of seven 19–25 feet long males were all completely full of herring, except one which was ¾ full. Two 16 and 27 feet long females had remains of herring and a full stomach respectively.

Capelin was found in the stomachs of nine minke whales caught in the Bear Island area and 31 caught off East Greenland. In the Bear Island area the stomach of one 25 feet long male caught in July was completely full of capelin. Eight females 18–29 feet in length were caught in May, June and July. Three of the stomachs were full, and the fourth contained a large quantity of capelin. All animals examined off East Greenland in July and August 1968 had fed upon capelin. Large quantities were found in almost all stomachs. Of these 11 whales were males ranging in length from 17 to 27 feet, and 20 were females 16–29 feet long.

Sand-eel was recorded in the stomach of a 26 feet male and a 19 feet female, both caught off West Greenland in August.

Table 4 shows the number of stomachs which contained a *mixed food* of fishes, or fish and pelagic crustaceans, by area, season and month. Altogether 19 stomachs or 8% of all whales examined belong to this category. In the Bear Island area as many as 12 whales had fed upon a mixture of capelin and *T. inermis*. Two of these were males, 17 and 23 feet long, and 10 females ranged from 18 to 29 feet in length. Almost all stomachs contained large quantities of food, *T. inermis* usually dominating. One 19 feet long female caught in Lofoten on 11 June had a half full stomach containing remains of large coal-fish (*Pollachius virens*) and flatfish (Pleuronectidae).

DISCUSSION

Minke whale stomach contents show that in the northern North Atlantic this species feeds upon several species of fish and pelagic crustaceans. Altogether 119 stomachs (50.2%) of all stomachs examined contained fish, while 89 stomachs (37.6%) contained crustaceans. Empty stomachs were almost exclusively recorded in Lofoten where 34 out of 98 animals belonged to this category. This high percentage may be understood when keeping in mind that adult minke whales pass through the Lofoten area during their spring migration to the feeding grounds in eastern North Atlantic waters (Jonsgård, 1951). This view is supported by the fact that empty stomachs were most commonly recorded in Lofoten early in the season. As many as 25 whales, mainly medium and large sized animals of both sexes had empty stomachs in April and May.

In contrast to other baleen whales, minke whales also feed upon large fish, e.g. mature Norwegian-Arctic cod, large coal-fish and large haddock, but they probably prefer smaller shoal-fish like herring and capelin. However, the composition of the stomach contents seems to depend both on the time of examination and on where the whales were caught. In the Lofoten area (Vestfjorden) large females moving northwards in the spring, feed upon Norwegian-Arctic cod at the time when the cod congregates in these waters to spawn. In the summer when small herring is concentrated in the outer part of Vestfjorden, this fish species is hunted by small as well as large minke whales. In the autumn male minke whales on their southern migration feed almost exclusively upon small herring (Group I) outside the Vesterålen Islands, where small herring usually was plentiful at this time of the year.

There can be no doubt that minke whales to a large extent feed upon the food species available to them in different areas through the feeding season. In 1950 all 31 whales examined off East Greenland had eaten capelin. Christensen (1974) reported that in 1973, 55% of the minke whales examined in this area had fed only upon capelin, while all the other stomachs except for two empty ones, contained a mixture of capelin and krill (euphausiids) or krill only. According to Christensen (1974), the food in Svalbard waters (Hopen) consisted mainly of capelin and also capelin mixed with some krill, while most of the stomachs examined in 1950 contained pelagic crustaceans (*T. inermis* and *C. finmarchicus*). Capelin was not recorded at all. On the other hand, both sets of material show that in the Barents Sea krill was the main food, but also capelin and haddock had been eaten.

In accordance with the present data, more recent investigations off West Greenland clearly demonstrate that krill and sand-eel are important food items for minke whales in these waters (Christensen, 1974; Larsen and Kapel, 1981). Larsen and Kapel, however, point out that

Table 4

Minke whale stomachs containing a mixed food of fish, or fish and pelagic crustaceans by area, season and month

Area	Season	Small herring and sand-eel		Remains of large coal-fish and flatfish	Small cod (20 cm) and *T. inermis*	Herring and *T. inermis*	Capelin and *T. inermis*		Otholiths and 'krill'	Sum
		VII	VIII	VI	VI	VII	V	VI	V	
Spitsbergen	1950				1	1				2
Bear Island	1950						1	11		12
Lofoten	1943	1	1	1						3
	1944	1							1	2
Total		2	1	1	1	1	1	11	1	19

this is true for offshore waters, while small fish (particularly capelin) are found in most of the stomachs from whales taken inshore.

Capelin also play an important role as food for minke whales in Newfoundland waters (Mitchell and Kozicki, 1975).

From the data presented above it may be concluded that some economically important species of fish as well as euphausiids form the basic food source for minke whales in the northern North Atlantic. There can be no doubt that large quantities of fish are eaten by minke whales inhabiting these waters during their feeding season, although the data available on food quantities are not yet sufficient for estimates of consumption. Intensive exploitation of several fish stocks makes it necessary to take into account the interactions between whales and fish. Quantitative data on food consumption are therefore important as a basis for the development of whaling regulations aimed at a control of the impact of whales upon fish stocks as well as the maintenance of the stocks of whales.

REFERENCES

Christensen, I. 1974. Undersøkelser av vågehval i Barentshavet og ved Øst-og Vest-Grønland i 1973. (Minke whale investigations in the Barents Sea and off East and West Greenland in 1973). *Fiskets Gang*. 60: 278–86.

Jonsgård, Å. 1951. Studies on the little piked whale or minke whale (*Balaenoptera acuto-rostrata* Lacépède). *Norsk Hvalfangsttid*. 40: 209–32.

Larsen, F. and Kapel, F. O. 1981. Collection of biological material of minke whales off West Greenland, 1979. *Rep. int. Whal. Commn* 31: 279–85.

Mitchell, E. and Kozicki, V. M. 1975. Supplementary information on minke whale (*Balaenoptera acutorostrata*) from Newfoundland fishery. *J. Fish. Res. Bd Can*. 32: 985–94.

SC/33/Mi5

Norwegian Minke Whaling Off West Greenland, 1976–80 and Biological Studies of West Greenland Minke Whales

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ABSTRACT

Body measurements, biological material, and information on weather conditions were collected during whaling operations between late June and late August 1980 on board the Norwegian small-type whaling vessel *Kato* operating off West Greenland. Corresponding data for the 1976–79 seasons were extracted from the ship's log book.

The weather and the catch were reasonably good in 1980 apart from the fact that visibility was frequently reduced by fog which hindered operations for periods, especially in early August.

The mean length of all animals actually measured in 1979 and 1980 was 755 cm for males and 764 cm for females. Using length data estimated by the crew to the nearest foot, the result is 749 cm and 759 cm for males and females, respectively.

The percentage of females in the 1980-catch was 83%. The average for the period 1976–80 was 76% females.

Age determination based on tympanic bullae proved to be more difficult than expected due to the possible existence of secondary growth layers. The ages ranged from 3 to 8 years for primary growth layers only, and from 3 to 13 years where all growth layers were counted.

Of 81 females for which ovaries were examined 57 (70%) were found to be sexually mature and 52 of these (91%) were classified pregnant. These values are the same as those given by Christensen (1975) for the same stock.

Age at sexual maturity for females was estimated at 2.2 growth layers (primary growth layers only) or 3.7 growth layers (all growth layers), but these values are considered to be far too low to reflect the real age at maturity. Measurements of 50 foetuses indicate a difference in the mean data of ovulation between 1979 and 1980. The foetal sex ratio is not significantly different from 50:50.

Examination of stomach contents confirms that sand eel (*Ammodytes* sp.) is an important food item for minke whales in the offshore waters of West Greenland.

INTRODUCTION

For the second time arrangements were made in 1980 to have a Danish scientist on board the Norwegian small-type whaling vessel *Kato*, which operated off West Greenland. This paper should be considered a follow-up of a previous one by the same authors (Larsen and Kapel, 1980), and it presents information on the catches of minke whales by the *Kato*. Whale sightings, and a marking experiment carried out immediately after the whaling season are reported in more detail elsewhere (Kapel and Larsen, 1982; Anon., 1982). Biochemical analyses of tissue samples collected during the season are described in Simonsen, Kapel and Larsen (1982).

MATERIAL AND METHODS

1. The *Kato* Cruise in 1980

A short description of the vessel and its way of operating was given in the account of the 1979 cruise (Larsen and Kapel, 1981).

In 1980 *Kato* left Norway 26 May and arrived in the Davis Strait on 3 June. The first minke whale was caught 19 June, and three more were secured before one of the authors (FL) boarded the ship in Sisimiut (Holsteinsborg) on 27 June. During the following month catching was successful, and 57 additional minke whales had been processed when he disembarked in Nuuk (Godthaab) 4 August. The second author (FOK) was picked up in Sisimiut 13 August, and the last 14 whales of the allowed quota were caught between 14 and 24 August.

The ship operated from 63°30′N to 71°N with emphasis on the western slope of Store Hellefiske Banke (66°15′N to 68°30′N) as reflected on the map of catch positions (Fig. 1). The distance sailed within each subarea and 10-days periods are summarised in Tables 1–2.

The subarea divisions used here are based partly on oceanographic characteristics and bottom topography, and partly on distribution of catches and observations of whales.

Table 1

Estimated total distance sailed within each subarea and period (Nautical miles).

	10-days periods starting:									
Subarea	3/6	13/6	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
4 N. of 70°00′N	0	0	0	0	0	165	0	0	221	386
3 70°–68°30′N	0	0	0	0	99	359	0	40	219	717
2 68°30′–66°15′N	190	159	601	420	869	524	376	877	219	4,237
1 66°15′–64°15′N	127	250	0	0	0	0	286	0	135	797
0 S. of 64°15′N	536	234	0	0	0	0	140	0	510	1,420
All subareas	853	643	601	420	968	1,049	803	917	1,304	7,557

Table 3

Number of minke whales caught by *Kato*, per subarea and 10-days periods, 1976–80.

Subarea	10-days periods starting										
	3/6	13/6	23/6	3/7	13/7	23/7	2/8	12/8	22/8	1/9	Total
3.1 1976											
4 N. of 70°00′N	—	—	—	—	—	8	8	1	—	—	17
3 70°00′–68°30′N	—	—	35	—	—	0	—	0	—	—	35
2 68°30′–66°15′N	—	2	0	—	—	0	—	3	5	—	10
1 66°15′–64°15′N	—	1	—	—	3	0	—	—	—	—	4
0 S. of 64°15′N	—	0	—	—	—	—	—	—	—	—	0
All subareas	—	3	35	—	3	8	8	4	5	—	66
3.2 1977											
4 N. of 70°00′N	—	—	—	—	—	—	1	—	—	—	1
3 70°00′–68°30′N	0	0	10	11	4	0	23	14	—	—	62
2 68°30′–66°15′N	0	2	3	—	4	0	—	3	—	—	12
1 66°15′–64°15′N	0	—	—	—	0	0	—	—	—	—	0
0 S. of 64°15′N	0	—	—	—	0	0	—	—	—	—	0
All subareas	0	2	13	11	8	0	24	17	—	—	75
3.3 1978											
4 N. of 70°00′N	—	—	—	—	—	—	1	—	—	—	1
3 70°00′–68°30′N	—	—	6	11	7	1	8	—	—	—	33
2 68°30′–66°15′N	—	4	9	1	—	1	13	12	—	—	40
1 66°15′–64°15′N	—	1	—	—	—	0	—	—	—	—	1
0 S. of 64°15′N	0	—	—	—	—	0	—	—	—	—	0
All subareas	0	5	15	12	7	2	22	12	—	—	75
3.4 1979											
4 N. of 70°00′N	—	—	—	—	—	4	0	1	—	—	5
3 70°00′–68°30′N	—	0	—	—	—	0	0	1	—	—	1
2 68°30′–66°15′N	—	10	21	15	2	1	1	1	8	4	63
1 66°15′–64°15′N	—	0	—	—	—	—	—	—	—	4	4
0 S. of 64°15′N	0	0	—	—	—	—	—	—	—	2	2
All subareas	0	10	21	15	2	5	1	3	8	10	75
3.5 1980											
4 N. of 70°00′N	—	—	—	—	—	0	—	—	5	—	5
3 70°00′–68°30′N	—	—	—	—	2	3	—	0	0	—	5
2 68°30′–66°15′N	0	2	20	20	9	4	0	9	0	—	64
1 66°15′–64°15′N	0	0	—	—	—	—	0	—	—	—	0
0 S. of 64°15′N	0	0	—	—	—	—	1	—	—	—	1
All subareas	0	2	20	20	11	7	1	9	5	—	75

Table 4

Ratios of distance sailed during searching and chasing compared to total distance sailed per subarea and period, *Kato* 1980.

Subarea	10-days periods starting							
	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Average
4 N. of 70°00′N	—	—	—	0.06	—	—	0.78 (0.87)	0.47 (0.52)[1]
3 70°00′–68°30′N	—	—	1.00	0.72	—	0	0.16 (0.69)	0.55 (0.71)
2 68°30′–66°15′N	0.58	0.82	0.77	0.37	0.12	0.40	0.15 (0.21)	0.47 (0.47)
1 66°15′–64°15′N	—	—	—	—	0.21	—	0 (0.35)	0.07 (0.13)
0 S. of 64°15′N	—	—	—	—	0.65	—	0 (0.18)	0.06 (0.13)
All subareas	0.58	0.82	0.79	0.44	0.24	0.37	0.18 (0.40)	0.36 (0.39)

[1] Figures in parentheses include distance sailed during sighting and marking.

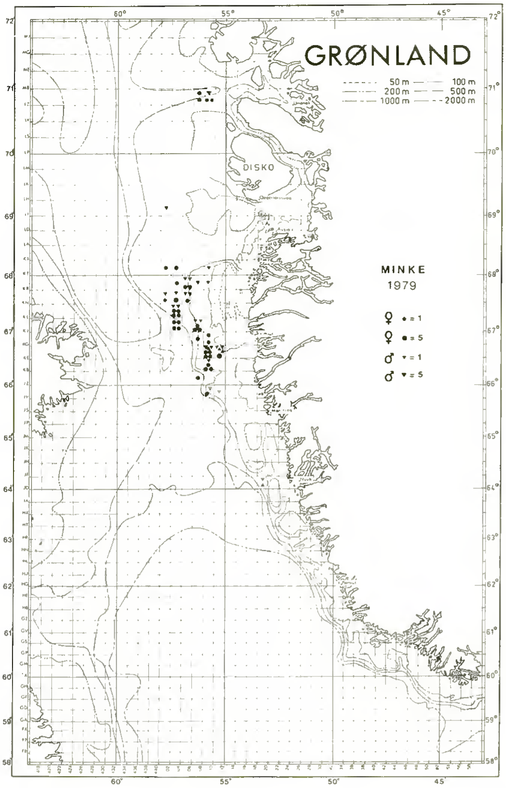

Fig. 4. Geographical distribution of male and female minke whales caught off West Greenland, *Kato*, 1979.

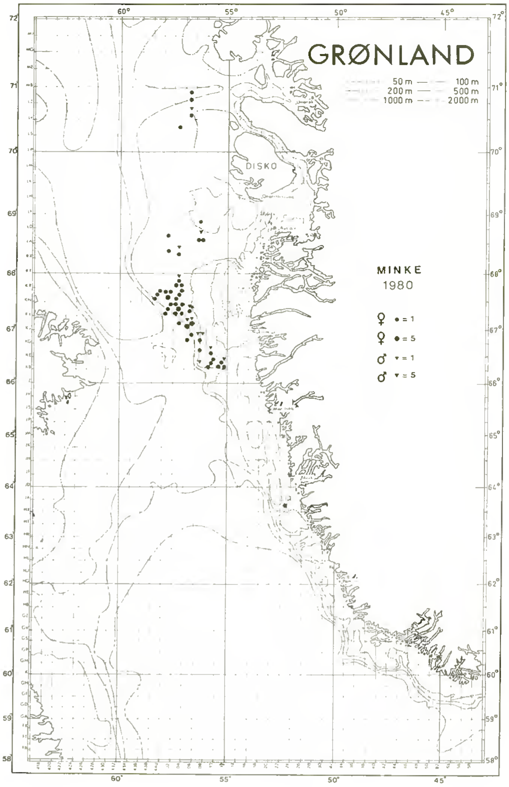

Fig. 5. Geographical distribution of male and female minke whales caught off West Greenland, *Kato*, 1980.

From Table 4 it can be seen that the period 23 June to 22 July offered good opportunities for hunting (58–82% of the total distance sailed used for searching and chasing), whereas the period 23 July to 21 August, and particularly 2–11 August was dominated by adverse conditions (24–44% spent on these activities). The poor conditions in August are even better reflected when the total distance is compared with the distance sailed during optimal sighting conditions, i.e. windforce 0–2, visibility 5–4 (Table 5).

The above findings agree reasonably well with the hunting results shown in Table 3.5. It is not possible, however, to find a correlation between hunting results and observation conditions for every single subarea and period. The exceptions may be due to the fact that the measure of sighting condition (windforce/visibility) does not take all the relevant factors into account (e.g. swell, surface colour), and by the possibility that minke whales are not evenly distributed along the west coast of Greenland.

1.3 Considerations of catch/effort (CPUE) indices

With the reservations considered above the distance sailed during searching and chasing can be used as a measure of the effort, and this has been done in Table 6.

Table 5

Ratios of distance sailed during optimal sighting conditions (windforce 0–2, visibility 5–4) compared to total distance sailed per subarea and period, *Kato* 1980.

	10-days periods starting							
Subarea	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Average
4 N. of 70°00′N	—	—	—	0	—	—	0.78 (0.87)[1]	0.47 (0.52)[1]
3 70°00′–68°30′N	—	—	0.16	0.72	—	0	0.16 (0.69)	0.43 (0.59)
2 68°30′–66°15′N	0.42	0.58	0.52	0.35	0	0.16	0.15 (0.15)	0.31 (0.31)
1 66°15′–64°15′N	—	—	—	—	0	—	0 (0.35)	0 (0.06)
0 S. of 64°15′N	—	—	—	—	0	—	0 (0.18)	0 (0.06)
All subareas	0.42	0.58	0.49	0.42	0	0.16	0.18 (0.39)	0.24 (0.27)

[1] Figures in parentheses include distance sailed during sighting and marking.

Table 6

Catch of minke whales per 100 nautical miles of searching, chasing, and sighting, *Kato* 1980.

Subarea	10-days periods starting							
	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Average
4 N. of 70°00'N	—	—	—	0	—	—	2.91	2.74
3 70°00'–68°30'N	—	—	2.03	1.16	—	—	0	1.28
2 68°30'–66°15'N	5.79	5.84	1.35	2.05	0	2.59	0	3.24
1 66°15'–64°15'N	—	—	—	—	0	—	—	0
0 S. of 64°15'N	—	—	—	—	1.10	—	—	1.10
All subareas	5.79	5.84	1.44	1.51	0.51	2.59	2.09	2.78

If only the distance sailed during optimal sighting conditions, and the corresponding catches are used, similar but slightly higher values are arrived at (windforce 0–2, visibility 5–4):

	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Average
All subareas	6.71	6.16	2.12	1.59	0	3.48	2.09	3.29

For previous seasons the same detailed data are not available, but some information has been obtained from the log books. It is possible to divide the season in days of resting, steaming, strong wind, fog, etc. Using days of 'good weather' (windforce 0–3, visibility 5–3) as a crude measure of effort, the CPUE can be calculated as given in Table 7.

The values calculated for 1980 by this less accurate method are similar to those given in Table 6 although a different index of effort has been used. For all five years there appears to be great variation in hunting success within the season, but the average for the whole season shows no clear trend over this five year period.

Although this is still a crude measure of effort, this 'good weather index' is slightly more refined than ship days previously used by Christensen (1980) to demonstrate that CPUE has not declined in West Greenland since 1976. The present analysis seems to support that opinion.

2. Biological Parameters

2.1 Sex ratio

Of the 75 minke whales caught in 1980, 62 (83%) were females and 13 (17%) males. This is a much higher percentage of females than found in the 1979 catch (59%; Larsen and Kapel, 1981), but is similar to the previously calculated sex ratios for the Norwegian catches off West Greenland (cfr. Kapel, 1980). The average for the five year period 1976–80 for the *Kato* is 76%.

Examination of the sex ratio within seasons appears to reveal a difference between the pattern in 1976–78 and in 1979–80 (Table 8).

In the first three seasons very few males were caught

Table 7

Catch of minke whales per day of good weather by *Kato* in West Greenland, 1976–80.

Year	10-days periods starting									
	13/6	23/6	3/7	13/7	23/7	2/8	12/8	22/8	1/9	Average
1976	2.00	6.36	—	6.00	1.60	2.67	1.33	5.00	—	3.38
1977	0.67	2.60	1.57	1.45	0.00	3.43	2.13	—	—	2.11
1978	0.83	2.14	1.85	3.50	0.67	3.38	4.80	—	—	2.24
1979	1.82	4.67	2.73	1.33	2.50	0.67	3.00	8.00	1.54	2.59
1980	0.80	5.00	4.00	2.20	2.00	1.00	2.57	1.67	—	2.79

Table 8

Per cent females in Norwegian catches of minke whales off West Greenland, 1976–78.

Years		10-days periods starting									
		13/6	23/6	3/7	13/7	23/7	2/8	12/8	22/8	1/9	Total
1976–78	No. ♂♂	2	3	0	5	2	11	19	2	—	44
	No. ♀♀	8	60	23	13	8	43	14	3	—	172
	% ♀♀	80	95	100	72	80	80	42	60	—	80
1979–80	No. ♂♂	5	15	5	0	4	1	3	5	6	44
	No. ♀♀	7	26	30	13	8	1	9	8	4	106
	% ♀♀	58	63	86	100	67	50	75	62	40	71

however, it appears that the results of the age-readings are generally too low, independent of the mode of age reading.

2.4 Studies of reproduction

A total of 81 ovaries have been examined for reproductive condition.

2.4.1 Ovulation and pregnancy rates

Taking the presence of one or more *corpus luteum* or *albicans* in the ovaries as evidence of sexual maturity, 57 (70%) females were found to be sexually mature.

A *corpus luteum* of pregnancy considered to be active was found in 52 of the mature females giving a mean ovulation rate of 0.91. Two of the remaining females (K1980/25 and K1980/43) each had an exceptionally large *c. albicans* with a pigmentation different from the smaller *c. albicantia*. As the two animals also had a young *c. albicans* judged by the stage of regression to be of the last completed sexual cycle, it is tempting to assume that these two animals had in fact ovulated at the beginning of the current sexual cycle, but had failed to become fertilized. This would result in a mean ovulation rate of 0.95.

Only 50 of the 52 animals with a *c. luteum* had a macroscopically visible foetus giving an apparent pregnancy rate of 0.88. The *c. lutea* of the remaining two animals showed no signs of regression, and we believe that these two animals had ovulated and become pregnant quite recently which means that the apparent pregnancy rate should be 0.91. It should be noted that these two animals must have ovulated considerably later than would be expected from statements in the literature (Jonsgård, 1951; Slijper, 1962).

Of the 25 females in the combined 1979–80 material for which ovaries were not sampled a foetus was present in 23. The remaining two females measured 655 and 720 cm, and were considered to be immature. In the total sample of 81 females examined by the authors and 25 females for which presence or absence of a foetus was recorded by the crew, 80 (75%) were considered to be mature. Of these 75 were pregnant giving an apparent pregnancy rate of 0.94.

The values found by Christensen (1975) for the Norwegian catch at West Greenland in 1973 were 71% mature females and a pregnancy rate of 0.90, whereas he found 43.7% mature females and a pregnancy rate of 0.99 in the Barents Sea (Christensen, 1981). Mitchell and Kozicki (1975) found 34.1% mature females and a pregnancy rate of 0.857 in the Newfoundland catch.

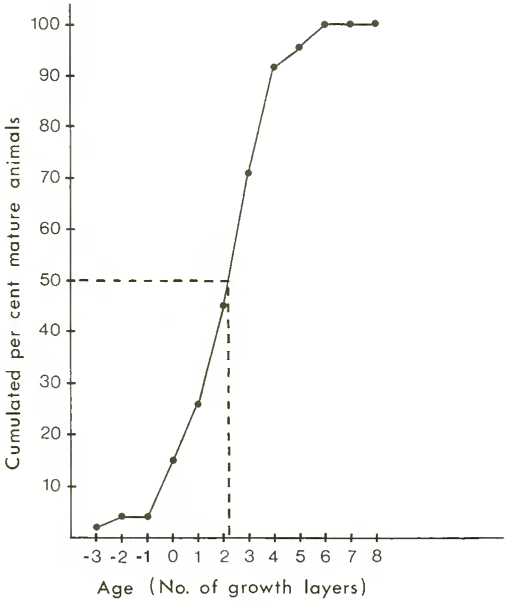

Fig. 13. Cumulated per cent mature females in each age group, using age determination based on primary layers only in the tympanic bulla. Age at 50% maturity: 2.2 years.

2.4.2. Age at sexual maturity

The mean age at sexual maturity of the females was estimated on the basis of each of the two sets of bulla age determinations under the following assumptions:

(1) *C. albicantia* accumulate in the ovaries and do not disappear.
(2) Only one *c. luteum* is formed at each ovulation.
(3) There is a regular, one-year cycle.

The results are given in Tables 9 and 10 and depicted in Figs 13 and 14. Mean age at sexual maturity was estimated at 2.2 growth layers on the basis of primary growth layers only, and at 3.7 growth layers on the basis of all growth

Table 9

Distribution of sexually mature females on the age at first ovulation. West Greenland 1979–80. Age determination based on counts of primary growth layers only.

Age	No. mature	No. total	Age at first ovulation −3	−2	−1	0	1	2	3	4	5	6	7	8
3	2	4		1	0	1	0	0	0					
4	5	11				2	1	1	0	1				
5	13	18	1	0	0	1	4	4	2	1	0			
6	14	18				1	0	2	8	3	0	0		
7	9	9						1	2	4	1	1	0	
8	4	5						1	0	1	1	1	0	0
Sum	47	65	1	1	0	5	5	9	12	10	2	2	0	0
Percentage sexually mature			2	2	0	11	11	19	26	21	4	4	0	0
Cumulated percentages			2	4	4	15	26	45	71	92	96	100	100	100

Table 10

Distribution of sexually mature females on the age at first ovulation. West Greenland 1979–80. Age determination based on counts of all growth layers.

			Age at first ovulation															
Age	No. mature	No. total	−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
3	1	1	1	0	0	0	0	0										
4	2	6			1	0	0	0	1									
5	5	9				1	3	1	0	0								
6	8	12			1	1	0	4	2	0	0							
7	10	12		1	0	0	1	3	2	2	1	0						
8	6	9							3	2	1	0	0					
9	5	6								1	3	1	0	0				
10	5	5									1	3	0	1	0			
11	0	0														0		
12	4	4									1	0	1	1	1	0	0	
13	1	1													1	0	0	0
Sum	47	65	1	1	2	2	4	8	8	5	7	4	1	2	2	0	0	0
Percentage sexually mature			2	2	4	4	9	17	17	11	15	9	2	4	4	0	0	0
Cumulated percentages			2	4	8	12	21	38	55	66	81	90	92	96	100	100	100	100

layers. As up to 15% of the animals have had their first ovulation before the first year of age according to Figs 13 and 14, it is obvious that both estimates are far too low suggesting that the results of the age-readings should be raised by at least 4–5 years.

Christensen (1981) estimated the age at sexual maturity of female minke whales in the Barents Sea at 7.1 bulla growth layers, whereas Mitchell and Kozicki (1975) found a value of 7.3 ear plug growth layers for the Newfoundland female minke whale.

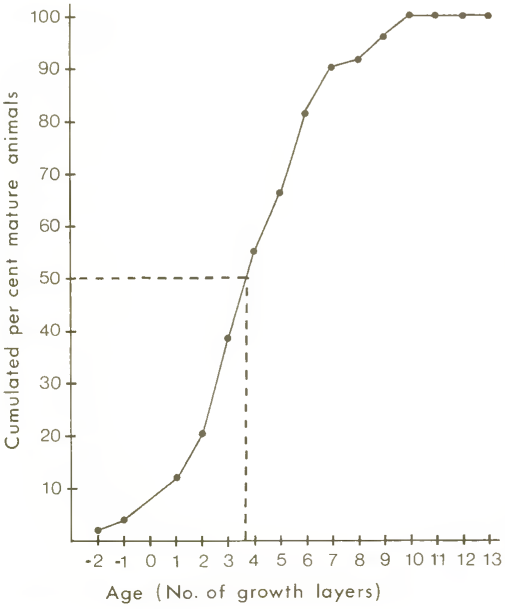

Fig. 14. Cumulated per cent mature females in each age group, using age determination based on all layers in the tympanic bulla. Age at 50% maturity: 3.7 years.

2.4.3 Foetal development

Total body lengths of the individual foetuses in the *Kato*-1979 and *Kato*-1980 samples in relation to the dates of capture are shown in Fig. 15 together with the growth curve presented in Sergeant (1963).

There is obviously a large variation in foetal length within the same time-period, probably reflecting a large variation in the individual dates of conception.

The foetal lengths of the *Kato*-1980 sample correspond reasonably well with Sergeant's growth curve, whereas the foetuses of the *Kato*-1979 sample are generally smaller. This indicates a difference in the mean date of conception between 1979 and 1980.

The sex ratio of the foetuses is estimated at 40% females on the basis of 43 foetuses of known sex. This sex ratio is, however, not significantly different from a 50 : 50 ratio (Chi Square Test: $p > 0.10$).

2.5 Feeding

Information on feeding is available for 32 animals in the 1980 sample. Of these 30 had fed on sand eel (*Ammodytes*), one on small unidentified fish, and the last one on krill. The conclusion indicated by the 1979-sample that sand eel is an important food item for minke whales in offshore areas of West Greenland, is thus supported by the 1980-sample.

Nematode parasites were found in three stomachs. These parasites have not been identified to species, and a sample was taken from only one whale.

CONCLUSIONS

The 1980 season offered good opportunities for collection of data on the Norwegian catch of minke whale off West Greenland, and for collecting specimens for biological studies of the stock. Danish scientists who stayed on board during the major part of the cruise recorded detailed information on weather and catching activities, and 71 of 75 minke whales caught were thoroughly examined. Furthermore, some relevant information on the 1976–79 seasons was obtained from a study of the ship's log books which were made available.

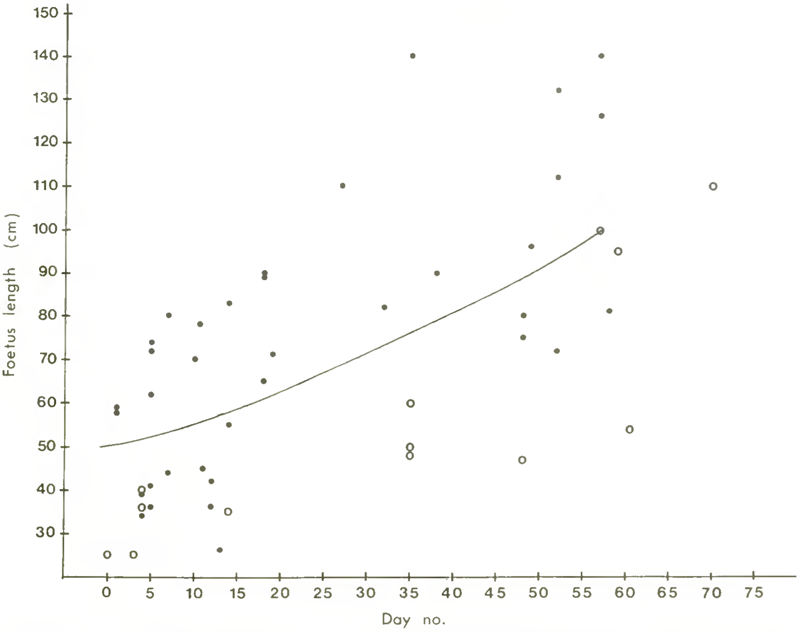

Fig. 15. Length of foetuses of minke whales caught off West Greenland, 1979 (○) and 1980 (●) compared with data from Sergeant's growth curve (1963). Day No. 0 = 27th June.

Analyses of these data show that 1980 was a reasonably good season although adverse weather conditions (especially fog) hindered operation for short periods, particularly in early August. The catch per unit of effort measured as catch per 100 nautical miles sailed or catch per day of good weather appears to be the same for the season as a whole as in previous seasons or slightly higher.

The ratio of females to males in the Norwegian catch of minke whales in 1980 (83 : 17) was similar to that found for this stock in previous studies (Christensen, 1975; Kapel, 1980). An analysis of the possible segregation of sexes in respect to time and place did not lead to convincing results.

According to measurements carried out in 1979 and 1980 and estimates available for previous seasons the mean length of minke whales caught off West Greenland is in the order of 750–765 cm, and the length distribution not significantly different for males and females. This is in agreement with the findings of Christensen (1975), who concluded that the difference in length-group frequencies between animals caught off West Greenland, and animals caught in the eastern part of the North Atlantic might be taken as evidence of separate stocks. However, this conclusion assumes that the differences are not just caused by segregation of animals of different size, sex, and age, and implies that the age of the animals is accurately known.

Unfortunately, the ageing method applied in the present study has given results which are inconsistent with the result of the studies of reproduction. The ages obtained have generally been too low by at least 4–5 years. Whether this difference is real or is a result of failures in the ageing method has not been possible to verify.

The analysis of female reproductive tracts shows that the percentage of sexually mature females in the catch of minke whales off West Greenland in 1979 and 1980 was the same as that found by Christensen (1975) as opposed to much lower values found in the Barents Sea (Christensen, 1981), and off Newfoundland (Mitchell and Kozicki, 1975).

The mean ovulation rate found in this study is at least 0.91, and possibly as high as 0.95.

The apparent pregnancy rate found in this study is 0.91 (possibly as high as 0.94), very much the same value as calculated by Christensen (1975) for this stock, but higher than the values found by Mitchell and Kozicki (1975) for the Newfoundland stock, and lower than the value found by Christensen (1981) for the Barents Sea minke whale.

The age at sexual maturity of the female minke whale at West Greenland is estimated in this study at 2.2 growth layers or 3.7 growth layers depending on the mode of age reading. It is considered, however, that these values are far too low to reflect the real age, probably due to deficiencies in the age determination.

Information on foetal length (50 specimens) shows that the *Kato*-1979 foetuses are generally smaller than those of the *Kato*-1980 sample at the same date. This indicates an earlier mean date of conception in 1980 than in 1979, but the reason for this is not known. The sex ratio of the foetuses is not different from a 50 : 50 ratio.

In summary, among the studies necessary for evaluating the status of the West Greenland stock of minke whales a crucial point is the development of a method for accurate age determination. The interpretation of other biological material is depending on the reliability of these determinations.

Another crucial point is collecting of data to elucidate the degree of segregation by sex and age, and the delineation between this stock and neighbouring stocks. Extensive marking may be the solution to these problems, especially if modern marking techniques are used.

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Without the kind assistance of the owners and crew of the Norwegian vessel *Kato* it would not have been possible to collect the data which form the basis of this paper. We wish to express our gratitude for this help.

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REFERENCES

Christensen, I. 1975. Preliminary report on the Norwegian fishery for small whales: Expansion of Norwegian whaling to Arctic and North-west Atlantic waters, and Norwegian investigations of the biology of small whales. *J. Fish. Res. Bd Can.* 32 (7): 1083–94.

Christensen, I. 1980. Catch and effort in the Norwegian Minke Whale Fishery in the 1978 Whaling Season. *Rep. int. Whal. Commn* 30: 209–12.

Christensen, I. 1981. Age determination of minke whales, *Balaenoptera acutorostrata*, from laminated structures in tympanic bullae. *Rep. int. Whal. Commn* 31: 245–53.

Christensen, I. 1982. Catch and effort and the sex composition in the Norwegian minke whale fishery 1976–1980. Paper SC/33/Mi2 (published in this volume).

Jonsgård, Å. 1951. Studies of the Little Piked Whale or Minke Whale (*Balaenoptera acutorostrata* Lacépède). Report on Norwegian investigations carried out in the years 1943–50. *Norsk Hvalfangsttid.* 40 (5): 209–32.

Kapel, F. O. 1980. Sex ratio and seasonal distribution of catches of minke whales in West Greenland. *Rep. int. Whal. Commn* 30: 195–9.

Kapel, F. O. and Larsen, F. 1982. Whale sightings from Norwegian small-type whaling vessel off West Greenland, June-August 1980. Paper SC/33/O 12 (published in this volume).

Larsen, F. and Kapel, F. O. 1981. Collection of biological material of minke whales off West Greenland, 1979. *Rep. int. Whal. Commn* 31: 279–85.

Mitchell, E. and Kozicki, V. M. 1975. Supplementary information on minke whale (*Balaenoptera acutorostrata*) from Newfoundland fishery. *J. Fish. Res. Bd Can.* 32 (7): 985–94.

Sergeant, D. E. 1963. Minke whales, *Balaenoptera acutorostrata* Lacépède, of the Western North Atlantic, *J. Fish. Res. Bd Can.* 20: 1489–504.

Simonsen, V., Kapel, F. and Larsen, F. 1982. Electrophoretic variation in the minke whale, *Balaenoptera acutorostrata* Lacépède. Paper SC/33/Mi6 (published in this volume).

Slijper, E. J. 1962. *Whales.* Hutchinson & Co., Ltd., London. 475pp.

SC/33/Mi6

Electrophoretic Variation in the Minke Whale, *Balaenoptera acutorostrata* Lacépède

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ABSTRACT

Fifteen enzymes present in liver, muscle and kidney tissues of the minke whale, *Balaenoptera acutorostrata* Lacépède, have been studied by starch gel electrophoresis. Three of the enzymes are polymorphic, and the variation is in accordance with a simple genetic model assuming one locus with two codominant alleles. Two other enzymes express variation but the material is not sufficient for explaining the inheritance of the variation observed. All in all, the genetic variability seems to be low as in other large mammals.

INTRODUCTION

The aim of this paper is to present an electrophoretic investigation of fifteen enzymes found in liver, muscle and/or kidney tissues from the minke whale in order to see if the method can be useful for differentiating stocks in the northern Atlantic Ocean.

The minke whale is widespread in the northern Atlantic Ocean. Previous works on pregnancy rate in the area off West Greenland (Larsen and Kapel, 1981; Christensen, 1975) report that the pregnancy rate is around 0.90, and about 71–72% of all females captured are sexually mature. Comparative figures of 0.99 and 43.7% were found for the population in the Barents Sea (Christensen, 1981). Around Newfoundland the figures are 0.86 and 34.1% (Mitchell and Kozicki, 1975). The population off West Greenland seems to have a remarkably high level of mature females compared to the other areas.

The chromosomal number for the minke whale is $2n = 44$ (Árnason, 1972; Árnason *et al.*, 1977). The karyotypes of 17 cetaceans and 18 pinnipeds have been reported. Within the Cetacea only two different chromosomal numbers have been found, i.e. $2n = 44$ and $2n = 42$. The $2n = 42$ whale karyotypes have presumably evolved from the general $2n = 44$ karyotype through a fusion of two pairs of chromosomes (Árnason *et al.*, 1977). The orders Cetacea and Pinnipedia are both characterized by a remarkable stability of their karyotypic patterns. The phenomenon may be due to the reproductive biology of these species (Árnason, 1972), but other explanations are also possible (Bengtsson, 1980).

Previous studies of the minke whale by electrophoresis have not revealed any variation between individuals in haemoglobin, myoglobin and lactate dehydrogenase (Borisov, 1981a and 1981b) whereas studies of the minke whales of the Southern Hemisphere (Wada and Numachi, 1979) have shown that among forty investigated enzyme loci three were polymorphic. Liver samples from 2,418 individuals were analysed for these polymorphic enzymes. Judging from the three polymorphic enzymes the authors claimed that it is possible to recognize four genetic stocks in the Southern Hemisphere. This interpretation of the electrophoretic observations has been critically discussed (van Beek, 1981; van Beek and de la Mare, 1981; Wada, 1981a and 1981b). Analyses of additional polymorphic loci might help in solving the problem. In any case, the genetic variability in the minke whale seems to be low just as found for the polar bear (Allendorf *et al.*, 1979) and several other species of carnivores (Simonsen, 1981), both studies based on starch gel electrophoresis.

Low genetic variability has also been observed for the Macquarie Island elephant seal (McDermid, Anathakrishan and Agar, 1972) and the Northern elephant seal (Bonnell and Selander, 1974). One hundred and fifty nine Northern elephant seals have been studied for 24 loci and none of these were found to be polymorphic. The authors explain this observation as a result of a bottleneck effect: the Northern elephant seal was very close to extinction about a hundred years ago. In general, several species of mammals have been studied for genetic variation by electrophoresis, and all species show a very low level of variation compared to man.

MATERIALS AND METHODS

The minke whales were caught in an area off West Greenland between 65° and 71°N during two successive years. Liver, muscle, and kidney samples were removed as fast as possible from the killed animals and kept at −18°C until use. During the summer of 1979, 25 muscle samples were collected, and from 20 of these animals a liver sample was also taken. In the summer of 1980, 70 muscle samples were collected. From 64 of the animals a liver sample was taken, but only from 13 of these animals a kidney sample was removed and stored.

The method of analysis used was ordinary horizontal starch gel electrophoresis with procedures and staining methods as described by Simonsen (1981).

RESULTS

The results of the analysis of the minke whales were as follows:

Acid phosphatase (ACP). The zymogram consists of one faintly stained band in liver and in kidney tissue, and three faintly stained bands in muscle tissue. No variation between animals was observed.

Adenosine deaminase (ADA). The sample from 1979 shows only one faintly stained band in liver and in muscle tissue, whereas the muscle samples from 1980 reveal a three-banded zymogram, which is the same for all the individuals tested. A similar zymogram is seen in the kidney sample. In liver samples from 1980 three other zones of activity are expressed. Two of them show a correlated polymorphism, i.e. if one zone consists of two bands, then the other does that, too; if one shows the slower anodic migrating band, then the other zone does that, too; etc. The results are interpreted as being due to one locus with two codominant alleles which causes activity in one zone, and a non-variable modification of the gene product which causes activity in the other zone. The genotypic distribution is 21 individuals with the faster anodic migrating allele only, 32 individuals with both alleles expressed, and 11 individuals with the slower anodic migrating allele only. The frequency of the faster anodic migrating allele is 0.578, and the genotypic distribution fits well to the expected Hardy-Weinberg proportions ($X^2 = 0.040$ with one degree of freedom which implies $0.80 < P < 0.90$).

Adenylate kinase (AK). All three tissues express one heavily stained band and two faintly stained bands. No variation is found.

Catalase (CAT). Liver reveals one band without variation among the animals. No activity is observed in muscle and in kidney tissues.

Diaphorase (DIA). Muscle tissue shows one faint but distinct band, whereas liver and kidney tissues show two bands with variable activity. With respect to the migration rate no variation is seen.

Esterase (EST). All three tissues reveal two zones of activity. There is no variation among the individuals.

Glucose-6-phosphate dehydrogenase (G6PD). The zone found in liver shows a smear of activity on the gel. However, muscle tissue and kidney tissue both reveal one faint band without variation in migration among the whales studied.

Glutamin-oxaloacetic transaminase (GOT). Two bands found in the zymograms from the three different tissues. No variation in migration rate is observed.

Glutamin-pyrovic transaminase (GPT). No activity is found in liver or in kidney tissue. Muscle tissue expresses one heavy band and two additional, but weaker bands. No variation among the individuals is found.

Isocitrate dehydrogenase (ICD). In all three different tissues two bands are found, but again no variation.

Lactate dehydrogenase (LDH). All three tissues express, as in other mammals, a five-banded zymogram. The common interpretation is that two loci are involved in building up a tetrameric molecule. The two loci are named Ldh A and Ldh B, and the bands are determined by 4 A subunits, 3 A + 1 B subunits, 2 A + 2 B subunits, 1 A + 3 B subunits, and 4 B subunits. The enzyme with 4 A subunits migrates towards the cathode. Three individuals in our investigation, No. 790905/3, No. K 1980/38, and No. K 1980/44, have a slightly slower migrating band corresponding to 4 A subunits. Then, if the genetic model is correct, there should be two different alleles at the A locus. The surprising observation is that no heterozygous individuals are observed, and an explanation for the observation is then that one of the alleles is dominant to the other. Furthermore, the individual K 1980/44 has a slower migrating form of the Ldh 4 B band, but no heterozygotes in the Ldh B locus are seen. Here again a possible genetic explanation is that the Ldh B locus possesses two alleles, one dominant and one recessive.

Malate dehydrogenase (MDH). All three different tissues reveal two zones of activity, each with a heavily stained band and one or two additional weaker stained bands. The same three individuals as described in the previous paragraph have a slightly faster migrating form of the cathodic band determined by Mdh II locus. The observed variants in LDH and MDH are depicted in Fig. 1.

Peptidase (PEP). In muscle tissue activity in two zones is found, one consisting of a single faint band and the other of two heavily and one faintly stained band. In liver and kidney only the three bands corresponding to the second zone in muscle tissue are found. Two heterozygotes in the second zone have been observed.

6-phosphogluconate dehydrogenase (PGD). Neither liver nor kidney tissue reveal any distinct zymogram, whereas muscle tissue expresses three different zymograms. The variation is interpreted as being due to differences between two codominant alleles of one locus. When the two samples, collected in 1979 and 1980 respectively, are tested for homogeneity, the X^2 test value with two degrees of freedom is 0.739, $0.60 < P < 0.70$, and therefore the two samples are pooled. In total 41 individuals have been observed with the fast anodic migrating allele only, 38 with both alleles, and 16 with the slow migrating allele only. The gene frequency of the faster migrating allele is 0.632, and the genetypic distribution fits well to the expected Hardy-Weinberg proportions ($X^2 \times 1.875$ with one degree of freedom, $0.10 < P < 0.20$).

Phosphoglycerate kinase (PGK). Activity is found in all three tissues, but the zymogram is only distinct in muscle tissue and consists of two bands. No variation among the individuals is observed.

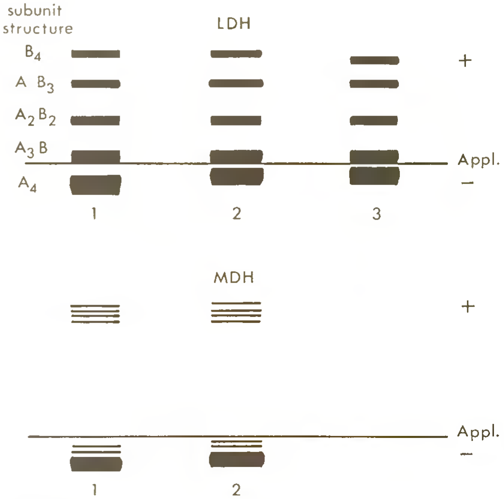

Fig. 1. Zymogram of lactate dehydrogenase (LDH) and of malate dehydrogenase (MDH) in minke whales. Slot 1: normal zymogram; slot 2: individual no. K 1980/38; slot 3: individual no. K. 1980/44.

DISCUSSION

Only five enzymes out of fifteen show variation. The variation for three of the enzymes is in accordance with a genetic model assuming one locus with two codominant alleles; the three enzymes are ADA, PEP, and PGD. The variation found in LDH and MDH is strange. A possible genetic model would be that there is one locus with two alleles, one allele dominant and the other recessive, for each of the two enzymes. However, the variation in LDH A and MDH II is correlated. Another genetic model which could explain this situation is that the variation is due to post translational modification of the gene products from both loci, but on the basis of the present data other suggestions can also be presented.

For only two loci, PGD and GOT, is it possible to compare the minke whale population off West Greenland to the populations of the Southern Hemisphere. The frequency of the most common allele of the PGD locus is 0.632 for the population off West Greenland and 0.662–0.728 for the populations of the Southern Hemisphere (Wada and Numachi, 1979). If the two alleles are identical it seems as if there is only a small difference between the two populations. Furthermore, there is no evidence for the population off West Greenland being a mixture of different sub-populations.

The deficiency of heterozygotes at the PGD locus is far too small to be of statistical importance. The GOT locus has nearly the same gene frequency of the most common allele in the different populations of the Southern Hemisphere, i.e. 0.994–0.962 and is monomorphic for the population off West Greenland. More polymorphic loci and a comparison of the alleles between the populations are needed to determine if the populations are genetically different.

The fraction of polymorphic loci in the present study is 0.095 based on the 99% criterion for polymorphism. The genetic interpretation for the individual enzymes is listed in Table 1. The calculated heterozygosity is 0.046 ± 0.01. This value is rather low compared to human heterozygosity (Bruce and Ayala, 1979), but is in the same range as values found for several carnivores (Simonsen, 1982). As in the case of the Northern elephant seal (Bonnell and Selander, 1974) a possible explanation of the low level of genetic variation could be a bottleneck effect as a result of near extinction of the species. But since several genetic models will lead to the same observation, it is not possible to explain why the genetic variation is low on the basis of the present investigation.

Table 1

Enzymes studied, loci involved in determination of the enzymes and number of alleles.

Enzyme	Locus	Number of alleles
ACP	*Acp*	1
ADA	*Ada*	2
AK	*Ak*	1
CAT	*Cat*	1
DIA	*Dia*	1
EST	*Est I*	1
	Est II	1
G6PD	*G6pd*	1
GOT	*Got I*	1
	Got II	1
GPT	*Gpt*	1
ICD	*Icd I*	1
	Icd II	1
LDH	*Ldh A*	1*
	Ldh B	1*
MDH	*Mdh I*	1
	Mdh II	1*
PEP	*Pep I*	1
	Pep II	2
PGD	*Pgd*	2
PGK	*Pgk*	1
Σ	21	24

* Counted as one allele because of the unknown genetic explanation.

In conclusion, the fifteen enzymes from the minke whales, studied by starch gel electrophoresis, show a limited amount of genetic variation, less than in human populations but of the same level as for many other large mammals.

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REFERENCES

Allendorf, F. W., Christiansen, F. B., Dobson, T., Eanes, W. F., and Frydenberg, O. 1979. Electrophoretic variation in large mammals. I The polar bear, *Thalassarctos maritimus*. *Heriditas* 91: 19–22.

Árnason, U. 1972. The role of chromosomal rearrangement in mammalian speciation with special reference to Cetacea and Pinnipedia. *Hereditas* 70: 113–18.

Árnason, U., Benirschke, K., Mead, J. G., and Nichols, W. W. 1977. Banded karyotypes of three whales: *Mesophodon europaeus*, *M. carlhubbsi*, and *Balaenoptera acutorostrata*. *Heriditas* 87: 189–200.

Bengtsson, B. O. 1980. Rates of karyotype evolution in placental mammals. *Hereditas* 92: 37–47.

Bonnell, M. L. and Selander, R. K. 1974. Elephant seals: Genetic variation and near extinction. *Science* 184: 908–9.

Borisov, V. I. 1981a. A comparative analysis of electrophoretic spectro of proteins in whales of Antarctic region. 1. Hemoglobins and myoglobins of 3 species of baleen whales and sperm whales. *Zoo. Zh.* 60: 438–42.

Borisov, V. I. 1981b. A comparative analysis of electrophoretic spectra of proteins in the Antarctic whales. 2. Lactate dehydrogenase of three species of baleen whales and sperm whales. *Zool. Zh.* 60: 595–600.

Bruce, E. J. and Ayala, F. J. 1979. Phylogenetic relationships between man and apes: Electrophoretic evidence. *Evolution* 33: 1040–56.

Christensen, I. 1975. Preliminary report on the Norwegian Fishery for small whales: Expansion of Norwegian whaling to Arctic and Northwest Atlantic waters, and Norwegian investigations of the biology of small whales. *J. Fish. Res. Bd Can.* 32: 1083–94.

Christensen, I. 1981. Age determination of minke whales, *Balaenoptera acutorostrata*, from laminated structures in tympanic bullae. *Rep. int. Whal. Commn* 31: 245–53.

Larsen, F. and Kapel, F. 1982. Norwegian minke whaling off West Greenland, 1976–1980, and data on biological parameters. Paper SC/33/Mi5 (published in this volume).

McDermid, E. M., Anathakrishan, R., and Agar, N. S. 1972. Electrophoretic investigation of plasma and red cell proteins and enzymes of Macquarie Island Elephant Seals. *Anim. Blook Grp. Biochem. Gen.* 3: 85–94.

Mitchell, E. and Kozicki, V. M. 1975. Supplementary information on minke whale (*Balaenoptera acutorostrata*) from Newfoundland fishery. *J. Fish. Res. Bd Can.* 32: 985–94.

Sergeant, D. E. 1963. Minke whales, *Balaenoptera acutorostrata* Lacépède, of the western North Atlantic. *J. Fish. Res. Bd Can.* 20: 1489–1504.

Simonsen, V. 1982. Electrophoretic variation in large mammals. II. The red fox, *Vulpes vulpes*, the stoat, *Mustela erminea*, the weasel, *Mustela nivalis*, the pole cat, *Mustela putorius*, the pine marten, *Martes martes*, the beech marten, *Martes foina*, and the badger, *Meles meles*. *Hereditas* 96(2) (submitted).

van Beek, J. G. 1981. A review of the morphological and biochemical research on stock identification of southern minke whales. Paper SC/Jn 81/MiS3 (published in this volume).

van Beek, J. G. and de la Mare, W. K. 1981. A statistical review of the biochemical evidence for minke whale stock identity in the Antarctic. *Rep. int. Whal. Commn* 31: 114.

Wada, S. 1981a. Homogeneous results can be obtained even in a sample taken from plural distinct stocks. *Rep. int. Whal. Commn* 31: 114–15.

Wada, S. 1981b. Analysis of the biochemical data by G-statistics. Paper SC/33/Rep 3, appendix 4 (published in this volume).

Wada, S. and Numachi, K. 1979. External and biochemical characters as an approach to stock identification for the Antarctic minke whale *Rep. int. Whal. Commn* 29: 421–32.

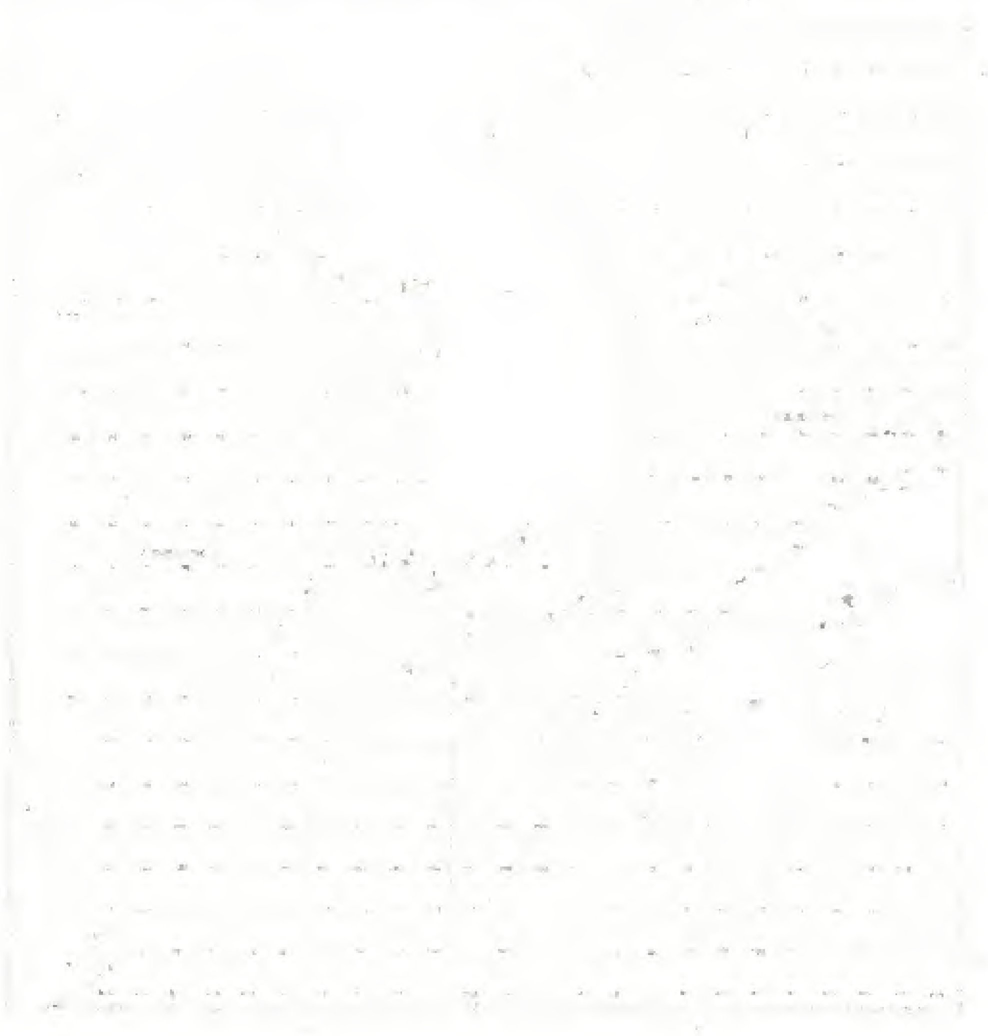

Table 1

Monthly minke whale catch by sea block in Korean waters, 1980.

Sector	Sea Block	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Total
Western	98		1		3					4
	99	4	8	1	4					17
	159		5			1				6
	160	3	11	8	7	3				32
	161	7	10	8	9	3				37
	162	13	14	15	5	17	2			66
	163	1		1		3				5
	167						1			1
	168					1				1
	169		15	11	11	16	10			63
	170		16	18	21	29	9	1		94
	171	8	18	19	18	11	9	12		95
	172	10	32	39	26	15	10			132
	173		9	11	6	6	7			39
	178						1			1
	179		2			2	3			7
	180		3	2	8	11	6			30
	181		8	1	3	5	11	6		34
	182		1	1	2	1	8	1		14
	183							1		1
	189						2			2
	190		2			1	1	1		5
	191						2			2
	201							2		2
Sub-total		46	155	135	123	125	82	24		690
Eastern	65							1		1
	70					1		3	3	7
	72							5		5
	76			1		1		1		3
	77			2	1			4		7
	78							2		2
	79							1		1
	82			10	2	1	2	3		18
	83			8	3			9		20
	84							2		2
	85							1		1
	87			11	4	1	2	11	22	51
	88			9	1			19	18	47
	89							3	3	6
	92			1	1					2
	93			15	1		1	16	6	39
	94			7	1			14	1	23
Sub-total				64	14	4	5	95	53	235
Total		46	155	199	137	129	87	119	53	925

Table 2

Monthly minke whale catch, effort and CPUE by sector in Korean waters, 1980.

	Total			Western Sector			Eastern Sector		
Month	Number of boats	Animal	CPUE	Number of boats	Animal	CPUE	Number of boats	Animal	CPUE
March	15	46	3.07	15	46	3.07	—	—	—
April	20	155	7.75	20	155	7.75	—	—	—
May	20	199	9.95	13	135	10.38	13	64	4.92
June	20	137	6.85	14	123	8.79	10	14	1.40
July	19	129	6.79	11	125	11.36	8	4	0.50
August	21	87	4.14	13	82	6.31	8	5	0.63
September	19	119	6.26	8	24	3.00	19	95	5.00
October	14	53	3.79	—	—	—	14	53	3.79
Total	21	925	44.05	21	690	32.86	21	235	11.19

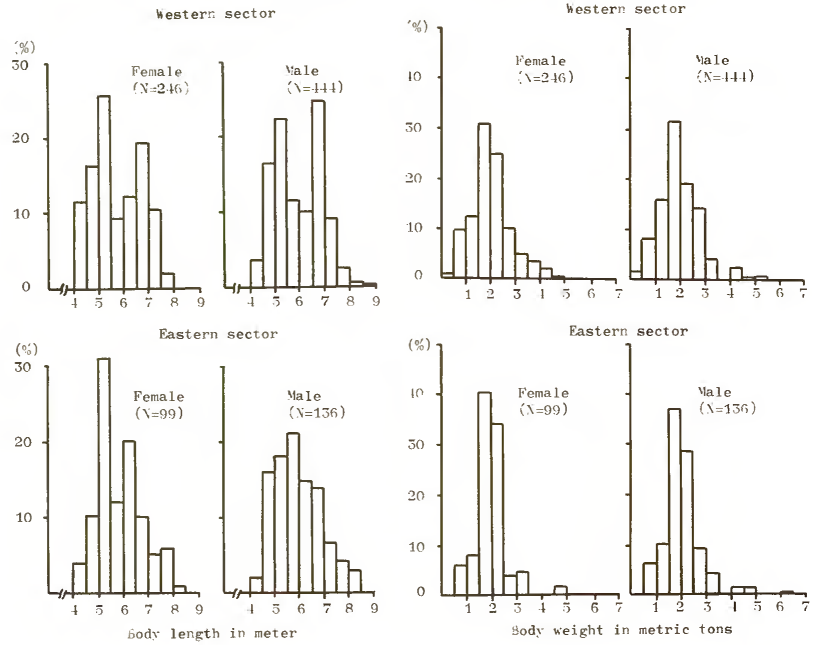

Fig. 3. Body length and body weight composition of minke whale taken in Korean waters, 1980.

Table 3

Monthly size of minke whale by sex in Korean waters, 1980.

Sector	Items	March	April	May	June	July	August	September	October	Total
Western	Catch	46	155	135	123	125	82	24	—	690
	Sex, F/M	20/26	53/102	46/89	44/79	46/79	27/55	10/14	—	246/444
	Sex ratio	1 : 1.30	1 : 1.92	1 : 1.93	1 : 1.80	1 : 1.72	1 : 2.04	1 : 1.40	—	1 : 1.80
	Mean length (m)	6.49	5.77	5.75	5.82	5.94	6.04	6.41	—	5.91
	Mean weight (kg)	2,739	2,011	1,956	2,010	2,012	2,139	2,020	—	2,065
Eastern	Catch	—	—	64	14	4	5	95	53	235
	Sex, F/M	—	—	25/39	5/9	/4	2/3	43/52	24/29	99/136
	Sex ratio	—	—	1 : 1.56	1 : 1.80	—	1 : 1.50	1 : 1.21	1 : 1.21	1 : 1.37
	Mean length (m)	—	—	5.73	5.73	5.30	5.52	6.11	6.13	5.96
	Mean weight (kg)	—	—	2,177	1,975	1,783	1,890	2,072	2,000	2,069
All areas	Catch	46	155	199	137	129	87	119	53	925
	Sex F/M	20/26	53/102	71/128	49/88	46/83	29/58	53/66	24/29	345/580
	Sex ratio	1 : 1.30	1 : 1.92	1 : 1.80	1 : 1.80	1 : 1.80	1 : 2.00	1 : 1.25	1 : 1.21	1 : 1.68
	Mean length (m)	6.49	5.77	5.75	5.79	5.92	6.01	6.17	6.13	5.92
	Mean weight (kg)	2,739	2,011	2,027	2,007	2,005	2,125	2,061	2,000	2,066

SC/33/Mi8

Minke Whales in the Coastal Waters of Japan, 1980 and a Population Assessment of the Okhotsk Sea – West Pacific Stock

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OPERATIONS IN 1980

Small-type whaling was carried out by eight catcher boats in the coastal waters of Japan in 1980 (Table 1). Over 90% (379) of the animals taken were minke whales.

The 1980 season was the first under a 5 year block quota set for this stock: the total catch in the years 1980–84 should not exceed 1,678 (average: 335.6 whales) with an upper limit of 421 in any one year. Most of the minke whales (364) were taken in Regions A, B and C, and thus from the Okhotsk Sea – West Pacific stock. The other 15 whales were caught from region G, which is in the Sea of Japan-Yellow Sea stock (Table 2). Fig. 1 shows the positions of minke whales caught in Japanese coastal waters in 1980. The whaling areas have remained similar in recent years (c.f. Ohsumi, 1980; 1981).

Table 3 shows the operation times and the CPUE represented as the number of minke whales caught per operation hour, by region and by month in 1980. Data for 1977 to 1979 were presented by Ohsumi (1980; 1981). CPUE data of this kind have only been collected for four years; they reveal no trend.

Only one of the eight catcher boats did not use a motor boat for chasing. The efficiency of motor boats was estimated to be at most 1.95 times that of non-motor boats (Ohsumi, 1980). Therefore the efficiency of boats in 1980 was calculated to be 1.83, and from this, tonnage and motor boat corrected CPUE of the Okhotsk Sea – West Pacific stock in 1980 was 0.648.

YEARLY CHANGE IN CPUE

Fig. 2B shows the yearly change in CPUE corrected for size of catcher boats (tonnage) and efficiency. Regression analysis reveals a small (but not statistically significant) trend of increase (slope = 0.0054; t = 0.925). There is clearly no significant decrease over the time period.

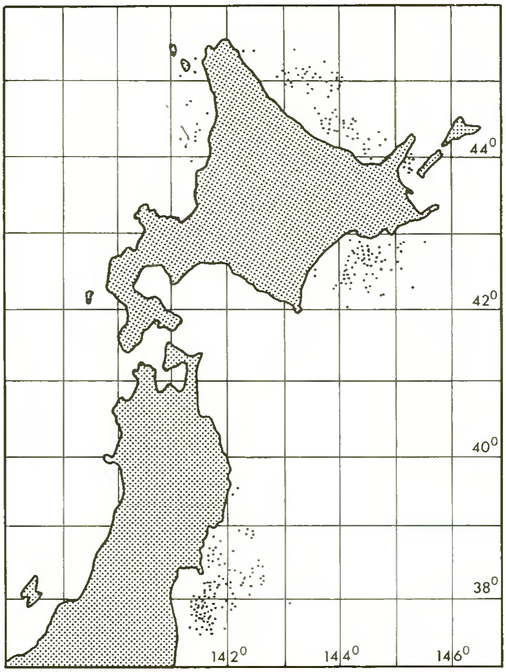

Fig. 1. Positions of minke whales caught in 1980.

Table 1

Number of catcher boats and whales caught in the small-type whaling in 1980.

Catcher boat		Number of whales caught					
Name	Tonnage	Minke	Baird's	Cuvier's	Killer	Pilot	Total
Yasumaru No. 1	44.55	60	—	—	—	—	60
Takashimamaru No. 8	46.21	56	—	—	—	—	56
Taishyomaru	42.35	53	—	—	—	—	53
Taishyomaru No. 2	45.39	53	—	—	—	—	53
Koeimaru No. 7	36.99	55	—	—	—	—	55
Sumitomomaru No. 11	42.22	35	14	—	—	—	49
Sumitomomaru No. 21	34.09	40	10	—	—	—	50
Katsumaru	15.20	27	7	—	2	1	37
Total	307.00	379	31	—	2	1	413

Table 2

Number of minke whales caught in each region by small-type whaling in 1980.

Region	Males	Females	Total
A	39	82	121
B	72	13	85
C	88	70	158
G	10	5	15
Total	209	170	379

A: Okhotsk Sea, B: Hokkaido, Pacific side, C: Sanriku, G: Hokkaido, Japan Sea side.

CATCH HISTORY OF THE OKHOTSK SEA – WEST PACIFIC STOCK

Although Norwegian whaling methods and equipment were introduced to Japan in the 1890s, the first reported catches of minke whales were given by Matsuura (1936) for the period 1932–35. According to his paper, the main minke whaling ground was around Korea, and only 7 whales were caught on the Okhotsk and Pacific sides of Hokkaido in the 3 years, 1932–34. Thus minke whales of the Okhotsk Sea-West Pacific stock began to be taken by large type whaling boats in 1932 at the latest but the average annual catch was only 2–3 animals. Matsuura (1936) noted that the economic value of the minke whale was small compared with other larger whales and that it was quite difficult to catch. He also reported that some small whaling catcher boats operated from Akukawa (Miyagi Prefecture) in the 1930s, and that they took about 20–30 minke whales annually. Matsuura (1943) presented catch statistics of whales taken by small-type whaling boats in 1941, and noted that 22 minke whales were caught by 6 catcher boats in only the Sanriku Region (Region C).

Mr Y. Kikuchi (pers. comm.), reported that a small-type catcher boat (*Yukomaru* 7 GRT) first took minke whales from Akukawa in 1930, and that the number of this type of catcher boat gradually increased after then. Small-type whaling for minke whales was also carried out from Kamaishi Port (Iwate Prefecture) from 1938. The number of small-type catcher boats operating in the Sanriku Region before the end of World War II is shown in Table 4. They ranged from 7–24 tons in size, and pilot whales as well as minke whales were taken, but there are no reliable catch data. According to Matsuura (1936), 20–30 minke whales were caught annually in the early 1930s when 1–2 catcher boats were operating. Therefore the average catch per boat was between 15–20 whales annually. However, Matsuura (1943) reported that 22 minke whales were caught by 6 catcher boats in 1941–average annual catch 3.7 whales. In this paper I have taken a value of 11 as the average annual catch of the minke whales in this period (Table 4). Matsuura (1936) reported that 2–3 minke whales were caught each year by large-type whaling in Hokkaido annually. I have assumed that 2 minke whales were caught annually in the Hokkaido Region (Regions A and B) in this period.

Ohsumi (1975) presented catch statistics for minke whales since 1948 when governmental regulation was first established for small-type coastal whaling. These statistics included catches in the waters of Kyushyu and the Sea of Japan and these should be excluded if the data are to be used for the population assessment of minke whales of the Okhotsk Sea-West Pacific stock. Table 5 shows the yearly change in catches of the Okhotsk-West Pacific stock. The number of minke whales caught in 1946 and 1947 were estimated from the yearly change in the catch (Fig. 2A).

The minke whales of Okhotsk – West Pacific stock began to be exploited in 1930, and the annual catch gradually increased until the beginning of the 1950s. Since then the annual catch has been reasonably stable but with large annual fluctuations.

ESTIMATION OF YEARLY CHANGE IN POPULATION SIZE

There have been no previous attempts to estimate the size of the Okhotsk Sea-West Pacific minke whale stock. Neither sightings nor marking studies have been carried out

Table 3

Fishing effort, catch and CPUE of the minke whales in each region in 1980.

Region		April	May	June	July	August	Sept.	Total
A	N	2	2	5	5	5	5	5
	W	174.1	374.9	658.3	227.1	122.0	264.9	1,821.3
	C	8	44	40	7	9	13	121
	CPUE	0.046	0.117	0.061	0.031	0.074	0.049	0.066
B	N	—	—	1	5	5	6	6
	W	—	—	14.5	517.3	244.3	679.0	1,455.1
	C	—	—	0	35	10	40	85
	CPUE	—	—	0.000	0.068	0.041	0.059	0.058
C	N	6	6	5	5	2	—	6
	W	1,068.7	1,081.0	603.3	275.3	38.0	—	3,066.3
	C	69	45	32	12	0	—	158
	CPUE	0.065	0.042	0.053	0.044	0.000	—	0.052
G	N	—	—	1	1	1	—	3
	W	—	—	58.5	49.7	33.5	—	141.7
	C	—	—	5	5	5	—	15
	CPUE	—	—	0.085	0.101	0.149	—	0.106
Total	N	8	8	8	6	6	8	8
	W	1,242.8	1,455.9	1,334.6	1,069.4	437.8	943.9	6,484.4
	C	77	89	77	59	24	53	379
	CPUE	0.062	0.061	0.058	0.055	0.055	0.056	0.058

N: Number of catcher boats, W: Fishing effort (hrs), C: Number of minke whales caught, CPUE: Catch per unit of fishing effort.

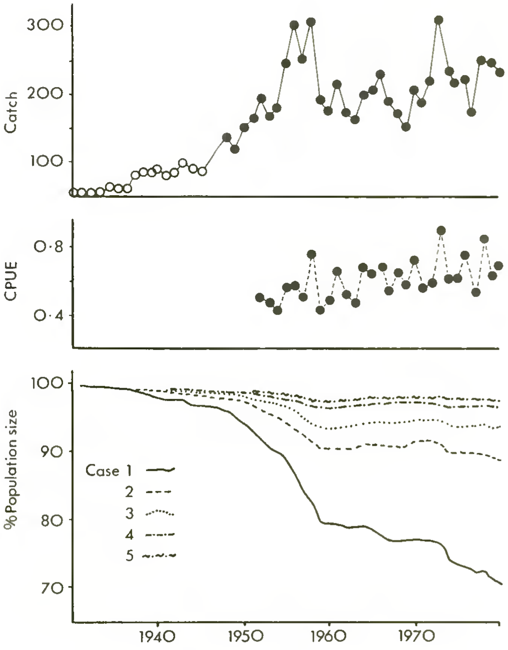

Fig. 2. Yearly change in catch. CPUE and relative population sizes of the Okhotsk Sea – West Pacific stock of minke whales.

for this stock. Assessment methods requiring CPUE are not applicable since there is no trend of decrease in the CPUE despite the long catch history shown in Table 5. In order to obtain some idea of the initial and present population sizes I have attempted to simulate the yearly changes in population size by using the available catch data and several arbitrary chosen initial population sizes and comparing the resultant trajectories with the recent CPUE data.

Table 4

Number of catcher boats and estimated number of minke whales in Regions A, B and C in the pre-war period.

Year	Region C		Regions A and B	Total
	Boats	Whales	Whales	Whales
1930	1	11	2	13
1931	1	11	2	13
1932	1	11	2*	13
1933	1	11	3*	14
1934	2	22	2*	24
1935	2	22	2	24
1936	2	22	2	24
1937	5	55	2	57
1938	6	66	2	68
1939	6	66	2	68
1940	7	77	2	79
1941	5	55	2	57
1942	6	66	2	68
1943	9	99	2	101
1944	7	77	2	79
1945	6	66	2	68

* Actual figures.

Table 5

Yearly change in catch and population sizes of the minke whales of Okhotsk Sea-West Pacific stock.

Year	Catch	Cases of calculations				
		1	2	3	4	5
1930	13	10,000	20,000	30,000	50,000	70,000
1931	13	9,988	19.988	29,988	49,988	69.988
1932	13	9,978	19.978	29,978	49.978	69,978
1933	14	9,968	19,968	29,968	49,968	69.968
1934	24	9,958	19,958	29,958	49.958	69,958
1935	24	9,941	19,943	29,944	49.941	69,941
1936	24	9,927	19,933	29,934	49,927	69,928
1937	57	9,916	19,926	29,924	49,916	69,917
1938	68	9,878	19,891	29,895	49,878	69,878
1939	68	9,836	19,852	29,856	49,838	69,838
1940	79	9,799	19,818	29,820	49,805	69,807
1941	59	9,758	19,781	29,780	49,770	69,774
1942	68	9,741	19,767	29,762	49,761	69,765
1943	101	9,720	19,749	29,738	49,746	69,751
1944	79	9,674	19,705	29,686	49,704	69,711
1945	68	9,654	19,690	29,659	49,687	69,697
1946	96	9,648	19,689	29,648	49,682	69,697
1947	115	9,620	19,662	29,616	49,654	69,672
1948	171	9,579	19,620	29,574	49,562	69,632
1949	134	9,494	19,531	29,487	49,481	69,546
1950	199	9,395	19,484	29,444	49,443	69,502
1951	223	9,305	19,385	29,350	49.353	69,403
1952	288	9,204	19,276	29,246	49,252	69,292
1953	227	9,054	19,120	29,097	49,106	69,133
1954	262	8,975	19,036	29,025	49.031	69,047
1955	392	8.876	18,936	28,939	48,943	68,948
1956	502	8.673	18,739	28,751	48,757	68,754
1957	397	8,395	18,470	28,489	48,495	68,493
1958	512	8,234	18,332	28,251	48,363	68,366
1959	280	7,982	18,107	28,043	48,153	68,168
1960	253	7,962	18,118	28,074	48,191	68,224
1961	332	7,963	18,115	28,134	48,267	68,323
1962	238	7,886	18,124	28,124	48,275	68,369
1963	220	7,895	18,181	28,224	48,369	68,489
1964	301	7,920	18,250	28,319	48,473	68,608
1965	314	7,868	18,240	28,330	48,494	68,638
1966	363	7,808	18,220	28,324	48,503	68,649
1967	275	7,709	18,156	28,273	48,460	68,609
1968	239	7,698	18,178	28,304	48,493	68,647
1969	202	7,718	18,230	28,363	48,550	68,708
1970	309	7,768	18,310	28,450	48,629	68,794
1971	269	7,715	18,285	28,431	48,600	68,767
1972	337	7,703	18,297	28,452	48,607	68,777
1973	521	7,630	18,246	28,409	48,549	68,719
1974	364	7,398	18,032	28,204	48,329	68,494
1975	329	7,329	17.980	28,160	48,282	68,438
1976	340	7,293	17.962	28,152	48,282	68,416
1977	246	7,238	17.939	28,135	48,283	68,394
1978	400	7,266	18,002	28,210	48,378	68,484
1979	392	7,148	17,922	28,060	48,320	68,426
1980	364	7,045	17.856	28,018	48,270	68,381

The following assumptions were made for the simulation:

(1) the carrying capacity has remained constant;

(2) the population size changes in accordance with the following equation:

$$N_{t+1} = (N_t - C_t)(1 - M) + R_{t+1} \qquad (1)$$

where N is the exploitable population size, C is the catch, M is the natural mortality coefficient, R is recruitment and t is a given year;

(3)
$$R_{t+1} = r_{t-i} \cdot N_{t-i} \qquad (2)$$

where r is the recruitment rate and i is the age at recruitment;

(4) M for this stock is the same value, 0.095, as M for the Antarctic minke whale as estimated by Ohsumi (1979) and remains constant at each population level;
(5) r changes with population size as shown in Fig. 3: r = M at the initial population level and becomes 0.135 at 60% of the initial population;
(6) i is three years as estimated from the catch data and growth curve of the minke whale;
(7) the annual catches in Table 5 are correct.

The resultant trajectories for the five initial population sizes (1 = 10,000; 2 = 20,000 3 = 30,000; 4 = 50,000; 5 = 70,000) are shown in Fig. 2C and Table 5. Case 1 shows a steep decline in population size – and an 11.7% decrease between 1959 and 1980. This clearly does not correspond with the CPUE data. Case 2 also shows a declining population, although much less than the decline in Case 1—a 1.4% drop between 1959 and 1980. In view of the uncertainty of the assumptions and the fluctuations in the annual catches, it is not inconceivable that a 1.4% decline might be undetected in the CPUE. Cases 3, 4 and 5 show populations which have remained almost constant between 1959 and 1980 (−0.1%; +0.2%; +0.3% respectively). These trajectories clearly all correspond with the CPUE pattern obtained in the previous section, which revealed a slight (non-significant) increase.

From this analysis then, the present population size is at least 17,800 (Case 2) and possibly at least 28,000 (Case 3). As no other methods of directly assessing the population size are available for comparison it is impossible to choose between the estimates.

The whaling grounds form only a small part of the range of this stock which is thought to be widespread in the Okhotsk Sea, the north-western North Pacific and the western Bering Sea from spring to autumn. To estimate the population size using sightings methods therefore, a very large area must be covered; it would be very difficult for this to be carried out by small-type whaling operations. In addition, the whales are abundant in the fishing zones of the USA and USSR and their co-operation is essential. Similar problems apply to the use of mark recapture techniques as marking is generally carried out by scouting vessels.

For these reasons, a refinement of the technique I have outlined above would appear to be the most promising method of obtaining an estimate of the population size of this stock.

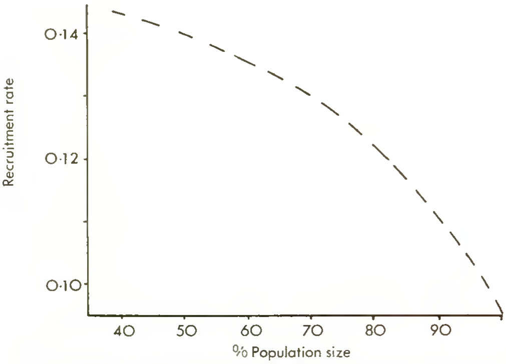

Fig. 3. Relationship between population level and recruitment rate for the calculation of the yearly change in population size and recruitment.

CLASSIFICATION AND CATCH LIMITS

From the previous section, it appears that the initial population is at least 20,000 and possibly at least 30,000. In the simulation model used, the population size (MSYL) which gives the maximum sustainable yield (MSY) is 60% of the initial population and the exploitation rate for MSY is 0.04. Assuming the model to be correct, then according to the IWC management procedure catch limits may be calculated as shown below:

	Case (2)	Case (3)
(A) Initial population	20,000	30,000
(B) Current population (1981)	17,821	28,010
(C) MSYL	12,000	18,000
(D) B/C (%)	148.5	155.6
Classification	IMS	IMS
Catch limit (i): 90% MSY	432	648
(ii): 5% initial	1,000	1,200

This stock has been classified in the past as a Sustained Management Stock based on the knowledge that the stock has a long history of exploitation and that the CPUE has remained relatively constant. As there have been no estimates of population size, MSYL and MSY, the catches have been set in accordance with the average catch in recent years.

The present assessment, albeit preliminary, suggests that the classification should be changed to IMS, and that the annual catch limit may be set at at least 432 and possibly at least 648.

Table 6

Estimated replacement yields of minke whales for 1981–85, under the condition that population sizes are the same as those in 1981.

Year	Case 1	Case 2	Case 3	Case 4	Case 5
Population size in 1981	6,974	17,823	28,009	48,245	68,365
1981	288	331	356	346	348
1982	281	329	353	351	354
1983	276	327	352	361	365
1984	269	325	349	372	378
1985	269	325	349	372	378
Average	276.6	327.4	351.8	360.4	364.6

In Table 7, the replacement yield was calculated to ensure that the 1981 population size is kept for the next 5 years, for each case. The current average yearly catch limit (335.6) is close to the RYs for cases 2–5.

REFERENCES

Matsuura, Y. 1936. On the lesser rorqual found in the adjacent waters to Japan. *Bull. Jap. Soc. Fish.* 4(5): 325–30 (in Japanese).

Matsuura, Y. 1943. *Marine Mammals.* Tennenshia, 289pp. (in Japanese).

Ohsumi, S. 1975. Review of Japanese small-type whaling. *J. Fish. Res. Bd Can.* 32(7): 1,111–21.

Ohsumi, S. 1979. Interspecies relationships among some biological parameters in cetaceans and estimation of natural mortality coefficient of Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 29: 379–406.

Ohsumi, S. 1980. Minke whales in the coastal waters of Japan, 1978. *Rep. int. Whal. Commn* 30: 307–12.

Ohsumi, S. 1981. Minke whales in the coastal waters of Japan, 1979. *Rep. int. Whal. Commn* 31: 307–11.

SC/33/Mi9

Icelandic Minke Whaling 1914–1980

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ABSTRACT

The paper describes the small-type whaling for minke whales (*Balaenoptera acutorostrata*) in the coastal waters off Iceland. Undocumented Icelandic catches since 1914 prior to official regulation of this whaling in 1974 are estimated and reported catches for the period 1974–80 are given. Before 1960 the annual catches were below 100 animals. The average annual catches for 1966–70, 1971–75 and 1976–80 were 105, 137 and 200 animals, respectively. During the past 20 years the annual catch has been around 200 animals when the Norwegian catches in the area are taken into account. The whale products have always been used for human consumption. Since 1977 an Icelandic catch quota of 200 animals has been set for this area and about 10 vessels have participated in the fishery each year. An analysis of the catch per unit effort for the period 1974–80 did not reveal any definite trends. The whales are caught mainly within 30 nautical miles off the coast of W-, N- and E-Iceland. More than 70% of the catches have been made off N-Iceland. Minke whales are most abundant off Iceland during July–September, but animals have been caught from the beginning of March to early December. In the period 1974–80, 53.4% of the catches were males. Females are more abundant during the first part of the season, while males are more abundant from July onwards.

INTRODUCTION

The purpose of the present paper is to give a brief description of the past and present minke whale fishery in Iceland.

Whaling for minke whales (*Balaenoptera acutorostrata*) along the Icelandic coast began in 1914 (Saemundsson, 1931). Since then the demand for minke whale meat for local consumption has steadily increased and resulted in a gradual increase in this limited coastal small-type whaling operation. Nevertheless this whaling has not been given much attention by fisheries biologists. Saemundsson (1931; 1937) gave some information on minke whaling for the period 1914–36, but since then and until 1974 when minke whaling was first regulated by the Icelandic Government, no official documentation of the catches made is available.

In this paper I have attempted to give some idea of the extent of the whaling activities. The catch estimates are mostly first hand, i.e. are based on information from gunners or skippers on minke whale catchers, or on private notes they have made regarding their catches in the past. Tens of people have thus been contacted and information on their activities documentated. Although this search has not covered every whaler who has operated since the start of minke whaling in Iceland, it has certainly covered the most active ones.

Since 1974 licences for minke whaling have been issued by the Ministry of Fisheries and from that time catch records are available. These catch records are discussed and the catch per unit effort in the most recent years analysed.

THE MINKE WHALE CATCHERS

Table 1 gives information on catchers in operation since 1914. Information on boats in operation during the period 1914–73 comes mainly from the gunners themselves or from local people related to minke whaling. Since 1974 the same information has been taken from catch records received from the whalers. Technical information on all vessels has been taken from the Annual Fishermen Catalogue (*Sjómannaalmanak*, published by the Icelandic Fisheries Organization every year since 1926). The operational area for each catcher is also given in the Table. Fig. 1 gives a rough division of the Icelandic coast into operational areas and shows the statistical divisions of the whaling grounds.

The first boat to begin minke whaling in Iceland was *Margrét ÍS 314* (Fig. 2), a powered 4 ton fishing vessel with a small steerhouse and a 1½ inch bore harpoon gun mounted on the bow. The harpoon gun was bought from Norwegian sealers who frequently came into Ísafjördur (NW-Iceland) on their way to and from Norway. It was produced in Birmingham, England and used to catch small whales on the way to and from the West Ice (E-Greenland), where the seals were killed in early spring. In 1923 this old gun was replaced by a new 2 inch bore harpoon gun produced in Norway. During 1917–47 *Margrét ÍS 314* mainly caught minke whales. Other vessels involved in this fishery in the same period were of a similar or somewhat larger size and they caught minke whales on a more opportunistic basis together with fishing.

The size of the vessels has gradually increased since the beginning of the catches. In 1970 the average size of the catchers in operation was 12.5 ton (6 catchers), in 1975 16.1 ton (9 catchers) and in 1980 18.9 ton (8 catchers). Fig. 3 shows two of the catchers now in operation. In 1976 one boat of 276 tons was allowed to catch minke whales but since then the Ministry of Fisheries has only issued licences to boats under 30 tons. The operational range of the vessels is therefore limited to the coastal waters, mainly within 30 nautical miles from the fjord inlets. Most of the boats currently operating are of wooden construction equipped with diesel engines (70–300 hp: average for the 1980 season, 179 hp) and armed with the Norwegian *Kongsberg* 50 mm harpoon gun (Fig. 4) with a two-claw harpoon, although 66 mm and 40 mm harpoon guns are also in use. In 1980 each catcher was also equipped with a high-powered rifle (Cal. 458) to ensure that the animals are killed as quickly as possible. At least since 1970, most of the catchers have either a crow's nest or some kind of a chair in the mast or on the roof of the steer house for spotting the whales. Sometimes the catcher can be manoeuvred from the spotting position. The vessels have a crew of three or four persons.

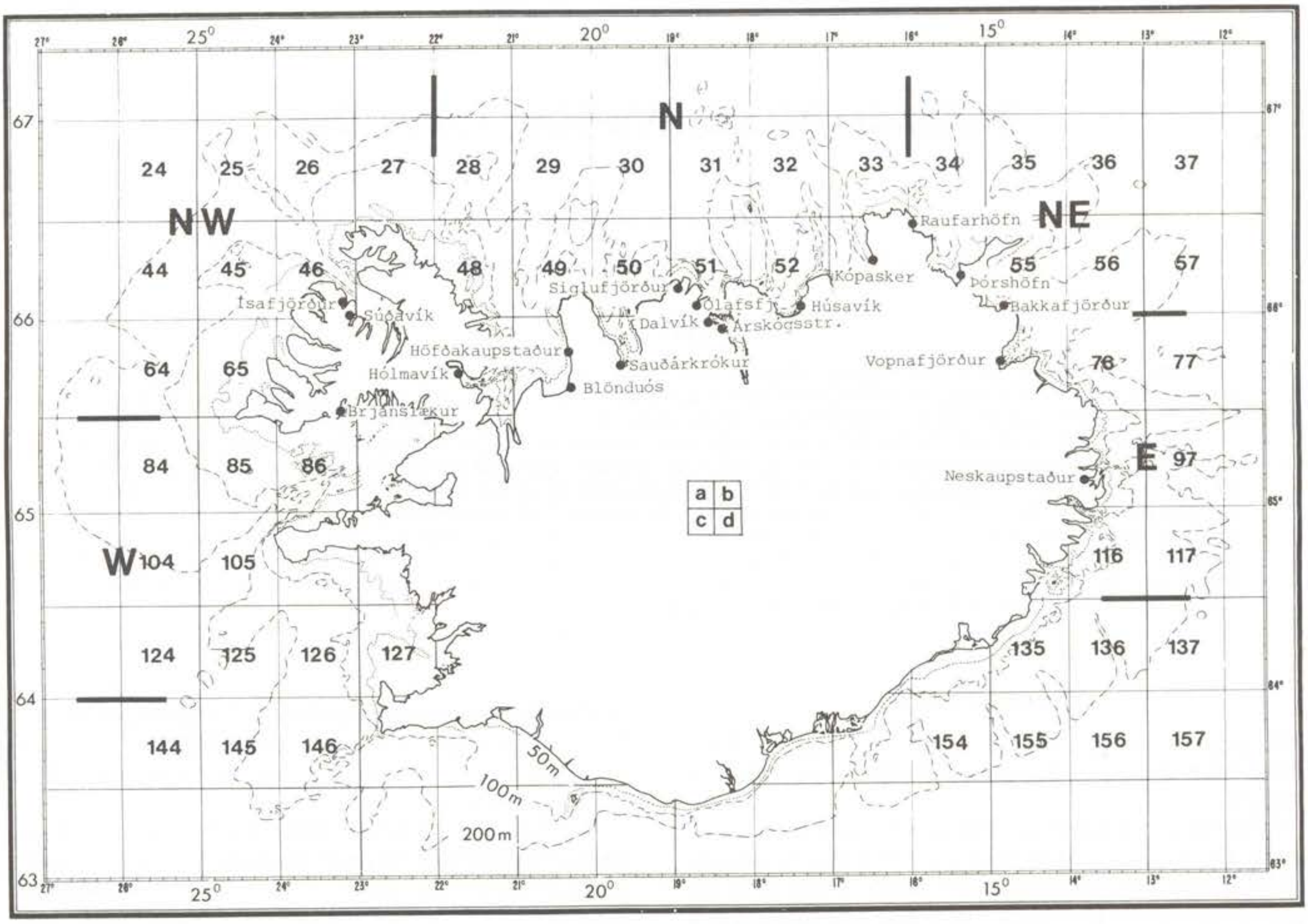

Fig. 1. Towns in Iceland where minke whales are frequently landed, statistical divisions of the whaling grounds and division of the grounds into operation areas (W, NW, N, NE, E).

Today all the minke whalers are also engaged in fishing activities outside the minke whale season. The fish species caught include cod (*Gadus morhua*), lumpsucker (*Cyclopterus lumpus*) and shrimp (*Pandalus borealis*). The catchers are therefore equipped with several instruments which are standard on small fishing vessels, such as far and short ranging radio telephone systems, echo sounders and radar, while in recent years some boats also have automatic direction finders and the loran navigation system.

PROCESSING AND DISTRIBUTION OF PRODUCTS

Meat has always been the most important product from minke whales in the coastal areas of Iceland, where human consumption of minke whale meat has a long tradition. In the past it was a most welcome addition to the poor variability of food items available to the people. The whales were fully utilized. Not only the meat itself was eaten but also the flukes, flippers, tongue, blubber and ventral grooves. In the past most of the products were eaten fresh or salted, although sometimes smoked or soured. The blubber was often boiled to extract the oil.

Although some catchers are now able to work up small animals on board at sea, this is usually considered too risky. Generally the whales are towed to the nearest town for flensing and cooling of the meat as was the practice in the past. As shown in Fig. 1 the landings are restricted to towns spreading clockwise from W- to E-Iceland.

Two landing places can be considered as land stations. The land station in Brjánslaekur, W-Iceland serves two vessels, while the Árskógsströnd station serves one catcher (see Fig. 1). A slipway has been constructed and a modern freezing plant (used also for fish products) is available.

Fig. 2. *Margrét ÍS 314,* a 4 ton minke whale catcher in operation 1914–47 (From: G. G. Gudmundsson, 'Vaskir menn', Reykjavik, Nordri, 1968.)

Table 1

Icelandic minke whale catchers in operation 1914–80

Catcher	Time in operation	Tonnage Btn	Length (m) of vessel	Total catch	Operational area	Source
Margrét ÍS 314	1914–47	4	8.5	161	NW	Gunner's catch records and Saemundsson (1931 and 1937)
Andvari ÍS 99	1948	16	12.6	6	NW, N	Gunner's catch records
Haukur ÍS 409	1949–67	7	10.2	94	NW	Gunner's catch records
Mummi ÍS 505	1968–75	10	10.8	105	NW	Gunner's catch records. Commercial catch records since 1974
Sigurborg í Dal ÍS 83	1975	17	12.7	6	NW	Commercial catch records
Various boats	1921–35	—	—	82	N, NE	Saemundsson 1931 and 1937
Skúli fógeti EA 461	1942–53	12	11.8	494	N, NE	Estimated catches based on information from local people and the gunner's catch records for 9 seasons
Björgvin EA 565	1954–60	13	12.7			
Björgvin EA 75	1961–64(?)	27	14.9			
Björgvin EA 75	1965(?)–72	8	9.5			
Björgvin EA 75	1973–76	8	9.5	84	N, NE	Gunner's catch record for 1973; commercial catch records since 1974
Einar ÍS 457	1946–50	5	9.6	246	NW, N	Estimated catches based on information from gunner
Einar ÍS 86	1951–60	18	13.8			
Einar ÍS 86	1969–75	18	13.8	26	NW, N	Commercial catch records; information on catches for 1969–73 not available
Björgvin	1960–62	—	—	380	N, NE	Estimated catches based on information from gunner
Hallsteinn EA 130	1963	22	15.0			
Njördur EA 108	1965–69	10	11.6			
Njördur EA 108	1970–73	10	11.6	235	N, NE	Gunner's catch records
Njördur EA 208	1974–80	12	12.9	407	N, NE	Commercial catch records
Sólrún EA 151	1969–74	12	11.5	95	N, NE	Gunner's catch records; commercial catch records for 1974
Sólrún EA 151	1975–80	28	16.4	241	N, NE	Commercial catch records
Sigurbjörg ST 55	1972–80	17	13.1	34	N	Gunner's catch records for 1972–73; commercial catch records since 1974
Faldur	1975–80	18	14.5	67	NE, E	Commercial catch records
Fiskanes NS 37	1979	17	13.9	2	NE	Commercial catch records
Óskar Halldórsson RE 157	1976	267	36.1	31	W, N, NE, E	Commercial catch records
Nökkvi HU 15	1976–80	29	14.8	53	W, NW, N	Commercial catch records
Háborg NK 77	1976–77	17	13.9	10	NE, E	Commercial catch records
Eygló NK 28	1978–80	10	12.4	12	NE, E	Commercial catch records
Thistill	1976–77	7	11.3	8	N, NE	Commercial catch records
Árný	1979–80	20	15.3	19	N, NE	Commercial catch records
Halldór Sigurdsson ÍS 14	1977–80	19	—	89	W, NW	Commercial catch records
Sólfaxi EA 75	1977–80	27	17.1	111	N, NE	Commercial catch records
Hrönn	1968	41	10.6	50	W, NW	Information from gunner
Gissur hvíti ÍS 114	1968–72	17	14.6	88	W, NW	Estimated catches based on information from gunner; commercial catch records since 1977
Gissur hvíti ÍS 114	1975–80	17	14.6	102	W, NW	
Dröfn ÍS 220	1968	26	14.8	10	W	Gunner's catch record
Hafrún ÍS 154	1976–80	13	13.2	9	W	Commercial catch records
David Ólafsson NS 77	1973–74	15	12.2	5	E	Gunner's catch records

Hired people flense the whales and pack the products for freezing. Most of the products are frozen, salted or smoked by a wholesale buyer for later distribution, but whale products are also sold directly by the whalers to local people in the old traditional way. Since 1976 part of the whale products have been exported to Japan, the Faroe Islands and Norway.

REGULATION

Licences issued

Icelandic minke whaling was unregulated until the 1974 season. Since 1975 licences have been issued by the Ministry of Fisheries to most of the vessels catching whales. Table 2 gives the number of licences issued each year and the number of boats participating in whaling. Not all the whalers have used their licence because some of them have been engaged in fisheries during the whaling season. No new licence has been issued since the 1977 season.

Catch quotas and the regulation of the whaling season

Catch limits were introduced into Icelandic minke whaling in 1977. Since then a quota of 320 whales has been set by the International Whaling Commission for the East Greenland – Iceland – Jan Mayen area (Central North-Atlantic stock). In a bilateral agreement with Norway, Iceland was allocated 200 whales per year. This led to competition between the whalers who wanted to take as large a share as possible, and the quota was taken as early as July or August. In 1979 and 1980 the Ministry of Fisheries restricted the season from 20 May onwards because weather conditions, availability of whales and the fatness of the animals is less favourable earlier in the year.

In addition to the fixed opening date, a seasonal quota for each catcher boat was introduced in 1981. This decision was made by agreement between the Ministry of Fisheries and the whalers, based upon the average catches of each vessel in recent years. A certain minimum number was set for each boat. The highest quota per vessel was set at 38 whales and the lowest at 12 whales for the 1981 season.

Fig. 3a.

Fig. 3b.

Fig. 3. Two minke whale catchers now in operation. (a) *Njördur EA 208*, a 12 ton catcher, (b) *Sólrún EA 151*, a 28 ton catcher.

Government ordinances

The recent governmental ordinances concerning Icelandic minke whaling are based on the IWC regulatory items. The main articles for the 1981 season were:

1. *Catch quota:* The total quota is 200 minke whales for the season. Each boat is allowed to take a fixed number of whales.
2. *Catch limits:* Only minke whales are allowed to be taken. Calves, and cows with calves are protected.
3. *Season:* The licences are issued for the period 20 May–1 September, but will be reviewed if less than 200 whales are caught by 1 September.
4. *Catch area:* Catches are only allowed to be taken within the 200 nautical miles Icelandic fisheries jurisdiction.
5. *Catch equipment:* Harpoon guns used for killing the whales have to be authorized by the Ministry of Fisheries.
6. *Handling:* After the whale is killed it has to be handled in the particular way outlined to ensure full utilization of the products. The whale should be landed within 18 hours of death.
7. *Scientific cooperation:* Cooperation with inspectors from the Ministry of Fisheries or scientific personnel from the Marine Research Institute is required.

Fig. 4. Kongsberg 50 mm harpoon gun mounted on the bow of *Sólrún EA 151*.

8. *Catch records:* Twice a month a catch record is to be filled out and sent to the Marine Research Institute, Reykjavík. The catch records shall include name of the catcher boat, name of gunner, date and position of whales caught (statistical divisions shown on Fig. 1), sex, body length, length and sex of foetus and other information on whales caught, such as food.
9. Any violation of the regulations listed above will be met with a punishment or fines according to Icelandic legislation.

The Ministry of Fisheries has no special arrangement to ensure that all of the articles are upheld. For economic reasons it would be very difficult to send an inspector on board every vessel since whaling operations are spread in both time and area. However, the Ministry sends inspectors to most of the fishing towns where minke whales are landed to control the fisheries and these inspectors are also instructed to keep an eye on minke whaling.

DEVELOPMENT OF THE WHALING

In his description of whales in Icelandic waters in the 18th century, Ólafsson (1772) writes that minke whales are seldom harpooned because the local people considered the minke whale a 'good' whale sent by God to defend the people and their boats against 'bad' species of whales. According to Saemundsson (1932) minke whales were not caught in Iceland until 1914 although a few animals may have been killed during whaling experiments in NW-Iceland and Eyjafjördur (N-Iceland) during the 17th century.

Icelandic catches in the period 1914–80

Table 1 gives all known information on catches taken by Icelandic whalers since 1914. The number of whales taken has been based on many different sources of information, as discussed below.

Saemundsson (1931; 1937) gave information on minke whales caught between 1914 and 1936 in NW- and N-Iceland. Saemundsson's catch records seem to be complete for NW-Iceland for that period since he received records of whales taken by *Margrét ÍS 314* which (according to local people) was the only catcher operating in that area. For N-Iceland, Saemundsson only reported the number of whales caught (see 'Various boats' in Table 1), without referring to any particular vessel. Information from local people indicates a somewhat higher total catch in N-Icelandic coastal waters than that given by Saemundsson (1931; 1937) for the period 1920–35, when according to local information no less than nine vessels were to some extent involved in whaling. The catches under 'Various boats' in Table 1 should therefore be regarded as minimum values.

Saemundsson (1931; 1937) did not mention minke whaling in any other coastal areas around Iceland. However, to my knowledge (local information) at least one vessel was operating in the coastal waters off E-Iceland in the 1920s. In 1923 fishermen in E-Iceland argued for a cessation of minke whaling inside the fjords, since it 'caused serious harm to the herring fisheries' (Anon., 1924). This proves that minke whaling already existed in this area, but no estimates of the number of whales taken can be made.

For the period 1937–73 no official catch data are available. Information on catches in this period is either based on private catch records made by the gunners or on my personal interviews with them. In this way an estimate of their catches through the years has been established. I attempted to avoid overestimating the catches, and therefore the figures in Table 1 are conservative. Since 1974 regular catch records have been received from minke whalers giving the true number of whales caught in the period 1974–80.

From Table 1, a minimum of 3,362 minke whales were killed in the period 1914–80. Fig. 5 shows the average (in 1914 only one whale was taken and in 1915 ten animals) annual catch for each five year period between 1916–80. It must be remembered that the data might be incomplete for the greater part of the period and in particular for the early years. However, it is evident that the number of whales taken has increased in the post-war years, especially in the 1960s and 1970s. The average annual catches for 1966–70, 1971–75 and 1976–80 were 105, 137 and 200, respectively.

Table 2

Number of licences issued to minke whalers in Iceland 1975–80 and number of catchers taking more than 10 whales each year

Year	No. of licences issued	No. of vessels participating	No. of boats taking more than 10 whales
1975[1]	6	9	4
1976	12	11	5
1977	14	10	6
1978	10	10	7
1979	11	10	5
1980	11	8	7

[1] In 1975 10 whales were caught by three unlicensed vessels.

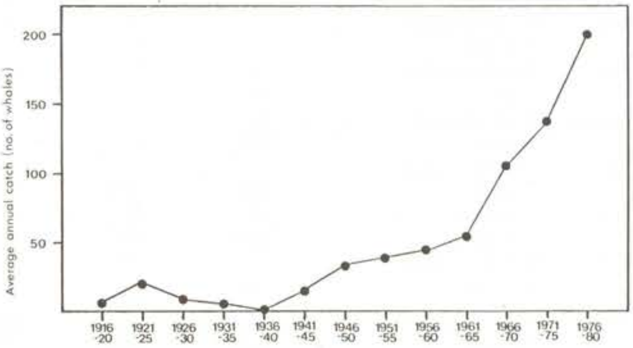

Fig. 5. Iceland—Estimated average annual catch of minke whales per 5 year period during 1916–80.

Norwegian minke whaling in Icelandic coastal waters

In the post-war years Norwegian small-type whalers have also caught minke whales in Icelandic coastal waters. Christensen (1975) discussed the westward expansion of the Norwegian small whale fleet in the North Atlantic. The first vessel moved into Icelandic waters to take minke whales in the 1948 and 1949 seasons. Between 1949 and the early 1960s only a few minke whales were caught off Iceland, mainly by Norwegian vessels fishing for basking sharks (*Cetrohinus maximus*). Norwegian whaling vessels did not move into the Jan Mayen area and the northern Icelandic waters until 1961. Christensen (1975) also reported that the first Norwegians started catching minke whales in the Denmark Strait in 1966.

Jonsgård (1976) presented maps showing the Norwegian minke whale catches in 1949–75. Less than one hundred animals were caught by Norwegians in Icelandic waters during the years 1949–60. However, the average annual catch for the period 1961–75 was about one hundred animals. After the extension of the Icelandic fisheries limits to 50 nautical miles in 1975, no foreign vessels were allowed to catch whales in these waters. It can thus be concluded that during the past twenty years, the total annual minke whale catches in Icelandic coastal waters have been of the same order of magnitude as they are today—around 200 whales per year.

SEASONAL DISTRIBUTION AND LOCATION OF CATCHES

Duration of season

In the past, the minke whale season in Iceland extended from the beginning of March to late November or even to early December, although most animals were caught during April–October.

Table 3 gives the monthly breakdown of minke whales reported caught by Iceland in the period 1974–80. As no catch quota was set for 1974–76, the catches made in this period may be taken as a measure of the seasonal abundance of minke whales on the Icelandic whaling grounds; the maximum catches occurred in July, August and September. However, other factors such as weather conditions may also influence the seasonal distribution of the catch. Regulation by catch quota since 1977 has shortened the season. In 1980 the catch quota was taken between 20 May–17 July i.e. within two months.

Sex ratio

Table 3 also gives the sex ratio in the catches. The average annual sex ratio for minke whales caught by Iceland in the period 1974–80 is 53.4% and 46.6% for males and females, respectively. Assuming that the sex ratio in the catches is representative of that on the grounds, females are more abundant than males during the first part of the season (up to and including June). This is in close agreement with the pattern reported by Jonsgård (1951) for minke whales inhabiting Norwegian coastal waters. Sex segregation in N-Atlantic minke whales has also been reported by Christensen (1974; 1975 and 1982) and Kapel (1980).

Catch distribution

Fig. 6 shows the distribution of the minke whales caught by Iceland in the years 1974–80. More than 70% of the whales were taken off N-Iceland. As shown by Jonsgård (1976) the Norwegian catches in the past were not only taken in the coastal waters where Icelanders traditionally have caught minke whales, but also further offshore.

From Fig. 6 it is also evident that no minke whales have been caught on the southern coast of Iceland. However, Saemundsson (1939) states that this species appears equally distributed around the country in the warmer part of the season. The only recent records of minke whales outside the main whaling area are unpublished sightings records made from large whale catchers operating off west Iceland. According to these records minke whales are often seen in that area during the summer months, mainly in squares 85, 126, 127 and 146 (see Fig. 1).

Topographically, the southern coast of Iceland is quite different from the rest of the country. Here we have vast areas of sand or gravel beaches, with no sheltered fjords

Table 3

Monthly breakdown of the Icelandic minke whale catches 1974–80 and percent males in the catches each month

		1974	1975	1976	1977	1978	1979[2]	1980[2]	1974–80
March	Number caught	6	3	1	3	0	0	0	13
	% males	16.7	33.3	0.0	33.3	—	—	—	23.1
April	Number caught	8	30	6	14	11	0	0	69
	% males	0.0	40.0	33.3	57.1	18.2	—	—	34.8
May	Number caught	9	13	5	34	29	14	7	111
	% males	33.3	38.5	40.0	60.6	27.6	28.6	57.1	41.8
June	Number caught	2	22	6	37	58	33	100	258
	% males	0.0	45.5	16.7	45.9	34.5	48.5	54.0	45.7
July	Number caught	9	37	42	74	92	62	94	410
	% males	55.6	56.8	52.4	57.5	54.3	61.3	64.9	58.4
August	Number caught	32	36	55	30	2	64	0	219
	% males	59.4	69.4	65.5	46.7	50.0	62.5	—	61.6
Sept.	Number caught	11	7	64	0	6	11	0	99
	% males	81.8	71.4	60.9	—	66.7	72.7	—	65.7
Oct.	Number caught	11	12	15	0	0	7	0	45
	% males	36.4	66.7	60.0	—	—	57.1	—	55.6
Nov.	Number caught	3	0	2	0	0	7	0	12
	% males	33.3	—	50.0	—	—	28.6	—	33.3
Total	Number caught	91	160	196	192	198	198	201	1,236[1]
	% males	46.2	54.4	57.1	53.7	42.9	56.6	59.2	53.4

[1] Sex not given for three animals; [2] Season did not start until 20 May.

Table 4

Effort data for catchers which caught ten or more whales in each of the seasons 1974 to 1980 (cf. text)

			Days in operation each month														
Year	Catcher	A	M	A	M	J	J	A	S	O	N	D	T	F	C	CPUE	CPBD
1974	*Sólrún EA 151*	N, NE	0	19	31	30	31	31	30	31	7	210	12	2,520	21	0.83	0.10
	Njördur EA 208	N, NE	19	30	31	30	31	31	30	31	1	234	12	2,808	45	1.60	0.19
	Total		19	49	62	60	62	62	60	62	8	444		5,328	66	1.24	0.15
1975	*Sólrún EA 151*	N, NE	0	27	31	30	31	23	0	0	0	142	28	3,976	35	0.88	0.25
	Njördur EA 208	N, NE	14	31	31	30	31	31	30	12	0	210	12	2,520	89	3.53	0.42
	Björgvin EA 75	N, NE	0	30	31	30	31	17	0	0	0	139	8	1,112	26	2.34	0.19
	Total[1]		14	88	93	90	93	71	30	12	0	491		7,608	150	1.97	0.31
1976	*Sólrún EA 151*	N, NE	0	0	0	0	30	31	30	31	10	132	28	3,696	49	1.33	0.37
	Njördur EA 208	N, NE	12	30	31	30	31	31	30	31	12	238	12	2,856	67	2.35	0.28
	Björgvin EA 75	N, NE	0	0	0	28	31	31	24	0	0	114	8	912	19	2.08	0.17
	Nökkvi HU 15	N	0	0	0	0	0	21	9	0	0	30	29	870	10	1.15	0.33
	Faldur	NE, E	0	0	0	0	4	0	11	8	0	23	18	414	10	2.42	0.43
	Óskar Halld.[3] (excl. from total)	W, NW, N, NE, E	0	0	0	0	21	9	0	0	0	30	267	8,010	31	0.38	1.03
	Total[2]		12	30	31	58	96	114	104	70	22	537		8,748	155	1.77	0.29
1977	*Sólrún EA 151*	N, NE	0	0	8	30	31	15	0	0	0	84	28	2,352	32	1.36	0.38
	Njördur EA 208	N, NE	9	30	31	30	31	18	0	0	0	149	12	1,788	63	3.52	0.42
	Sólfaxi EA 75	N, NE	0	17	22	30	31	18	0	0	0	118	27	3,186	25	0.78	0.21
	Nökkvi HU 15	W, N	0	2	31	30	30	0	0	0	0	93	29	2,697	21	0.78	0.23
	Faldur	NE, E	0	0	0	23	31	16	0	0	0	70	18	1,260	19	1.51	0.27
	Halld. Sig. ÍS 14	W, NW	0	0	0	26	31	17	0	0	0	74	19	1,406	17	1.21	0.23
	Total		9	49	92	169	185	84	0	0	0	588		12,689	177	1.39	0.30
1978	*Sólrún EA 151*	N, NE	0	4	31	30	19	0	0	0	0	84	28	2,352	39	1.66	0.46
	Njördur EA 208	N, NE	0	7	31	30	20	0	0	0	0	88	12	1,056	46	4.36	0.52
	Sólfaxi EA 75	N, NE	0	0	28	30	16	0	0	0	0	74	27	1,998	25	1.25	0.34
	Nökkvi HU 15	W, NW, N	0	0	19	30	20	0	0	0	0	69	29	2,001	13	0.65	0.19
	Faldur	NE, E	0	0	16	30	22	0	0	0	0	68	18	1,224	13	1.06	0.19
	Halld. Sig. IS 14	W, NW	0	0	0	15	21	0	0	0	0	36	19	684	27	3.95	0.75
	Gissur hv. ÍS 114	W, NW	0	0	0	29	21	0	0	0	0	50	17	850	22	2.59	0.44
	Total		0	11	125	194	139	0	0	0	0	469		10,165	185	1.82	0.39
1979	*Sólrún EA 151*	N, NE	0	0	0	19	31	27	0	0	0	77	28	2,156	31	1.44	0.40
	Njördur EA 208	N, NE	0	0	12	30	31	26	0	0	0	99	12	1,188	55	4.63	0.56
	Sólfaxi EA 75	N, NE	0	0	0	27	31	24	0	0	0	82	27	2,214	33	1.49	0.40
	Halld. Sig. IS 14	W, NW	0	0	5	30	14	19	0	0	0	68	19	1,292	17	1.32	0.25
	Gissur hv. ÍS 114		0	0	5	30	14	19	0	0	0	68	17	1,156	19	1.64	0.28
	Total[4]		0	0	22	136	121	115	0	0	0	394		8,006	155	1.94	0.39
1980	*Sólrún EA 151*	N, NE	0	0	11	30	17	0	0	0	0	58	28	1,624	48	2.96	0.83
	Njördur EA 208	N, NE	0	0	0	27	15	0	0	0	0	42	12	504	38	7.54	0.90
	Sólfaxi EA 75	N, NE	0	0	0	25	16	0	0	0	0	41	27	1,107	27	2.44	0.66
	Faldur	NE, E	0	0	10	30	15	0	0	0	0	55	18	990	23	2.32	0.42
	Eygló NK 28	NE, E	0	0	7	30	17	0	0	0	0	54	10	540	10	1.85	0.19
	Árný	N, NE	0	0	0	24	14	0	0	0	0	38	20	760	14	1.84	0.37
	Halld. Sig. IS 14	W, NW	0	0	2	30	17	0	0	0	0	49	19	931	21	2.26	0.43
	Gissur hv. ÍS 114	W, NW	0	0	3	30	17	0	0	0	0	50	17	850	20	2.35	0.40
	Total		0	0	33	226	128	0	0	0	0	387		7,306	201	2.75	0.52

[1] Catch data from *Einar ÍS* 86 not available (21 whales caught).

[2] Catch data from *Gissur hvíti ÍS 114* not available (15 whales caught).

[3] Excluded from the total and from the CPUE and CPBD analysis.

[4] Catches allowed to be taken after the season stop in August 1979 not included.

A: Approximate area of operation (see Fig. 1); D: No. of days in operation.

T: Size of catcher in tons; F: Fishing effort = D × T; C: Catch; CPUE = 100C/F: Tonnage-corrected catch per unit effort;
CPBD = C/D: Catch per boat-day.

Calculation of the average 'ton-day' (F/D) each season (Table 5) reveals that the increased CPUE during the period cannot be explained by an increase of the size of the catchers in operation. In fact, CPUE and CPBD were by far the highest in the 1980 season, whereas the ton-day value was lower than in the preceding seasons. Rather than simply accepting the CPUE and CPBD values in Fig. 7 as valid indexes of abundance of the whales on the grounds, there must be other factors affecting both parameters. In most recent years the catches have primarily been taken during the three summer months (Table 3), when hunting conditions are probably better. Also more competition between the whalers as a consequence of the catch quota introduced in 1977 may have influenced the effort. These and other possible factors cannot be measured, but it is evident that a more accurate index of the effort is needed.

Since the 1978 season (and part of the 1977 season) the whalers have been asked to fill in time budget forms for

Table 6

Available time budget data for Icelandic minke whale catchers in each of the seasons 1977 to 1980 (see text).

			May			June			July			August			May–August		
Year	Catcher	A	C	HD	CPHD	C	HD	CPHD	C	HD	CPHD	C	HD	CPHD	C	HD	CPHD
1977	*Njördur EA 208*	N, NE	—	—	—	—	—	—	19	17	1.12	10	13	0.77	29	30	0.97
	Faldur	NE, E	—	—	—	—	—	—	5	8	0.63	1	2	0.50	6	10	0.60
	Total		—	—	—	—	—	—	24	25	0.96	11	15	0.73	35	40	0.88
1978	*Njördur EA 208*	N, NE	2	7	0.29	12	11	1.09	17	15	1.13	—	—	—	31	33	0.94
	Sólrún EA 151	N, NE	8	15	0.53	14	11	1.27	16	12	1.33	—	—	—	38	38	1.00
	Faldur	NE, E	4	10	0.40	4	11	0.36	5	11	0.45	—	—	—	13	32	0.41
	Nökkvi HU 15	W, N	2	6	0.33	3	5	0.60	8	8	1.00	—	—	—	13	19	0.68
	Halldór Sig. ÍS 14	W, NW	—	—	—	—	—	—	14	16	0.88	—	—	—	14	16	0.88
	Gissur hvíti IS 114	W, NW	—	—	—	—	—	—	9	13	0.69	—	—	—	9	13	0.69
	Total		16	38	0.42	33	38	0.87	69	75	0.92	—	—	—	118	151	0.78
1979	*Njördur EA 208*	N, NE	11	9	1.22	9	11	0.82	18	13	1.38	17	13	1.31	55	46	1.20
	Nökkvi HU 15	N	—	—	—	—	—	—	5	7	0.71	—	—	—	5	7	0.71
	Halldór Sig. ÍS 14	W, NW	2	7	0.29	4	7	0.57	1	2	0.50	10	15	0.67	17	31	0.55
	Total		13	16	0.81	13	18	0.72	24	22	1.09	27	28	0.96	77	84	0.92
1980	*Njördur EA 208*	N, NE	0	6	0.00	19	19	1.00	19	15	1.27	—	—	—	38	40	0.95
	Sólrún EA 151	N, NE	1	3	0.33	25	18	1.39	22	15	1.47	—	—	—	48	36	1.33
	Halldór Sig. ÍS 14	W, NW	1	2	0.50	11	18	0.61	9	10	0.90	—	—	—	21	30	0.70
	Gissur hvíti ÍS 114	W, NW	2	3	0.67	10	19	0.53	8	11	0.73	—	—	—	20	33	0.61
	Total		4	14	0.29	65	74	0.88	58	51	1.14	—	—	—	127	139	0.91

C: Catch; HD: Number of hunting days; CPHD: Catch per hunting day; A: Approximate area of operation (cf. Fig. 1).

each catcher. The form includes information on number of days spent on the whaling grounds, statistical area, weather conditions, catch data and sightings.

Time budget data are now available (Table 6) for 18.2% 59.6%, 38.9% and 62.9% of the catch in 1977, 1978, 1979 and 1980, respectively. Catch per hunting day (CPHD) is calculated from the number of whales caught (C) and the number of hunting days on the grounds (HD). HD is defined as those days with a wind speed of less than Beaufort 5 and suitable visibility for searching.

The CPHD for each season is shown in Fig. 7. Since CPHD is based on effective hunting time i.e. excludes days in port and days with bad weather, the CPHD for the seasons 1977–80 is considerably higher than CPBD (Fig. 7). The CPHD values show smaller fluctuations between years than the CPUE and CPBD values, suggesting that days with bad weather and days in port significantly affect the outcome of the CPUE and CPBD analysis. However, data for the coming seasons are needed to detect any trends in the number of whales on the grounds each season by analysing CPHD.

Table 5

Average ton-day calculated from estimated fishing effort (F) and estimated number of days in operation (D) in each of the seasons 1974–80 (data from Table 4)

	D	F	Average ton-day (= F/D)
1974	444	5,328	12.0
1975	491	7,608	15.5
1976	537	8,748	16.3
1977	588	12,689	21.6
1978	469	10,165	21.7
1979	394	8,006	20.3
1980	387	7,306	18.9
1974–1980	467[1]	8,441[1]	18.0

[1] Average value for 1974–80.

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REFERENCES

Anon. 1924. Fjódungsping Fiskideilda Austfirdingafjórungs. *Ægir* 17: 20–23.

Christensen, I. 1974. Undersøkelser av vågehval i Barentshavet og ved Øst- og Vest-Grønland i 1973. *Fiskets Gang* 14: 278–86.

Christensen, I. 1975. Preliminary report on the Norwegian fishery for small whales: Expansion of Norwegian whaling to Arctic and Northwest Atlantic Waters, and Norwegian investigations of the biology of small whales. *J. Fish. Res. Bd. Can.* 32(17): 1083–94.

Christensen, I. 1982. Catch and effort and the sex composition in the Norwegian minke whale fishery, 1976–80. Paper SC/33/Mi2 (published in this volume).

Jonsgård, Å. 1951. Studies on the little piked whale or minke whale (*Balaenoptera acutorostrata* Lacépède). *Norsk Hvalfangsttid.* 40(5): 209–32.

Jonsgård, Å. 1976. Maps showing the approximate localities where the different species of whales (minke, bottlenose, killer, pilot) have been caught in each of the seasons 1949–75. Paper SC/28/Doc. 13 presented to the IWC Scientific Committee, June 1976.

Kapel, F. O. 1980. Sex ratio and seasonal distribution of catches of minke whales in West-Greenland. *Rep. int. Whal. Commn* 30: 195–9.

Ólafsson, E. 1772. *Ferdabók Eggerts Ólafssonar og Bjarna Pálsonar Um ferdir peirra á Íslandi árin 1752–57. Vol. 1* Reykjavik, 1943. 434 pp.

Saemundsson, B. 1931. Fiskirannsóknir 1929–30. Skýrsla til stjórnarrádsins. *Andvari* 56: 48–110.

Saemundsson, B. 1932. *Íslensk dýr III: Spendýrin.* Reykjavik. 437 pp.

Saemundsson, B. 1937. Fiskirannsóknir 1935–36. Skýrsla til stjórnarrádsins. *Andvari* 62: 22–61.

Saemundsson, B. 1939. Mammalia. *The Zoology of Iceland* IV (76): 1–38.

SC/33/Ba1

DDT and PCB Residues in the Fin Whale, *Balaenoptera physalus*, of the North Atlantic

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INTRODUCTION

Industrial and agricultural development has produced a continuous increase of the chemical contaminant load that the wild populations have to suffer. In recent years, many organochlorine compounds (DDTs, PCBs, etc.) and heavy metals (mainly mercury) have been detected in high concentrations in different components of the marine biota.

Although the bioaccumulation and magnification mechanisms are not completely understood, it appears that pollutant levels tend to proportionally increase with the trophic level and metabolic rate of the organisms.

A great number of marine mammals are at the end of their food chain and many of them, especially the small cetaceans, have a high metabolic rate. This makes them very vulnerable to chemical pollution.

In spite of this, and although the International Whaling Commission (1980) has repeatedly recommended that research into the effects of pollution in whale populations should be carried out, cetaceans, because of the evident difficulties of sampling, are one of the worst monitored groups of vertebrates.

The published data are, usually, the result of analysis made in tissues coming from stranded animals or from cetaceans which have died because of disease or the effect of parasites, probably following a long process of fasting and metabolic alterations. Experience gathered in pollution monitoring of human populations gives us a biologically reasonable basis to doubt that the results found in such cases are representative of the true situation in the population.

One of the factors which results in the accumulation of organochlorine pollutants is the inability or low capacity for removal of the pollutants by the organisms, and as what is usually determined is not the total contaminant load of the organism but its relative concentration in a small sample, the levels can appear substantially increased when the animal had suffered progressive fasting or when its metabolic centres have been handicapped by disease or the action of parasites.

In the present paper, the levels of DDT and PCB detected in samples from muscular tissues of fin whales (*Balaenoptera physalus*) caught during the 1980 whaling season in northwest Spain, are examined. The concentration of the same contaminants in the commercially extracted oils and in the krill upon which they feed have also been analysed.

Although some other organochlorine compounds can also be detected in the tissues of whales, DDTs and PCBs are the only ones which at present reach levels which are sufficient to represent a possible risk to the health of the population.

The DDT compounds, like many other organochlorine pesticides, have been restricted in recent years, and evidence exists which indicates a slow reduction of the levels in the marine biota, especially in that of the open sea, where there are no direct sources of this type of pollutant.

The load of PCBs in the sea, however, seems to be increasing in recent years, parallel to the increase in the population and industrialisation of the coasts.

ANALYTICAL PROCEDURES

The samples were collected during the whaling season (June to October) of 1980, packed in aluminium foil, and deep frozen until the analysis.

A 4 g piece of tissue was homogenized in the presence of anhydrous sodium sulphate and extracted in a soxhlet apparatus with n-hexane.

An aliquot of the extract was removed and the percentage of extractable fat determined. The remaining was concentrated to 1 ml and an adequate quantity of sulphuric acid was then added, and the mixture agitated to ensure efficient cleaning. After partitioning, the hexane phase was concentrated to 1 ml and injected into a Varian Aerograph gas chromatograph, equipped with an electron-capture detector and computer of areas. The column was packed with a mixture of 4% DC-200 plus 6% QF-1 on W-AW-DCMS chromosorb of 80–100 mesh.

Determination and quantification of PCBs was carried out by an alkaline transformation of DDTs into DDE.

Control experiments were carried out to ensure the purity of the system. Levels have been expressed in wet weight and extractable lipid bases, with no corrections for the recovery rates.

DISCUSSION

The mean and range values of the DDTs and PCB concentrations detected in the muscle are given in Table 1.

As expected, PCBs occur at the highest levels in the samples. The more abundant isomer was that resembling 1254, although 1260 appeared in many samples too.

The p p′DDE and o p′DDT are the most abundant forms of DDTs analysed. The p p′DDT is the form used most commonly in pesticide treatments. Although the metabolic pathways and the implied enzymes are not completely understood, the main route of detoxication in vertebrates is the conversion of DDT to DDE by a reductive dechlorination (Walker, 1975).

This process needs time and the greater or lesser proportions of p p′DDT and DDE can roughly be related to the time since pollutant intake by the ecosystem.

Nevertheless, the proportion among these compounds has to be examined with care, because it can be altered by many factors such as the time, way and quality of preservation of the sample (French and Jefferies, 1971). On the other hand, the status of some of these compounds

Table 1

Mean and range values of DDT and PCB compounds in the muscle of fin whales, expressed in ppm of extractable fat (LB) and wet weight (FWB).

Sex	% Extraction		pp'DDE	op'DDT	pp'TDE	pp'DDT	ΣDDTs	PCB	n
♂	3.31	LB	0.3484 (0.6796–0.0507)	0.3558 (2.2663–0)	0.25179 (0.5169–0)	0.0308 (0.2110–0)	0.80598 (2.9459–0.2083)	12.9142 (72.0737–0.6684)	29
		FWB	0.0115 (0.0225–0.0017)	0.0118 (0.0750–0)	0.0083 (0.0171–0)	0.0010 (0.0069–0)	0.0267 (0.0975–0.0069)	0.4275 (2.3856–0.0221)	
♀	4.04	LB	0.3391 (0.8376–0.0499)	0.2877 (1.0489–0)	0.0438 (0.4089–0)	0.0658 (0.3517–0)	0.6759 (1.5638–0.0499)	12.4604 (53.6648–0.1578)	39
		FWB	0.0137 (0.0338–0.0020)	0.0116 (0.0424–0)	0.0018 (0.0165–0)	0.0026 (0.0142–0)	0.0273 (0.063–0.0020)	0.5034 (2.1681–0.0064)	

Table 2

Mean values of total DDT and PCB, expressed in ppm of extractable fat (LB) and wet weight (FWB), in fin whales of the North Atlantic.

				FWB		LB		
Year	Locality	n	Tissue	ΣDDT	PCB	ΣDDT	PCB	Reference
?	South East Greenland	?	Blubber	2.38	3.6	—	—	Holden, 1975
1976	French coast	1	Blubber	—	—	61.9	47.29	Alzieu and Duguy, 1979
1970–71	Canada	12	Blubber	2.572	0.054	—	—	Saschenbrecker, 1973
1980	Spain	68	Muscle	0.0270	0.4710	0.7314	12.6540	Present paper

Table 3

Mean values of DDT and PCB, expressed as ppm of oil, for fin whales of North Atlantic

Year	Locality	n	ΣDDT	PCB	Reference
1967	Canada	2	13.64	N.D.	Addison *et al.*, 1972
1969	,,	1	22.27	1	,,
1970	,,	3	28.91	6.43	,,
1980	Spain	8	0.6476	7.0801	Present paper

in the vertebrate body is not clear enough and, as seems to occur in the case of the TDE, they can be produced in the post-mortem period (Walker, 1975).

The DDT levels detected do seem to indicate, however, that the intake of these pesticides is not a recent feature, which is reasonable as their use has been restricted in recent years in a great number of the countries bordering the North Atlantic.

Table 3 gives the results of the analysis made in the commercially extracted oil from whales taken in the same season; when comparing with previous similar work a progressive increase in PCB and decrease in DDT loads is apparent. PCBs were not detected in 1967 and concentrations in whale oil have been increasing since then. DDTs, however, were found at very low levels in Spanish fin whales when compared with the 1967–70 Canadian data (Addison *et al.*, 1972).

Although there does not appear to be a great difference, krill from Nova Scotia was more contaminated (0.06 ppm of DDT, wet weight basis) than the average of that coming from Spain (0.015 ppm of DDT, wet weight basis).

No similar data on PCBs are available for Canada. In Spain, the average was 0.0205 ppm, wet weight basis.

Other fin whale tissue analyses have been carried out (see Table 2) but the published results do not reveal any clear trend in the levels. The concentrations of pollutants found by Alzieu and Duguy (1979) in one fin whale on the French coast, although within the range of the PCB figures obtained in the present study, show very high DDT levels. The specimen was a stranded young female (12.5 m) and the cause of death was unknown; it is not possible to discard the view that disease and fasting could have produced a change in its original pollutant load.

Little is known about the influence of biological parameters such as age, size, sex or sexual state, on the contaminant levels of the animals. Male and female fin whales in the present study show similar PCB and DDT levels.

The meat pollutant levels are not above the maximum acceptable daily intake recommended by the FAO/WHO for human food. It is difficult, on the other hand, to predict the organochlorine levels which will be found in the oil after being processed and refined, since a removal of these compounds during the usual commercial treatment is known to occur (Addison, 1974).

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REFERENCES

Addison, R. F. and Ackman, R. G. 1974. Removal of organochlorine pesticides and polychlorinated biphenyls from marine oils during refining and hydrogenation for edible use. *J. Amer. Oil Chem. Soc.* 51(5): 192–4.

Addison, R. F., Zinck, M. E., Ackman, R. G. 1972. Residues of organochlorine pesticides and polychlorinated biphenyls in some commercially produced Canadian marine oils. *J. Fish. Res. Bd Can.* 29: 349–55.

Alzieu, C. and Duguy, R. 1979. Teneurs en composés organochlorés chez les cétacés et pinnipèdes fréquentant les côtes françaises. *Oceanologica Acta* 2(1): 107–20.

French, M. C. and Jefferies, D. J. 1971. The preservation of biological tissue for organochlorine insecticide analysis. *Bull. Environm. Contam. Toxicol.* 6(5): 460–3.

Holden, A. V. 1975. The accumulation of oceanic contaminants in marine mammals. *Rapp. p-v. Réun. Cons. int. Explor. Mer*, 169: 353–361.

International Whaling Commission 1980. Report of the subcommittee on small cetaceans (Annex I). *Rep. int. Whal. Commn* 30: 111–28.

Saschenbrecker, P. W. 1973. Levels of DDT and PCB compounds in North Atlantic fin-back whales. *Can. J. Comp. Med.* 37: 203–6.

Walker, C. H. 1975. Variation in the intake and elimination of pollutants. pp. 73–131. *In:* F. Moriarty (ed.), *Organochlorine Insecticides, Persistent Organic Pollutants*, Academic Press.

SC/33/Ba2

A Note on Populations of Bryde's Whales in the Southern Hemisphere

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The importance of correct stock boundaries for stock assessment and management has been pointed out by several authors (e.g. Yablokov and Berzin, 1978) and has been extensively discussed at meetings of the IWC Scientific Committee. At its 1980 meeting (IWC, 1981), the Scientific Committee established six management stocks of Bryde's whales in the Southern Hemisphere: South Atlantic[1]; Indian Ocean; Solomon Island; Western South Pacific; Peruvian; and Eastern South Pacific; although it recognised that there was probably 'more than one stock in the Indian Ocean'.

Best (1977) and Omura (1977) have discussed two forms of Bryde's whale: *Balaenoptera edeni brydei* (Olsin, 1913), the inshore form; and *B.e. edeni*, the offshore form[2]. It seems reasonable to examine the management stocks chosen in the context of these two forms.

The stock boundaries chosen were based largely on the results from the whaling for Bryde's whales which has recently developed, and sightings data. The Peruvian stock boundary for example, was based on the results of whaling by Peru, where in recent years some hundreds of animals have been taken each season. The rest of the South Pacific has been divided into two areas, the western area and the eastern area (boundary at 150°W), apart from a separate Solomon Islands Stock (20°S–10°N, 150°E–170°E). In addition one might also expect a Fijian stock to the east of this.

As the Scientific Committee had stated (IWC, 1981), there is almost certainly more than one stock of Bryde's whales in the Indian Ocean as suggested by its large area and the heterogeneity of its environment. Catches and sightings in this area have been reported around Madagascar (Sazhinov, 1975; Kuzmin *et al.*, 1979; Ohsumi, 1978), off Australia (Chittleborough, 1959; Bannister, 1964), the Gulf of Aden (Yuhov, 1969; Skryabin, 1970), the Persian Gulf (Mahdi, 1967; Al-Robbae, 1970) and in the northeastern part of the Ocean (Ohsumi, 1978; 1980). It seems likely at least three populations of oceanic Bryde's whale (*B.e. edeni*) exist in the Indian Ocean: a Madagascan stock (about 35°–60°E and 0°–40°S); a western/Australian stock (from the west coast of Australia to about 90° and 0°–40°S) and a northern Indian Ocean (or more probably two, separated along the meridian of the Maldives) stock. There may also be a fourth 'central' stock between 60°–90°E and 0°–45°S.

For a number of seasons whaling was carried out by a combined catcher/factory ship to the south of South Africa. According to the Bureau of International Whaling Statistics (IWS, 1980), up to 450 baleen whales were taken in a season, most of which were Bryde's whales (Best, 1977). It is not clear whether these whales were taken from the Madagascan or the West African populations. There appear to be at least two and possibly three populations in the South Atlantic: the eastern (or West African) and the western coastal stocks (off Brazil); with the possibility of a pelagic central stock.

Possible Bryde's whale stocks for the Southern Hemisphere are shown in Fig. 1.

Further information is clearly required before accurate

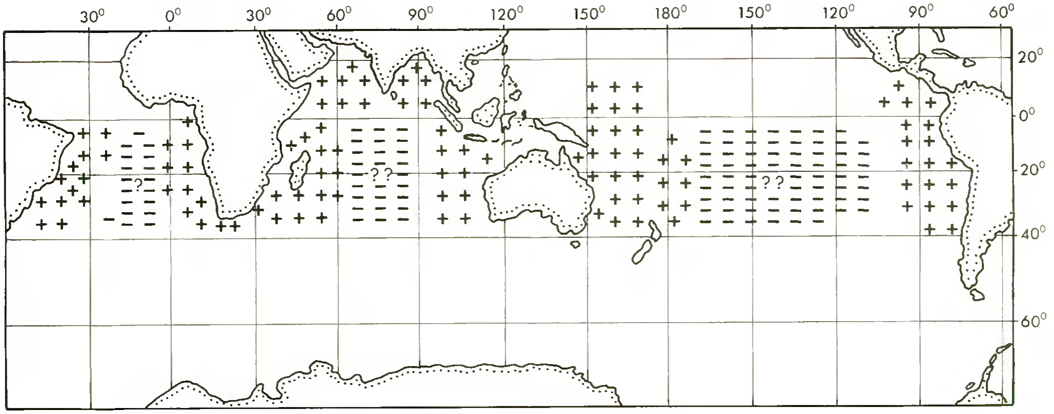

Fig. 1. Southern Hemisphere stocks of Bryde's whales.

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[1] Although listed in the Schedule as one stock, the sub-committee on other baleen whales (IWC, 1980, pp. 68–9) talked of 3 stocks: S. African coastal; pelagic; and Brazilian coastal.

[2] In Ivashin, 1980 (p. 234) the names of these two forms were accidentally transposed.

stock boundaries can be obtained for the Bryde's whale populations of the Southern Hemisphere. One of the most simple and effective ways is the morphological approach of Yablokov (1976) and such work should be carried out during any future harvesting of Bryde's whales.

REFERENCES

Al-Robbae, K. 1969. Bryde's whale on the coast of Iraq. *Saugetierkunde*, 54(2): 120–5.

Bannister, J. L. 1964. Australian whaling 1963. Catch results and research. *C.S.I.R.O., Aust. Div. Fish. Oceanogr. Rep.*, 38: 1–13.

Best, P. B. 1977. Two allopatric forms of Bryde's whale off South Africa. *Rep. int. Whal. Commn* (special issue 1): 10–38.

Chittleborough, R. G. 1959. *Balaenoptera brydei* Olsen on the west coast of Australia. *Norsk Hvalfangsttid.* 48(2): 62–6.

International Whaling Commission. 1980. Report of the Scientific Committee. *Rep. int. Whal. Commn* 30: 42–137

International Whaling Commission. 1981. Report of the Scientific Committee. *Rep. int. Whal. Commn* 31: 51–165.

International Whaling Statistics. 1980. Vol. LXXXV. 54pp.

Ivashin, M. V. 1980. On the populations of Bryde's whales (*Balaenoptera edeni* Anderson, 1978). *Rep. int. Whal. Commn* 30: 233–6.

Kuzmin, A. A., Ivashin, M. V. and Vladimirov, V.V. 1978. Preliminary report on Bryde's whales catch taken by special permit in the Southern Hemisphere during the 1977/78 whaling season. *Rep. int. Whal. Commn* 29: 377–9.

Mahdi, N. 1967. First record of Bryde's whale, *Balaenoptera edeni* Anderson, from Arab Gulf, with notes on earlier literature. *Bull. Iraq. Nat. Hist. Mus.* 3(7): 1–6.

Ohsumi, S. 1978. Provisional report on the Bryde's whales caught under special permit in the Southern Hemisphere in 1977/78 and the research programme in 1978/79. *Rep. int. Whal. Commn* 29: 267–73.

Ohsumi, S. 1980. Population study of the Bryde's whale in the Southern Hemisphere under scientific permit in the three seasons, 1976/77–1978/79. *Rep. int. Whal. Commn* 30: 319–31.

Omura, H. 1962. Bryde's whales occur on the coast of Brazil. *Sci. Rep. Whales Res. Inst., Tokyo* 16: 1–6.

Omura, H. 1977. Review of the occurrence of Bryde's whales in the northwest Pacific. *Rep. int. Whal. Commn* (special issue 1): 88–91.

Sazhinov, E. G. 1975. Some data on Bryde's whales of the Southern Hemisphere. *Trudy AtlantNIRO* 58: 197–202.

Skryabin, A. S. 1970. On the helminthofauna of Bryde's whales (*Balaenoptera edeni* Anderson) of the northwestern part of the Indian Ocean. *Vop. morsk. parazitol.* p. 112–3.

Yablokov, A. V. 1976. The population morphology as a new trend of the evolutionary morphological and population investigations. *Zh. obshey biol.* 37(5): 649–59. (In Russian).

Yablokov, A. V. and Berzin, A. 1978. Perspective of the development of cetacean investigations. *Biol. Morya* 5: 3–13.

Yuhov, V. L. 1969. Observations for the cetaceans in the Gulf of Aden and in the northwestern part of the Arabian Sea. Sb. pp. 327–8. *Morskye mlekopitayuschye,* Nauka, Moscow.

SC/33/Ba3

Historical Rates of Recruitment to Southern Hemisphere Fin Whale Stocks

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ABSTRACT

In most long-term assessments of whale stocks, net recruitment rates have been either assumed, or calculated from observed changes in female reproductive parameters. Except for Allen's work on fin whales, there have been no direct estimates of long-term changes in recruitment to an exploited stock, so while the population models used by the Scientific Committee are entirely reasonable, there has not yet been any empirical justification of their application to whales. Since Allen's estimates of early age compositions may well have been biased by the use of recent age-length keys, this paper attempts to obtain unbiased estimates by decomposing the length distributions in a different way, and then back-calculates year-class and parent stock sizes much as Allen did but with a more detailed age structure. Where Allen found no increase in recruitment rates and perhaps even a decline during the period of exploitation, the results obtained here are unequivocal in showing a decline in almost every stock. While this conclusion is firmly supported, even required, by the age-length data on which the estimates were based, there are some inexplicable differences between these data and other work on the growth of fin whales that directly challenge the fundamental assumption of the estimation procedure and therefore the validity of the results.

INTRODUCTION

Fin whales (*Balaenoptera physalus*) were exploited in the Antarctic from the early years of this century through the 1975/76 season, but pelagic effort was concentrated on them only during the relatively short period 1954/55 through 1961/62 (IWC, 1971). While large numbers were caught before that time, the blue whale (*B. musculus*) was the preferred species then, and after the apparent depletion of fin whales by the early 1960s fishing effort shifted northward to concentrate on sei whales (*B. borealis*), although some catching of fins continued.

Because fin whales were taken in mixed catches during most of the history of Antarctic whaling, most assessments based on changes in catch per effort have been necessarily restricted to data from the short episode of intense effort on fin whales. From a purely scientific viewpoint this episode was helpful because it caused a large decline in the relative abundance of the stocks, as measured by catch per effort, that permitted the absolute size of the stocks at the beginning and end of the episode to be estimated by the DeLury method.

As originally formulated, this method estimates initial stock size from the decline in catch per effort resulting from the cumulative catch in some period on the assumption that only fishing mortality caused a net change in stock size during the period. In fin whale assessments some allowance had to be made for the possible excess of gross recruitment over natural mortality during the period of intensive fin whaling, and this was done according to various assumptions (Chapman, 1970; Doi *et al.*, 1970), but because fishing mortality was evidently so much greater than any plausible excess of recruitment over natural mortality during this period, the various estimates of stock size before and after the period of high catches were all similar, and the Scientific Committee was able to report a generally agreed set of estimates in 1970 (IWC, 1971). Thus while the absolute size of the several stocks before and after intensive whaling was determined fairly well by the DeLury method, the actual rates of recruitment and natural mortality were not.

Allen (1970; 1971; 1972; 1974) approached the problem differently, estimating gross recruitment rates directly from changes in the age composition of the catch in successive years and deducting an independent estimate of natural mortality to obtain an estimate of the net recruitment rate in each year. With this series he estimated stock sizes during the period of heavy exploitation by a procedure akin to the DeLury method, and then back calculated stock sizes in earlier years on the basis of the total catch and the estimated recruitment in each year.

Allen's reconstructions showed no increase in recruitment rates as the stocks were reduced, and thus ran counter to both the theory of fishing and biological evidence of an increase in pregnancy rates and a decline in the age at sexual maturity during the same period (Gambell, 1976). Moreover, as Allen (1973) pointed out, his results might be biased because he had been obliged to use recent age-length keys to estimate the age composition of catches all the way back to 1931. An age-length key always tends to produce an age composition similar to the one underlying the key, regardless of the true age composition underlying any length sample to which the key is applied (Westrheim and Ricker, 1978), so it was possible that the keys were masking an increase in recruitment rates by erroneously producing similar estimates of age composition over the entire series.

The Scientific Committee, in its deliberations on fin whales and other species, has generally adhered to the theory of fishing and based its management advice on models that included some density dependent increase in recruitment rates, calculated either from observed changes in female reproductive parameters or as a direct function of stock size. While these models are certainly plausible, the recruitment rates they predict are nevertheless entirely theoretical. In no case have the mechanisms been based on empirical data, or the predictions verified by later developments.

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The aim of this paper is to obtain unbiased estimates of fin whale recruitment rates during the period of exploitation with a minimum of assumptions, and therefore to ascertain, at least for these stocks, how recruitment responded to a reduction in stock size. The method employed is cohort analysis, a simple back-calculation of year-class size that requires only an estimate of stock size and age composition at the end of a period, an estimate of natural mortality, and catches at each age in each year. The Southern Hemisphere fin whales are good subjects for cohort analysis because catches were taken over a long period, stock sizes around 1960 are well known from DeLury techniques, and age data collected after 1955 provide good estimates of the rate of natural mortality and the age composition of adults during the period of heavy exploitation.

The major obstacle to cohort analysis is the lack of age data for the years before 1955. What is available instead is the length distribution of catches, and while age compositions cannot be estimated from them with recent age-length keys, a method proposed by Clark (1981) can be applied. The basic assumption of this method is that the length distribution of each age group in the catch does not change over time. These age-specific length distributions can be obtained from recent age-length sampling data, and the age composition required to produce the observed total length distribution in each of the previous years can then be estimated by multiple regression.

Age groups are discriminated better by this method when there are more length groups in the data, and for that reason the analysis here is restricted to female fin whales. (The minimum size limit for most of the catch was 57 ft for both sexes, and owing to their greater size at maturity females were effectively spread over about twenty one-foot length intervals as opposed to about fifteen among the males.) The analysis is also restricted to years before about 1965, partly because the DeLury estimates provide a good starting point for the cohort analysis then and partly because at some point during the 1960s there was evidently a major change in the growth schedule of fin whales (discussed below), which of course violates the basic assumption of the regression procedure. Finally, no attempt has been made to treat the stock in Area I because there are very few age-length data for it.

In what follows, the basic age-length data will be used to obtain estimates of age-specific length distributions and natural mortality, the estimates of catch composition by age and cohort analyses will be explained, and the resulting series of recruitment rates discussed. All of the age-length sampling data for this study were provided at considerable effort by the Japanese Far Seas Fisheries Research Laboratory, to which the author expresses his thanks.

BASIC DATA

Insofar as they were reported, the basic data on catches and length distributions needed for this study were readily available from the *International Whaling Statistics* and the tape file of pelagic catches prepared by the Bureau of International Whaling Statistics. There is no such central source of age-length sampling data, and the one consolidated tape prepared for the Committee of Three Scientists, referring to the years 1956–61, is no longer fully useful because at that time it was believed two laminae were formed on the earplug each year instead of one, so in the data all the nominal age-groups are in fact pairs. Moreover, all ages beyond forty (nominal twenty) are grouped, so the age distribution of the older adults is invisible.

About 75% of the data assembled for the Committee of Three were Japanese, and for this study the Japanese Far Seas Fisheries Laboratory kindly sent all its fin whale age-length sampling data, covering seasons from 1956/57 until the end of the exploitation in 1976. For seasons after 1965/66 these data were on magnetic tape along with other data, one record per specimen, while for the earlier years only tabulations of the sample age-length frequencies were sent, broken down by sex, Area, season and series (D = 40°–50°S, A = 50°–60°S, B = 60°–70°S). These tabulations showed length to the nearest foot and age in years through 50, all older animals being grouped. There were of course very few animals less than the minimum length of 57 ft, and among females few greater than 77 ft long and very few younger than three years old.

For practical purposes, therefore, the data could in each case be put into a table or key with 21 length groups (57, 58, . . ., 76, 77+ ft) and 49 age groups (3, 4, . . ., 50, 51+). The distribution of lengths at each age was such that only about half of these 1,029 age-length categories would actually be represented in any joint distribution, but there were still on the order of 500 proportions to be estimated from the sampling data to construct a single key. The size of this task required that the data be grouped insofar as possible to increase the sample size for each key.

Fortunately this was possible. In each Antarctic Area Japanese catches over the span 1956–70 were concentrated in one or two clearly identifiable periods of three to five years each, and within each such period both the latitudinal distribution of samples and the ratio of samples to catches were reasonably consistent among most years. As a result it was possible to identify in each Area (except Area I) one or two periods of three to five successive years with large, comparable samples and consistent sampling ratios (Table 1). These periods also include all but a small fraction of the Japanese data.

All the age-length sampling data on females for each Area and period were combined to make a single key, in which the very rare two-year-olds were counted as three-year-olds, all lengths equal to or greater than 77 ft were treated as a single group, and all animals less than 57 ft were disregarded. This composite key was then applied to the length distribution of the total Japanese catch of females in that Area and period to estimate its joint age-length distribution. Tables[1] 2.1 through 2.5 show these distributions for Areas II–VI in periods before 1965, and Tables[1] 3.1 and 3.2 show the distributions in Areas III and IV in periods after 1965. Figs 1 and 2 show the tabulated age compositions for the earlier and later period, respectively.

DISTRIBUTIONS OF LENGTH AT AGE

The regression method of decomposing the early length distributions into component age groups requires that the relative length distributions of each age group in the catch remain constant over time. So long as this assumption holds, the method will provide unbiased estimates of any series of age compositions regardless of changes over time in the relative abundances or catchabilities of the various age groups.

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[1] Tables 2.1–2.5 and 3.1–3.2 are on pp. 318–24.

Table 1

Series of Japanese age-length sampling data on female fin whales combined to produce the keys used in this study. (Each entry is sample size/catch.)

Area	II	III	IV	V	VI
Season*					
59		254/417	2,610/3,440	410/717	134/153
60		1,635/2,483	835/1,094	96/119	662/922
61		3,326/5,032	970/1,495		
62	534/1,235	2,527/4,488	233/392		
63	837/2,726	933/1,929			
64	667/2,095				
65					
66					
67			274/343		
68		145/239	351/627		
69		407/623	238/379		
70		393/625	161/236		

* Season 59 = 59/60, etc.

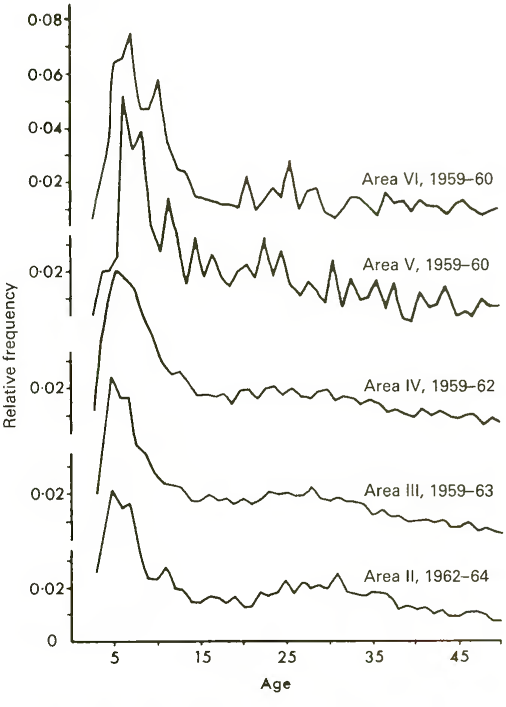

Fig. 1. Age composition of Japanese catches of female fin whales in periods before 1965. (Data from Tables 2.1–2.5.)

Any major change in the growth schedule of a stock would obviously violate the basic assumption, and in most cases so would selection by size in the fishery. When exploitation is size selective, the length distribution of the catch of a particular age-group in a particular season will depend, in a very complicated way, on the diverse natural growth schedules of its members, the pattern of selection, and the level of fishing mortality, all considered over the entire previous history of exploitation of that year-class (Beddington and Cooke, 1980).

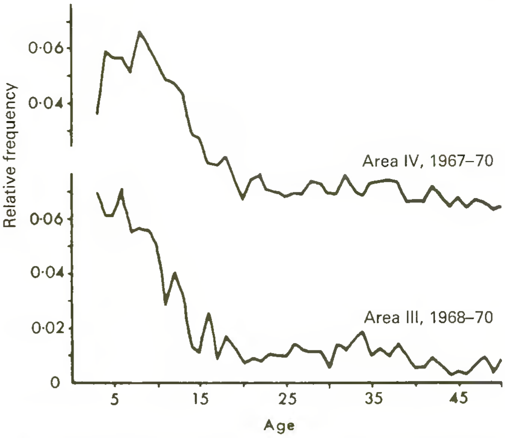

Fig. 2. Age composition of Japanese catches of female fin whales in periods after 1965. (Data from Tables 3.1 and 3.2.)

Both kinds of problems seem to be present in the age-length distributions in Tables 2 and 3. In the pre-1965 data the length distributions of the first several age groups appear to extend well below the 57 ft minimum size limit, so that during this period of heavy exploitation every year-class passed through several years when only its larger members were exploited. This differential mortality caused by the size limit could be expected to shift and skew the length distributions of the younger age groups, and selective catching of the larger animals among those greater than 57 ft would accentuate this effect. In the post-1965 data nearly all the distributions are well clear of the limit owing to a major upward shift in the length distributions of all the younger age groups.

These data show that at least in Areas III and IV, the length distributions of the younger age groups in the catch certainly did not remain constant between 1960 and 1970. There are several possible reasons for the difference, and a consideration of all of them will show whether any of the recent age-length data can be used in decomposing the early length distributions.

(i) *Size segregation.* After fin whales were depleted in the early 1960s, the industry turned to sei whales and effort shifted northward. If the larger members of the younger fin whale age groups had a more northerly distribution than the smaller members, this could account for the difference between the two data sets. It seems unlikely that the larger animals would prefer lower latitudes, and there is no sign of size segregation in a comparison of the age-length data from different series in the same Area and season. It is true that for Area III the pre-1965 data came mostly from series A and the post-1965 data entirely from series D, but for Area IV the great majority of data in both sets came from series A.

(ii) *Change in growth rate.* Lockyer (1972, 1977, 1979) found from studies of earplugs that the mean age of females at puberty had decreased as a result of exploitation. In Areas II and III the decrease was from 10.5–11 years to 6.0–7.8 years and in Area IV from 11.5 to 8.5 years. Meanwhile the mean lengths at sexual maturity (about 65 ft) and physical maturity (72–73 ft) had not changed, so Lockyer concluded that there had been an increase in growth rate. The mean lengths at age in the earlier and later Japanese catches show this change almost exactly (Table 4): a mean length of 65 ft was reached at about age 10 in Areas II, III and IV before 1965, and at age 6 in Areas III and IV after 1965.

Table 4

Female mean lengths at age in Japanese catches before and after 1965

			Mean lengths[1] at age (ft)				
Area	Series[2]	Season	6	8	10	12	51+
Before 1965							
II	A (D)	62–64	61.6	63.5	64.7	66.9	72.8
III	A (D)	59–63	61.2	63.4	65.7	68.0	72.6
IV	A (B)	59–62	60.4	62.2	64.7	66.4	72.5
V	B	59–60	60.3	61.9	64.5	66.1	71.8
VI	B	59–60	59.4	61.0	61.6	63.7	70.7
After 1965							
III	D	68–70	64.8	67.8	68.4	69.1	72.2
IV	A (D)	67–70	65.7	67.8	68.2	69.1	72.6

Notes

[1] Taking no account of the variance of the estimates of numbers in Tables 2 and 3, the standard errors of the mean lengths are typically 0.3–0.5 ft.

[2] The table shows the series where the majority of the samples were collected. If more than 10% of the material came from a different series, that is shown in parentheses.

It would be very convenient to conclude from this that the change in growth rate occurred after the period of heavy exploitation, so that the earlier Japanese data could be interpreted as estimating a growth schedule that prevailed in all earlier years, but there are two obstacles. First, Lockyer's (1979) earplug data show that the age at puberty had begun to decrease by 1930 in all Areas. Second, Lockyer's samples show females reaching 65 ft at age 6 in those years.

(iii) *Change in size selection.* It was not until the 1965/66 season that the Commission finally agreed to a drastic reduction in the Antarctic quota. Thereafter the Japanese fleet may have sought to obtain the greatest amount of product from its numerical quota by selectively harvesting larger animals, and for whatever reason the operation that provided Lockyer's (1972) material might have been conducted in the same way even before the quota was lowered.

The difficulty in this interpretation is that the length distributions of the younger age groups in Japanese catches before and after 1965 are so different that they could not be the result of any plausible and consistent change in selectivity. Table 5 shows the length distributions of the younger age groups in both periods in Areas III and IV, the length spectrum being divided into three intervals as follows:

a—57–63 ft
b—64–68 ft
c—>68 ft

If the earlier catches were non-selective, then the ratio of fishing mortalities on the different length classes within each age group in the later period can be obtained from, for example

$$\frac{p'_c}{p'_b} = \frac{F'_c}{F'_b} \cdot \frac{p_c}{p_b}$$

where the primes denote the later period. These ratios of fishing mortality rates between length groups are shown in Table 6. They suggest that if selection alone accounted for the difference, then the rate of fishing mortality in the later period on available small females (57–63 ft) was only about 1/12 that on large females (>68 ft) in Area III and only about 1/25 that on large females in Area IV. Meanwhile something like 1,000 large females were taken in Area IV during the later period so even if all in that length group were caught, the numbers of small whales (including males and animals under 57 ft) in Area IV at that time would have to have been incredibly large to explain the change in length-at-age distributions by some change in length selection by the fishery.

(iv) *Effect of the size limit.* The earlier Japanese data refer to a period of heavy exploitation, when any age group with a length distribution spread across the 57 ft minimum size limit would have experienced a significant differential mortality. This would produce, at least temporarily, a length distribution skewed to the left with a mean lower than would be obtained in the absence of differential mortality.

While this effect must be present in the data, it cannot explain the difference between the two sets of Japanese distributions. First, if the later data accurately portray the natural distributions during the earlier period, then the size limit could hardly have had any effect. Second, the samples from Area IV in 1958/59 and 1959/60, taken when that stock had previously been less exploited than others, are not noticeably different from other samples taken before 1965 from that Area or from samples taken before 1965 in Areas II and III. Third, in Area III, where exploitation was probably heaviest (among the Areas and periods covered by the pre-1965 data), there is no evidence of the expected positive skew. The length distributions of ages 3 through 9 are of course positively skewed owing to truncation at 57 ft, but from age 10 through age 20 the median length exceeds the mean length in 10 out of 11 cases. It might be argued that some positive skew in these distributions was masked by selection in favor of larger animals, but by age 20 the length distribution is very close to that of physically mature adults, and there was evidently no selection by size among them as there is no trend in mean length with age among older animals.

If only the two sets of Japanese data had been considered, the conclusion of the entire preceding discussion would be that a change in growth must have occurred during the eight or so years separating the two sampling periods, and that the earlier data could be used as estimates of age-specific length distributions in all earlier catches, as these data show no evidence of size selection and they do show the average length at puberty being reached at the same age as in the period before exploitation. That will in fact be the working hypothesis in what follows, but there remain two unsolved questions:

(i) If Lockyer's (1979) estimates of age at puberty since 1950 or so are correct, why are the animals of that age in Japanese catches taken between 1959 and 1963 so far below the established length at puberty?

(ii) Even if all of Lockyer's estimates of age at puberty during exploitation are wrong, why are her estimates of mean length at younger ages in Areas II and II during the period 1960–65 (Lockyer, 1972) so different from the corresponding values in Japanese data referring to virtually the same time and place? (Differences in aging criteria are not a problem with Antarctic fin whales [IWC, 1974], and as explained above real differences due either to length selection or to segregation by size within age groups are extremely unlikely.)

Table 5

Pre- and post-1965 female fin whale length-at-age distributions, Japanese catches

Age		4	5	6	7	8	9	10	11	12
					Area III					
Pre-1965	57–63	0.915	0.842	0.770	0.693	0.546	0.479	0.278	0.290	0.187
	64–68	0.066	0.134	0.201	0.250	0.363	0.343	0.491	0.420	0.312
	> 68	0.019	0.025	0.029	0.057	0.091	0.178	0.232	0.290	0.501
Post-1965	57–63	0.619	0.453	0.384	0.235	0.096	0.121	0.041	0	0.070
	64–68	0.341	0.390	0.426	0.471	0.429	0.271	0.527	0.322	0.418
	> 68	0.040	0.158	0.190	0.295	0.473	0.608	0.431	0.680	0.514
					Area IV					
Pre-1965	57–63	0.929	0.939	0.870	0.775	0.680	0.556	0.330	0.246	0.202
	64–68	0.055	0.056	0.107	0.209	0.261	0.347	0.541	0.499	0.534
	> 68	0.016	0.004	0.023	0.017	0.059	0.097	0.129	0.255	0.265
Post-1965	57–63	0.722	0.549	0.220	0.157	0.137	0.069	0.114	0.105	0.023
	64–68	0.174	0.279	0.593	0.480	0.364	0.491	0.378	0.329	0.407
	> 68	0.103	0.171	0.188	0.361	0.501	0.441	0.511	0.566	0.572

Table 6

Apparent ratios of fishing mortality rates between length groups after 1965 (a = 57–63 ft, b = 64–68 ft, c = > 68 ft. (Parentheses indicate ratios for which one or more of the proportions was less than 0.05.)

Age	4	5	6	7	8	9	10	11	12	Mean[1]
					Area III					
F'_b/F'_a	7.64	5.41	4.25	5.55	6.72	3.13	(7.28)	—	3.58	4.96
F'_c/F'_b	(2.03)	(2.17)	(3.09)	2.75	4.40	4.32	1.73	3.06	0.77	2.44
Product	15.51	11.74	13.13	15.26	29.57	13.52	12.59	—	2.76	12.10
					Area IV					
F'_b/F'_a	4.07	8.52	21.92	11.34	6.92	11.40	2.02	1.54	(6.69)	6.18
F'_c/F'_b	(2.03)	(8.58)	(1.47)	(9.25)	6.09	3.21	5.67	3.37	2.83	4.03
Product	8.26	73.10	32.22	104.89	42.14	36.59	11.45	5.19	18.93	24.91

[1] Geometric mean of unparenthesized values.

NATURAL MORTALITY

In the first thorough, quantitative assessment of Antarctic fin whales, the Committee of Three Scientists estimated natural mortality by applying recent age-length keys to the length distributions of early catches and then calculating Heincke estimates from the resulting age compositions. The value they adopted was 0.05, the mean of the estimates for males and females in the 1931/32 catch curves (IWC, 1964). This work assumed that two earplug layers were formed each year; since it was later established that only one layer is formed per year (IWC, 1969), the Committee of Three estimate should have been 0.025.

Doi *et al.* (1970) calculated estimates of natural mortality by Area from the relative abundance of older age groups in the catches. (The exact method is not stated.) For females the estimates ranged from 0.035 to 0.066, with the higher values occuring in Areas II–IV. The pooled estimate was 0.057, and the average of all Areas 0.049. Lower estimates were obtained for males (range 0.021–0.042, average 0.034).

After considering this work and other material at a special meeting on Antarctic fin whales in 1970, the Scientific Committee adopted 0.04 as the best estimate of the average natural mortality rate for both sexes and all Areas (IWC, 1971). Despite fairly consistent indications of differences by Area and sex, this agreed average has been the value most often used in later work.

For this study regression estimates of natural mortality have been computed from that part of each age composition in Table 2 referring to year-classes that were probably fully recruited to the fishery when exploitation began. In Area IV, for example, whaling commenced with pelagic operations around 1930, so the calculation took in year-classes born in 1920 and earlier (treated as ages 40 and over in the Table). In Areas V and VI whaling started much later, so more ages were included. In Area II whaling began before 1910, so no really proper estimate was possible, although one was calculated. In all cases animals older than 50 were excluded on the grounds that these were likely to have a higher natural mortality rate than younger adults.

The results (Table 7) are in line with earlier estimates except for Area VI, where the value is clearly much too low. The estimate for Area II is not reliable as it refers to a period (roughly 1910–20) when whaling was in progress, but if in error it should be too high rather than too low, and in fact it is at the low end of the range. On the whole these results confirm previous estimates in the range 0.04 to 0.07, but they are not precise enough to provide a single value for any Area, so in the cohort analyses reported below a range of values will be used.

At some point late in life the natural mortality rate probably increases, and this has to be considered in a long-term cohort analysis that necessarily involves back-calculating the abundance of a year-class from catches made at great ages. Rather than attempting to estimate age-specific rates, the approach here will be to treat all animals over 50 as a single group and to estimate what single rate must have applied to that group as a whole to account for its abundance relative to that of animals aged 41 to 50 in the age compositions shown in Table 2.

Table 7

Regression estimates of natural mortality from the age compositions in Table 2

Area	Ages	Estimate	Standard deviation
II	40–50	0.040	0.011
III	40–50	0.069	0.013
IV	40–50	0.060	0.021
V	32–50	0.039	0.033
VI	25–50	0.021	0.010

Except for Area II, all these data refer to year-classes that were at least ten years old at the start of whaling and therefore should have been equally abundant at birth and equally reduced by fishing. Letting N_{41} denote survivors to age 41, the total numbers aged 41 through 50 should be

$$N_{41-50} = N_{41}\,(1 - e^{-10M})/(1 - e^{-M})$$

and letting M* denote the rate of natural mortality beyond age 50, the total number of animals in that group should be

$$N_{51+} = N_{41}e^{-10M}/(1 - e^{-M^*}).$$

The ratio of the two is therefore

$$\frac{N_{51+}}{N_{41-50}} = \frac{e^{-10M}\,(1 - e^{-M})}{(1 - e^{-M^*})\,(1 - e^{-10})} = \frac{(1 - e^{-M})}{(1 - e^{-M^*})(e^{10M} - 1)}$$

If M were known the value of M* could be calculated from the ratio. M is not known precisely, but in fact the estimate of M* is not very sensitive to the precise value of M. As shown in Table 8, the ratio N_{51+}/N_{41-50} is quite consistent among Areas III–VI, and in each Area the range of calculated values of M* is much smaller than the range of trial values of M. Since the variation is not great, all the data have been pooled in the last column, and the approximate midpoint of those values (0.08) will be used as the single value of M* in all computations.

Table 8

Estimates of natural mortality rate among older females. (In the table, M* refers to the rate among animals over 50, M to the rate among younger adults, and N to the number of the given age range in the age compositions of Table 2.)

Area	III	IV	V	VI	Total
N_{51+}	985	477	60	100	1,622
N_{41-50}	1,091	464	56	94	1,705
N_{51+}/N_{41-50}	0.90	1.03	1.07	1.06	0.95
$M^*\|M = 0.04$	0.091	0.081	0.076	0.076	0.086
$M^*\|M = 0.05$	0.087	0.076	0.073	0.073	0.082
$M^*\|M = 0.06$	0.082	0.071	0.069	0.069	0.078
$M^*\|M = 0.07$	0.077	0.067	0.065	0.065	0.073

Before leaving the age compositions, some comment needs to be made on their unusual shape. In Areas II, III and IV the pre-1965 data (Tables 2.2–2.4) show no decline in relative abundance with age from about age 15 to about age 30 (Fig. 1), and the same plateau appears in the post-1965 data for Areas III and IV, shifted up to about 5 years to ages 20–35 (Fig. 2).

Presumably these age-groups were all fully recruited, so the catch composition should be an accurate reflection of their relative abundance in the stock. If the pre-1965 data are regarded as referring to 1960 on average, then the age-groups in question are the survivors of year-classes born between 1930 and 1945, and their apparently equal abundance in 1960 indicates a *decrease* during that period in the gross recruitment rate (r_I, recruits as a proportion of parent stock in the year of birth). To see why, suppose that all of each year-class recruited to the fishery at age 5. Let P_i denote the size of the parent stock in year i, r_i the gross recruitment rate pertaining to the year-class born in year i, $N_{i(j)}$ the size in year i of the year-class born in year j, and S the survivorship of recruited animals over the period indicated, so for example S_{35-60} will be the survivorship of fully recruited animals from 1935 to 1960. Then in 1935 the size of the 1930 year class was by definition

$$N_{35(30)} = r_{30}P_{30}$$

and in 1960

$$N_{60(30)} = r_{30}P_{30}S_{35-60}.$$

Similarly, the abundance of the 1945 year-class in 1960 was

$$N_{60(45)} = r_{45}P_{45}S_{50-60}.$$

But according to the age compositions the two year-classes were about equally abundant in 1960, so

$$r_{30}P_{30}S_{35-60} = r_{45}P_{45}S_{50-60} \text{ or } r_{30}P_{30}S_{35-50} = r_{45}P_{45}.$$

Since $S_{35-50} = S_{30-45} \cdot S_{45-50}/S_{30-35}$, the last equation can be rewritten as

$$r_{30}P_{30}S_{30-45} = r_{45}P_{45}S_{30-35}S_{45-50}.$$

Catches were considerably larger in 1945–50 than in 1930–35, so

$$(S_{30-35}/S_{45-50}) > 1 \text{ and } \frac{r_{30}}{r_{45}} > \frac{P_{45}}{P_{30}S_{30-45}}.$$

In the ratio on the right, the numerator exceeds the denominator by the number of animals that recruited after 1930 and survived to 1945. The ratio must substantially exceed unity, and therefore r_{30} must have substantially exceeded r_{45}.

It should be pointed out that this conclusion depends on the simple scheme assumed, namely knife-edge recruitment at age 5 and constant mortality with age thereafter. By varying age-specific rates with natural mortality and recruitment, and by assuming different levels of fishing mortality in the 1930s, one can generate predicted 1960 age compositions in a variety of shapes, including some with plateaux similar to those in Fig. 1. But while some of the possibilities are similar to the observed distributions, in none of them is the plateau so wide and so flat.

In the cohort analysis reported below it will be assumed that fishing and natural mortality were constant with age after about age ten, as in previous assessments. On this assumption the results show a decline in gross recruitment rates, but it is important to realize that the substance of this result is inherent in the 1960 age compositions in Areas II, III, and IV, and does not depend on the involved arguments and computations required to decompose the early length distributions and perform the back-calculations.

In Area V the 1960 age composition is quite orthodox; there is a good deal of scatter owing to sparse data (504 females 57 ft or longer), but on the whole there is a consistent decline in relative abundance with age among the adults. Area VI has the strangest age composition of all, relative abundance increasing with age from about 15 to 30, then dropping to a level that persists from 30 to 50. It is this flat section that produced the absurdly low regression estimate of natural mortality in Table 5.

ESTIMATES OF EARLY AGE COMPOSITION

As explained above, the Japanese age-length data taken before 1965 will be treated here as accurately estimating the length distribution of each age group in each Area from the beginning of exploitation through the seasons covered by the samples. For this purpose, the sampling data for each age group in each Area can be converted to proportions that estimate the fraction of that age group that falls into each length interval. To be precise, let X_{ij} denote the fraction of age group j that falls in length interval i, let p_i denote the fraction of the total catch in length interval i, and let π_j denote the fraction of the total catch represented by age group j. Then if there are J age groups

$$p_i = \sum_{j=1}^{J} X_{ij}\pi_j$$

This relationship can be described in matrix form for all I length intervals and J age groups as

$$\underline{X}\,\underline{\pi} = \underline{p}$$

where $\underline{p}$ is the total relative length distribution, $\underline{\pi}$ is the total relative age distribution, and $\underline{X}$ is a matrix of each of whose columns represents the relative length distribution of an age group. Thus, the total length distribution is obtained as a weighted sum of the length distributions of the component age groups, the weights naturally being the relative frequencies of the age groups.

If the matrix $\underline{X}$ is known and constant, and if the length data for a stock are divided into at least as many length intervals as there are age groups with distinct length distributions, unbiased estimates $\hat{\underline{\pi}}$ of the age composition corresponding to any sample length distribution $\hat{\underline{p}}$ can be calculated by multiple regression. In practice the matrix $\underline{X}$ is never known exactly, and even if it were, straightforward regression would fairly often produce some negative estimates of relative age frequencies. Clark (1981) has found that if sample sizes are large enough sample estimates of $\underline{X}$ will perform nearly as well as the true matrix, and has proposed a quadratic programming technique that locates the non-negative age composition estimates satisfying the least-squares criterion. These estimates are unbiased, and while their variances cannot be calculated by formula, the computer routine is fast enough that empirical variances can be calculated by simulating the effect of sampling error in the sample length distribution. (This procedure does not measure variance due either to sampling error in the estimate of the matrix $\underline{X}$ or to natural variability in its true value, which in some cases account for most of the variance.)

Sample sizes in the Japanese age-length data are large enough to provide reasonable estimates of age composition, and these can be obtained from the length distribution of the total catch in each season. Differences in selectivity among operations or seasons will not affect the estimates so long as catchability at any given time and place depends on age; if it depends heavily on size then the estimates will be biased. But as explained above, while fin whale catches must have been size selective if only because of the minimum size limit, the Japanese data do not show much effect of size selection, and the same will be assumed of catches taken in other operations.

Length data are available for most fin whale catches in Areas II–VI from the 1931/32 season forward, but there are some gaps that were filled as follows:

(i) The South Georgia catch in 1940/41 was assigned the sex and length distribution of the 1939/40 catch.

(ii) The South African catch in the summer season 1939 was assumed to be zero, none being recorded in the *International Whaling Statistics*. South African catches in the 1940–45 seasons were assigned the pooled sex composition of catches in the 1931–38 seasons, and all South African catches of females in the 1931–45 seasons were assigned the pooled length distribution of the 1936 and 1937 catches, these being the only length distributions reported in that period. Since most pelagic catches were taken in the southern summer, presumably after most whales had accomplished more than half their growth for the season, South African catches were combined with the previous season's pelagic catches to obtain a total length distribution for Area III catches in that season (e.g., 1948/49 catches included South African catches in the summer season 1949).

(iii) Pelagic catches in 1939/40 and 1940/41 were distributed by Area, sex and length in the same proportions as the 1938/39 pelagic catch.

(iv) Pelagic catches in 1943/44 and 1944/45 were ignored (1,205 males and females in all Areas).

The basic data in Table 2 refer to that part of each age group's length distribution from 57 ft onward, that being the minimum size limit, when the data were collected. But until 1937 there was no size limit, and thereafter it was 55 ft for pelagic operations (including South Georgia) until the 1951/52 season when it was increased to 60 ft, which remained in force until the 57 ft limit was established in the 1954/55 season. At South African land stations a size limit of 55 ft went into effect in 1952 and was not changed thereafter. Since the data available for this study provided no information about animals less than 57 ft, all catches in those length intervals were ignored. (These were a small percentage of the catch in all years, and since they must all have been young animals their inclusion would have little effect on estimates of year-class strength obtained by cohort analysis, which owing to the nature of the back-calculations gives greater weight to catches at greater ages.) Similarly for seasons when the pelagic size limit was 60 ft and animals of 57–59 ft were not present in any numbers in pelagic catches, all catches less than 60 ft were ignored and the regression matrix was adjusted to reflect only relative length distributions from 60 ft onward.

As explained by Clark (1981), the regression method of decomposing length distributions is very imprecise when the component distributions are poorly separated, i.e. when the difference between successive mean lengths at age is small relative to the standard deviations of the distributions. In all the fin whale data the length distributions of all physically mature age groups are of course the same, and even among the youngest age groups the mean lengths never differ by as much as half a standard deviation. (The standard deviations are typically 3–5 ft up to age 15 or so and 2–3 ft thereafter.) The method requires differences of at least one standard deviation, so for estimation purposes the age groups in each table were divided into five sets, containing respectively ages 3–5, 6–9, 10–14, 15–20 and 21+. For each set a composite relative length distribution was calculated as the arithmetic average of the component relative distributions, and these composite distributions formed the regression matrix used to analyze the length distributions from 1931/32 forward into the five age sets.

This expedient would be formally correct only if within each age set each component age group were equally abundant in the catches. They are not, but on the other hand the stocks and the fishery are such that large differences in abundance between successive age groups are unlikely, so treating them as equal in each set in each year should not introduce much error. And at least in trials with the Japanese length distributions corresponding to the sample data it does not; the composite matrix accurately decomposes them into the five age sets.

Once the age compositions of the catches by age sets had been estimated, the estimated catch from each set in each year was allocated among the component age groups. In the first four sets (through age 20), the catch was divided equally among the age groups in each set. In the last set (ages 21+), the catches were allocated according to a complicated scheme best explained by example. In Area III the basic data are the absolute joint age-length frequencies of the total Japanese catch of females in the seasons 1959/60–1963/64. This catch is treated as having been taken in 1959/60, and the relative frequencies therein of ages 21, 22, . . ., 50, 51+ are assumed to hold for the entire catch in that year. In the preceding season these age groups are 20, 21, . . ., 49, 50+. In this season the catch at age 20 is estimated by regression as part of the catch from age set 15–20, and the estimated catch from age set 21+ is allocated among the remaining adult age groups in proportion to their abundance in the reference season. As the process continues backward, one year-class leaves the reference adult age distribution each year, and the oldest age group discriminated decreases by one year. Thus the uppermost age group is 51+ in 1959/60, then 50+ in 1958/59, then 49+ in 1957/58, and so on down to 23+ in 1931/32, when the estimated catch from age set 21+ is allocated among age groups 21, 22, 23+ according to the relative abundance of age groups 49, 50, 51+ in the reference season 1959/60.

This procedure assumes and assures equal fishing mortality among all animals older than 20, which seems reasonable. While the allocation of catches among adult age groups is determined by their relative frequencies in the reference season, the total catch of adults to be allocated in each season is determined by regression.

In the course of estimating age compositions by age sets, variance estimates were also obtained by simulating the effect of sampling error in the length distributions. When the catch from age sets was allocated among age groups, the variances were passed along as well. In the case of subadult age sets the variance was divided equally among age groups to preserve the total. Among adult age groups the estimated variance of catch at age had two components, one due to error in the estimated total adult catch and the other due to error in the estimated frequency of that age group relative to other adult age groups in the reference season.

Owing to the numbers present in the sampling data and the length distributions, most of the estimated variances were small in comparison with the estimated catches at age and too small in comparison with the year-to-year fluctuations in the estimated relative frequencies of age sets in the catch. There is no question but that the purely statistical sources of error measured in the computations account for only a part of the random error in the estimates.

COHORT ANALYSIS

Since the Japanese catch of females in the reference seasons covered by the age-length sampling data in each Area was used as a starting point for allocating the catch of adults among age groups, it was also used to provide a starting estimate of the age composition of the exploited stock in each Area at the beginning of the first of the reference seasons. Thus in Area III, where the reference seasons were 1959/60–1962/63, the age composition of the exploited female stock at the start of the 1959/60 season was estimated by the age composition of the total Japanese catch of females during all four reference seasons.

The size of the exploited stock in each Area at this time was taken to be the DeLury estimate agreed by the Scientific Committee for the Antarctic as a whole (IWC, 1971) and broken down by Area by Chapman (1971). Since these stock estimates refer to the beginning of the 1957/58 and 1961/62 seasons, they had to be calculated ahead by one or two years in each Area to obtain an estimate for the beginning of the first reference season in each Area (Table 9).

Given an estimate of the total exploited stock at the beginning of this season, the exploited female stock was estimated to be half of it. Then the estimated numbers at each age (and their standard deviations) in the Japanese reference catch were raised by the appropriate factor to obtain the estimated numbers at each age (and their standard deviations) in the total exploited female stock. Thus the starting values took account of variance in the age compositions but not in the stock size estimates.

Since the total catches of females in Areas II and III during the four or five reference seasons were about equal to the estimates of exploited female stock in the beginning (Table 10), these estimates cannot be too high by very much, but they may be too low. To allow for this possibility all the cohort analyses were run with two sets of starting stock sizes: the ones shown in Table 8, and twice those values. Similarly, because of uncertainty as to the natural mortality rate, all the analyses were performed with a range of values of M (0.02, 0.04, 0.05, 0.06), except that, as explained above, a rate of 0.08 was applied to animals older than 50 in all cases.

Given the starting estimates and their variances, a natural mortality rate, and the estimated catches at age back to 1931/32, the cohort analysis itself was fairly simple. The abundance of N_{ij} age group i at the beginning of season j was estimated as

$$\hat{N}_{ij} = \hat{N}_{i+1,j+1}\, e^{M} + \hat{C}_{ij}$$

and its variance as

$$V(\hat{N}_{ij}) = e^{2M}\, V(\hat{N}_{i+1,j+1}) + V(\hat{C}_{ij})$$

It will be recalled that the last age group in each year's catch estimates consisted of all animals above a certain age, and this age decreased by one each year from 51+ in the starting season. The estimates of numbers at age in each year were obtained in the same form, i.e. as age groups 3, 4, . . ., 50, 51+ in the starting season, then 3, 4, . . ., 49, 50+ in the preceding season, and so on. In the calculations, of course, the component 51+ of the last age group was maintained separately so that animals could be resurrected from there at the higher natural mortality rate, but otherwise no attempt was made to distinguish the age composition of the oldest age group in each year's estimates.

Table 9

Forward calculation of DeLury estimates given by Chapman (1971) of total exploited fin whale stock sizes. (Chapman's figures are indicated by an asterisk; other stock sizes were computed from them with M = 0.05 and annual recruitment equal to 10% of the 1957/58 stock size.) All figures are in thousands; SS = stock size, C = catch

	Area II		Area III		Area IV		Area V		Area VI	
Season	SS	C	SS	C	SS	C	SS	C	SS	C
57/58	40.0*		66.5*	10.1	29.4*	3.6	16.1*	1.1	11.0*	4.1
58/59			60.0	10.3	27.3	7.3	15.8	2.6	7.6	2.1
59/60			53.7		21.8		14.1		6.3	
60/61										
61/62	28.7*	7.3								
62/63	24.1									

Table 10

Derivation of raising factors to relate Japanese catches of females during reference seasons to stock size estimates

	Area II	Area III	Area IV	Area V	Area VI
Reference Seasons	62–64	59–63	59–62	59–60	59–60
Total exploited stock at start (Table 7)	24.1	53.7	21.8	14.1	6.3
Exploited female stock N_f (half of above)	12.1	26.9	10.9	7.1	3.2
Total catch of females in reference seasons	10.1	27.7	7.2	4.2	1.8
Japanese catch of females in reference seasons C_{fj}	6.0	14.3	6.4	0.8	1.1
Raising factor N_f/C_{fj}	2.0	1.9	1.7	8.5	2.9
Coefficient of variation of estimated catch at age in Japanese reference catch	0.15	0.10	0.10	0.30	0.30
Standard deviation of raising factor	0.3	0.2	0.2	2.6	0.9

Because the number of age-groups distinguished individually in each year's estimates decreased steadily, only the year-classes that were 50 years old and younger in the starting season could be back-calculated individually to their abundance at age three. The earliest year-classes that could be estimated were three years old in 1912–15 (depending on the Area), and to reach that point it was necessary to make some assumptions about catches taken before 1931–32 where the length distribution data and age composition estimates begin (or end, in terms of the cohort analysis).

The fairly large pelagic catches (20,396 animals) specified only as 'West Antarctic' in the seasons 1927/28–1930/31 were divided between Areas II and III in proportion to the total pelagic catches taken in each Area in the seasons 1931/32–1933/34. The much smaller catches (2,628 animals) specified as 'Ross Sea' were ignored (*International Whaling Statistics* XVI). The remaining early catches (South Africa, South Georgia, etc.) could be placed without difficulty, and they were added to the estimated pelagic catch in Area II or III to obtain estimated totals by year for Area II and Area III. (In the other Areas earlier catches were therefore treated as nil.)

It was assumed arbitrarily that 40% of the early catches were females 57 ft and longer, and in the cohort analyses these numbers were simply distributed each year among all age groups 5 and older in proportion to their estimated abundance. The figures are such that only in Area II do these early catches have much effect on the estimates.

By these devices the cohort analysis was extended back to 1914, and provided estimates of total female stock, mature females (defined as 10+) and female recruits (age 3) for about 45 years in each Area. Note that the procedure began with the exploited stock in 1960 or so and back-calculated the size of each year-class to age three. There was no provision for partial recruitment in the starting year, so year-classes not yet fully recruited then were under-estimated as three-year-olds. Neither was there any provision for a higher mortality rate among very young animals, but this is not important. The critical issue is recruitment to the parent stock, and while a higher or lower mortality rate among very young animals would alter the estimates of year-class size at age three obtained by cohort analysis, it would have very little effect on the estimates of year-class size at age ten, and therefore little bearing on the relationship between the recruitment and mortality rates of the breeding stock.

RESULTS

In Areas II and III, which had long series of large catches, the results of cohort analysis were not much affected by starting stock size. In Areas IV, V, and VI this factor had more influence, and in all Areas the estimated numbers were quite sensitive to the rate of natural mortality used in the back calculations. But while the absolute numbers varied considerably among trials in each Area, the estimated series of gross recruitment rates (r_I) was practically invariant. This meant that in Areas III–VI, where the cohort analysis extended back to well before the beginning of exploitation, the rate of change of the unexploited stock was determined by the natural mortality rate in each trial, and a single rate could be chosen as the one that balanced gross recruitment in the period. In Area IV, for example, the total female stock in the years 1914–31 increased from about 36,000 to 40,000 with M = 0.04, held steady at about 48,000 with M = 0.05, and decreased from 63,000 to 55,000 with M = 0.06. The natural mortality rates adopted in this way are obviously convenient choices rather than accurate estimates, but

Table 11.1

Results of cohort analysis for Area II. (M = 0.06, balancing r_I = 0.093)

	Females at age ('000)			Catch		
Season	3	10+	Total	Female	Total	r_I
14	—	(90.7)	143.9	(1.448)	3,619	0.144
15	11.4	(91.7)	145.5	(2.041)	5,102	0.143
16	11.0	(92.0)	146.1	(883)	2,208	0.124
17	13.0	(94.4)	149.8	(708)	1,771	0.096
18	13.2	(96.8)	153.6	(1,116)	2,791	0.080
19	11.5	(97.7)	155.1	(1.285)	3.213	0.093
20	9.1	(97.0)	153.9	(2.196)	5.491	0.080
21	7.7	87.5	150.6	(997)	2,492	0.097
22	9.2	88.9	150.1	(1,471)	3,677	0.086
23	7.5	89.6	147.5	(1,210)	3,025	0.093
24	8.5	91.8	146.3	(1,739)	4,347	0.077
25	7.6	93.5	143.7	(3,471)	8,678	0.093
26	8.3	92.6	140.4	(1.936)	4,841	0.102
27	7.0	91.3	137.4	(1.156)	(2,891)	0.100
28	8.7	89.9	137.1	(1,921)	(4,803)	0.088
29	9.4	88.8	136.7	(2.652)	(6,629)	0.082
30	9.1	86.3	135.3	(1,915)	(4,787)	0.081
31	7.9	85.1	133.5	955	2,215	0.102
32	7.3	84.4	132.2	1.064	2,493	0.073
33	7.0	83.8	130.4	1.262	2,831	0.067
34	8.7	82.6	130.2	1,487	3,095	0.063
35	6.1	82.1	127.3	1.678	3.899	0.070
36	5.6	82.0	123.8	2,864	7,081	0.054
37	5.2	80.7	119.1	5.252	12,313	0.054
38	5.7	76.8	113.0	3,450	7,490	0.050
39	4.4	74.2	107.6	(2.967)	(6,593)	0.049
40	4.4	73.7	105.3	(1.362)	(3.004)	0.040
41	3.9	74.5	102.6	355	1,189	0.031
42	3.6	73.6	99.9	352	776	0.030
43	3.0	72.6	96.6	254	632	0.027
44	2.3	71.3	93.0	507	987	0.026
45	2.2	70.4	89.2	2.671	6.357	0.029
46	2.0	66.7	83.4	3,300	6.325	0.034
47	1.9	63.1	77.3	3,668	8,270	0.035
48	2.0	59.2	71.4	3,170	6,935	0.041
49	2.3	55.6	66.5	4,371	9,134	0.044
50	2.2	50.4	60.8	3,493	7,078	0.046
51	2.4	46.2	56.5	3,993	7,936	0.056
52	2.4	41.8	51.9	3,153	6,167	0.055
53	2.3	38.2	48.2	5,225	10,272	0.052
54	2.6	33.7	43.0	3,920	7,632	0.052
55	2.3	30.2	39.1	4,723	9,240	0.066
56	2.0	26.7	34.4	6.383	12,710	0.075
57	1.8	21.7	28.1	4,031	7,426	0.076
58	2.0	18.4	24.7	2,993	5,574	0.051
59	2.0	16.0	22.5	3.193	6.063	0.019
60	1.6	13.5	19.8	3,484	6.581	—
61	0.9	11.4	16.4	3,910	7,306	—
62	0.3	8.7	12.1	3.055	5,570	—

Table 11.2

Results of cohort analysis for Area III. (M = 0.06, balancing r_I = 0.093)

	Females at age ('000)			Catch		
Season	3	10+	Total	Female	Total	r_I
14	10.3	(92.6)	142.5	(113)	283	(0.094)
15	7.4	(92.0)	141.5	(114)	285	(0.083)
16	11.3	(93.9)	144.4	(168)	420	(0.106)
17	8.7	(94.0)	144.6	(161)	402	(0.083)
18	7.6	91.6	143.6	(99)	247	0.090
19	10.0	91.5	145.2	(146)	364	0.081
20	7.8	91.6	144.4	(155)	387	0.077
21	8.2	92.9	144.0	(154)	385	0.090
22	7.4	92.2	142.9	(181)	452	0.089
23	7.1	94.1	141.1	(258)	646	0.099
24	8.3	94.1	141.3	(380)	950	0.084
25	8.2	93.3	140.9	(436)	1,090	0.104
26	9.3	94.1	141.6	(487)	1,218	0.106
27	7.9	93.3	140.8	(1,064)	(2.659)	0.098
28	9.7	92.3	141.3	(1,106)	(2,766)	0.094
29	10.0	90.8	142.0	(1,964)	(4.909)	0.081
30	9.1	88.6	141.0	(2.005)	(5,012)	0.079
31	8.7	87.1	139.6	190	407	0.083
32	7.4	87.0	138.6	1.001	2.036	0.063
33	7.0	86.8	136.4	1,393	2,777	0.058
34	7.2	85.5	134.3	4.035	8,606	0.058
35	5.4	83.5	128.0	2,832	5,758	0.055
36	5.1	82.5	122.8	2,540	5,571	0.051
37	5.0	81.1	118.2	4,917	10,190	0.043
38	4.6	77.9	111.2	3,071	6,249	0.042
39	4.2	75.4	105.9	(2,580)	(5,226)	0.048
40	3.5	73.0	100.7	(1,174)	(2,409)	0.053
41	3.3	72.0	96.9	(87)	193	0.060
42	3.6	70.9	94.7	(91)	204	0.063
43	3.9	69.8	92.9	(134)	301	0.064
44	4.4	68.7	91.6	(101)	227	0.064
45	4.4	67.6	90.5	1,506	2,960	0.063
46	4.5	65.0	88.2	2,381	4,527	0.061
47	4.4	61.0	85.1	3,221	7,006	0.065
48	4.3	56.7	81.3	3,426	7,017	0.069
49	4.0	52.5	77.2	2,836	5,758	0.068
50	3.9	49.6	73.9	2,352	4,687	0.062
51	3.9	47.7	71.2	3,942	8,282	0.055
52	3.6	44.7	66.8	5,913	12,121	0.058
53	3.1	40.0	60.4	5,915	12,016	0.045
54	2.6	35.6	53.9	7,040	14,121	0.055
55	2.6	30.6	46.6	3,771	7,566	0.040
56	1.8	27.7	42.1	2,231	4,425	0.020
57	2.0	25.9	39.4	5,113	10,087	—
58	1.2	22.2	33.5	5,195	10,322	—
59	0.5	18.9	27.2	5,134	10,266	—

choosing a single mortality rate and starting stock size (the DeLury estimate) for each Area will simplify the presentation of the recruitment rates, which are practically the same under all assumptions. For Area II it was not possible to choose a balancing natural mortality rate because there was no unexploited prelude there, so the value from Area III (M = 0.06) was adopted.

Tables 11.1–11.5 show the series of estimates in each Area. The total female stock comprises all animals aged 3 and older, and the estimated gross recruitment rate (r_I) given for each year is the number of three-year-olds three years later divided by the breeding stock. In the first few years of each series the estimate of numbers at age did not distinguish age groups as far as age ten, so for those years the 10+ component was calculated as the total stock multiplied by the proportion mature in the first few years in which mature animals were distinguished. Those figures, the corresponding r_I values, and any catches that had to be estimated, are parenthesized. The table captions show the value of M used in the calculations and the balancing value of r_I that corresponds to it, which is the gross recruitment rate of three-year-olds that will just offset natural mortality among the animals aged 10 and over.

Variances are not reported among the results because they were all so small. In Areas V and VI, where the age-length data were fewest and the catch series shortest, the coefficient of variation of estimated year-class size at age three was only about 10%, and for the breeding stock 5%. In part these low values result from the unrealistically low estimates of variance in catch at age mentioned above, but a more important reason is the summing procedure by which all the estimates were back-calculated. Some variance is added at each step, but the coefficient of variation decreases. Thus even if a much larger variance

Table 11.3

Results of cohort analysis for Area IV. (M = 0.05, balancing r_1 = 0.075)

	Females at age ('000)			Catch		
Season	3	10+	Total	Female	Total	r_1
14	1.7	(32.5)	47.8			(0.074)
15	3.2	(33.2)	48.8			(0.078)
16	3.0	(33.5)	49.3			(0.090)
17	2.4	(33.5)	49.2			(0.063)
18	2.6	33.6	49.4			0.071
19	3.0	33.5	50.0			0.041
20	2.1	34.1	49.7			0.044
21	2.4	33.7	49.6			0.048
22	1.4	34.3	48.6			0.042
23	1.5	34.7	47.7			0.060
24	1.6	34.7	47.0			0.066
25	1.4	34.8	46.2			0.060
26	2.1	35.2	46.0			0.073
27	2.3	35.0	46.0			0.075
28	2.1	35.0	45.9			0.075
29	2.6	34.2	46.2			0.087
30	2.6	33.6	46.6			0.087
31	2.6	33.1	47.0	201	423	0.076
32	3.0	32.3	47.3	536	969	0.072
33	2.9	31.6	47.3	1,029	2,179	0.072
34	2.5	30.6	46.5	618	1.364	0.055
35	2.3	29.9	45.9	329	548	0.052
36	2.3	29.9	45.5	1,161	2.283	0.046
37	1.7	29.2	43.8	3,002	6.611	0.038
38	1.6	26.9	40.3	2,618	5.539	0.042
39	1.4	25.3	37.1	(2.395)	(5.067)	0.044
40	1.1	23.9	34.1	(956)	(2,022)	0.049
41	1.1	23.4	32.6	—	—	0.061
42	1.1	23.6	32.1	—	—	0.053
43	1.2	23.9	31.6	—	—	0.061
44	1.4	23.8	31.5	—	—	0.066
45	1.3	23.7	31.1	—	—	0.059
46	1.5	23.4	31.0	1,589	3,355	0.058
47	1.6	21.6	29.5	2,027	4.638	0.058
48	1.4	19.5	27.5	1,488	3,075	0.061
49	1.4	17.9	26.0	1,470	2.940	0.067
50	1.3	16.5	24.6	2,035	4.209	0.069
51	1.2	15.0	22.6	873	2,110	0.080
52	1.2	14.2	21.8	711	1,450	0.076
53	1.1	13.8	21.2	946	2,195	0.060
54	1.2	13.3	20.4	1,410	2.790	0.048
55	1.1	12.3	19.1	1,543	3.208	0.036
56	0.8	11.2	17.5	159	291	0.011
57	0.6	11.2	17.1	1,817	3.579	—
58	0.4	10.0	14.9	3,622	7.276	—
59	0.1	7.3	10.9	3,464	6,501	—

Table 11.4

Results of cohort analysis for Area V. (M = 0.04, balancing r_1 = 0.059)

	Females at age ('000)			Catch		
Season	3	10+	Total	Female	Total	r_1
14	1.5	(14.9)	20.7		—	(0.027)
15	0.3	(14.5)	20.2		—	(0.145)
16	0.6	(14.4)	20.0		—	(0.069)
17	0.4	(14.1)	19.6		—	(0.057)
18	2.1	14.5	20.9		—	0.091
19	1.0	14.8	21.1		—	0
20	0.8	15.1	21.0		—	0.011
21	1.3	15.7	21.5		—	0.090
22	0	15.3	20.7		—	0.027
23	0.2	15.1	20.0		—	0.089
24	1.4	14.8	20.6		—	0.053
25	0.4	15.8	20.2		—	0.042
26	1.4	15.9	20.8		—	0.083
27	0.8	15.9	20.8		—	0.031
28	0.7	16.3	20.6		—	0.095
29	1.3	15.6	21.1		—	0.039
30	0.5	15.1	20.8		—	0.054
31	1.5	15.6	21.5		—	0.057
32	0.6	15.2	21.2		—	0.044
33	0.8	15.6	21.1		—	0.048
34	0.9	15.5	21.1		—	0.058
35	0.7	15.3	20.9	7	17	0.046
36	0.7	15.6	20.7		—	0.060
37	0.9	15.3	20.8		—	0.043
38	0.7	15.8	20.6	854	1,975	0.046
39	0.9	14.9	19.8	(781)	(1.807)	0.044
40	0.7	14.1	18.9	(312)	(721)	0.043
41	0.7	13.9	18.5		—	0.046
42	0.7	13.7	18.4		—	0.053
43	0.6	13.7	18.2		—	0.048
44	0.6	13.7	18.1		—	0.055
45	0.7	13.7	18.1		—	0.039
46	0.7	13.8	18.0	225	478	0.047
47	0.8	13.5	17.7	791	1,603	0.052
48	0.5	12.7	16.8	1.284	2,491	0.043
49	0.7	11.5	15.5	817	1,665	0.053
50	0.7	10.6	14.7	983	2,199	0.082
51	0.6	9.7	13.7	1,511	2,784	0.078
52	0.6	8.5	12.3	886	1,700	0.097
53	0.9	8.0	11.8	316	654	0.026
54	0.8	7.8	11.8	1,539	3,021	0.020
55	0.8	6.6	10.7	770	1,494	0.022
56	0.2	6.0	9.7	12	23	0.005
57	0.2	6.1	9.4	574	1,130	—
58	0.1	5.8	8.6	1.274	2,625	—
59	0.0	5.0	7.1	2,480	4,730	—

were arbitrarily assigned to the estimates of catch at age, the standard deviations of the estimated numbers at age would still be small over most of each series.

In each Area the last three to five r_1 values show a steep decline from some previously established level to very low values. This reflects the incomplete recruitment of animals up to about age 10 in the starting season, so these values should be ignored. What remains in each Area is therefore a series of estimates running from 1914 to about 1952. During this period the breeding stock (ages 10+) declines to around half its initial value in all Areas, and as mentioned above the gross recruitment rates all decline as well, although there are differences among Areas in the timing of events (Fig. 3).

Area II shows recruitment rates holding steady about the replacement level during the decade or so of land station operations that preceded the start of pelagic whaling. Thereafter the estimated rates fall steadily from about 1930 to 1945. After the war they increase again, but not enough to reach the replacement level.

In Area III recruitment is stable at the replacement level until the first large catches are taken around 1930, then drops to a lower level that persists to the end of the series with apparently some increase between 1940 and 1950. Area IV shows much the same pattern except for a run of poor recruitments (below replacement) in 1919–25 before the start of exploitation, and a more pronounced recovery in recruitment to replacement level in 1949–52, just at the effective end of the series.

In Areas V and VI the recruitment estimates between 1914 and 1935 are quite variable, but both stocks are stable and unexploited during this period. At the start of exploitation in Area V in 1938, recruitment drops slightly below the replacement level and remains slightly below until the series ends with three good recruitments from the years 1950–52. Recruitment in Area VI, after remaining at

Table 11.5

Results of cohort analysis for Area VI. (M = 0.04, balancing r_1 = 0.058)

	Females at age ('000)			Catch		
Season	3	10+	Total	Female	Total	r_1
14	0.8	(15.8)	22.2		—	(0.082)
15	1.1	(15.9)	22.4		—	(0.044)
16	1.5	(16.4)	23.1		—	(0.061)
17	1.3	(16.6)	23.4		—	(0.066)
18	0.7	16.4	23.2		—	0.076
19	1.0	16.7	23.3		—	0.042
20	1.1	16.8	23.5		—	0.069
21	1.2	16.7	23.8		—	0.058
22	0.7	16.9	23.6		—	0.079
23	1.2	17.4	23.8		—	0.028
24	1.0	17.7	23.8		—	0.046
25	1.3	17.6	24.2		—	0.057
26	0.5	17.6	23.8		—	0.057
27	0.8	17.7	23.7		—	0.034
28	1.0	18.0	23.7		—	0.018
29	1.0	17.8	23.8		—	0.026
30	0.6	18.0	23.5		—	0.053
31	0.3	18.0	22.9		—	0.043
32	0.5	18.2	22.4		—	0.018
33	1.0	17.8	22.4		—	0.056
34	0.8	17.7	22.2		—	0.025
35	0.3	17.7	21.6		—	0.025
36	1.0	17.6	21.7		—	0.013
37	0.4	17.3	21.2		—	0.007
38	0.4	16.8	20.7		—	0.013
39	0.2	16.4	20.0		—	0.012
40	0.1	16.4	19.3		—	0.015
41	0.2	16.3	18.7		—	0.020
42	0.2	15.8	18.1		—	0.024
43	0.3	15.9	17.6		—	0.026
44	0.3	15.5	17.1		—	0.027
45	0.4	15.2	16.8		—	0.027
46	0.4	14.7	16.4		—	0.023
47	0.4	14.1	16.1		—	0.030
48	0.4	13.7	15.8	41	72	0.046
49	0.3	13.2	15.4	425	1,003	0.043
50	0.4	12.4	14.8	602	1,212	0.042
51	0.6	11.5	14.2	976	2,287	0.045
52	0.6	10.3	13.2	1,030	1,901	0.030
53	0.5	9.2	12.1	1,139	2,616	0.030
54	0.5	8.0	11.0	673	1,227	0.020
55	0.3	7.3	10.2	1,256	2,585	0.013
56	0.3	6.1	8.8	2,254	5,068	0.003
57	0.2	4.3	6.5	2,019	4,107	—
58	0.1	2.9	4.4	1,134	2,102	—
59	0.0	2.1	3.1	196	401	—

replacement level on average since 1914, drops abruptly to less than half that level in 1934 and remains very low through 1947, so female stock size declines from about 22,000 to 16,000 in the fifteen years before the start of whaling in 1948. The rates are somewhat better in 1948–52, but still below replacement.

To summarize, all of these stocks appear to have had lower gross recruitment rates during exploitation than during the years before 1930, and if the natural mortality estimates are correct, the results indicate that recruitment dropped below replacement level in every Area at some point during the 1930s. In Areas III–V this decline corresponded closely to the start of pelagic whaling, but in Area II it came long after the start of modern operations and in Area VI long before. In every Area I, there was an increasing trend from sometime in the late 1930s or 1940s to around 1950 (among the last rates reliably estimated).

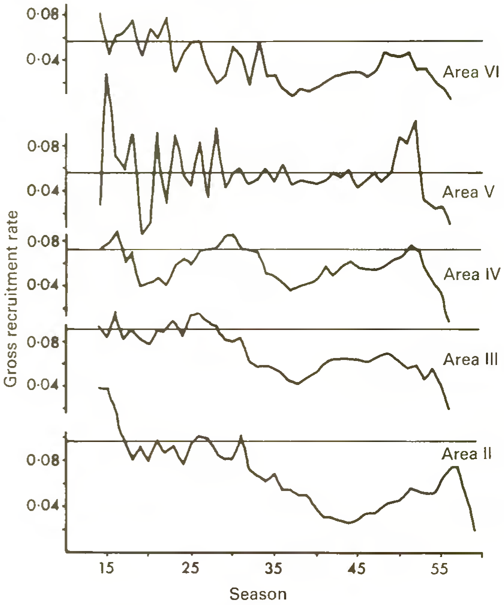

Fig. 3. Estimated gross recruitment rates, by Area and season. The horizontal line is the replacement rate.

These results are surprising enough to need some detailed explanation, which will be given in the form of year-class histories for Area IV as an example. The age compositions of the catches as estimated from length distributions (Table 12) indicate that before the war older animals (21+) made up a disproportionate share of the catch. For five years after the war age groups 15–20 were unusually well represented, and in the 1950s relatively more animals aged 6–14, and especially 6–9, were taken. On the face of it this does not appear to be an unusual progression, but in combination with the age frequencies in Table 2.4 it leads directly to the results of the cohort analyses, which basically reflect certain marked changes in the size of entering year-classes:

(i) The good year-classes of 1911–18 (entering at age 3 in 1914–21) were taken in large numbers among older age-groups both during the 1930s and after the war, so their back-calculated size at age 3 is large.

(ii) The 1920 year-class, like the other poor ones of 1919–25, was not among the older age-groups prevalent in the catches of the 1930s, and for that reason its abundance at age 3 is estimated to be much less than that of the 1914 year-class. (Its greater numerical abundance in the 1959–62 reference catch just compensates for the shorter period of back calculation.)

Table 12

Estimated composition of catch by age set in Area IV

	Age set				
Seasons	3–5	6–9	10–14	15–20	21+
30–39	0	10–20%	10–30%	0–20%	50–80%
46–50	0	10–20%	10–30%	30–50%	15–35%
51–59	0–10%	20–40%	15–40%	0–20%	20–55%
Expected frequency with M = Z = 0.05 and recruitment at age 6.					
6	0	18%	18%	17%	47%

(iii) The 1923–44 year-classes were all about equally abundant in the 1959 reference catch, and the first few are estimated to be larger at age 3 than the nearby 1920 year-class simply because they were more abundant in 1959. Owing to the steadily shorter periods of back-calculation, the later year-classes at this level of abundance in 1959 would have been calculated as steadily smaller, but the 1926–33 year-classes all appeared in quantity in the large catches of animals aged 15–20 in 1946–50.

(iv) The 1937 year-class was one of the first of the poor ones that characterized most of the period of exploitation. It was not represented in the large catches of animals aged 15–20 in 1946–50, and in 1959 at age 22 it was no more abundant than the older age-groups that had provided those catches.

(v) The 1951 year-class was one of the (relatively) good ones that appeared at the end of the series. Its estimated abundance results from the increased catches of animals aged 6–9 in the 1950s.

In summary then, while the change in the age composition of the catch in Area IV during the period of exploitation seems perfectly normal, when combined with the age composition of the adult stock in 1959 it implies a short run of poor year-classes from 1919 to 1925 and a long run of poor year-classes after 1933, followed by some recovery around 1950.

The same sort of interaction is responsible for the results in other Areas, but the changes in estimated age composition of the catch are not all the same.

In Area II the frequency of animals under age 10 increases after the war at the expense of animals aged 10–20, but there is no overall trend in the frequency of animals over age 20. There is no large change in the estimated age compositions of the catch in Area III (which are reasonable), so the results there are determined largely by the age composition of the 1959–63 reference catch. In Areas V and VI the changes in age composition of the catch are similar to those in Area IV, but faster.

DISCUSSION

The results obtained, if not contrary to fact or reason, are at least contrary to expectation, so the assumptions and data that led to them should be carefully examined. As explained above, the starting stock sizes and natural mortality rates have no important effect. The critical elements are the following:

(i) The distributions of length at age in the regression matrix used to decompose the length distributions into age groups in each Area. These are in doubt because of the large, inexplicable differences between the distributions of length at age in the Japanese data used here and those reported by Lockyer (1972). While a full discussion of the possible effects of different sorts of bias in the matrix is beyond the scope of this paper, it does seem likely that a steady increase in growth rate could produce erroneous estimates of a decline in year-class size over time, if the regression matrix referred to the growth schedule that prevailed before the increase began. The question is: if there was a substantial increase in growth rate between 1920 and 1960, how could the age-length distribution of the Japanese reference catches (28,616 females measured, 16,632 aged), taken in 1959–63, possibly preserve the growth schedule of 1920? It seems more likely that the basic data used here would reflect the recent age-length distribution, and in that case the danger in back-calculating through a period of increasing growth rate would be erroneous estimates of an *increase* in recruitment rates.

(ii) The age compositions of Japanese catches. Quite apart from the task of decomposing length distributions, the Japanese age-length sampling data were used straightforwardly as keys to obtain the age composition of the Japanese reference catches, and it was assumed that this age composition accurately estimated the relative abundance of each age group older than 20 in the stock. This does not seem to be a very bold assumption, but in fact the peculiar shape of the age distributions foretold the results of all the computations.

(iii) The reported length distributions. Misreporting, or worse a trend in misreporting, would have much the same effect as systematic error in the reference distributions of length at age.

(iv) Size selection in the fishery (including the effect of the minimum size limit). The Japanese data did not show any effect of size selection, but it was only an assumption that the same was true of other catches.

REFERENCES

Allen, K. R. 1970. A re-examination of recruitment in Antarctic fin whale stocks. *Rep. int. Whal. Commn* 20: 48–53.

Allen, K. R. 1971. Notes on the assessment of Antarctic fin whale stocks. *Rep. int. Whal. Commn* 21: 58–63.

Allen, K. R. 1972. Further notes on the assessment of Antarctic fin whale stocks. *Rep. int. Whal. Commn* 22: 43–53.

Allen, K. R. 1973. Analysis of the stock-recruitment relationships in Antarctic fin whales. *Rapp. P.-V. Reun. CIEM.* 164: 132–7.

Allen, K. R. Revised estimates of Antarctic fin whale populations. *Rep. int. Whal. Commn* 23: 99–114.

Beddington, J. R. and Cooke, J. G. 1980. Development of an assessment technique for male sperm whales based on the use of length data from the catches, with special reference to the North-West Pacific stock. *Rep. int. Whal. Commn* 31: 747–60.

Chapman, D. G. 1970. Re-analysis of Antarctic fin whale population data. *Rep. int. Whal. Commn* 20: 54–9.

Chapman, D. G. 1971. Analysis of 1969/70 catch and effort data of Antarctic baleen whale stocks. *Rep. int. Whal. Commn* 21: 67–75.

Clark, W. G. 1981. Restricted least-squares estimates of age composition. *Can. J. Fish. Aquat. Sci.* 38: 297–307.

Doi, T., Ohsumi, S., Nasu, K. and Shimadzu, Y. 1970. Advanced assessment of the fin whale stock in the Antarctic 1970. *Rep. int. Whal. Commn* 20: 60–87.

Gambell, R. 1976. Population biology and the management of whales, pp. 217–343. *In:* T. H. Coaker (ed.) *Applied Biology*, Vol. 1. Academic Press, London.

International Whaling Commission. 1964. Reports of the Committee of Three Scientists on the special scientific investigation of the Antarctic whale stocks. *Rep. int. Whal. Commn* 14: 32–106.

International Whaling Commission. 1969. Report of the meeting on age determination in whales. *Rep. int. Whal. Commn* 19: 131–7.

International Whaling Commission. 1971. Report of the special meeting on Antarctic fin whale stock assessment. *Rep. int. Whal. Commn* 21: 40–50.

International Whaling Commission. 1974. Report of the meeting on age determination in baleen whales. *Rep. int. Whal. Commn* 24: 62–8.

Lockyer, C. 1972. The age at sexual maturity of the southern fin whale (*Balaenoptera physalus*) using annual layer counts in the ear plug. *J. Cons. Int. Explor. Mer.* 34: 276–94.

Lockyer, C. 1977. A preliminary study of variations in age at sexual maturity of the fin whale with year class, in six areas of the Southern Hemisphere. *Rep. int. Whal. Commn* 27: 141–7.

Lockyer, C. 1979. Changes in growth parameter association with exploitation of southern fin and sei whales. *Rep. int. Whal. Commn* 29: 191–6.

Westrheim, S. J. and Ricker, W. E. 1978. Bias in using an age-length key. *J. Fish. Res. Bd Can.* 35: 184–9.

Table 2.1

Area II, Seasons 1962–64. Female fin age-length distribution in Japanese catch, based on 2,039 samples.

AGE LENGTH	3	4	5	6	7	8	9	10	11	12	13	14	15
57	68.6	68.6	91.4	73.1	32.0	9.1	13.7	13.7	9.1	0	0	0	0
58	28.7	25.1	50.2	21.5	28.7	14.3	14.3	3.6	7.2	7.2	0	0	10.8
59	26.4	42.2	26.4	34.3	26.4	10.5	5.3	7.9	7.9	7.9	10.5	0	0
60	6.9	34.6	24.2	13.9	41.6	20.8	13.9	3.5	6.9	0	6.9	3.5	0
61	2.9	17.6	32.3	26.4	17.6	20.5	8.8	17.6	5.9	11.7	0	0	0
62	8.1	13.5	27.0	29.7	29.7	18.9	18.9	8.1	21.6	2.7	0	0	2.7
63	2.7	13.3	16.0	26.6	34.6	21.3	10.6	8.0	10.6	5.3	2.7	2.7	0
64	3.7	7.4	14.7	18.4	7.4	14.7	7.4	0	3.7	3.7	3.7	0	3.7
65	2.7	5.4	16.3	19.1	24.5	10.9	8.2	2.7	2.7	2.7	5.4	8.2	0
66	0	3.6	17.8	7.1	7.1	17.8	3.6	10.7	7.1	7.1	10.7	7.1	3.6
67	0	3.1	3.1	0	15.4	3.1	3.1	18.5	21.6	3.1	9.3	3.1	9.3
68	0	2.8	2.8	11.0	13.8	13.8	11.0	16.5	5.5	5.5	0	8.3	5.5
69	0	2.9	2.9	2.9	14.4	5.7	8.6	11.5	17.2	14.4	8.6	2.9	0
70	0	2.8	2.8	2.8	0	2.8	5.6	8.3	8.3	16.7	13.9	11.1	8.3
71	0	0	0	2.9	2.9	5.9	0	0	8.8	8.8	8.8	8.8	5.9
72	0	0	8.3	5.5	0	2.8	2.8	0	5.5	11.1	13.9	13.9	16.6
73	0	5.2	2.6	0	15.6	2.6	2.6	2.6	7.8	2.6	7.8	5.2	10.4
74	0	0	3.0	3.0	0	5.9	0	3.0	0	0	5.9	3.0	3.0
75	2.8	2.8	0	0	0	0	2.8	0	0	2.8	2.8	2.8	0
76	0	0	0	0	0	0	0	0	2.8	2.8	0	5.6	8.4
77	0	0	0	0	0	0	0	3.1	6.2	0	3.1	0	0
TOTAL	153.5	250.8	341.6	298.1	311.6	201.4	141.1	139.3	166.6	116.1	114.1	86.1	88.1

AGE LENGTH	16	17	18	19	20	21	22	23	24	25	26	27	28
57	0	0	0	0	0	4.6	0	4.6	4.6	0	0	0	0
58	3.6	7.2	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	5.3	0	0	0	0	0	2.6	0	0	0
60	0	0	3.5	3.5	0	3.5	0	0	0	0	0	0	0
61	0	0	0	2.9	0	0	2.9	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	2.7	0	0
63	2.7	2.7	0	2.7	0	0	2.7	2.7	0	0	0	0	0
64	7.4	3.7	7.4	3.7	3.7	0	0	0	0	3.7	0	3.7	0
65	0	0	0	0	0	2.7	0	2.7	0	0	2.7	2.7	0
66	3.6	7.1	7.1	0	0	0	0	0	0	3.6	0	3.6	0
67	6.2	6.2	0	6.2	0	0	9.3	9.3	0	3.1	0	0	3.1
68	0	2.8	2.8	2.8	2.8	2.8	0	5.5	0	19.3	0	0	0
69	8.6	0	11.5	2.9	8.6	0	2.9	2.9	2.9	17.2	2.9	8.6	0
70	8.3	11.1	2.8	5.6	11.1	13.9	8.3	2.8	8.3	8.3	2.8	8.3	8.3
71	11.8	14.7	11.8	11.8	8.8	11.8	5.9	11.8	11.8	11.8	11.8	20.6	11.8
72	8.3	8.3	8.3	13.9	5.5	0	19.4	11.1	25.0	16.6	25.0	19.4	22.2
73	13.0	18.3	7.8	15.6	15.6	7.8	23.5	13.0	18.3	26.1	20.9	18.3	23.5
74	11.9	11.9	8.9	3.0	11.9	5.9	3.0	14.9	11.9	8.9	5.9	5.9	11.9
75	8.5	0	5.7	8.5	2.8	11.3	8.5	8.5	8.5	5.7	11.3	11.3	11.3
76	5.6	0	2.8	5.6	0	8.4	8.4	2.8	11.2	2.8	14.0	8.4	11.2
77	0	3.1	3.1	9.3	6.2	6.2	15.5	9.3	6.2	9.3	6.2	21.7	15.5
TOTAL	99.4	96.9	83.3	103.0	77.1	78.9	110.2	101.7	108.6	138.9	106.1	132.5	118.8

AGE LENGTH	29	30	31	32	33	34	35	36	37	38	39	40	41
57	4.6	0	0	0	0	0	0	0	0	0	4.6	0	0
58	0	3.6	0	0	0	0	0	0	0	0	0	0	0
59	2.6	2.6	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	2.9	0	0	0	0	0	0	2.9	0	0	0	0	0
62	0	0	0	0	0	0	0	2.7	0	0	0	0	0
63	0	0	0	2.7	0	0	0	0	0	0	0	0	0
64	0	0	3.7	0	0	0	0	0	3.7	0	0	0	0
65	0	2.7	0	0	0	0	0	0	0	0	0	0	0
66	3.6	7.1	0	0	0	3.6	7.1	0	0	0	0	7.1	0
67	3.1	3.1	0	0	6.2	0	0	3.1	0	0	0	0	0
68	0	2.8	2.8	0	2.8	2.8	2.8	2.8	5.5	2.8	0	0	0
69	11.5	0	11.5	0	2.9	2.9	5.7	2.9	11.5	2.9	0	0	0
70	2.8	5.6	13.9	11.1	11.1	8.3	0	5.6	8.3	8.3	2.8	2.8	2.8
71	14.7	8.8	29.4	2.9	2.9	17.6	8.8	14.7	5.9	2.9	11.8	5.9	8.8
72	8.3	19.4	5.5	19.4	13.9	13.9	22.2	16.6	2.8	11.1	8.3	0	11.1
73	20.9	18.3	23.5	31.3	28.7	18.3	15.6	13.0	15.6	20.9	18.3	13.0	28.7
74	17.8	8.9	20.8	17.8	14.9	11.9	14.9	14.9	23.8	8.9	3.0	20.8	8.9
75	17.0	28.3	22.7	11.3	5.7	14.2	14.2	5.7	8.5	0	19.8	8.5	11.3
76	2.8	2.8	8.4	11.2	11.2	5.6	8.4	11.2	2.8	8.4	8.4	11.2	0
77	12.4	3.1	12.4	3.1	6.2	3.1	9.3	12.4	12.4	3.1	3.1	0	3.1
TOTAL	125.0	117.1	154.5	110.9	106.4	102.0	109.0	108.4	100.8	69.3	80.0	69.3	74.7

AGE LENGTH	42	43	44	45	46	47	48	49	50	51	TOTAL
57	0	0	0	0	4.6	0	0	0	0	9.1	416.0
58	0	0	0	0	0	0	0	0	0	0	226.0
59	0	0	0	0	2.6	0	0	0	0	2.6	224.0
60	0	0	0	0	0	0	0	0	0	0	187.0
61	0	0	0	0	0	0	0	0	0	0	173.0
62	0	0	0	0	0	0	0	0	0	0	186.0
63	0	0	0	0	0	2.7	0	0	0	0	173.0
64	3.7	0	3.7	0	0	0	0	0	0	0	136.0
65	0	0	0	0	0	0	0	0	2.7	2.7	128.0
66	0	0	0	0	0	0	0	0	0	3.6	160.0
67	3.1	3.1	3.1	3.1	0	3.1	0	0	0	6.2	173.0
68	0	0	0	0	0	8.3	2.8	0	0	5.5	176.0
69	0	2.9	2.9	2.9	2.9	8.6	0	0	0	14.4	247.0
70	2.8	11.1	5.6	2.8	13.9	5.6	2.8	2.8	2.8	27.8	345.0
71	11.8	5.9	0	8.8	2.9	2.9	8.8	5.9	5.9	32.3	429.0
72	8.3	2.8	13.9	11.1	5.5	8.3	8.3	0	11.1	44.4	530.0
73	5.2	18.3	10.4	2.6	5.2	18.3	13.0	10.4	2.6	91.3	730.0
74	14.9	3.0	3.0	11.9	20.8	3.0	5.9	8.9	5.9	35.7	443.0
75	5.7	11.3	5.7	2.8	2.8	2.8	11.3	2.8	2.8	73.7	408.0
76	2.8	5.6	0	8.4	0	2.8	2.8	8.4	0	42.0	266.0
77	3.1	6.2	6.2	3.1	3.1	0	3.1	6.2	9.3	27.9	276.0
TOTAL	61.3	70.1	54.3	57.5	64.4	66.3	58.9	45.4	43.2	419.1	6032.0

Table 2.2

Area III, Seasons 1959–63. Female fin age-length distribution in Japanese catch, based on 8,651 samples.

AGE LENGTH	3	4	5	6	7	8	9	10	11	12	13	14	15
57	125.9	163.5	181.2	97.2	66.3	28.7	22.1	11.0	11.0	4.4	2.2	4.4	2.2
58	68.5	119.3	146.7	95.8	90.0	27.4	33.3	9.8	5.9	5.9	3.9	2.0	2.0
59	23.1	94.1	109.5	94.1	92.2	48.0	23.1	9.6	17.3	7.7	5.8	0	0
60	26.5	59.7	84.5	87.8	81.2	43.1	29.8	11.6	9.9	1.7	3.3	3.3	1.7
61	9.7	38.8	97.1	80.9	63.1	43.7	38.8	16.2	14.6	12.9	16.2	3.2	4.9
62	3.3	47.6	78.7	77.1	95.1	52.5	34.4	18.0	13.1	16.4	9.8	3.3	3.3
63	6.4	17.6	59.4	70.6	64.2	51.3	44.9	30.5	25.7	11.2	6.4	8.0	4.8
64	5.0	15.1	41.9	58.7	68.7	40.2	30.2	41.9	31.8	10.1	10.1	15.1	5.0
65	4.6	10.7	30.6	44.3	45.9	35.2	41.3	26.0	16.8	22.9	15.3	7.6	10.7
66	3.2	3.2	25.3	23.7	42.7	39.5	41.1	60.0	31.6	26.9	30.0	19.0	7.9
67	3.3	10.0	11.6	16.6	23.3	39.9	24.9	33.2	34.9	13.3	33.2	24.9	23.3
68	1.5	0	10.7	13.8	18.3	41.3	24.5	27.5	26.0	27.5	35.2	21.4	22.9
69	1.7	5.0	0	6.6	21.5	13.3	21.5	19.9	28.2	24.9	26.5	24.9	29.8
70	1.6	1.6	3.3	4.9	3.3	9.9	16.4	21.4	23.0	37.8	26.3	26.3	31.3
71	0	1.6	3.2	1.6	8.1	13.0	17.8	11.3	11.3	21.1	25.9	27.6	25.9
72	1.6	0	6.3	3.2	1.6	1.6	14.2	15.8	19.0	22.1	22.1	22.1	34.8
73	0	1.6	6.4	1.6	6.4	4.8	6.4	12.8	12.8	22.3	23.9	22.3	19.1
74	0	0	0	0	1.6	3.3	4.9	1.6	1.6	14.6	9.8	9.8	11.4
75	0	1.6	3.2	1.6	1.6	3.2	1.6	3.2	1.6	12.7	1.6	9.5	3.2
76	0	0	0	1.6	0	0	0	1.6	0	3.2	3.2	1.6	8.1
77	0	0	0	1.5	1.5	0	1.5	1.5	0	3.0	0	1.5	3.0
TOTAL	285.9	591.0	899.6	783.3	796.5	539.7	472.7	384.5	336.1	322.7	310.8	257.9	255.2

AGE LENGTH	16	17	18	19	20	21	22	23	24	25	26	27	28
57	2.2	0	0	0	0	0	0	0	0	2.2	0	0	0
58	2.0	0	0	0	0	0	0	0	0	0	0	0	2.0
59	0	0	0	0	1.9	0	0	0	1.9	0	0	0	1.9
60	1.7	3.3	0	1.7	0	0	0	0	0	0	1.7	0	1.7
61	1.6	1.6	0	0	1.6	0	0	1.6	0	0	0	3.2	0
62	0	1.6	3.3	0	0	3.3	0	1.6	0	0	1.6	0	0
63	3.2	4.8	1.6	1.6	0	1.6	3.2	0	0	1.6	0	0	0
64	1.7	6.7	5.0	1.7	1.7	0	0	0	1.7	0	0	3.4	0
65	12.2	6.1	1.5	1.5	0	4.6	6.1	3.1	0	1.5	0	3.1	1.5
66	17.4	7.9	19.0	7.9	3.2	3.2	6.3	4.7	3.2	0	3.2	3.2	1.6
67	13.3	21.6	15.0	15.0	3.3	10.0	3.3	5.0	5.0	5.0	3.3	6.6	6.6
68	30.6	10.7	19.9	13.8	13.8	10.7	6.1	7.6	6.1	3.1	13.8	4.6	6.1
69	28.2	23.2	26.5	21.5	29.8	13.3	18.2	26.5	16.6	23.2	18.2	16.6	24.9
70	26.3	26.3	31.3	24.7	23.0	36.2	26.3	31.3	19.7	37.8	24.7	29.6	31.3
71	32.4	45.4	38.9	29.2	29.2	19.4	30.8	29.2	32.4	19.4	16.2	35.7	27.6
72	42.7	28.5	31.6	23.7	44.3	26.9	33.2	42.7	45.9	36.4	36.4	30.0	52.2
73	25.5	28.7	33.5	36.7	47.9	33.5	41.5	57.4	49.4	60.6	51.0	47.9	51.0
74	14.6	6.5	13.0	22.8	24.4	30.9	16.3	32.5	40.6	34.1	45.5	24.4	29.3
75	14.3	14.3	17.5	17.5	22.3	20.7	25.5	19.1	23.9	28.6	25.5	41.4	33.4
76	6.5	8.1	6.5	9.7	8.1	4.9	16.2	17.8	13.0	14.6	16.2	16.2	21.1
77	6.0	7.5	3.0	6.0	13.4	10.4	23.9	16.4	20.9	25.4	10.4	10.4	26.8
TOTAL	282.3	252.9	267.0	234.8	267.8	229.5	256.9	296.6	280.3	293.6	267.7	276.2	318.9

AGE LENGTH	29	30	31	32	33	34	35	36	37	38	39	40	41
57	2.2	0	0	0	0	0	2.2	0	0	0	0	0	4.4
58	2.0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	1.9	0	0	0	0	0	0	0	0	0	0	0
60	1.7	0	0	0	0	1.7	1.7	1.7	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	1.6	0	0	1.6	0	0	0	0	0	0
63	0	1.6	0	1.6	0	0	0	0	0	0	1.6	0	1.6
64	0	1.7	0	0	0	1.7	0	0	1.7	1.7	0	0	0
65	1.5	0	0	0	1.5	1.5	0	0	0	3.1	0	0	0
66	4.7	1.6	3.2	3.2	0	0	0	1.6	1.6	0	1.6	0	0
67	0	3.3	3.3	1.7	10.0	0	1.7	0	5.0	3.3	0	0	3.3
68	6.1	6.1	7.6	4.6	3.1	1.5	4.6	4.6	3.1	6.1	0	3.1	3.1
69	11.6	11.6	24.9	9.9	11.6	8.3	11.6	11.6	5.0	6.6	3.3	3.3	11.6
70	16.4	24.7	23.0	23.0	14.8	16.4	16.4	19.7	14.8	8.2	8.2	13.2	9.9
71	30.8	24.3	16.2	27.6	27.6	32.4	14.6	24.3	19.4	16.2	19.4	21.1	14.6
72	36.4	31.6	26.9	44.3	39.5	23.7	25.3	31.6	23.7	26.9	19.0	7.9	19.0
73	41.5	46.3	55.8	49.4	44.7	33.5	27.1	38.3	25.5	38.3	30.3	46.3	22.3
74	40.6	34.1	24.4	19.5	35.8	40.6	17.9	24.4	21.1	11.4	14.6	17.9	16.3
75	25.5	22.3	33.4	22.3	8.0	31.8	19.1	25.5	14.3	11.1	19.1	12.7	17.5
76	21.1	11.4	21.1	21.1	30.8	14.6	13.0	11.4	11.4	19.5	6.5	8.1	13.0
77	19.4	23.9	20.9	13.4	13.4	17.9	10.4	8.9	20.9	14.9	10.4	7.5	10.4
TOTAL	261.5	246.3	260.7	243.2	240.7	225.7	167.2	203.5	167.5	167.3	134.1	140.9	146.9

AGE LENGTH	42	43	44	45	46	47	48	49	50	51	TOTAL
57	0	0	0	0	0	0	0	0	0	4.4	738.0
58	0	2.0	0	0	2.0	0	0	0	0	2.0	622.0
59	0	0	0	0	0	0	0	1.9	0	0	534.0
60	0	1.7	0	0	0	0	0	0	0	1.7	464.0
61	1.6	0	0	0	1.6	0	0	0	0	0	453.0
62	0	0	0	0	0	0	0	0	0	1.6	469.0
63	1.6	0	0	0	0	0	1.6	0	0	1.6	430.0
64	0	1.7	0	1.7	0	0	0	0	0	3.4	409.0
65	1.5	0	0	0	1.5	0	0	1.5	0	4.6	370.0
66	0	1.6	0	0	1.6	1.6	1.6	0	0	4.7	463.0
67	1.7	1.7	0	1.7	1.7	0	0	0	1.7	16.6	462.0
68	3.1	6.1	0	3.1	1.5	0	3.1	1.5	0	16.8	506.0
69	8.3	5.0	5.0	1.7	1.7	0	5.0	3.3	9.9	43.1	724.0
70	4.9	3.3	6.6	11.5	14.8	3.3	3.3	1.6	4.9	92.1	931.0
71	11.3	24.3	17.8	9.7	8.1	9.7	8.1	6.5	13.0	108.6	1060.0
72	22.1	20.6	20.6	7.9	22.1	20.6	7.9	19.0	11.1	134.4	1281.0
73	16.0	31.9	16.0	20.7	25.5	12.8	23.9	12.8	11.2	177.1	1552.0
74	21.1	21.1	13.0	14.6	19.5	8.1	14.6	11.4	4.9	115.4	956.0
75	12.7	9.5	9.5	12.7	9.5	4.8	15.9	17.5	8.0	114.6	826.0
76	9.7	9.7	6.5	8.1	4.9	11.4	8.1	1.6	1.6	76.2	519.0
77	13.4	7.5	6.0	13.4	11.9	6.0	8.9	1.5	4.5	65.6	525.0
TOTAL	129.1	147.6	100.9	106.8	128.0	78.1	102.0	80.2	70.7	984.5	14294.0

Table 2.3

Area IV, Seasons 1959–62. Female fin age-length distribution in Japanese catch, based on 4,645 samples.

AGE	3	4	5	6	7	8	9	10	11	12	13	14	15
LENGTH													
57	26.9	49.0	64.8	64.8	39.5	17.4	9.5	4.7	4.7	0	1.6	0	1.6
58	20.9	50.7	59.6	74.5	34.3	37.3	19.4	8.9	3.0	3.0	1.5	0	0
59	15.2	37.2	60.6	52.4	42.7	30.3	23.4	8.3	2.8	2.8	2.8	1.4	0
60	3.9	39.2	48.3	49.6	49.6	43.1	36.6	14.4	9.1	2.6	1.3	1.3	0
61	4.2	31.1	36.8	45.3	50.9	34.0	12.7	9.9	9.9	5.7	1.4	2.8	0
62	1.4	17.6	19.0	33.9	46.1	47.5	35.3	12.2	9.5	9.5	6.8	1.4	1.4
63	0	5.2	17.0	31.4	36.7	34.1	24.9	22.3	6.6	7.9	6.6	1.3	1.3
64	1.3	8.0	5.3	9.3	40.1	36.1	21.4	24.0	20.0	13.4	8.0	4.0	8.0
65	0	0	9.0	16.7	20.5	24.4	24.4	33.3	14.1	19.2	9.0	7.7	3.8
66	1.3	1.3	2.5	6.3	10.1	17.7	21.5	34.1	29.1	12.6	21.5	11.4	6.3
67	0	1.4	1.4	4.3	10.0	7.1	17.2	25.7	12.9	20.0	10.0	17.2	8.6
68	0	2.8	0	6.9	0	8.3	16.5	15.1	16.5	17.9	28.9	12.4	13.8
69	0	1.2	0	3.6	3.6	7.2	7.2	13.3	18.1	13.3	8.4	15.7	13.3
70	0	0	0	1.4	0	2.8	8.5	4.3	5.7	7.1	9.9	12.8	14.2
71	0	2.8	0	1.4	1.4	4.2	5.5	6.9	8.3	6.9	20.8	20.8	9.7
72	0	0	1.4	0	1.4	4.2	4.2	5.6	2.8	5.6	8.4	8.4	4.2
73	0	0	0	2.8	0	2.8	0	1.4	5.5	4.2	8.3	4.2	5.5
74	0	0	0	0	0	0	1.4	0	1.4	2.7	4.1	5.4	4.1
75	0	0	0	0	0	0	1.4	0	2.8	1.4	4.2	0	4.2
76	0	0	0	0	0	0	0	0	1.5	0	0	4.4	2.9
77	0	0	0	0	0	0	0	0	1.3	0	0	1.3	1.3
TOTAL	75.0	247.5	325.9	404.7	387.0	358.3	290.9	244.5	185.6	155.7	163.4	133.8	104.2

AGE	16	17	18	19	20	21	22	23	24	25	26	27	28
LENGTH													
57	0	0	0	0	0	0	0	0	0	1.6	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	2.8	1.4	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	1.3	2.6	0	0	0	0	0	0	0	0
61	0	0	1.4	0	0	0	1.4	1.4	0	0	0	0	0
62	2.7	0	1.4	0	0	0	0	0	0	0	0	0	0
63	2.6	0	2.6	0	0	1.3	0	0	0	0	0	0	0
64	0	2.7	2.7	1.3	1.3	1.3	1.3	0	0	0	0	0	0
65	3.8	0	2.6	1.3	2.6	1.3	0	0	1.3	0	0	0	1.3
66	7.6	5.1	6.3	2.5	1.3	6.3	2.5	2.5	1.3	0	1.3	0	0
67	5.7	10.0	10.0	7.1	5.7	5.7	4.3	7.1	4.3	1.4	8.6	0	0
68	13.8	12.4	8.3	8.3	5.5	13.8	1.4	4.1	6.9	6.9	5.5	1.4	1.4
69	14.5	13.3	10.9	4.8	14.5	7.2	9.7	2.4	4.8	6.0	8.4	2.4	7.2
70	18.5	15.6	9.9	7.1	18.5	18.5	17.0	28.4	9.9	9.9	8.5	17.0	9.9
71	6.9	6.9	15.2	9.7	19.4	15.2	15.2	18.0	18.0	6.9	15.2	18.0	8.3
72	9.8	14.1	8.4	16.9	14.1	14.1	12.6	18.3	16.9	18.3	16.9	11.2	8.4
73	13.8	11.1	12.5	9.7	8.3	9.7	9.7	15.2	24.9	16.6	24.9	18.0	23.5
74	2.7	5.4	6.8	12.2	13.5	8.1	8.1	9.5	10.8	18.9	20.3	9.5	12.2
75	0	1.4	2.8	1.4	11.2	5.6	1.4	9.8	12.6	5.6	5.6	11.2	15.4
76	0	0	2.9	0	0	2.9	2.9	2.9	10.3	5.9	2.9	1.5	4.4
77	1.3	2.7	5.4	0	0	5.4	5.4	1.3	4.0	5.4	2.7	9.4	2.7
TOTAL	106.6	102.0	110.0	83.6	118.4	116.5	93.1	121.1	126.0	103.5	120.9	99.6	94.8

AGE	29	30	31	32	33	34	35	36	37	38	39	40	41
LENGTH													
57	0	0	1.6	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	1.4	0	0	1.4	0	0	0	0	0	0	0
60	1.3	1.3	0	0	0	0	0	0	0	1.3	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	1.4	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	1.3	0	0	1.3	1.3	0	1.3	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	1.3	1.3	0	0	0	0	0	0	0	0	0	0
66	1.3	0	1.3	0	2.5	1.3	1.3	0	1.3	0	0	0	0
67	0	0	0	5.7	0	1.4	0	0	1.4	1.4	0	0	1.4
68	2.8	6.9	2.8	2.8	8.3	1.4	2.8	1.4	4.1	4.1	0	1.4	2.8
69	9.7	8.4	3.6	4.8	3.6	7.2	1.2	1.2	1.2	3.6	3.6	1.2	3.6
70	8.5	12.8	7.1	5.7	2.8	11.4	8.5	7.1	9.9	5.7	2.8	5.7	7.1
71	12.5	19.4	8.3	13.8	15.2	4.2	13.8	4.2	5.5	2.8	2.8	5.5	12.5
72	19.7	18.3	15.5	15.5	5.6	12.6	22.5	12.6	7.0	4.2	15.5	2.8	5.6
73	26.3	12.5	16.6	18.0	19.4	15.2	11.1	26.3	12.5	19.4	13.8	13.8	11.1
74	8.1	8.1	9.5	9.5	14.9	10.8	8.1	18.9	8.1	13.5	1.4	6.8	8.1
75	11.2	5.6	9.8	9.8	7.0	4.2	9.8	2.8	4.2	2.8	7.0	4.2	9.8
76	1.5	8.8	5.9	5.9	4.4	4.4	5.9	2.9	0	1.5	2.9	0	1.5
77	8.1	10.8	4.0	6.7	8.1	2.7	4.0	2.7	1.3	4.0	4.0	4.0	4.0
TOTAL	110.8	114.1	89.9	98.2	93.2	78.2	89.0	81.5	58.0	64.4	55.2	45.5	67.5

AGE	42	43	44	45	46	47	48	49	50	51	TOTAL
LENGTH											
57	0	1.6	0	0	0	0	0	0	0	1.6	291.0
58	0	0	0	0	0	0	0	0	0	0	313.0
59	0	0	0	0	0	0	0	0	0	1.4	288.0
60	0	0	0	0	0	0	0	0	0	0	307.0
61	0	0	0	0	0	0	0	0	0	0	249.0
62	0	0	0	0	0	0	0	0	0	0	247.0
63	0	0	0	0	0	0	0	0	0	0	207.0
64	0	1.3	0	0	1.3	0	0	0	0	2.7	215.0
65	0	0	0	0	0	0	0	0	0	1.3	200.0
66	0	0	1.3	0	0	0	0	0	0	2.5	225.0
67	0	5.7	1.4	0	1.4	1.4	0	1.4	0	4.3	233.0
68	2.8	1.4	1.4	0	2.8	0	1.4	0	0	6.9	286.0
69	1.2	4.8	4.8	0	1.2	3.6	2.4	2.4	2.4	21.7	309.0
70	1.4	5.7	7.1	1.4	9.9	4.3	1.4	2.8	1.4	52.6	439.0
71	5.5	4.2	8.3	12.5	8.3	8.3	2.8	6.9	4.2	65.1	508.0
72	11.2	4.2	2.8	4.2	8.4	5.6	5.6	5.6	7.0	81.5	520.0
73	12.5	13.8	8.3	11.1	4.2	9.7	4.2	8.3	1.4	85.9	608.0
74	9.5	5.4	5.4	6.8	2.7	4.1	4.1	6.8	6.8	48.7	383.0
75	1.4	7.0	2.8	4.2	2.8	7.0	1.4	2.8	2.8	46.1	264.0
76	2.9	1.5	1.5	0	2.9	4.4	1.5	1.5	1.5	22.1	131.0
77	1.3	4.0	2.7	1.3	2.7	1.3	0	4.0	1.3	32.4	166.0
TOTAL	49.8	60.7	47.8	41.5	48.7	49.7	24.7	42.6	28.8	476.6	6389.0

Table 2.4

Area V, Seasons 1959–60. Female fin age-length distribution in Japanese catch, based on 504 samples.

AGE LENGTH	3	4	5	6	7	8	9	10	11	12	13	14	15
57	3.2	6.4	8.0	3.2	9.5	1.6	1.6	0	0	1.6	0	0	0
58	0	0	2.4	2.4	2.4	7.1	0	0	0	0	0	0	0
59	0	0	2.0	6.0	8.0	2.0	8.0	0	2.0	0	0	0	0
60	0	1.5	0	1.5	5.9	7.4	8.8	0	0	1.5	1.5	0	0
61	0	1.9	1.9	3.9	11.6	5.8	1.9	0	0	1.9	0	0	0
62	0	1.7	0	1.7	13.9	8.7	1.7	12.2	0	0	0	0	0
63	0	1.8	0	0	3.6	5.4	9.0	0	3.6	1.8	1.8	0	0
64	0	0	1.3	0	3.8	6.3	7.5	6.3	6.3	8.8	1.3	1.3	1.3
65	0	1.5	0	1.5	3.1	3.1	4.6	3.1	3.1	1.5	3.1	1.5	0
66	0	0	0	0	4.8	3.2	4.8	1.6	1.6	3.2	4.8	3.2	3.2
67	0	0	0	0	2.9	1.5	5.8	2.9	2.9	7.3	1.5	1.5	2.9
68	0	0	1.5	1.5	1.5	0	1.5	1.5	0	1.5	3.0	1.5	7.5
69	0	0	0	0	0	1.6	1.6	1.6	3.2	1.6	6.4	0	4.8
70	0	1.5	0	0	0	0	0	1.5	0	0	3.1	1.5	4.6
71	0	0	0	0	0	0	3.1	0	0	4.6	1.5	0	3.1
72	0	0	0	0	0	0	0	0	0	1.7	0	1.7	0
73	0	0	0	0	0	0	0	0	0	2.1	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3.2	16.4	17.0	21.7	71.0	53.6	60.0	30.7	22.6	39.1	27.8	12.1	27.3

AGE LENGTH	16	17	18	19	20	21	22	23	24	25	26	27	28
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	2.4	0	0	0	0	0	0	0	2.4	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	1.9	0	0	0	1.9	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	1.3	0	0	0	1.3	1.3	0	0	0	0	0	0
65	1.5	1.5	0	1.5	0	0	1.5	0	0	0	0	0	0
66	0	1.6	0	0	1.6	0	0	0	0	0	1.6	0	0
67	2.9	1.5	1.5	0	0	1.5	0	0	1.5	0	1.5	0	0
68	3.0	0	1.5	0	1.5	1.5	1.5	1.5	1.5	0	3.0	0	3.0
69	1.6	3.2	3.2	1.6	3.2	1.6	3.2	8.0	0	4.8	3.2	0	0
70	0	1.5	3.1	1.5	1.5	1.5	1.5	4.6	4.6	1.5	0	0	1.5
71	1.5	4.6	0	1.5	3.1	4.6	0	1.5	1.5	4.6	1.5	4.6	1.5
72	1.7	0	1.7	3.4	3.4	5.0	3.4	1.7	1.7	1.7	1.7	1.7	3.4
73	0	0	0	0	2.1	0	2.1	2.1	2.1	2.1	0	2.1	2.1
74	2.4	2.4	2.4	0	0	0	0	2.4	0	2.4	0	0	0
75	0	2.0	2.0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	1.5	0	3.0	1.5	0	0	0	1.5
77	0	0	0	0	0	0	0	0	0	3.3	0	0	0
TOTAL	14.7	22.0	15.3	11.5	16.3	18.5	14.5	26.8	14.4	22.8	12.4	8.4	13.0

AGE LENGTH	29	30	31	32	33	34	35	36	37	38	39	40	41
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	1.3	0	0	0	0	0	0	0	0	0
65	0	1.5	0	1.5	0	0	1.5	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	1.5	0	1.5
68	1.5	3.0	1.5	0	1.5	1.5	0	0	1.5	0	0	0	1.5
69	3.2	0	1.6	0	1.6	0	0	0	0	3.2	0	0	0
70	1.5	0	6.2	0	1.5	0	3.1	4.6	0	1.5	0	0	1.5
71	1.5	1.5	3.1	0	1.5	0	0	1.5	0	0	0	0	1.5
72	0	0	3.4	0	1.7	1.7	3.4	1.7	0	0	0	0	3.4
73	0	0	4.2	2.1	4.2	0	0	0	0	2.1	0	0	0
74	2.4	0	0	0	2.4	2.4	0	2.4	2.4	2.4	0	0	0
75	0	0	0	0	0	0	0	0	0	2.0	0	0	0
76	0	0	0	0	0	1.5	0	3.0	0	1.5	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10.2	6.1	19.9	4.9	14.4	7.1	8.0	13.3	3.9	12.7	1.5	0	9.4

AGE LENGTH	42	43	44	45	46	47	48	49	50	51	TOTAL
57	0	0	0	0	0	0	0	0	0	0	35.0
58	0	0	0	0	0	0	0	0	0	0	19.0
59	0	0	0	0	0	0	0	0	0	0	28.0
60	0	0	0	0	0	0	0	0	0	0	28.0
61	0	0	0	0	0	0	0	0	0	0	33.0
62	0	0	0	0	0	0	0	0	0	0	40.0
63	0	0	0	0	0	0	0	0	0	0	27.0
64	0	0	0	0	0	0	0	0	0	0	49.0
65	0	0	0	0	0	0	0	0	0	0	37.0
66	0	0	1.6	0	0	0	0	1.6	0	0	38.0
67	0	0	0	0	0	0	0	0	0	2.9	45.0
68	1.5	0	0	0	0	0	0	0	1.5	0	54.0
69	0	1.6	1.6	0	0	0	1.6	0	0	6.4	75.0
70	1.5	0	0	0	0	0	0	0	0	13.9	71.0
71	0	0	1.5	0	0	1.5	0	0	1.5	6.2	65.0
72	1.7	0	1.7	0	0	0	1.7	1.7	0	6.7	62.0
73	0	4.2	2.1	0	0	0	4.2	2.1	2.1	6.3	50.0
74	0	0	0	0	0	0	0	0	0	9.6	36.0
75	0	0	0	2.0	0	0	0	0	0	4.0	12.0
76	0	0	0	0	0	0	0	0	0	4.5	18.0
77	0	0	3.3	0	3.3	0	0	0	0	0	10.0
TOTAL	4.7	5.8	11.8	2.0	3.3	1.5	7.4	5.3	5.1	60.4	832.0

Table 2.5

Area VI, Seasons 1959–60. Female fin age-length distribution in Japanese catch, based on 793 samples.

AGE LENGTH	3	4	5	6	7	8	9	10	11	12	13	14	15
57	3.5	8.7	8.7	12.2	3.5	7.0	5.2	0	1.7	1.7	0	0	0
58	3.1	1.6	3.1	12.4	7.8	9.3	9.3	4.7	1.6	1.6	0	0	0
59	0	2.7	8.2	16.4	10.9	15.0	5.5	5.5	10.9	4.1	0	1.4	2.7
60	0	5.5	4.1	12.3	6.8	12.3	4.1	8.2	6.8	0	0	2.7	0
61	0	0	4.0	5.3	13.3	8.0	5.3	6.7	9.3	4.0	4.0	2.7	2.7
62	0	1.4	1.4	5.6	7.0	7.0	2.8	8.4	7.0	1.4	5.6	1.4	0
63	0	1.4	2.8	1.4	8.5	4.3	7.1	4.3	1.4	1.4	5.7	2.8	0
64	0	1.3	1.3	0	5.4	5.4	5.4	6.7	8.0	5.4	1.3	1.3	1.3
65	0	0	1.6	0	1.6	3.2	1.6	3.2	3.2	3.2	3.2	6.4	0
66	0	0	1.4	1.4	5.5	2.7	2.7	2.7	2.7	4.1	0	0	4.1
67	0	0	1.4	1.4	0	2.8	0	0	4.1	4.1	1.4	1.4	1.4
68	0	0	0	0	0	0	1.3	0	2.5	2.5	1.3	3.8	0
69	0	0	0	0	0	2.7	0	0	1.3	1.3	2.7	0	1.3
70	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	1.2	0	0	1.2
72	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	1.1	0	0
74	0	0	0	0	0	0	0	0	1.3	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	6.6	22.6	38.1	68.4	70.3	79.6	50.3	50.3	62.1	36.1	26.3	23.9	14.8

AGE LENGTH	16	17	18	19	20	21	22	23	24	25	26	27	28
57	0	0	0	0	0	0	0	0	0	0	0	1.7	0
58	0	0	0	0	0	1.6	0	0	0	0	0	0	0
59	2.7	0	0	0	0	0	0	0	0	0	0	0	0
60	0	1.4	0	0	1.4	0	2.7	0	0	0	0	0	1.4
61	0	0	1.3	0	0	0	0	0	0	1.3	0	0	0
62	1.4	1.4	0	0	0	0	0	0	0	0	1.4	0	0
63	1.4	0	0	0	0	0	0	0	0	0	1.4	0	0
64	1.3	1.3	1.3	2.7	0	1.3	0	0	0	0	2.7	0	1.3
65	1.6	0	0	0	0	1.6	0	0	1.6	0	1.6	1.6	0
66	0	4.1	1.4	1.4	2.7	2.7	0	2.7	0	0	2.7	0	2.7
67	2.8	1.4	4.1	1.4	0	2.8	1.4	0	4.1	2.8	2.8	0	0
68	1.3	1.3	1.3	1.3	3.8	1.3	2.5	2.5	3.8	2.5	5.0	0	1.3
69	0	0	1.3	2.7	0	5.3	1.3	2.7	1.3	2.7	0	0	1.3
70	0	0	0	0	0	1.3	0	2.6	2.6	0	1.3	1.3	3.8
71	0	1.2	0	1.2	1.2	2.4	0	2.4	2.4	3.6	1.2	1.2	2.4
72	1.2	1.2	1.2	1.2	0	1.2	1.2	0	1.2	0	3.7	1.2	0
73	0	0	0	0	1.1	0	0	0	0	0	3.4	0	2.3
74	0	0	0	0	0	0	0	0	0	1.3	1.3	1.3	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	1.1	1.1	0	1.1	0	0
77	0	0	0	0	0	1.5	0	0	0	0	0	0	0
TOTAL	13.8	13.3	12.0	11.8	10.2	23.0	9.2	14.0	18.2	14.2	29.7	8.4	16.6

AGE LENGTH	29	30	31	32	33	34	35	36	37	38	39	40	41
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	1.4	0	0	0	0
63	1.4	0	0	0	0	0	0	0	0	0	0	0	0
64	1.3	1.3	0	0	0	1.3	0	0	0	0	0	0	0
65	0	0	0	0	0	0	1.6	0	0	0	0	0	0
66	1.4	2.7	0	0	1.4	0	0	1.4	0	0	0	0	0
67	0	0	0	2.8	0	0	0	0	0	1.4	1.4	0	4.1
68	3.8	0	0	1.3	1.3	1.3	1.3	0	0	0	1.3	0	0
69	2.7	1.3	0	0	2.7	0	0	0	0	1.3	2.7	1.3	1.3
70	1.3	0	1.3	1.3	2.6	1.3	1.3	0	2.6	3.8	2.6	1.3	1.3
71	1.2	0	0	1.2	1.2	3.6	3.6	1.2	2.4	0	0	1.2	3.6
72	2.5	0	2.5	0	2.5	2.5	1.2	1.2	2.5	1.2	3.7	1.2	1.2
73	1.1	1.1	1.1	1.1	1.1	1.1	0	1.1	2.3	2.3	1.1	0	0
74	0	0	0	0	1.3	1.3	0	0	2.6	0	0	1.3	0
75	1.1	1.1	0	0	0	1.1	0	1.1	1.1	0	0	1.1	1.1
76	0	0	0	1.1	0	0	0	0	1.1	1.1	0	0	0
77	0	0	0	0	0	0	1.5	0	0	0	0	0	0
TOTAL	17.7	7.6	4.9	8.8	14.0	13.5	10.5	6.0	16.0	11.2	12.7	7.4	12.7

AGE LENGTH	42	43	44	45	46	47	48	49	50	51	TOTAL
57	0	0	0	0	0	0	0	0	0	0	54.0
58	0	0	0	0	0	0	0	0	0	0	56.0
59	0	0	0	0	0	0	0	0	0	0	86.0
60	0	0	0	0	0	0	0	0	0	1.4	71.0
61	0	0	0	0	0	0	0	0	0	0	68.0
62	0	0	0	0	0	0	0	0	0	1.4	56.0
63	0	1.4	0	0	0	0	0	0	0	0	47.0
64	0	0	0	0	0	0	0	0	0	0	59.0
65	0	1.6	0	0	1.6	0	1.6	0	0	3.2	45.0
66	1.4	0	0	0	0	0	0	0	0	6.8	63.0
67	1.4	1.4	2.8	0	1.4	0	0	0	0	0	58.0
68	1.3	0	0	1.3	1.3	1.3	0	1.3	0	8.8	64.0
69	1.3	1.3	0	2.7	0	1.3	1.3	0	2.7	9.3	61.0
70	2.6	1.3	1.3	2.6	1.3	2.6	0	2.6	2.6	10.2	60.0
71	0	1.2	0	1.2	1.2	2.4	2.4	1.2	0	12.1	63.0
72	2.5	1.2	1.2	1.2	1.2	0	0	1.2	0	13.6	58.0
73	0	0	1.1	2.3	1.1	1.1	1.1	1.1	1.1	14.9	46.0
74	0	0	0	0	2.6	0	0	0	0	10.5	25.0
75	0	0	0	0	1.1	0	0	0	2.1	4.3	15.0
76	0	0	0	0	0	0	0	0	0	3.3	10.0
77	0	0	0	0	0	0	0	0	0	0	3.0
TOTAL	10.4	9.5	6.4	11.2	12.8	8.7	6.5	7.4	8.5	99.9	1068.0

Table 3.1

Area III, Seasons 1968–70. Female fin age-length distribution in Japanese catch, based on 945 samples.

AGE LENGTH	3	4	5	6	7	8	9	10	11	12	13	14	15
57	35.8	12.6	6.3	2.1	0	2.1	0	0	0	0	0	0	0
58	10.3	5.9	4.4	1.5	0	0	0	0	0	0	0	0	0
59	10.2	8.5	1.7	3.4	1.7	1.7	0	0	0	0	0	0	0
60	16.0	4.0	8.0	4.0	2.7	0	2.7	0	0	0	0	0	0
61	6.1	12.1	6.1	9.1	4.6	0	1.5	1.5	0	0	0	1.5	0
62	11.4	10.0	4.3	8.5	5.7	2.8	1.4	0	0	2.8	0	0	0
63	6.0	3.0	10.5	12.0	4.5	1.5	4.5	1.5	0	1.5	0	0	0
64	0	8.2	9.9	14.8	4.9	3.3	3.3	0	0	1.6	0	0	0
65	2.7	5.5	5.5	5.5	4.1	8.2	0	5.5	1.4	2.7	0	1.4	0
66	1.7	5.1	5.1	11.9	5.1	6.8	5.1	8.5	1.7	1.7	5.1	3.4	1.7
67	0	4.7	9.4	10.9	18.8	14.1	3.1	6.3	4.7	14.1	6.3	0	0
68	1.9	7.4	5.6	1.9	5.6	3.7	11.1	18.5	5.6	5.6	1.9	3.7	1.9
69	1.6	0	4.9	6.6	9.9	8.2	13.1	6.6	8.2	6.6	8.2	3.3	1.6
70	0	3.6	1.8	7.2	12.5	10.7	7.2	14.3	5.4	5.4	9.0	1.8	1.8
71	0	0	3.4	3.4	1.7	12.0	10.3	3.4	3.4	5.2	3.4	1.7	0
72	0	0	2.8	1.4	0	2.8	12.6	1.4	7.0	2.8	4.2	1.4	2.8
73	0	0	0	1.5	0	4.6	3.1	4.6	1.5	3.1	4.6	1.5	3.1
74	0	0	0	0	0	1.5	3.0	0	1.5	1.5	1.5	0	0
75	0	0	1.5	0	0	0	1.5	0	0	3.0	1.5	0	0
76	0	0	0	0	0	0	0	1.4	0	1.4	0	0	1.4
77	0	0	0	0	0	0	0	0	1.3	2.6	0	0	1.3
TOTAL	103.7	90.6	91.1	105.7	81.7	84.1	83.5	73.6	41.6	61.5	45.6	19.7	15.6

AGE LENGTH	16	17	18	19	20	21	22	23	24	25	26	27	28
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	1.3	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	1.5	0	0	0	0	0	0	0	0	0	0	1.5	0
64	0	1.6	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	1.7	0	1.7	0	0	0	0	0	0	0	0	0	1.7
67	1.6	1.6	0	3.1	0	1.6	0	1.6	0	0	0	1.6	1.6
68	3.7	0	3.7	0	0	0	0	0	0	0	0	0	0
69	3.3	0	1.6	1.6	0	0	1.6	1.6	0	0	1.6	1.6	0
70	5.4	1.8	1.8	1.8	3.6	1.8	0	0	0	1.8	5.4	1.8	0
71	5.2	1.7	3.4	0	0	0	0	1.7	0	0	1.7	0	1.7
72	4.2	1.4	7.0	5.6	0	2.8	1.4	1.4	2.8	5.6	1.4	5.6	7.0
73	4.6	1.5	3.1	1.5	1.5	4.6	3.1	1.5	1.5	4.6	4.6	3.1	4.6
74	5.9	0	1.5	0	1.5	1.5	0	4.4	5.9	0	4.4	0	0
75	1.5	1.5	1.5	3.0	3.0	0	1.5	3.0	3.0	1.5	0	1.5	0
76	0	0	0	1.4	0	1.4	2.8	0	0	0	1.4	0	1.4
77	0	1.3	0	1.3	1.3	0	1.3	0	1.3	1.3	1.3	1.3	0
TOTAL	38.5	12.4	26.6	19.4	10.9	13.7	11.7	15.3	14.5	14.8	21.9	17.9	18.0

AGE LENGTH	29	30	31	32	33	34	35	36	37	38	39	40	41
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	1.7	0	0	0	0	0	0	0	0	0
60	0	0	0	0	1.3	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	1.5	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	1.6	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	1.7	0	0	0	0	0	0	0	0	0	1.7
67	0	0	1.6	0	0	0	0	0	0	0	0	0	0
68	0	0	0	1.9	1.9	0	0	0	0	0	0	0	0
69	0	1.6	1.6	1.6	3.3	1.6	0	0	1.6	1.6	0	0	0
70	0	0	1.8	0	1.8	1.8	1.8	0	0	0	0	0	0
71	1.7	1.7	3.4	0	0	3.4	6.9	3.4	3.4	1.7	0	0	0
72	2.8	0	1.4	4.2	5.6	2.8	1.4	4.2	1.4	1.4	1.4	0	1.4
73	3.1	1.5	1.5	0	3.1	9.2	0	3.1	1.5	3.1	4.6	1.5	0
74	3.0	0	3.0	5.9	0	4.4	1.5	3.0	0	5.9	4.4	0	1.5
75	3.0	1.5	3.0	1.5	3.0	3.0	0	1.5	0	4.4	0	3.0	1.5
76	0	1.4	2.8	1.4	1.4	0	1.4	1.4	1.4	1.4	4.3	1.4	0
77	3.9	0	0	0	2.6	2.6	1.3	1.3	5.2	0	0	1.3	2.6
TOTAL	17.4	7.8	21.8	18.2	23.9	28.9	14.3	19.4	14.6	21.2	14.7	7.2	8.7

AGE LENGTH	42	43	44	45	46	47	48	49	50	51	TOTAL
57	0	0	0	0	0	0	0	0	0	0	59.0
58	0	0	0	0	0	0	0	0	0	0	22.0
59	0	0	0	0	0	0	0	0	0	0	29.0
60	0	0	0	0	0	0	0	0	0	0	40.0
61	0	0	0	0	0	0	0	0	0	0	44.0
62	0	0	0	0	0	0	0	0	0	0	47.0
63	0	0	0	0	0	0	0	0	0	0	48.0
64	0	1.6	0	0	0	0	0	0	0	0	51.0
65	0	0	0	0	0	0	0	0	2.7	0	45.0
66	0	0	0	0	0	1.7	0	0	1.7	0	75.0
67	0	0	0	3.1	0	0	0	0	0	1.6	111.0
68	0	0	0	0	0	0	0	0	0	3.7	89.0
69	1.6	0	0	0	0	0	0	0	0	3.3	110.0
70	0	0	0	0	1.8	0	0	0	0	5.4	120.0
71	1.7	3.4	0	0	3.4	0	1.7	0	1.7	8.6	110.0
72	1.4	1.4	2.8	1.4	0	1.4	2.8	2.8	2.8	4.2	134.0
73	3.1	1.5	0	0	0	1.5	3.1	0	1.5	9.2	120.0
74	4.4	0	0	0	0	0	3.0	1.5	0	1.5	77.0
75	0	0	0	0	0	3.0	1.5	0	0	4.4	62.0
76	0	1.4	0	1.4	0	2.8	1.4	0	0	5.7	44.0
77	2.6	0	1.3	0	0	0	1.3	1.3	2.6	2.6	48.0
TOTAL	14.9	9.4	4.1	5.9	5.2	10.4	14.7	5.6	13.1	50.1	1485.0

Table 3.2

Area IV, Seasons 1967–70. Female fin age-length distribution in Japanese catch, based on 1,024 samples.

AGE	3	4	5	6	7	8	9	10	11	12	13	14	15
LENGTH													
57	10.3	12.3	6.2	2.1	0	2.1	0	2.1	0	0	0	0	0
58	10.1	8.4	3.4	1.7	0	0	0	0	1.7	1.7	0	0	0
59	7.8	7.8	3.1	1.6	0	1.6	0	1.6	1.6	0	0	0	0
60	10.9	14.0	6.2	1.6	1.6	1.6	0	0	0	0	0	0	0
61	9.4	7.5	9.4	1.9	0	0	1.9	1.9	0	0	0	0	0
62	3.8	13.4	15.3	1.9	3.8	1.9	1.9	0	1.9	0	0	1.9	0
63	1.5	4.5	5.9	8.9	7.4	7.4	3.0	4.5	3.0	0	0	0	0
64	1.8	5.5	3.6	14.5	7.3	5.5	3.6	3.6	3.6	1.8	3.6	0	0
65	0	4.4	7.3	11.6	5.8	5.8	7.3	1.5	2.9	1.5	2.9	2.9	1.5
66	2.0	2.0	3.9	11.7	9.8	5.9	7.8	7.8	2.0	5.9	9.8	2.0	2.0
67	0	3.1	6.3	12.6	9.4	9.4	18.9	11.0	6.3	7.9	3.1	3.1	1.6
68	0	1.4	4.1	2.7	6.8	12.2	10.9	9.5	10.9	13.6	12.2	16.3	2.7
69	0	4.7	0	1.6	9.4	18.9	9.4	11.0	12.6	12.6	11.0	3.1	4.7
70	0	3.5	6.9	3.5	5.2	10.4	13.8	10.4	10.4	8.6	8.6	3.5	1.7
71	0	1.5	0	6.1	6.1	10.7	6.1	9.2	1.5	6.1	7.6	4.6	12.2
72	0	0	3.0	3.0	3.0	6.0	6.0	4.5	7.4	8.9	4.5	4.5	3.0
73	0	0	1.5	0	3.0	6.1	1.5	6.1	4.5	3.0	1.5	1.5	4.5
74	0	0	1.3	2.6	0	1.3	2.6	1.3	2.6	1.3	3.9	1.3	3.9
75	0	0	2.7	0	2.7	0	4.1	1.4	2.7	1.4	0	1.4	2.7
76	0	0	0	0	0	0	0	1.3	1.3	0	0	0	1.3
77	0	0	0	0	0	0	0	0	1.2	1.2	0	1.2	1.2
TOTAL	57.6	94.0	90.2	89.5	81.4	106.6	98.7	88.4	78.1	75.4	68.8	47.2	43.0

AGE	16	17	18	19	20	21	22	23	24	25	26	27	28
LENGTH													
57	0	0	0	0	0	0	0	0	0	0	0	0	2.1
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	1.5	0	1.5	0	0	0	0	0	0	0	0	0	0
64	0	1.8	0	0	0	1.8	0	0	0	0	0	0	0
65	0	1.5	0	0	0	2.9	0	0	0	0	0	0	0
66	2.0	2.0	3.9	0	0	0	0	0	0	0	0	0	2.0
67	3.1	0	3.1	0	1.6	0	1.6	0	0	0	1.6	0	0
68	6.8	2.7	0	2.7	0	0	1.4	2.7	0	0	0	1.4	0
69	4.7	6.3	3.1	0	0	1.6	1.6	1.6	0	0	1.6	0	1.6
70	0	3.5	6.9	8.6	3.5	6.9	0	1.7	0	0	0	1.7	3.5
71	1.5	1.5	4.6	3.1	0	1.5	4.6	1.5	0	0	1.5	1.5	1.5
72	4.5	3.0	3.0	0	0	3.0	3.0	0	4.5	4.5	4.5	0	0
73	3.0	6.1	4.5	4.5	0	1.5	4.5	1.5	1.5	1.5	0	3.0	0
74	1.3	0	0	1.3	1.3	0	1.3	3.9	2.6	2.6	0	1.3	3.9
75	0	0	0	1.4	0	1.4	4.1	0	1.4	0	0	0	1.4
76	0	0	2.6	0	1.3	0	0	0	0	0	2.6	1.3	1.3
77	0	0	0	0	0	0	1.2	0	2.4	1.2	0	1.2	1.2
TOTAL	28.4	28.3	33.3	21.6	7.6	20.6	23.2	12.9	12.3	9.8	11.7	11.4	18.3

AGE	29	30	31	32	33	34	35	36	37	38	39	40	41
LENGTH													
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	1.6	0	0	0	0	0	0	1.6	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	1.5	0	1.5	0	1.5	0
66	0	0	0	0	0	0	0	0	2.0	0	2.0	0	0
67	1.6	0	0	1.6	0	0	0	0	0	0	0	1.6	0
68	0	0	0	0	0	0	0	0	2.7	0	0	0	0
69	0	0	1.6	1.6	0	0	3.1	0	1.6	0	0	0	0
70	3.5	0	0	0	1.7	0	0	0	1.7	5.2	1.7	1.7	0
71	1.5	1.5	1.5	1.5	3.1	1.5	3.1	0	4.6	4.6	0	0	0
72	0	1.5	1.5	3.0	1.5	1.5	6.0	3.0	1.5	0	0	0	1.5
73	3.0	4.5	0	1.5	1.5	4.5	3.0	4.5	0	1.5	1.5	0	1.5
74	3.9	0	2.6	6.4	2.6	1.3	2.6	3.9	5.1	1.3	1.3	2.6	0
75	1.4	2.7	1.4	1.4	0	0	0	4.1	0	0	0	0	0
76	1.3	1.3	1.3	3.9	2.6	1.3	0	1.3	0	1.3	0	0	2.6
77	1.2	0	0	2.4	1.2	0	1.2	1.2	1.2	2.4	0	0	1.2
TOTAL	17.3	11.6	11.4	23.2	14.1	10.1	19.0	19.4	20.4	19.3	6.5	7.3	6.8

AGE	42	43	44	45	46	47	48	49	50	51	TOTAL
LENGTH											
57	0	0	0	0	0	0	0	0	0	0	37.0
58	0	0	0	0	0	0	0	0	0	0	27.0
59	0	0	0	0	0	0	0	0	0	0	25.0
60	0	0	0	0	0	0	0	0	0	0	39.0
61	0	0	0	0	0	0	0	0	0	0	32.0
62	0	0	0	0	0	0	0	0	0	0	46.0
63	0	0	0	0	0	0	0	0	0	0	49.0
64	0	0	0	1.8	0	0	0	0	0	0	60.0
65	0	0	0	0	0	0	0	0	0	0	64.0
66	0	0	0	0	0	0	0	0	0	3.9	90.0
67	1.6	0	0	0	0	0	0	0	0	0	110.0
68	0	0	0	1.4	0	0	0	0	0	0	125.0
69	0	1.6	1.6	0	0	1.6	0	0	0	3.1	137.0
70	1.7	1.7	0	0	0	1.7	1.7	0	0	0	145.0
71	1.5	0	0	1.5	0	1.5	3.1	0	0	13.7	139.0
72	0	3.0	1.5	1.5	0	4.5	0	0	1.5	14.9	131.0
73	3.0	0	0	0	1.5	0	0	0	1.5	10.6	109.0
74	2.6	0	0	1.3	1.3	0	0	1.3	0	9.0	90.0
75	4.1	1.4	0	2.7	0	0	1.4	1.4	0	5.5	56.0
76	0	1.3	0	0	1.3	0	0	0	1.3	1.3	35.0
77	2.4	1.2	1.2	0	0	0	1.2	0	0	6.0	36.0
TOTAL	16.9	10.1	4.3	10.2	4.1	9.3	7.3	2.7	4.3	68.1	1582.0

SC/33/Ba4

Pregnancy Rates of Fin Whales in the Icelandic Catch

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ABSTRACT

A technique is described for calculating the true pregnancy rate of a baleen whale population using routine biological samples and standard catch data. Currently about 48.5% of the mature females in the fin whale stock exploited by Iceland become pregnant each year. This figure is little affected by allowance for foetal and neonatal deaths but could be a few percentage points out if some assumptions based on relatively few data are not valid. Time series of pregnancy data from the catch are probably unreliable indicators of real trends in the population.

INTRODUCTION

Fin whales *(Balaenoptera physalus)* have been exploited in Icelandic waters, particularly off the west coast in the Denmark Strait, since the last years of the 19th century (Rørvik *et al.*, 1976). The estimated annual catch for this species averaged 130 for the 1890s and subsequently varied between about 200 and 700 until a decline started in 1912; whaling from land stations ceased in 1916. Norwegian pelagic expeditions took at least 560 fin whales from waters west of Iceland during the 1930s and a further 375 were captured during the operation of a land station on the west coast between 1935 and 1939 (Jonsgård, 1966). The existing factory in Hvalfjördur began operating in 1948 and has taken over 8,000 fin whales since that time; an average of 243 per year. The length and sex of each animal has been recorded since 1948 and the position of each capture since 1951.

Previously published information on reproductive parameters for this species in Icelandic waters has included estimates of ovulation frequency and mean lengths at sexual maturity (Lockyer and Brown, 1979), but no calculation of pregnancy rates. Lockyer (1981) reported a marked decline in the age at sexual maturity for both sexes in this stock during the post-war period. The pregnancy rate might also be expected to alter in these circumstances, as found in the Southern Hemisphere (Gambell, 1973).

This paper describes a technique for estimating the true pregnancy rate (TPR) from routine biological samples and reviews the pregnancy data available for the Icelandic fin whale catch in years before biological sampling began.

MATERIALS AND METHODS

Station records have kindly been made available by the Marine Research Institute, Reykjavik and the whaling company, Hvalur H.F.. These contain the species, length, sex and position of capture of every whale taken since 1951, together with details of any foetuses observed by the shift foremen.

Biological collections were made from the catch in 1967, 1969, 1972, 1973 and 1976–80, although only a small number of samples were obtained in 1972. Ovaries were preserved in 10% formalin for laboratory examination whenever possible. Mammary glands were examined and their maximum depth measured. Uteri were carefully searched and foetuses were sexed, measured and weighed when encountered. In later years, the diameter of the collapsed cornua was recorded for both uterine horns.

Ovaries were subsequently cut into 3–4 mm slices in order to detect all corpora and large follicles. Corpora lutea were measured on three perpendicular axes and other corpora, together with the largest follicles in each ovary, were measured on two perpendicular axes at their plane of maximum diameter. The mean of the diameters has been used to represent the size of each corpus and follicle.

In the following analysis, ovary data have been used only in the cases where both ovaries of a pair were collected and sectioned. These represented 86% of the females examined which were, in turn, 51% of the female fin whales delivered to the station during the years in which biological collections were made. During the period 1977–80, a biologist has been present for the major part of each season and 77% of the female catch during this time has been sampled.

ASSESSMENT OF PREGNANCY RATES

Two major problems occur when trying to establish a true pregnancy rate from catch data. Firstly, the proportion of animals caught in each sexual category (e.g. immature, lactating, pregnant) will probably not reflect the true proportions of these categories on the catching grounds; for example the ban on taking animals accompanied by a calf will obviously bias the catch against lactating females. Secondly, even if the true proportions within the group of animals on the grounds can be determined, these will not necessarily be representative of the proportions within the whole population because, for example, of differential migration of different sexual classes.

Five mutually exclusive reproductive categories of mature females have been recognised for the purposes of this analysis:

(a) Pregnant only.
(b) Lactating only or lactating and ovulating simultaneously.
(c) Pregnant and lactating simultaneously.
(d) Resting, or ovulating with a small corpus luteum (<75 mm).
(e) Ovulating, with a large corpus luteum (⩾75 mm).

By analogy with the Antarctic (Laws, 1961), it can be expected that the proportion of females in each of these categories will change with time, both in the total population and in the group of animals which are found in the Denmark Strait during the summer months. In particular, since most pregnant Southern Hemisphere fin whales are known to calve during the northern winter and lactate for a period of six or seven months (Laws, 1961) it seems likely that their North Atlantic counterparts will be lactating during the spring and weaning calves during the summer. The Icelandic whaling season of May/June–September/October would then bracket the period during which females, having conceived 18 months previously during the main winter oestrus, would now be changing from lactation to a resting or ovulating phase and might thus lose their protection from the fishery.

Strong support for the assumption that North Atlantic and Southern Hemisphere fin whales are six months out of phase is to be found when the growth of fin whale foetuses measured in Iceland is compared with Laws' (1959) larger sample from the Antarctic (Fig. 1.). The curve derived from mean length-at-date values from Icelandic records was overlaid onto Laws' growth curve (his text—Fig. 9, p. 296). Although the spread of lengths in each time period is large, in both data sets, the best fit by eye occurs when the corresponding dates on the two curves are about six months apart. Foetuses in the North Atlantic thus appear to be at about the same length at the same period of the season as Southern Hemisphere foetuses. Even allowing for possible differences in growth rates, it seems justifiable to assume that these populations adhere to very similar reproductive time schedules.

The wide spread of foetal lengths occurring within a short space of time at the Icelandic station indicates that conceptions must occur during many months of the year. However the distribution of these lengths is unimodal and all but a few successfully fertilized ovulations must take place during the winter months. By examination of foetal lengths from Antarctic catches, Laws (1961) considered that 4.8% of the conceptions in his sample occurred during the summer months equivalent to May/June through September/October in the Northern Hemisphere. Icelandic data suggest that 19 of 553 foetuses (3.4 ± 1.5%) were conceived during these months although some small foetuses must have been missed and the true figure will be a little higher than this.

Thus, the proportion of females which conceive within the summer catching season is small and, for simplicity, these animals have been ignored in the current analysis.

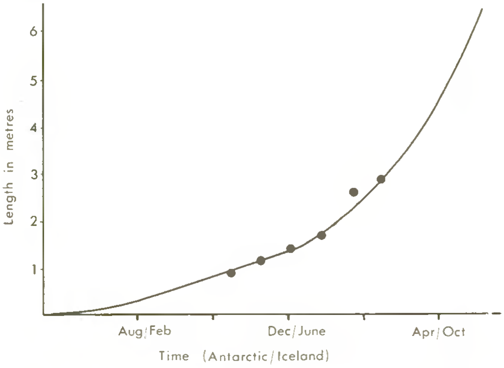

Fig. 1. Foetal growth rates of Antarctic (solid line, after Laws, 1959) and Icelandic fin whales. The Icelandic values are the mean lengths within successive 20-day intervals during the whaling season and have been positioned in such a way that the two curves are exactly six months out of phase with each other.

Let the proportion of all females in the population within the five sexual categories be denoted thus:

P = Pregnant only.
$\emptyset$ = Ovulating only (with a corpus luteum ≥75 mm);
R = Resting, or ovulating with a small corpus luteum (<75 mm);
L = Lactating only or lactating and ovulating simultaneously;
PL = Pregnant and lactating simultaneously;

and let the subscript 'a' denote the proportions of mature females in the catch within these categories.

Then, the apparent pregnancy rate (APR) of the catch is

$$P_a + PL_a$$

and the true pregnancy rate (TPR) is

$$P + PL.$$

The significance of the division between large and small corpora lutea is that, in this stock, 75 mm is just below the diameter of the smallest corpus which has been known to support a pregnancy. Thus animals in category R_a cannot have been pregnant at capture and can be separated from those in categories $\emptyset_a$ and P_a by a quick examination of the ovaries.

In the Antarctic, females of different reproductive categories arrive on and depart from the catching grounds at different times (Laws, 1961). The numbers of animals in these categories available for capture will thus vary across the season. A single ratio derived by lumping data from different periods may therefore be misleading and should be avoided or used with caution. July is the month which yields the greatest catch in the Icelandic operation; almost certainly this reflects a greater abundance of fin whales on the grounds than in any other month and it seems appropriate to concentrate on data collected at this time of the season. The only group which is probably not fully represented on the grounds by this time is that which comprises lactating females. However, these animals occur at an artificially low level in the catch anyway and their apparent abundance has thus not been used in the calculation of pregnancy rates. Of the three categories of mature females fully at risk to the Icelandic catch (i.e. pregnant only, ovulating and resting), only the pregnant group seems likely to be under-represented towards the end of the season because of the early departure of some animals in this class. Laws (1961) demonstrated that the mean length of foetuses encountered in the Antarctic catch from March onwards appeared to be lower than expected by extrapolation from the rest of the curve and he concluded that this was because females with large foetuses left early for warmer waters. A similar situation apparently exists in the Icelandic stock (Fig. 1) where the length of foetuses measured in September is low compared to those recorded in late August. Nevertheless, it seems reasonable to suppose that very few pregnant animals will have departed from Icelandic waters as early as July and it is thus assumed that the ratio of pregnant:ovulating:resting females in the Icelandic catch in July is the same as that in the population as a whole, i.e. $P_a = kP$, $\emptyset_a = k\emptyset$, $R_a = kR$, where k is a constant.

Estimates of the ratio $P_a : \emptyset_a : R_a$ rely on measurements and samples collected by biologists at the station, in particular the data derived from ovaries and the size of the uterine cornua. Lactating animals can immediately be distinguished and discounted by the size and appearance of the mammary glands, together with the presence of at least some milk. In recent years, the practice of slitting the ventral abdominal blubber to allow cooling of the carcase has resulted in most uteri being ruptured before examination at the factory and the absence of a foetus clearly does not, in itself, indicate that an animal was not pregnant. However, resting females do not have a large ($\geqslant$75 mm) corpus on either ovary so the presence of such a corpus indicates that the female was either pregnant, had recently ovulated or was about to ovulate when captured. All females with at least one corpus on an ovary but without a large corpus luteum are thus assigned to category R_a.

Of 47 mature female fin whales examined by a biologist in 1969, when all animals were delivered to the station intact, 38 (81%) were found to have a corpus luteum (all > 75 mm) on one ovary and, of these, 37 (97%) were known to have been pregnant.

Between 1977 and 1980 the cornua diameter of 31 females with a corpus luteum of diameter $\geqslant$ 75 mm has been recorded. Of these, one was almost certainly ovulating (CL = 75mm, very large follicles), another was probably ovulating and two others were possibly ovulating.

Thus, of 69 animals with a corpus luteum large enough to support a pregnancy, between 1 and 5 (1.4%–7.2%) could have been ovulating, the true figure probably being around 5%. It is thus assumed that $\emptyset_a = 0.05(\emptyset_a + P_a)$, i.e. $\emptyset_a = 0.053P_a$.

Two further categories (L and PL) remain to be examined, neither of which is fully represented in the catch because of the IWC ban on taking nursing females. Assuming a gestation period of 11 or 12 months in this species (Laws, 1961), females which conceive at the main winter oestrus and are pregnant in year t will be lactating in the early part of year (t + 1). Let n_t be the number of mature females in the population in July of year t and let s be the annual survival rate of mature females. Then, if n_t. (P + PL) females are pregnant in July of year t, sn_t (P + PL) will survive to July in year (t + 1) of which a proportion, x, will still be suckling a calf. An estimate of this proportion has been made by applying Laws' (1959) foetal growth curve to time-specific length frequency histograms of Icelandic caught fin whale foetuses in order to estimate dates of birth and weaning (assuming a seven-month lactation period). A value for x of 0.3 was derived by this method. Thus the total number of lactating females in July of year (t + 1) is $0.3s(P + PL) = (L + PL)$; assuming $n_t = n_{t+1}$, i.e. that the population size is stable. Growth rates and gestation length may differ slightly between these populations and the possible effects of such differences on the estimation of the TPR are calculated below.

The rate of occurrence of foetal and neonatal deaths is not known but it can be taken into account by letting s represent both these and adult deaths between one July and the next. It was decided to ignore such mortality at this stage but it is shown below that, unless high, it has little effect on the value of the TPR.

Two difficulties must be taken into account when examining foetal length data of this kind. Firstly some small foetuses are unlikely to be found and recorded by the factory staff, leading to artificially high estimates of mean foetal lengths early in the season and under-estimation of the number of late conceptions. Secondly, as mentioned earlier, large foetuses are under-represented in September and possibly late August because their mothers have already left the feeding grounds for warmer waters. In order to minimise these biases, foetal length distributions in the period 14 July–27 August were used for the analysis, giving a sample of 192. It is worth noting that the proportions of weanings finished at particular dates as predicted by these middle-series data are very similar to the figures derived from the complete data set. It seems probable that the two biases cancel each other out during the season as a whole. A few small foetuses will be missed even late in the season, however, and the true proportions finishing weaning at a particular time will thus be slightly smaller than estimated by this technique.

Data on which to base an estimate of the proportion of lactating females which are also pregnant are scarce since very few lactating females are seen at the factory (1.9% of all females in recent years). Of 13 animals with milk in the mammary glands which were examined by biologists between 1967 and 1980, 2 (15.4 ± 20.0%) were definitely pregnant and the remaining 11 were definitely not pregnant. The confidence limits of this figure are wide but it is the only estimate available and it is close to Laws' (1961) best estimate of 17.9 ± 8.7% for the Antarctic fishery. Thus I assume that PL = 0.15 (L + PL).

In July of the years 1973 and 1976–80, a complete pair of ovaries was collected from 101 mature female fin whales. Later examination showed that 57 (56.4 ± 9.9%) of these ovary pairs had a corpus luteum of $\geqslant$ 75 mm attached.

Thus $P_a + \emptyset_a = 0.564$

and, since $\emptyset_a = 0.053\,P_a$,

$P_a = 0.536$ and $R_a = 1–0.564 = 0.436$

$= 0.812\,P_a$

$\therefore R = 0.812P$

Summarising,

(1) $\emptyset = 0.053P$
(2) $L + PL = 0.3s(P + PL)$
(3) $PL = 0.154(L + PL)$
(4) $R = 0.812P$

It is also possible to express PL and L in terms of P.

From (2) and (3) $L + PL = 1.95sP/(6.5 - 0.3s)$

Now $P + L + PL + \emptyset + R = 1$

So, if s = 0.9 (Cooke and Beddington, 1981):

$P(1 + 0.282 + 0.053 + 0.812) = 1$
$P = 0.466$
$P + PL =$ True Pregnancy Rate $= 0.485$

If allowance is made for, say, a 10% mortality of foetuses and young calves from one summer to the next, $L = 0.216P$ and $PL = 0.039P$.

Thus TPR = 0.490.

The effect of, say, a 10% error in the estimate of the proportion of lactating females which had completed weaning by July would be that the TPR is

(a) underestimated by 0.016 if $P + PL = 0.2s(P + PL)$,
(b) overestimated by 0.015 if $L + PL = 0.4s(P + PL)$.

Confidence limits of some of the values incorporated into these calculations are wide and, in order to establish the approximate size of the error of the final TPR figure, lowest and highest values have been derived by taking the appropriate 95% confidence interval of each component. The true 95% confidence limits of the TPR will lie within these values.

Using this technique, the upper confidence bound of the TPR is 0.605, and the lowest confidence bound is 0.383.

HISTORICAL PREGNANCY DATA FOR THIS CATCH

Unfortunately, no biologist was at the station to make collections prior to the 1967 season and the only records available to shed some light on the pregnancy rate in early years are the numbers of foetuses found by factory staff each summer.

Fig. 2 illustrates the proportion of females 62 feet and over for which a foetus was recorded in each year. Although not all females are mature by the time they reach 62 ft (Fig. 3), an error of only 5.2% is introduced if this is assumed to be the lower limit of sexual maturity. The adoption of a greater length as the criterion, while slightly decreasing this error, would simultaneously unacceptably reduce the number of animals available for subsequent analysis. Comparison of the mature female: recorded foetus ratio in July with that for the complete season in each year showed that there is no consistent difference between the two and that the shapes of the curves are similar. Biases caused by between-year differences in the number of fin whales caught in each month are thus small. The values for each complete season have been chosen for illustration simply because of the larger sample sizes available.

The average expected number of foetuses per mature female in the catch between 1973 and 1980, if the practice of slitting the ventral blubber had not been introduced and if all foetuses were found by the station staff, is the APR of

$$P_a = 0.536$$

This is shown as a horizontal dotted line on Fig. 2.

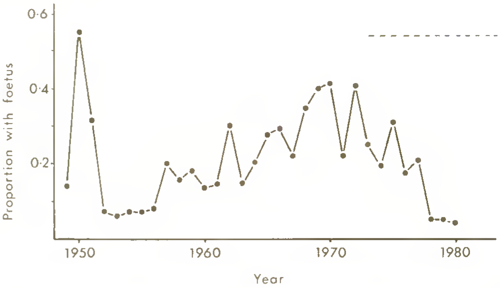

Fig. 2. The proportion of mature (⩾ 62 feet) fin whales, by year, in the Icelandic catch for which a foetus was recorded by station staff. The dotted line represents the average number of foetuses which would be expected between 1973 and 1980 if none were lost at sea or went unrecorded at the factory (see text).

DISCUSSION

Despite the rather small sample size used in some parts of this analysis it is clear that the current true pregnancy rate of the stock from which Icelandic caught fin whales are taken is close to 50%.

A baleen whale population in which all mature females became pregnant every second year and no foetal, neonatal or adult deaths occurred would theoretically have a true pregnancy rate of 50%. Since the proportion of females which are simultaneously lactating and pregnant

% mature 0 7 0 17 25 43 53 54 87 89 97 100 (i.e. which have an inter-conception period of less than two years) appears to be low, the majority of females must be adhering to a standard 2-year cycle which would leave about 5 or 6 months between the weaning of one infant and the conception of the next.

This method of calculating the TPR has been shown to be fairly insensitive to the allowance of a reasonable mortality rate for foetuses in the second half of pregnancy and for neonates, though a large error in the calculation of the proportion of weanings which have occurred by July will influence the TPR.

Comparison of the best estimate of the TPR with the apparent pregnancy rate from which it was derived shows that

$$\text{(a)}\quad \frac{\text{TPR}}{\text{APR}}=\frac{0.485}{0.564},\ \text{i.e. TPR} = 0.859.\text{APR, and}$$

$$\text{(b)}\quad \frac{\text{TPR}}{\text{APR}}=\frac{0.485}{0.536},\ \text{i.e. TPR} = 0.905.\text{APR,}$$

where APR is the proportion of mature females in the catch (a) with a large ($\geqslant$ 75 mm) corpus on at least one ovary and (b) which are pregnant. These ratios will, however, increase continually through the year as the number of females protected from the fishery by the presence of a nursing calf decreases.

Comparison with pregnancy rates quoted by other authors is difficult because invariably only an apparent rate is given and this will vary dramatically depending both on the time of the season when data were collected and what criteria have been used to establish the pregnancy rate. Given the proximity of the Norwegian fin whale fishery to Icelandic waters, though, it should be pointed out that Haug's (1981) APR of 0.523 for West Norway and 0.403 for North Norway are equivalent to the figure of 0.536 for Iceland.

The time series of apparent pregnancy rates (Fig. 2) presents a rather confusing picture. A high ratio of foetuses to mature females in the very early years was immediately followed by a period of several seasons when the figure was below 10%. A steady increase then occurred until 1970

1951 must make it doubtful that the observed increase over the following 19 years reflects a real change in the exploited population. Equally likely is that enthusiasm on the part of station staff to record foetuses waned after the first few years and then slowly rose again as outside interest in the catch increased.

Although the station records are unlikely to be an accurate reflection of the real pregnancy rate of this population, the suggestion that an increase in the pregnancy rate has occurred should not be ignored. Gambell (1973) has demonstrated that an exploited stock of fin whales may exhibit an increase in pregnancy rate in parallel with a decrease in the age at sexual maturity. Since Lockyer (1981) has shown that a significant decline in the age of both sexes at sexual maturity has occurred in Icelandic fin whales during the post-war fishery, some change in the proportion of females found to be pregnant may be expected.

The choice between the two explanations of these historical data is not easy, since their corollaries, of a six-fold increase in the proportion of mature females which are pregnant or of a substantially unchanged APR of rather more than 50%, imply such contradictory circumstances for the exploited stock.

REFERENCES

Cooke, J. and Beddington, J. 1981. The fin whale in Icelandic waters: growth, reproduction and sustainable yields. Paper SC/33/Ba8 presented to the IWC Scientific Committee, June 1981.

Gambell, R. 1973. Some effects of exploitation on reproduction in whales. *J. Reprod. Fert.*, suppl. 19: 533–53.

Haug, T. 1981. On some reproduction parameters in fin whales. *Rep. int. Whal. Commn* 31:373–8.

Jonsgård, Å. 1966. Biology of the North Atlantic fin whale, *Balaenoptera physalus* (L). Taxonomy, distribution, migration and food. *Rit. Fisk.* 49: 1–62.

Lockyer, C. and Brown, S. G. 1979. A review of recent biological data for the fin whale population off Iceland. *Rep. int. Whal. Commn* 29: 185–9.

Lockyer, C. 1981. the age at sexual maturity in fin whales off Iceland. *Rep. int. Whal. Commn* 31: 389–94

SC/33/Ba5

Influence of Date and Position of Capture on the Length of Fin Whales Taken by Iceland

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ABSTRACT

Examination of the temporal and geographical distribution of capture of fin whales in the Icelandic catch revealed consistently large differences in the mean length of whales taken at different times of the season and in different regions of the whaling grounds. Longer-than-average whales are caught at the beginning and end of the season and towards the west and north of the Denmark Strait. Correcting the annual mean length of the catch for these effects showed that the current situation is similar to that at the start of the post-war fishery, although the mean length of both sexes rose to a peak in 1968 and has subsequently declined.

INTRODUCTION

The post-war Icelandic whaling industry has exploited fin, sei and sperm whales in the Denmark Strait since 1948. Previous work on fin whales in this stock (Rørvik *et al.*, 1976) demonstrated that the date and position of capture can influence the length of animals taken by the catcher-boats, but the scope and magnitude of these effects were not accurately known.

Since the mean length of the catch may be expected to alter in the event of marked changes within the exploited population itself, it is important to be able to recognise any real trends in this parameter. Correction of the annual mean length of the catch for within-year and between-year variability in the focus of catching effort may also throw some light on the causes of any observed long-term trends. This paper presents an analysis of these effects using methods which were originally developed for a study of the Icelandic sperm whale catch (Martin, 1981).

A whale length can then be 'corrected' for a parameter by subtracting from it the category anomaly appropriate to the year, time period or quadrat in which the animal was captured.

An examination of the effect of one parameter (e.g. position) on the length of the catch is thus made by correcting all whale lengths for the other two catch variables (year and time period) and subsequently finding the average corrected length of all whales taken in each separate category (quadrat, in this example) of the 'subject' parameter.

In this analysis, male and female fin whales have been treated separately, while mature and immature females, identified as such by length, have also been examined independently where appropriate. Ovaries were examined from 252 females taken between 1977 and 1980. Fig. 1 shows the proportion which were sexually mature in each 1-foot length class. It has been assumed that the length at sexual maturity has not changed in this stock since the

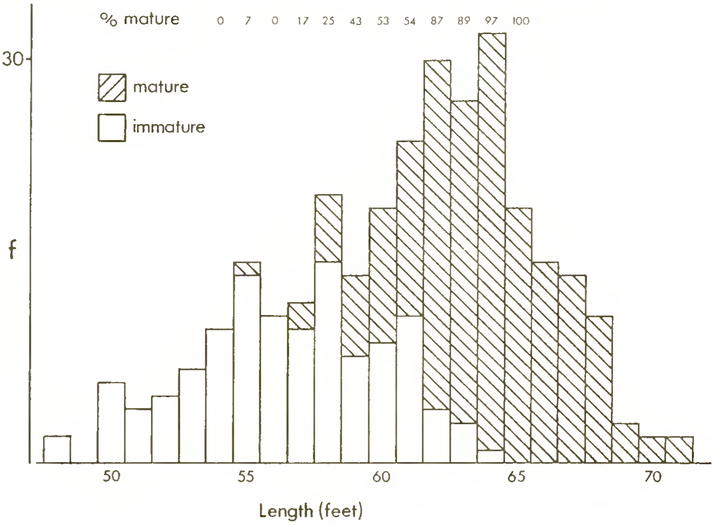

Fig. 1. The length frequency distribution of sexually mature and immature female fin whales in the 1977–80 Icelandic catch. Maturity was determined by examination of both ovaries. An error of 5.2 ± 3.6% occurs if all females ⩾ 62 ft in length are assumed to be mature and an error of 4.2 ± 4.7% if all females ⩽ 57 ft are considered immature.

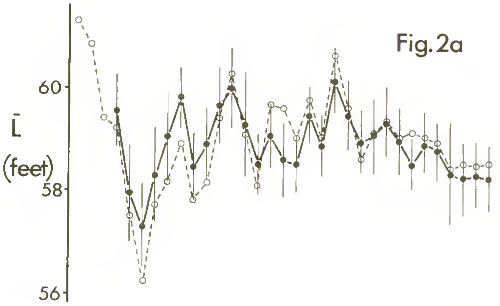

Fig. 2(a). Mean length (open circles and dotted lines) and corrected mean length (closed circles and solid lines) of the post-war Icelandic male fin whale catch. Vertical bars indicate 95% confidence limits for the corrected annual catch length.

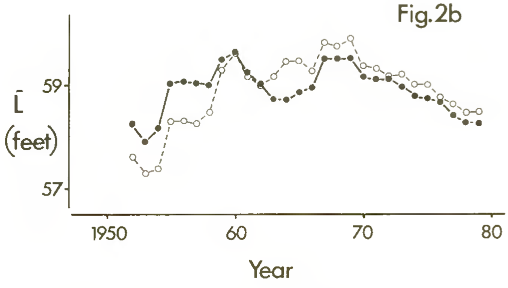

Fig. 2(b). Sliding average (of three consecutive years) of the mean length (open circles and dotted lines) and corrected mean length (closed circles and solid lines) of the post-war Icelandic male fin whale catch.

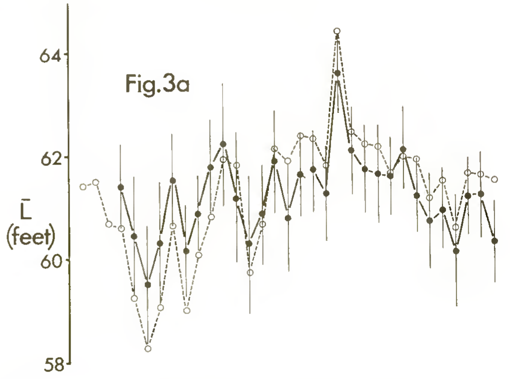

Fig. 3(a). Mean length (open circles and dotted lines) and corrected mean length (closed circles and solid lines) of the post-war Icelandic female fin whale catch. Vertical bars indicate 95% confidence limits for the corrected annual catch length.

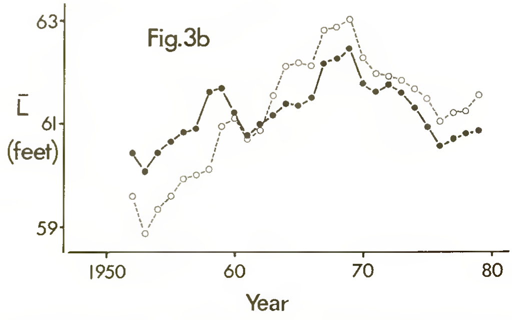

Fig. 3(b). Sliding average (of three consecutive years) of the mean length (open circles and dotted lines) and corrected mean length (closed circles and solid lines) of the post-war Icelandic female fin whale catch.

However, in contrast to the sperm whale catch, the mean length of fin whales found in some quadrats to the south and south-west of the Reykjanes peninsula is also high. The maximum difference between any two quadrats in which at least 20 whales have been caught is 2.7 ft for males and 3.2 ft for females.

3. Differences during the season

When allowance has been made for the year and position of capture of each animal, the overall pattern of length change across the season, for both sexes, is one of a peak in June followed by a decline during July and August with a steep increase again to early-season levels in September (Figs 6a and 6b).

The August minimum is 1.6 ft below the peaks of June and September for all males and 2.9 ft below for all females but a difference emerges between immature and mature females when these groups are analysed independently (Figs 6c and 6d). The average length of immatures is highest at the beginning of the season and decreases until mid-August when it fluctuates but remains below the mean across-season length. This trend has a significant linear regression (P <0.001, slope = 0.1014, intercept = 0.6726).

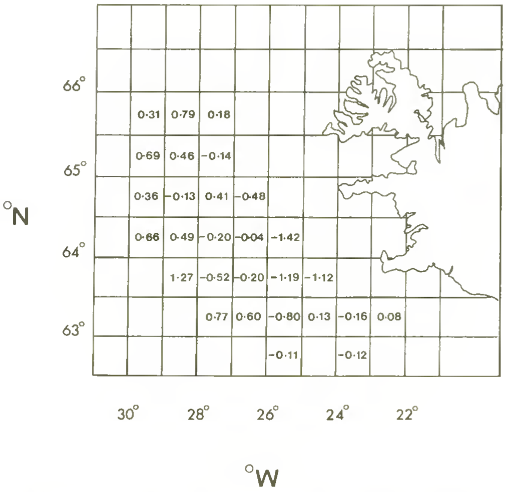

Fig. 4. Mean length of the post-war Icelandic male fin whale catch by area, corrected for the date and year of capture of each animal and expressed as deviations from the mean length of all males in the catch. Values are given for those cells from which at least 20 male fin whales were taken between 1951 and 1980.

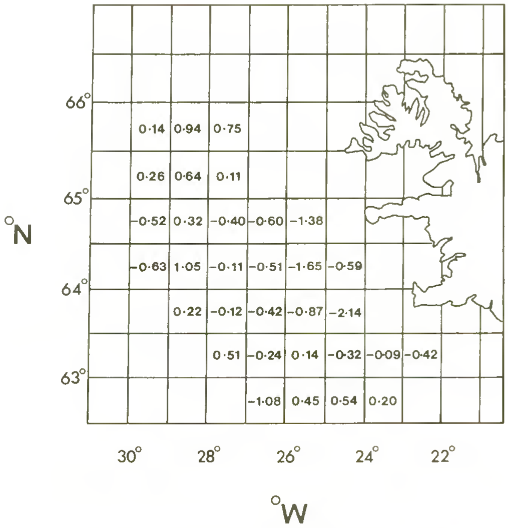

Fig. 5. Mean length of the post-war Icelandic female fin whale catch by area, corrected for the date and year of capture of each animal and expressed as deviations from the mean length of all females in the catch. Values are given for those cells from which at least 20 female fin whales were taken between 1951 and 1980.

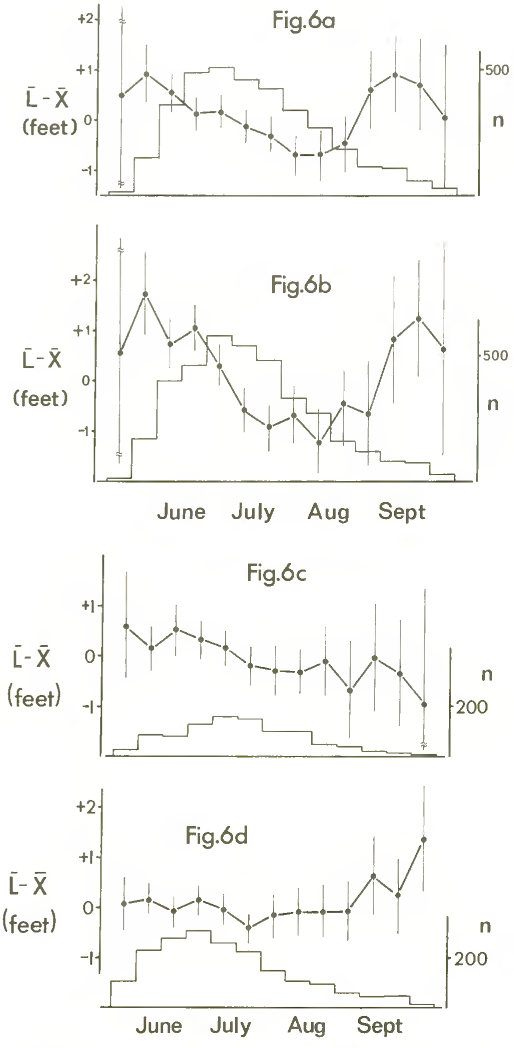

Fig. 6. Left hand axes. The corrected mean length of (a) male, (b) female, (c) immature female, and (d) mature female fin whales within ten-day periods across the Icelandic whaling season expressed as deviations from the mean across-season length. Vertical bars represent 95% confidence intervals of these values.

Right hand axes. The number of animals of the appropriate sex and maturity captured in each 10-day period since 1951.

By contrast, the mean length of mature animals remains at about the across-season average through June and early July, drops in mid-July and increases sharply in early September to a peak at the end of the month. The mid-July value is significantly below that of early and late September.

DISCUSSION

There can be little doubt that year-to-year fluctuations in both the corrected and uncorrected mean catch length of this species are not solely due to the influence of the Icelandic catching operations. Sea temperature and the abundance of food, either in the Denmark Strait itself or to the south of Iceland, are likely to be important factors in determining the abundance and size distribution of fin whales on the grounds. The large differences between the corrected mean lengths of whales captured in various regions of the whaling grounds must indicate dissimilar environmental preferences or limitations of different length classes of fin whales. Environmental parameters can also generate short-term between-year differences of corrected mean length in each sexual class of this species. It is thus interesting to observe that between only 9 of the 29 (31%) pairs of consecutive years within this study did the corrected mean length of immature and mature females change in the same direction. Annual fluctuations of length were more similar between the sexes as a whole (62% agreement).

The considerable variation in the corrected mean catch length across the season in both sexes presumably reflects movements of animals of different length classes to and from, or through, the whaling grounds. In males, and in females as a whole, the proportion of larger animals (Figs 6a and 6b) is higher at the beginning and end of the season than in July and August. This may be due to large animals passing in a north or northwesterly direction to feeding grounds probably out of range of the Icelandic catcher boats then returning, many weeks later, through the Denmark Strait on their way southwards.

Despite an average annual catch of 243 fin whales since 1948, the mean catch length of females in this fishery was higher in 1968 than in any other year and in males the 1968 figure was above that of all years except 1948 and 1949. The number of fin whales taken by Iceland has not varied sufficiently, or in the necessary direction, to account alone for the dramatic changes in catch length observed during the 33 years of this fishery.

The current IWC stock classifications treat the fin whales off Iceland, North Norway and Spain as being from different management stocks and fin whales off West Norway and Faroes combined from a further stock. There is, however, no conclusive evidence to prove that whales taken in these areas are from discrete population units. Other North Atlantic whaling operations may thus have taken fin whales from the same stock that occurs in the Denmark Strait in summer and may have been partly responsible for length changes in the Icelandic catch. Spain, the Faroes and North and West Norway have sustained substantial catches for many years during and after the middle of this century and are most likely to be involved. North Norway's catch varied relatively little between re-starting operations in 1948 and ending in 1971 during which time the average catch was only 61 whales. The data for Spain are incomplete and it is not possible to suggest a link on the basis of the available catch records. Details for Faroe and West Norway show a marked decline in the number of fin whales taken annually during the early/mid 1950s (Jonsgård, 1977). If either or both of these operations were taking animals from the same stock as Iceland, therefore, it is conceivable that this reduction in the number caught may have been partly responsible for the overall increase in the length of whales taken by Iceland until 1968. Since no whales were taken off West Norway after 1969 and the Faroese catch dropped to an insignificant level during the mid 1960s, however, these fisheries were certainly not responsible for the decline in the average length of the Icelandic catch which has been evident since that time.

SC/33/Ba6

Mark-Recapture Estimates of Abundance for the Western Northern Pacific Stock of Bryde's Whales[1]

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ABSTRACT

Estimates of abundance for the western North Pacific stock of Bryde's whales were derived from analysis of a series of Japanese mark-recapture data available since 1972. The analysis took account of presumed catches of Bryde's whales by four Taiwanese factory/catcher vessels. A synthesis of results gave estimated stock sizes of 29,918 whales in 1970 and of 23,805 in 1981.

INTRODUCTION

Ohsumi (1981) reviewed previous estimates of abundance for the western North Pacific stock of Bryde's whales and criticized those derived from analyses of catch per unit effort (CPUE) data. He particularly noted that latitudinal shifts in whaling grounds between years, changes in time budgets of pelagic operations between years, and within-season variations in availability of whales on the grounds would confound the determination of reliable whaling effort. Without a reliable measure of effort, CPUE data may not accurately reflect trends in abundance of this stock and, hence, may yield biased estimates of abundance when analyzed using procedures such as the modified DeLury method (Tillman and Grenfell, 1980; Tillman, 1981).

Given the above problems with CPUE data, Ohsumi (1981) utilized available sightings data to estimate abundance for this stock. However, as pointed out by the recent Workshop on the Design of Sightings Surveys (IWC, 1982), both practical and theoretical problems exist

by Japanese scientists since 1972. We have also made use of further information about Taiwanese whaling.

TOTAL CATCHES FOR WESTERN NORTH PACIFIC

Whaling by a single Taiwanese factory/catcher, the *Hai Yen*, began in April 1976 (Tillman and Grenfell, 1980). According to Frizell (1980) three more Taiwanese factory/catchers joined the first in 1979. Catches and effort reported for the *Hai Yen* are given in Table 1.

Table 1

Annual effort and catches of the Taiwanese factory/catcher *Hai Yen*

Year	Days whaling[1]	Whales captured
1976	175	119[1]
1977	206	171[1]
1978	155	118[2]
1979	239	182[2]

Taiwanese catch and effort data were not available for 1980. However, the four vessel fleet ceased operations on 1 October 1980. From the effort data reported by Frizell (1980) and Allan (1980, pers. comm.) for vessels which operated a full year, the following proportions of each year's effort occurred during the last quarter:

Vessel	Year	Proportion
Hai Yen	1977	0.19
	1979	0.25
Hai Hwa	1979	0.22

Assuming that all four vessels whaled during 1980 at the same level of effort as 1979, losing the last quarter of operation would represent, on average, a 22% loss of effort. Assuming that all else remained equal, such a reduction in effort would also yield a 22% reduction in catch. We thus estimated the total 1980 catch as 78% of the total 1979 catch of 574, or 448 whales.

Catches of Bryde's whales from the western North Pacific stock are shown in Table 3 by country and type of operation. Catches from the East China Sea are not included since that area is treated as a separate stock unit (IWC, 1980). Implementation of the moratorium on factory ship operations, except for minke whales, accounts for the zero catches of pelagic operations in 1980.

Table 3

Catch of Bryde's whales from the western North Pacific stock

Year	Japan Coastal	Japan Pelagic	Soviet Pelagic	Taiwan	Total
1970	73	0	66	0	139
1971	172	109	638	0	919
1972	84	5	71	0	160
1973	40	2	651	0	693
1974	147	522	654	0	1,323
1975	116	688	629	0	1,433
1976	83	578	679	119[1]	1,459
1977	76	424	275	171[1]	946
1978	62	200	216	118[1]	596
1979	52	175	227	574[2]	1,028
1980	307[3]	0	0	448[4]	755

[1] From Table 1.
[2] From Tables 1–2.
[3] Source: Ohsumi (1981, pers. comm.).
[4] See text.

MARK-RECAPTURE ESTIMATES

Table 4 gives the results of mark-recapture experiments undertaken by Japanese scientists since 1972. In seven of nine years, Discovery marks were implanted during special charter cruises undertaken in January–April. In all years, additional Discovery marks were implanted from scouting vessels during the May–September baleen whale season.

Of the 346 marks applied since 1972, only 12 have been recovered. Of these recoveries, four were returned in the same year that they were applied. However, all four had been applied during the January–April marking period prior to the start of the baleen whale season. Given this result, we have assumed that whales marked during January–April would be available for recapture during the ensuing baleen whale season but that those marked during the season would not be available.

Table 4

Mark and recovery data for Japanese experiments on Bryde's whales in the western North Pacific

Year	Number marked Jan–Apr	Number marked May–Sep	Recoveries Total	Recoveries Year marked
1972	5	3	0	
1973	11	13	0	
1974	0	9	0	
1975	35	16	2	2—1975[1]
1976	29	3	4	1—1973, 1—1975, 2—1976[2]
1977	6	1	3	1—1976, 2—1976
1978	31	46	1	1—1976
1979	6	77	0	
1980[3]	0	55	2	1—1976, 1—1979

[1] One tag recovered by USSR.
[2] Two tags recovered by USSR.
[3] Source: Ohsumi (1981, pers. comm.).

According to Chapman (1952), a series of mark and recapture data may be used to estimate abundance as follows:

$$\hat{N} = \frac{\sum_{i=1}^{n} M_i C_i}{(\sum_{i=1}^{n} m_i) + 1}$$

where n = number of seasons, M_i = effective number of marks present in season i, C_i = effective catch in season i, and m_i = number of marks recaptured in season i. The effective number of marks present in each season has been calculated as the number of whales marked in the January–April period immediately prior to the baleen whale season plus those marked animals, less recoveries, surviving from previous seasons:

$$M_{i+1} = M'_{i+1\,(\text{Jan-Apr})} + (M_i + M'_{i\,(\text{May-Sep})} - m_i)e^{-M}$$

where the instantaneous rate of natural mortality, M, was taken as 0.085 (Ohsumi, 1977a). Following Best and Butterworth (1980), we have also assumed that marking mortality would result in an immediate 5% loss of marked animals.

According to Seber (1973, p. 189), an approximate 95% confidence interval for $\hat{N}$ is given by

$$\frac{4d}{(1.96 + \sqrt{(4L - 1)})^2} < \hat{N} < \frac{4d}{(-1.96 + \sqrt{(4L - 1)})^2}$$

$$\text{where } d = \sum_{i=1}^{n} M_i C_i \text{ and } L = \sum_{i=1}^{n} (m_i) + 1$$

The limits defined are asymmetrical about the estimate.

From Table 4 we noted that, of the 12 recoveries, nine came from Japanese vessels while only three came from Soviet vessels. During 1972–79, the catch of Bryde's whales was roughly equivalent for both countries (Table 3) so that equal opportunities likely existed for recovering marks. Although the unequal recoveries may have been due to chance, the Scientific Committee earlier concluded that low Soviet mark recoveries in past experiments suggested that the Soviet catch should be reduced to compensate (IWC, 1979). We thus reduced the Soviet catch to 3/9 to account for possible inefficiency in detecting and reporting recoveries. Thus the effective catch in each season was the sum of Japanese catches plus the adjusted Soviet pelagic catch.

Also from Table 4, we noted that the first recovery was a 1973 mark recaptured in 1976 and that the most consistent series of recoveries began in 1975. We thus examined two series of mark-recovery data for possible use in estimating abundance: 1973–80 and 1975–80.

Table 5

Effective mark, effective catch, and recovery data for western North Pacific Bryde's whales

Year	Effective marks (M_i)	Effective catch (C_i)	Recoveries (m_i)
A. *First recovery: 1973 mark in 1976*			
1973	10.5	259.0	0
1974	20.9	887.0	0
1975	60.3	1,013.7	2
1976	95.1	887.3	4
1977	92.0	591.7	3
1978	112.1	334.0	1
1979	147.9	302.7	0
1980	203.0	307.0	2
			12
B. *Most consistent series: 1975 onward*			
1975	33.3	1,013.7	2
1976	70.2	887.3	3[1]
1977	69.1	591.7	3
1978	91.1	334.0	1
1979	128.6	302.7	0
1980	185.3	307.0	2
			11

[1] Excluded recovery of 1973 tag in 1976.

Table 5 gives the effective mark-recapture data used in calculating estimates and Table 6 summarizes results for the two data series examined. Assuming the estimates to be the average stock sizes within series, they were adjusted to the start of 1976 and 1977, respectively, using (1) and extrapolated iteratively to obtain the 1970 estimate using (2):

$$\hat{N}_I = N_I + 1/2\, C_I \qquad (1)$$

$$\hat{N}_I = (N_{I-1} - C_{I-1})e^{-M} + (1 - e^{-M})N_o. \qquad (2)$$

where N_0, the 1970 value, was obtained which gave N_I when forward calculated.

Table 6

Mark-recapture estimates of average stock size within a series, 95% confidence limits about the estimated averages, estimates adjusted to midpoint in the series, and back calculated estimates for 1970

Data series	$\bar{N}$	Confidence limits	Year of estimate	$\hat{N}$	$\hat{N}$ (1970)
Total series (1973–80)	28,133	(17,661–54,491)	1976	28.863	32.631
Consistent series (1975–80)	21,931	(13,545–43,922)	1977	22.404	27.205

SYNTHESIS OF RESULTS

No obvious basis presents itself for distinguishing between the estimates derived from the two data series. Their confidence limits have very similar ranges and overlap broadly. We therefore took a simple average as the estimates for 1970, the start of pelagic whaling on this stock: 29,918 Bryde's whales. This, of course, is not the 'initial' or pre-exploitation stock size since Japanese land stations took an average of 166.5 Bryde's whales each year during 1946–69. Calculations along the lines proposed by Tillman and Grenfell (1980) could be made to estimate the initial level, provided that one were willing to make assumptions about the population dynamics of Bryde's whales.

The simple iterative model given in (2) was used to estimate stock sizes at the start of 1981: 23.805 Bryde's whales. The use of this model is problematical though, since it assumes that recruitment is constant at the 1970 level. Given that the average age at recruitment is about 10 years for this stock (Ohsumi, 1977b), 1981 marks the first year that recruitment which was affected by exploitation would be entering. Without knowledge of Bryde's whale population dynamics, though, it is difficult to estimate how recruitment would respond to exploitation. However, this problem may be minor relative to the lack of accurate 1980 catch data from the Taiwanese operation.

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REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Chapman, D. G. 1952. Inverse, multiple, and sequential sample censuses. *Biometrics* 8(4): 286–306.

Doi, T. 1974. Further development of whale sighting theory. pp. 359–68. *In:* W. E. Schevill (ed.), *The Whale Problem, a Status Report*, Harvard University Press, Cambridge, 419 pp.

Frizell, J. 1980. Taiwan-Bryde's whaling. Paper SC/32/O 21, presented to the IWC Scientific Committee meeting, Cambridge June 1980 (unpublished).

International Whaling Commission. 1979. Report of the sub-committee on sei and Bryde's whales (Annex C). *Rep. int. Whal. Commn* 29: 55–60.

International Whaling Commission. 1980. Report of the sub-committee on Bryde's whales (Annex D). *Rep. int. Whal. Commn* 30: 64–73.

International Whaling Commission. 1982. Report of the workshop on the design of sighting surveys. Paper SC/33/Rep 2 (published in this volume).

Ohsumi, S. 1977a. Further assessment of population of Bryde's whales in the North Pacific. *Rep. int. Whal. Commn* 27: 156–60.

Ohsumi, S. 1977b. Bryde's whales in the pelagic whaling ground of the North Pacific. *Rep. int. Whal. Commn* (special issue 1): 140–50.

Ohsumi, S. 1981. Estimation of the population size of the western North Pacific Bryde's whale using sightings data. *Rep. int. Whal. Commn* 31: 417–24.

Seber, G. A. F. 1973. *The Estimation of Animal Abundance and Related Parameters*. Hafner Press, New York, 506 pp.

Tillman, M. F. 1981. Estimated abundance of the western North Pacific stock of Bryde's whales. *Rep. int. Whal. Commn* 31: 385–8.

Tillman, M. F. and Grenfell, B. 1980. Estimates of abundance for western North Pacific stock of Bryde's whales. *Rep. int. Whal. Commn* 30: 369–73.

SC/33/Ba9 (revised)

A Note on the East Greenland–Iceland Fin Whale Stock Assessments in 1980

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ABSTRACT

In 1980 the sub-committee on other baleen whales used BALEEN for the first time to calculate the replacement yield of the East Greenland–Iceland fin whale stock. The resulting RY was very low, 0.5% of the present stock size, and concern was expressed over it. A preliminary attempt was made to identify one of the factors which cause such a low RY and as a possible reason the very high natural juvenile mortality—67% was put forward. This is probably caused by the low natural adult mortality rate, $m = 0.04$, which had been obtained from research on the southern fin whales. A suggestion was made to increase the natural adult mortality rate slightly in any new assessments.

In 1980 for the first time an estimation model–BALEEN–was used to assess the status of the East Greenland–Iceland fin whale stock (IWC, 1981a). The values of the biological parameters used in the model were: p (pregnancy rate) = 0.35, t_p (age of first parturition) = 12, t_m (age at sexual maturity for males) = 11, m_a (natural adult mortality rate) = 0.04. A density dependent response was applied to t_m and t_p. The value of p was obtained from research on the North Norway fin whale stock (Haug, 1981): the values of t_p and t_m were determined by Lockyer (1981). The value of m_a set equal to the value of m_a which is accepted for the Southern Hemisphere fin whales (IWC, 1971). This value was calculated by Japanese scientists from the age-frequency distribution of older fin whales (Doi *et al.*, 1970). Allen (1972) confirmed this value, with slight sex differences, in a theoretical study.

Besides the above-mentioned parameters the natural juvenile mortality rate, m_j, and the time over which it operates have to be known in assessments. In BALEEN this time is fixed at two years and the value of m_j is calculated with the following balance equation, which is applicable in an unexploited stationary stock, given the three mentioned parameters:

$$1 - e^{-m_a} = \tfrac{1}{2}.p.e.^{-2m_j}.e^{-m_a\cdot(t_p-2)}$$

(knife-edge maturity and integer values of t_p are supposed, otherwise a slightly different formula has to be used). In the case of the East Greenland–Iceland fin whale stock an m_j value of 0.55 was calculated, which means a juvenile survival in two years of 0.33 (e^{-2m_j}).

Two assessments have been carried out with different effort series, which resulted in current stock sizes between 30–60% of the initial stock size and in replacement yields which were very low, roughly 0.5% of the current stock size. In general, the replacement yields are higher than this value, depending on the status of the stock. In the normally used recruitment model for baleen whales a yield of 4% is accepted at a stock size level of 60% of the initial stock size level. Some members of the sub-committee on other baleen whales therefore expressed their concern about this low value and doubted the correct application of the model.

Two possible reasons for the low RY can be put forward, viz. the absence of a density dependent response in other parameters than t_p and t_m and the low survival of the juveniles. The latter possibility is discussed in this note.

The calculated rate implies that two years after birth only one-third of the juveniles are still alive which deviates rather strongly from the adult survival in two years viz. 92%. A high juvenile mortality is found in a number of land and marine mammals (e.g. Caughley, 1966, who also found indications for a U-shaped mortality rate curve in mammals). It is not the fact that juvenile and adult mortality are different which is surprising, but the great difference between the values of these parameters. Moreover this difference had to be maintained during the whole period over which the assessments were applied, 1948–79, because no density dependent response due to exploitation is applied to m_j.

The high juvenile mortality can be adjusted by a change in the other parameters of the balance equation. Due to unavailability of BALEEN to the author at the moment he is not sure whether the RY will change after such an adjustment. However, not only the result of an assessment is of interest, but also the several dynamic processes in time, which ought to be simulated as true to nature as possible. In trial assessments of the Area IV minke whale stock last year, an increase in m_a caused an increase in RY and so did the ratio of present to initial stock size (IWC, 1981b). This ratio is the basis for the current classification under the NMP.

Enlargement of the time over which the juvenile mortality operates (e.g. to four years) results with the same combination of parameter values in a decrease of m_j, however the survival in these four years equals the survival in two years juvenile and two years adult mortality. This can be shown mathematically:

$$\left.\begin{array}{ll} \text{4 years } m_{j1}: & \\ \quad 1 - e^{-m_a} = & p.\tfrac{1}{2}.e^{-m_{j1}\cdot 4}.e^{-m_a\cdot(t_p-4)} \\ \text{2 years } m_{j2} \text{ and 2 years } m_a: & \\ \quad 1 - e^{-m_a} = & p.\tfrac{1}{2}.e^{-m_{j2}\cdot 2}.e^{-m_a\cdot(t_p-2)} \end{array}\right\} \Rightarrow$$

$$e^{-4m_{j1}-m_a t_p+4m_a} = e^{-2m_{j2}-m_a t_p+2m_a}$$

$$4m_{j1} = 2m_{j2} + 2m_a$$

Table 1

The juvenile mortality rate (first value) and the juvenile survival in one year (second value) calculated with the balance equation and the indicated parameter values.[1]

p:	0.30						0.35						0.40						0.45					
t_p	10		12		14		10		12		14		10		12		14		10		12		14	
m_a																								
4	51	60	47	62	43	65	59	56	55	58	51	60	65	52	61	54	57	56	71	49	67	51	63	53
5	36	70	31	73	26	77	44	64	39	68	34	71	51	60	46	63	41	67	56	57	51	60	46	63
6	23	79	17	84	11	89	31	73	25	78	19	83	38	69	32	73	26	77	44	65	38	69	32	73
7	12	89					20	82	13	88			26	77	19	83	12	88	32	73	25	78	18	83
8							9	91					16	85	8	92			22	81	14	87		

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[1] Values of m_a, m_j and e^{-m_j} times 1/100; m_j values less than m_a values have been omitted

Table 1 shows for several parameter values m_j and the juvenile survival in one year, e^{-m_j}, calculated with the balance equation. An increase of t_p causes a decrease of m_j, an increase of p causes an increase of m_j and an increase of m_a gives a decrease of m_j. The juvenile mortality rate is very sensitive to the changes in m_a and less to changes in t_p and p.

The values of t_m, t_p and p were obtained and calculated in a way which seems not very biased. The value of m_a, however, is very sensitive to the method of analysis, e.g. the age-interval which is used for the regression. Moreover, the Icelandic value is obtained from the southern fin whale stocks and the possibility of stock differences in the value of m_a cannot be denied.

The conclusion can be drawn that the most reasonable way of changing–decreasing–the juvenile mortality is by an increase in the adult mortality rate. The former parameter is most sensitive to changes in the latter and m_a is derived in a relatively unreliable way. At the next assessment with BALEEN on the East Greenland–Iceland fin whale stock the sub-committee on other baleen whales should look carefully at the input parameter values used, especially the

0.07 is indicated if $m_j = 2m_a$ or $3m_a$ is accepted with the above-mentioned parameters (Table 1).

REFERENCES

Allen, K. R. 1972. Further note on the assessment of Antarctic fin whale stocks. *Rep. int. Whal. Commn* 22: 43–53.

Caughley, G. 1966. Mortality patterns in mammals. *Ecology* 47(6): 906–18.

Doi, T., Ohsumi, S., Nasu, K. and Shimadzu, Y. 1970. Advanced assessment of the fin whale stock in the Antarctic. *Rep. int. Whal. Commn* 20: 60–87.

Haug, T. 1981. On some reproduction parameters in fin whales *Balaenoptera physalus* (L.) caught off Norway. *Rep. int. Whal. Commn* 31: 373–8.

International Whaling Commission. 1971. Report of the Special Meeting on Antarctic fin whale stock assessment. *Rep. int. Whal. Commn* 21: 34–9.

International Whaling Commission. 1981a. Report of the sub-committee on other baleen whales. *Rep. int. Whal. Commn* 31: 122–32.

International Whaling Commission. 1981b. Report of the sub-committee on minke whales, Appendix 5. *Rep. int. Whal. Commn* 31: 116–8.

Lockyer, C. 1981. The age at sexual maturity in fin whales off Iceland

SC/33/PS1

The Marking of Gray Whales (*Eschrichtius robustus*)

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INTRODUCTION

The Soviet marking programme for whales in the North Pacific began in 1954 (Sleptsov, 1955), with most attention being paid to the commercial species. At the end of 1966, almost 85% of the 1,452 whales marked were sperm whales; 29 gray whales were marked during the same period (Ivashin and Rovnin, 1967). Twenty-three gray whales were marked in later years but only on an opportunistic basis (Table 1). Most of the animals marked (88.5%) were single animals but four groups of two animals, one group of three animals and one group of six animals have also been marked.

1980 MARKING PROGRAMME

A special programme for gray whales began in 1980 and a marking gun and Soviet (Discovery type) standard marks were kept on board the *Zvezdny* which takes gray whales on behalf of the people of Chukotka. Although certain unforeseen happenings affected the programme, 47 whales were marked between 4 July and 24 October 1980. About 75% of the marked animals were 10 m and over. In addition, 42 gray whales were marked between 18 September and 7 November 1980 by N. Doroshenko from the vessel *Razayashi* during the second Joint Soviet–American Expedition to study marine mammals in the Chukchi and Bering Seas.

Table 1

Soviet marking of gray whales, 1958–80, by statistical square

Season	Q24	Q25	Q26	Total
1958	3			3
1959	1	6		7
1962	10	1		11
1964		3	5	8
1973		15	1	16
1979		7		7
1980	5	80	3	88
Total	19	112	9	140

DISCUSSION

Votrogov and Bogoslovskaya (1980) reviewed the available data and concluded that there may be six spring-summer migration paths, suggesting that the Eastern stock of gray whales may not be homogenous but may comprise several large units with their own separate summering and wintering areas. Of course this is not to say that no changes in the migration routes taken occur or that animals do not spend some time in neighbouring feeding areas. For example, the whales taken in the Bering Sea in 1977 were heavily infected with ectoparasites whereas of the animals taken in the same area in 1978, a large proportion had no parasites.

An increase in the scale of marking, to include the winter breeding as well as the summer feeding areas, and the use of radio tags, will improve our knowledge of gray whale migratory behaviour, in particular with respect to the timing and the routes taken, thus leading to a better understanding of gray whale distribution throughout the year. A better knowledge of the structure of the population and the sub-groups within it can be used to develop the management strategy for this stock.

The gray whale is one of the more accessible cetacean species for study and in order to make the most of the opportunities it provides, co-ordinated joint studies should be carried out between biologists from the USSR, USA, Canada and Mexico.

REFERENCES

Ivashin, M. V. and Rovnin, A. A. 1967. Some results of the Soviet whale marking in the waters of the North Pacific. *Norsk Hvalfangst-tid.* 6: 123–35.

Sleptsov, M. M. 1955. Tagging of whales near the Kuril Islands in 1954. *Tr. Inst. Okeanol* 18: 134–41.

Votrogov, L. M. and Bogoslovskaya, L. S. 1980. Gray whales off the Chukotka Peninsula. *Rep. int. Whal. Commn* 30: 435–37.

SC/33/PS2

Populations of Humpback Whales in the Northwest Atlantic

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ABSTRACT

Ship censuses and capture–recapture analyses of fluke photograph data both suggest that the northwest Atlantic humpback whale population numbers about 3,000 animals (2,300–4,100). The great majority of these winter on Silver and Navidad Banks in the West Indies, and most summer off eastern Newfoundland and southern Labrador. There is no evidence that the population has increased or decreased during the 1970s. The recruitment rate is estimated to be between 0.039–0.118, and was significantly higher in 1980 than 1978.

INTRODUCTION

During winter, humpback whales are found along the Antillean chain in the West Indies, but particularly on Silver and Navidad Banks (Winn *et al.*, 1975). In spring, they are found on the banks southwest of Bermuda (Payne and McVay, 1971). The major concentrations in summer are in the Gulf of Maine and off eastern Newfoundland and southern Labrador, although humpbacks are occasionally sighted in the Gulf of St Lawrence and off West Greenland (Katona *et al.*, 1980; Kapel, 1979).

Approximately 1,000 individual humpbacks in the northwest Atlantic have been identified from fluke photographs, which are catalogued by Katona *et al.* (1980). These identifications have allowed Katona *et al.* (1980) to examine stock divisions: there are many within- and between-year matches in both the Gulf of Maine and Newfoundland/Labrador regions, but no animals have been photographed in both. Thus it is reasonable to consider the Gulf of Maine and Newfoundland/Labrador as distinct summer substocks. However animals from both these areas have been photographed on Silver Bank in winter and off Bermuda in spring.

There have been considerable changes in the humpback sighting rates in different parts of the northwest Atlantic during the past few years: in the late 1970s sighting rates of humpbacks have fallen off Bermuda (R. Payne, pers. comm.), off southern Newfoundland (Lien, 1980), and in the northern part of the Gulf of Maine (S. Katona, pers. comm.), but risen in the southern part of the Gulf of Maine (C. Mayo, pers. comm.) and along the northeast coast of Newfoundland (Whitehead, 1979).

There have been a number of estimates of the population of humpback whales in the northwest Atlantic over the last few years; the different results have been ascribed by some to increasing population size (e.g. Lien, 1980), while others have criticized the methodologies of some of the surveys and their analyses (IWC, 1980). In this paper I present some estimates of population size, using line transect methods from ship censuses in winter, capture-recapture methods from fluke photographs in summer and when comparing the winter and summer populations.

POPULATIONS IN WINTER

During the winter most humpbacks in the northwest Atlantic are fairly evenly distributed on Silver and Navidad Banks, which are well defined. The whales rarely show their flukes in winter so that identification photographs are hard to obtain. In these circumstances, censuses from ships or aeroplanes are appropriate for determining population sizes.

Field methods

Regina Maris made standard circuits of Silver, Navidad and, sometimes, Mouchoir Banks at approximately two-weekly intervals of the 1978 and 1980 winter seasons. The circuit route was designed for safety, ease of sailing, and to sample fairly the different geographical areas of the Banks, and regions near but off the Banks. Unfortunately, for several reasons, including imprecise navigation, the exact route could not always be maintained; the actual tracks sailed by *Regina Maris* are shown in Fig. 1. The mean ship speeds during the circuits varied between 5.9 and 8.3 km/hr^{-1}.

Two observers were aloft at all times, of whom at least one was a member of the permanent scientific crew. Observers watched one side of the ship each, recording all whales as they came abeam, the numbers in the groups, approximate sizes (adult, immature, calf), movements, and activities (such as 'breaches'), as well as the range, side, and time of passage abeam. The time of passage abeam was estimated for groups of whales seen ahead and astern, but not sighted at the surface when exactly abeam. Other cetacean species, birds, turtles and large fish sighted were also recorded. The eye heights of the observers were usually between 23 m and 27 m above sea level. In heavier weather (Beaufort Scale 5 or above) the heights of eye were generally 15 m. Ranges when abeam were estimated by eye, but frequent calibrations were made: the ranges of buoys, whales and small boats were calculated by measuring their dip below the horizon with a sextant from a known height.

At each half hour an observer on deck logged the ship's position and certain environmental variables such as wave height and wind speed. Changes in the ship's course and speed were also logged.

Navigation was by celestial navigation, electronic aid (Loran), depth soundings, and dead reckoning, and was usually accurate to within 4 km. A chart of the Banks was prepared using the soundings made on these surveys.

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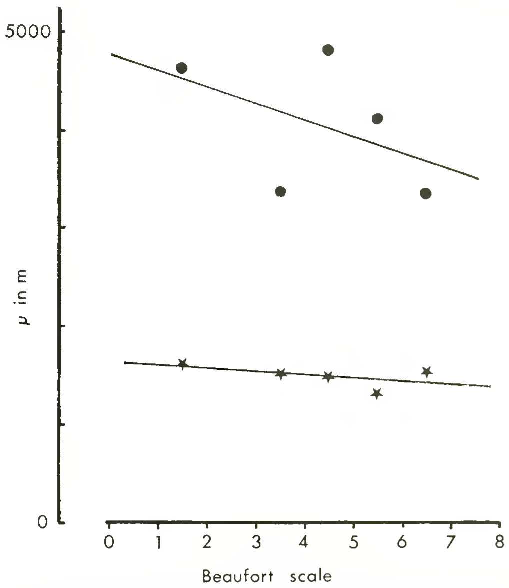

Fig. 2. Effective strip width (μ) vs wind speed for *Regina Maris'* 1978 and 1980 surveys, with weighted regression lines for each year.

speed for the two years are shown in Fig. 2. Fitting weighted regression lines produced:

$$\mu_s = 1.62 - 0.032 \times s \text{ km for 1978}$$
$$\mu_s = 4.76 - 0.162 \times s \text{ km for 1980}$$

where s is the wind speed in Beaufort Scale. The reasons for the large differences in these two equations will be discussed later.

The effective area surveyed was then:

$$a = \sum_s 2.\mu_s.l_s \text{ km}^2$$

where l_s km is the distance travelled in wind strength s.

For each Bank on each two-week circuit the mean group size m, was calculated:

$$m = \frac{\sum_k k.n_k}{\sum_k n_k}$$

where n_k is the number of groups of size k sighted less than 1.75 km from the transect line. Outside this range it was felt that estimates of group size might be inaccurate. Whale densities, d_I, and populations, P, were estimated for each Bank on each circuit in each year:

$$d_I = N_G.m/a \text{ whales km}^{-2}$$
$$P = d_I.A \text{ whales}$$

where N_G is the number of groups sighted, and A km² the area of the Bank calculated from *Regina Maris'* 1978 surveys. Density estimates were also made for the parts of the surveys which were off the Banks but within 15 km of them (using m calculated from the data for the entire circuit).

Approximations to the coefficients of variation, cv, of these estimates were also calculated:

$$cv^2 = 1/N_G + 3\mu/2\Delta.N_T + (\sum_k k^2.n_k/N_G.m^2 - 1)/N_G$$

The term $1/N_G$ is the sampling error assuming randomly distributed groups, the second term an estimate of the errors in measuring μ from Eberhardt (1978) (N_T is the total number of observations used in the estimation), and the third term the error in the estimation of m. This is because the expected value of $(\Sigma k^2.n_k/N_G)$ is (Variance (m) + mean²(m)), and thus the term given is an approximately unbiased estimate of the square of the coefficient of variation of m.

Using normal approximation, 95% confidence intervals were calculated from:

$$(P - 2.cv), (P + 2.cv)$$

However when no groups were sighted this methodology gave unreasonable confidence intervals (negative lower bounds), and therefore binomial distribution theory was used to estimate confidence intervals:

$$P: 0, -m \log_e (0.05)/\log_e (1-a/A).$$

The population estimates, with their confidence intervals are given in Fig. 3.

Errors and biases

Since the computer programs for the above analysis were written, the Fourier methods described by Burnham *et al.* (1980) have become widely used in line transect analysis (e.g. Hay, 1981). Reviewing Cox's (1969) method, Burnham *et al.* (1980) state that it is robust and easy to use but the estimate of μ has a large variance and requires substantial subjectivity in the selection of Δ. Robustness and ease of use are of course desirable qualities. In this analysis, due to the large sample size (1,520 groups counted in 1978; 3,131 in 1980), the portion of the variance accounted for by the errors in estimation of μ is small compared with the other sampling errors and biases considered below. Since the results were substantially the same for all reasonable values of Δ, the arbitrary nature of its choice is not a significant factor. Therefore the above approach is still reasonable despite the recent introduction of more powerful methods.

The errors in the estimates given in Fig. 3 are only the sampling errors. There are sources of bias which cannot be estimated statistically. Some of these were pointed out by the Scientific Committee of the International Whaling Commission (IWC, 1980), but there are others which should also be considered when assessing the accuracy of these and other estimates:

(1) Double sighting. This is a frequently discussed problem in whale census methodology. By counting the whales as they pass abeam, or when they are estimated to pass abeam, this problem is virtually eliminated.

(2) Speed of movement. Faster moving whales are more likely to come close to the ship, purely by their movement. Computer simulation shows that for transects in which whales are counted in triangular or fan-shaped areas ahead of the ship, a significant bias (~ 15%) will be introduced when the ratio of whale speed to ship speed exceeds about 0.6. However if whales are counted only when they come abeam the speed of movement of the whales is irrelevant (Hiby, 1981).

(3) Non-random whale movement. There are two kinds of non-random whale movement which could have affected the census estimates:

(a) Patterns of movement on the Banks. The surveys were approximately clockwise circuits of Silver Bank. If whales were also circling the Bank, going clockwise more

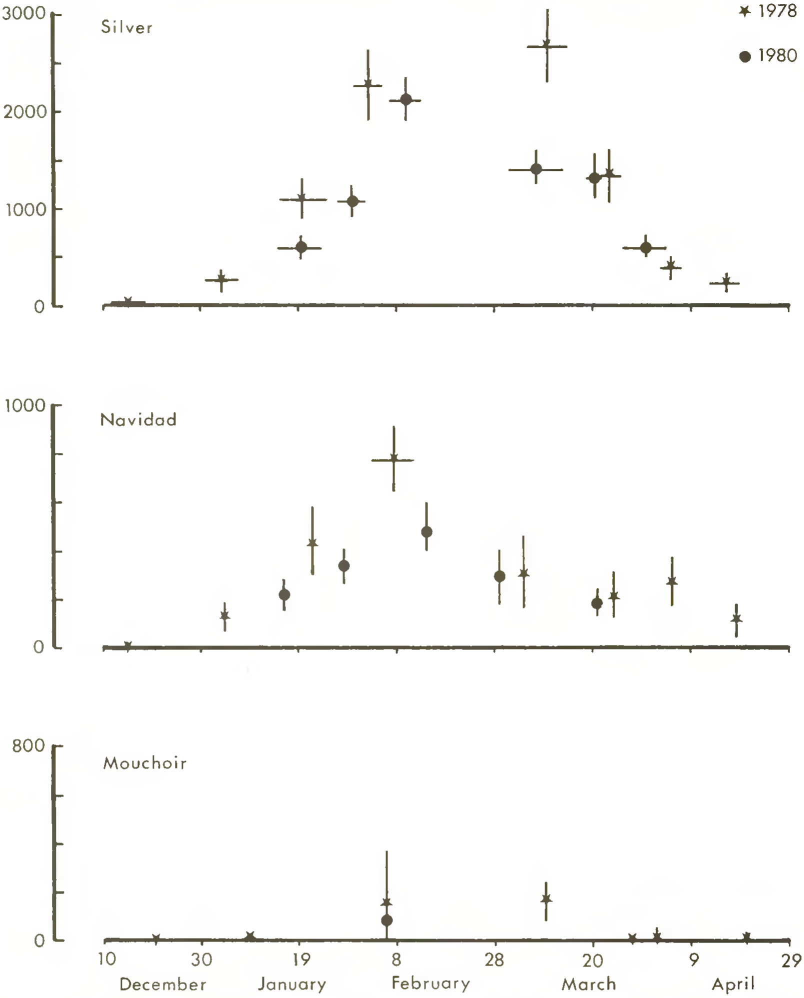

Fig. 1. Population estimates of humpback whales on Silver, Navidad and Mouchoir Banks, from *Regina Maris* surveys in 1978 and 1980, with estimated 95% confidence limits (vertical bars), and range of dates on which runs were made (horizontal bars).

often than anticlockwise as suggested by Scott and Winn (1980), or vice versa, then the estimates would be biased. Analyses of the observed directions of movement on transects and the tracks taken by the groups that we followed in 1980 showed no such patterns (Whitehead, 1981).

(b) If the whales approached or avoided *Regina Maris* the census estimates will be biased. We have watched a few hundred humpback whales in the presence of ships and boats, both our own and others, from land and sea, and although humpbacks often react to ships and boats, sometimes approaching and sometimes avoiding them, they only do so when within 150 m of the ship or boat. As whales this close to the survey vessel are almost certainly sighted whatever their activity, there is unlikely to be any serious bias in any humpback census estimate from this cause. Furthermore the sighting rates at different ranges, given in Fig. 4, show no obvious dip or peak close to the track, which would indicate avoidance or attraction respectively.

(4) Whales missed on transect line. This analysis assumes that all whales on the transect line were sighted. *Regina Maris* travelled at an average of 7.2 km/hr^{-1}, and the sighting rates at different distances from the transect line given in Fig. 4 suggest that few whales were missed within 1,300 m of the ship when at the surface. At 7.2 km/hr^{-1} *Regina Maris* would be within 1,300 m of a stationary whale for 21.6 minutes, and only 5 of the 578 dive times recorded in 1980 were longer than 21.6 minutes, so that very few whales can have been missed because they were underwater as the ship passed.

(5) Area of the Banks. Silver and Mouchoir Banks are not shaped as on the British Admiralty and US Hydrographic Office charts used by Winn *et al.* (1975). This analysis uses

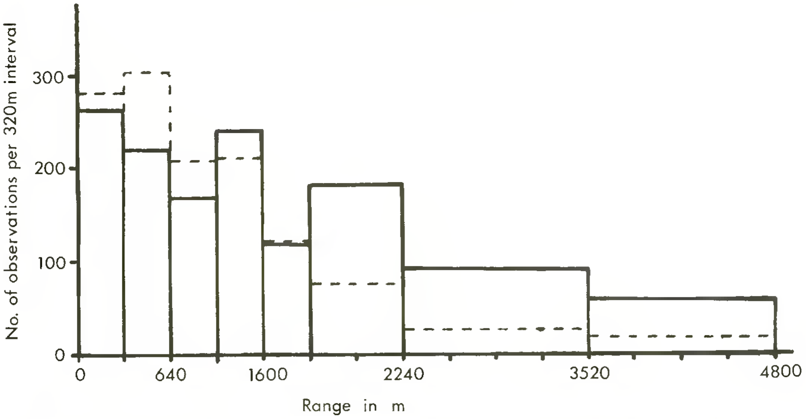

Fig. 4. Numbers of sightings of humpback whale groups at different ranges from the transect line – *Regina Maris*' 1978 (--) and 1980 (——) surveys.

areas of the Banks calculated from *Regina Maris*' 1978 surveys. The shape of Silver Bank is similar, but not identical, to that on a tracing of a satellite photograph kindly provided by Dr Winn's group, and used to calculate the area of the Bank in Scott and Winn's (1980) analysis (°of accuracy):

From	Silver	Navidad	Mouchoir
Winn *et al.* (1975)	2,903 km^2	528 km^2	964 km^2
This Analysis	2,328	604	917
Scott and Winn (1980)	2,402	528	—

Surveys in 1980 suggest that both of these last two maps are slightly in error, but the area used here is unlikely to be wrong by more than 5%.

(6) Non-random distributions of whales and/or transects. The mean circuit path samples the different geographical and topographical areas of the Banks as fairly as possible, with the exception of the parts containing coral reefs where *Regina Maris* could not travel. Analysis of whale distributions in a small area near the reef in 1980 showed little change in overall whale distribution in and around the reef (Whitehead, 1981), and a comparison of indices of whale density over different parts of Silver Bank calculated from this census data and the routes given in Fig. 1 (Whitehead, 1981) further suggest that sampling was fair with respect to whale density. For these reasons I believe that non-random whale and transect distributions are not producing significant biases in this analysis.

(7) Errors in the estimation of range. The determination of effective strip width depends directly on the estimates of range when the whales were abeam. If these were overestimated by a factor of 2, the strip widths would be doubled and the population estimate halved. During 1978, when I was on board *Regina Maris* for all the circuits, the range estimates of the observers were frequently checked against boats, buoys and whales at known ranges (from sextant angle dips). I believe that the estimates of range in these circuits had no consistent bias greater than 10%. During 1980 I was not on board *Regina Maris* for any of the surveys, ranges were less often checked, and the estimates of effective strip width, μ, are approximately twice the 1978 ones. While part of this discrepancy is certainly due to better sighting efficiency at longer ranges in 1980 (Fig. 4), M. Moore, who was an observer for approximately half the 1980 surveys, and I, both feel that range may have been overestimated by up to 50%, leading to reductions in the population estimates by 33%. This may explain some or all of the apparently lower whale numbers in 1980, which are not necessarily the result of a reduction in the population.

Estimates

The resultant population estimates for Silver, Navidad and Mouchoir Banks, with their 95% confidence intervals, are given for different dates through both seasons in Fig. 3. Bearing in mind the sources of error considered below the surveys suggested a peak combined population of 2,000–3,500 humpbacks. There is no evidence that the population using these Banks increased or decreased between 1978 and 1980.

The surveys of Winn *et al.* (1975) found that about 85% of the humpbacks in the West Indies during winter were on Silver and Navidad Banks. Although a few humpbacks have been seen wintering in northern waters (Williamson, 1961), no substantial concentrations of humpbacks have been found in winter other than on these Banks. This suggests that the northwest Atlantic population size is between about 2,300 and 4,100 animals.

POPULATIONS IN SUMMER

In summer, humpback whale distributions are heavily clumped in areas of food abundance (Whitehead *et al.*, 1980), which are often close to a very uneven shore. In such circumstances direct censuses of whale numbers are difficult: a point estimate of the population size can be obtained, but the confidence limits are large and difficult to determine (see Hay, 1981).

Thus capture-recapture techniques using the fluke photograph data are a more appropriate method of estimating population sizes in summer. The statistical methodology available had been summarized by Cormack (1968). Methods vary from those which make many assumptions and produce precise results, such as the Petersen method, to the Jolly-Seber method (Jolly, 1965;

Seber, 1965) which makes few assumptions, allowing death, birth, immigration and emigration, but produces estimates with wide confidence intervals.

The data used in the capture-recapture analyses were those for individuals with fluke photographs catalogued by Katona *et al.* (1980), supplemented by a sample from Bay de Verde, Newfoundland in 1980. Each photograph was graded from 1 (excellent) to 5 (poor), and only those individuals with at least one photograph better than grade 4 were considered, to avoid duplicates. The numbers of distinct individuals photographed at different places during the summer are given in Table 1. Many of the Newfoundland photographs were taken during studies of the behaviour and ecology of the humpback whales off the Bay de Verde Peninsula, in 1978, 1979 and 1980.

Table 1

Number of distinct individual northwest Atlantic humpbacks; identified from fluke photographs during the Bay de Verde studies, off the Newfoundland coast (including the Bay de Verde studies), off the Labrador coast, and in the Gulf of Maine, during the years 1975–1980.

	Bay de Verde	Newfoundland including Bay de Verde	Labrador	Gulf of Maine
1975		7		1
1976		10		35
1977		13	1	16
1978	145	184	31	12
1979	150	329	62	27
1980	66	75		17

For the Bay de Verde, Bay de Verde plus Newfoundland, and Bay de Verde plus Newfoundland plus Labrador series of data, Jolly-Seber methods were applied. The equations of Jolly (1965) were used to estimate the population and its standard error in each year, assuming:

1. No individual left the population to later re-enter it.
2. The probability that an individual in the population was photographed during any year was independent of whether it had been photographed in a previous year.

With population defined as the number of humpbacks frequenting each area in summer these assumptions seem reasonable. The population estimates obtained (and 95% confidence intervals) are given in Table 2. The Jolly-Seber method also produces estimates of immigration/birth numbers and emigration/death rates, but in this instance the estimates had such large variances as to be meaningless, and are not given here.

In contrast to the Jolly-Seber method which makes few assumptions and gives estimates with wide confidence intervals, the Petersen method, which compares resightings between two samples, produces a more precise answer but has stricter conditions. A population estimate with confidence intervals, can be obtained for the time of the second sample if:

(1) No animals photographed in the first sample left the population before the second.

(2) The probability of an animal being photographed in the second sample was independent of whether it was photographed in the first sample.

Petersen estimates were used on the comparison between the returns to particular areas in different years. In these cases assumption (1) was almost certainly violated as animals died or emigrated. However the bias introduced is proportional to the rate at which animals left the population. Thus if 0.1 of the animals photographed in the first sample had left the population by the second its size would be overestimated by 0.1. Given the usual mortality rates in mysticete populations (e.g. 0.05–0.09, Chittleborough, 1965, for the humpbacks off Australia), it is unlikely that estimates using samples 1 year apart are overestimated by more than 10%, and 2 years apart by more than 20%, assuming no substantial emigration. There are no large concentrations of humpbacks in summer outside Newfoundland and Labrador, except the Gulf of Maine, where Newfoundland/Labrador animals did not go in any numbers, so that considerable emigration seems improbable.

Petersen estimates were also made within each year comparing the individuals photographed at Bay de Verde with those taken elsewhere on the Newfoundland coast or

Table 2

Population estimates of humpbacks frequenting Bay de Verde (B.d.V.) the northeast Newfoundland coast (Nfld), and northeast Newfoundland plus southern Labrador (Nfld-Lab.) in summer, using Jolly-Seber (J.–S.) method and Petersen method, from returns between years, and from Bay de Verde to other areas. Estimated 95% confidence intervals, and possible maximum biases discussed in the text are given. Biases marked + are possible overestimates due to mortality, and those marked – are possible underestimates, due to lack of random mixing.

For	Year	Method	Estimate	95% Confidence interval	Bias
B.d.V.	1979	J.–S.	709	–2–1,421	
B.d.V.	1979	Petersen 1978, 1979	946	687–1,516	+ 0.1
B.d.V.	1980	Petersen 1979, 1980	1,414	832–4,721	+ 0.1
B.d.V.	1980	Petersen 1978, 1980	1,595	905–6,728	+ 0.2
Nfld	1978	J.–S.	1,835	–992–4,662	
Nfld	1979	J.–S.	1,141	208–2,075	
Nfld	1978	Petersen B.d.V., Nfld	2,030	971–22,444	–?
Nfld	1979	Petersen B.d.V., Nfld	2,068	1,375–4,173	–?
Nfld	1979	Petersen 1978, 1979	1,636	1,255–2,349	+ 0.1
Nfld	1980	Petersen 1979, 1980	1,898	1,270–3,753	+ 0.1
Nfld	1980	Petersen 1978, 1980	1,971	1,156–6,692	+ 0.2
Nfld–Lab.	1978	J.–S.	2,395	–1,203–5,994	
Nfld–Lab.	1979	J.–S.	2,666	739–4,593	
Nfld–Lab.	1978	Petersen B.d.V., Nfld–Lab.	3,093	1,497–29,526	–?
Nfld–Lab.	1979	Petersen B.d.V., Nfld–Lab.	2,241	1,536–4,144	–?
Nfld–Lab.	1979	Petersen 1978, 1979	1,955	1,525–2,723	+ 0.1

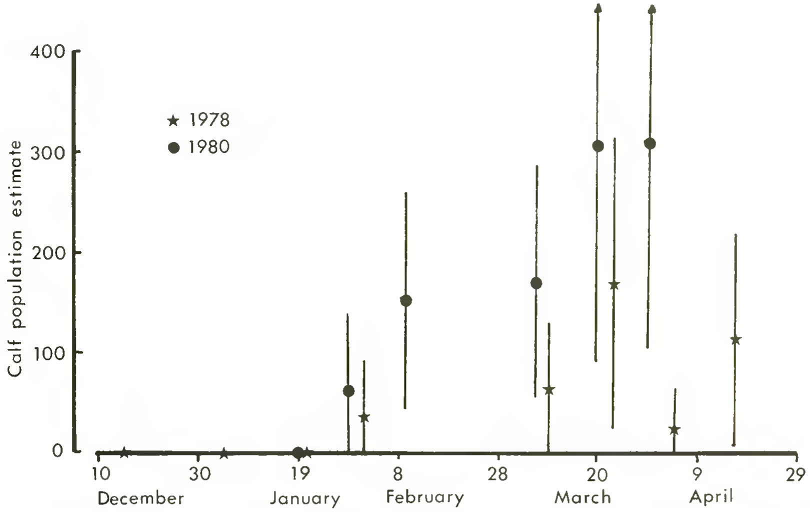

Fig. 5. Estimated calf populations on Silver Bank from *Regina Maris'* 1978 and 1980 survey with 95% confidence limits.

off Labrador. In these circumstances assumption (1) is reasonable but, as mixing is incomplete, assumption (2) does not strictly hold: whales photographed at Bay de Verde were more likely to be photographed in the other surveys, which were mostly close to Bay de Verde or actually went through the study area. This failure would bias these estimates downwards by an unknown amount.

The results of the Petersen estimates are given in Table 2 together with confidence intervals, calculated from DeLury's (1951) normal approximation, and indications of possible biases.

The Petersen and Jolly-Seber estimates consistently suggest a population of 905–1,400 animals using Bay de Verde during the study years, with 1,375–2,075 off the Newfoundland coast, and 1,535–2,720 off Newfoundland and Labrador combined.

The much greater inclination of Gulf of Maine animals to return to and remain in preferred areas (C. Mayo, pers. comm.), makes random sampling difficult, and capture-recapture estimates dubious. However there are 113 Gulf of Maine animals in Katona *et al.'s* (1980) catalogue, and many within- and between-year returns, suggesting that the Gulf of Maine population numbers a few hundred animals.

Migrating populations

Petersen capture-recapture methods were also used to estimate the total northwest Atlantic population based on returns between the northern and southern areas. During a study on Silver Bank during the winter of 1980, 74 individual humpback flukes were identified. Comparing the matches between this sample and those for Newfoundland/Labrador and the Gulf of Maine in 1978 and 1979 gave the population estimates in Table 3. Once again these may be expected to be biased upwards because of mortality, as for the summer populations, although in this case the intervals between the samples are ½ and 1½ years. This analysis indicates a total population using Silver Bank, the Gulf of Maine, and Newfoundland/Labrador of between 2,000 and 6,000 animals.

Table 3

Petersen population estimates obtained by comparing fluke photographs taken on Silver Bank during the winter of 1980, with those taken in Newfoundland, Labrador and the Gulf of Maine in 1978 and 1979, with approximate 95% confidence intervals, and possible maximum biases, due to mortality.

Winter sample	Summer sample	Estimate	95% Confidence interval	Bias
1980 Silver Bank	1978	3,360	1,820–21,874	+0.15
1980 Silver Bank	1979	3,071	1,948– 7,250	+0.05
1980 Silver Bank	1978 + 1979	3,145	2,137– 5,953	+0.10

Table 4

Sightings of calves on *Regina Maris'* census runs in 1978 and 1980.

	1978	1980
Silver	19	56
Navidad	1	1
Mouchoir	1	0
≥5,000 m from Banks	1	0

Recruitment

The great majority of the calf sightings on *Regina Maris'* surveys were on Silver Bank (Table 4). A similar methodology to that used in the estimation of total population sizes, and described for winter populations above, produced calf population estimates (Fig. 5). There were insufficient data to make separate estimates of effective strip width, μ, for different wind speeds, and as there were no significant differences between the sighting ranges for the two years, all the data were pooled to produce a single effective strip width ($\mu = 461$ m). Despite the wide confidence limits for the estimates in Fig. 5, some conclusions can be drawn:

Table 5

Population estimates of northwest Atlantic humpback whales, with the assumed strip width within which all whales were assumed to have been sighted.

Authority	Year of census	Population estimates		Strip width
		Silver & Navidad	NW Atlantic	
Mitchell (1973)	1966–1969	—	1,259[H]	14,830 m
Winn *et al.* (1975)	1973	631–1,003[C]	785–1,157[C]	5,560 m
Balcomb and Nichols (1979)	1977	900	—	7,410 m
Balcomb *et al.* (1980)	1980	—	2,000–3,000[C]	Various
Scott & Winn (1980)	1978	1,375–1,747	2,055[C]	3,750 m
This Paper	1978–1980	2,000–3,500	2,300–4,100	Not Assumed
Hay (1981)	1980	—	235–1,242[C]	Aerial survey

[H] = Considered a high estimate. [C] = Considered a conservative estimate.

1. Very few calves were born before the last week in January, the great majority being born in February and March. This is in agreement with the evidence for the Southern Hemisphere where most calving takes place between mid-July and mid-September (Chittleborough, 1958; Matthews, 1937).
2. Calf production on Silver Bank is approximately 100–300 per annum, or 3–10% of the total population.
3. Calf production was significantly higher in 1980 than in 1978 ($P < 0.01$). This is borne out by calf sighting rates in the Bay de Verde study in summer: calf sightings significantly increased between 1978 and 1980 ($P < 0.025$). However the rate was significantly lower in 1978, just after the crash of the Grand Banks capelin stock. Mitchell (1973) found capelin to be the major food of the humpbacks off Newfoundland.

COMPARISON OF POPULATION ESTIMATES

The winter estimates suggest a population of about 2,300–4,100 humpbacks using the West Indies, while the capture-recapture estimates for Newfoundland/Labrador and assuming a few hundred in the Gulf of Maine, gives approximately 1,700–3,200 animals for the northern area. Some of the West Indian animals probably do not summer in either the Gulf of Maine or Newfoundland/Labrador: there are a few in the Gulf of St Lawrence, and the humpbacks off West Greenland remain to be studied. Thus the estimates for the northern and southern parts of the northwest Atlantic range by and large agree with each other and with the estimate obtained from comparing returns between them of 2,000–6,000 animals.

There is also reasonable agreement with the other estimates of humpback numbers on Silver and Navidad Banks and in the northwest Atlantic summarized in Table 5. The generally increasing population estimates produced during the 1970s from 1,259 (Mitchell, 1973) to my estimate of about 3,000 are principally due to improving census methodology: earlier workers used unrealistically wide strip widths in which they assumed all whales were seen (Table 5), and thus underestimated the population size. There is no evidence that the population substantially increased or decreased during the time period of these estimates, despite the dramatic changes in densities in some areas.

Calf production on Silver and Navidad Banks in 1980 was estimated to be 100–300 per year, and as Winn *et al.* (1975) estimate 85% of the humpbacks in the West Indies were on these Banks, this suggests a total annual production of 118–353 calves. Assuming a population of 3,000 animals this works out at a recruitment rate of 0.039–0.118, which can be compared with Chittleborough's (1965) estimate of 0.116 for the Antarctic Group IV population.

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REFERENCES

Balcomb, K. C. and Nicols, G. 1978. Western North Atlantic Humpback Whales. *Rep. int Whal. Commn* 28: 159–64.

Balcomb, K. C., Nichols, G. and Haenel, N. J. 1980. Western North Atlantic Humpback Whale census near Hispaniola – Winter 1980. Paper SC/32/PS25 presented to the IWC Scientific Committee, June 1980.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 72: 202 pp.

Chapman, D. G., Eberhardt, L. L. and Gilbert, J. R. 1977. A review of marine mammal census methods. Final report to US Marine Mammal Commn. 55 pp.

Chittleborough, R. G. 1965. Dynamics of two populations of the humpback whale. *Austr. J. Mar. Freshw. Res.* 16: 33–128.

Cormack, R. M. 1968. The statistics of capture-recapture methods. *Oceanogr. Mar. Biol. Ann. Rev.* 6: 455–506.

Cox, D. R. 1969. Some sampling problems in technology. pp. 505–27 In: N. L. Johnson (ed.). *New Developments in Survey Sampling.* Wiley, Interscience, New York.

DeLury, D. B. 1951. On the planning of experiments for the estimation of fish populations. *J. Fish. Res. Bd Canada,* 8: 281–307.

Eberhardt, L. L. 1978. Transect methods for population studies. *J. Wildl. Manage.* 42(1): 1–31.

Hay, K. 1981. Aerial line-transect estimates of abundance of humpback, fin, and long-finned pilot whales in the Newfoundland/Labrador area. Paper SC/33/O 4 (published in this volume).

Hiby, A. R. 1981. The effect of random whale movement on density estimates obtained from whale sighting surveys. Paper SC/33/MiS7 (published in this volume).

International Whaling Commission 1980. Report of the sub-committee on protected species and aboriginal whaling. *Rep. int. Whal. Commn.* 30: 103–9.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration – stochastic model. *Biometrica* 52: 225–47.

Kapel, F. O. 1979. Exploitation of large whales in West Greenland in the 20th century. *Rep. int. Whal. Commn* 29: 197–214.

Katona, S., Harcourt, P. M., Perkins, J. S. and Kraus, S. 1980. *Humpback whales in the Western North Atlantic: a catalogue of identified individuals.* (2nd ed.) College of the Atlantic, Bar Harbor, Maine, USA.

Lien, J. 1980. Whale entrapment in inshore fishing year in Newfoundland. Final Report to Canadian Government.

Matthews, L. H. 1937. The humpback whale, *Megaptera nodosa. Discovery Rep.* 17: 7–92.

Mitchell, E. 1973. Draft report on humpback whales taken under special scientific permit by Eastern Canadian land stations, 1969–1971. *Rep. int. Whal. Commn* 23: 138–54.

Payne, R., and McVay, S. 1971. Songs of humpback whales. *Science* 173: 583–97.

Scott, G. P. and Winn, H. E. 1980. Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales. Final Report to U.S. Marine Mammal Commission. Report No. MMC–77/24. PB81–109852.

Seber, G. A. F. 1965. A note on the multiple-recapture census. *Biometrika* 52: 249–59.

Whitehead, H. 1979. The baleen whales off the northeast coast of Newfoundland. Paper SC/31/5 presented to the IWC Scientific Committee, June 1979.

Whitehead, H. P. 1981. The behaviour and ecology of the humpback whale in the northwest Atlantic. Unpubl. Ph.D. thesis, University of Cambridge. 180 pp.

Whitehead, H., Harcourt, P., Ingham, K. and Clark, H. 1980. Migration of the humpback whales past the Bay de Verde Peninsula, Newfoundland. *Can. J. Zool.* 58(5): 687–92.

Williamson, G. R. 1961. Winter sighting of a humpback suckling its calf on the Grand Bank of Newfoundland. *Norsk Hvalfangsttid.* 50: 335–41.

Winn, H. E., Edel, R. K. and Taruski, A. G. 1975. Population estimate of the humpback whale in the West Indies by visual and acoustic techniques. *J. Fish. Res. Bd. Canada* 31:499–506.

the period 21 July–7 August and 12 August–11 September (Fig. 3). Two biologists attached to the University of Oslo, Mr Svein Fevolden, former whaling inspector in Iceland, and Mr Bengt Christiansen were on the look-out for bowhead whales during the first cruise.

On 3 August 1980, a concentration of polar bears was seen in the drift ice at 79°55.3′N, 29°49.5′E (Siggerud and Kristoffersen, 1981). A close inspection showed that about 30 polar bears were gathered close to the floating remains of a whale carcass; some of them were resting on surrounding patches of ice. In addition more than 20 polar bears were observed within 20 km from the carcass. From notes made *in situ* and photos taken the whale was identified as either a bowhead or a right whale (*Balaena glacialis*).

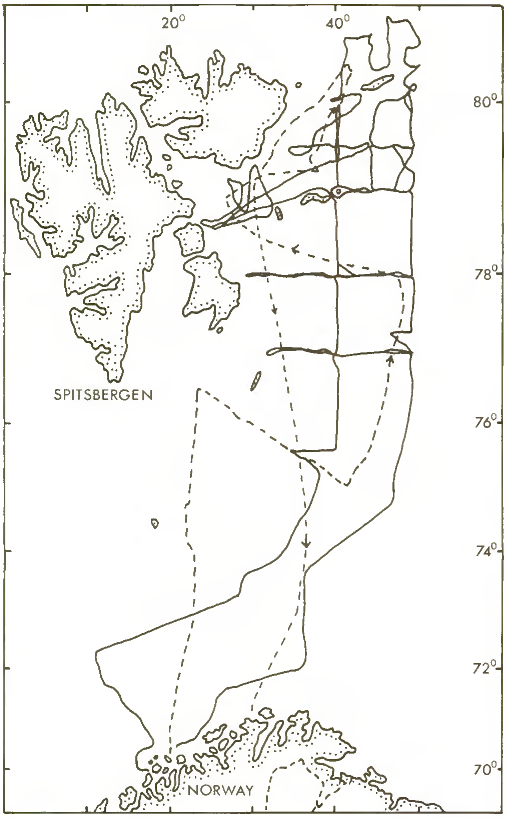

Fig. 3. Map showing the routes followed by the sealing vessel *Norvarg* in 1980. From Norsk Polarinstitutt, Oslo.
-------- 21 July to 7 August.
——— 12 August to 11 September.

No living bowhead whale was seen during the two cruises of the *Norvarg* expedition.

DISCUSSION

As a result of whale sightings made during the cruises of *Ymer* and *Norvarg* in 1980 it can be stated that no living bowhead whales were seen. The appearance of the carcass of the *Balaena* sp. made the observers conclude that the whale probably had been dead for a long time. Since right whales (Nordkaper) have not been observed in Arctic northeast Atlantic waters in modern times and never have been known to move so far north, a dead right whale would have had to drift in a northerly direction to reach the position where the carcass was sighted. This is not at all likely since the currents in the northern Barents Sea and further east move westerly, and in the particular area of finding, southerly (Vinje, 1976). This fact strongly indicates that the dead whale had drifted from high latitudes further east. It therefore may be concluded that the whale carcass in all probability was a bowhead.

The negative results of the extensive surveys made on the *Ymer* and on the *Norvarg* cruises in 1980 strongly indicate that the very few bowhead whales reported seen in Arctic northeast Atlantic waters in postwar years are stragglers which have strayed into the area during summer.

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REFERENCES

Edelstam, C. 1981. Däggdjur och fåglar i polarisen. pp. 139–45. *In: Expedition Ymer-80.* Generalstabens litografiska Anstalts förlag. Stockholm.

Jonsgård, Å. 1981. Bowhead whales, *Balaena mysticetus,* observed in Arctic waters of the eastern North Atlantic after the Second World War. *Rep. int. Whal. Commn* 31: 511.

Siggerud, T. and Kristoffersen, Y. 1981. Svalbard-ekspedisjonen 1980. Rapport tokt 1. Marinbiologiske undersøkelser. Norsk Polarinstitutt, Oslo. 35 pp. (Mim.)

Vinje, T. E. 1976. Sea ice conditions in the European sector of the marginal seas of the Arctic, 1966–75. *Norsk Polarinstitutts Årbok 1975:* 163–74.

SC/33/PS5

Bowhead Whale Studies, Autumn 1980–Spring 1981: Harvest, Biology and Distribution

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ABSTRACT

A joint US–USSR cruise was conducted in the Chukchi Sea 17 September–1 October 1980 to study the distribution of bowhead whales, *Balaena mysticetus*. Bowheads were observed along the north coast of the Chukotka Peninsula to the East Siberian Sea, farther west than they have been reported previously. During autumn 1980, Alaskan Eskimos at Kaktovik on Barter Island landed one bowhead whale, struck but lost a second, and killed but failed to land a third animal.

The 1981 spring bowhead whale research was conducted 11 April–2 June. The census, harvest, and biological collection of elements of our research were contracted to the Alaska Eskimo Whaling Commission who subcontracted to Arctic Technical Research. The bowhead migration past Point Barrow, Alaska, occurred in two major phases this year, one 11 April–3 May and the other from 19 May–2 June. It was the earliest migration we have witnessed since our studies began in 1974. Spring 1981 bowhead whaling by Alaskan Eskimos resulted in 14 whales landed; 11 others were struck, 2 of which are known to have been killed but lost, and 2 strikes were unused. Since the total number of strikes allotted for 1981 was 32, 3 additional whales landed or 5 strikes, whichever occurred first, remained for the 1981 autumn season.

Results are encouraging from the aspartic acid racemization of eye lens nuclei for age determination of bowheads; ages of four animals ranging from 0.57 to 44 years were estimated. Proteins from bowhead whale tissues examined by electrophoretic techniques indicate that variability in the bowhead population may be higher than expected when compared to other whales studied. Stomach and intestinal contents from whales landed in autumn 1980 consisted primarily of euphausiids and copepods. Competition with arctic cod for prey may be important in some years.

Aerial surveys were conducted 6–21 May 1981 near the ice camp census team at Point Barrow to determine the spatial distribution of migrating whales across the lead. Up to 95% of the whales passed within 5 km of the edge of the shorefast ice. No bowheads were seen beyond 7 km or in leads or open water beyond the nearshore lead west of Point Barrow. A total of 14 calves were counted from the ice camp. The proportion of calves to total whales seen was 2.0% to 5.6%. A negative correlation resulted between distance away from the edge of the shorefast ice and proportion of calves in the population. Two possible explanations are that the calves migrated closer to shore than the larger whales and/or that the calves were more difficult to see as distance increased across the lead.

INTRODUCTION

The following report is of research activities by the National Marine Mammal Laboratory (NMML) of the National Marine Fisheries Service (NMFS) on the bowhead whale, *Balaena mysticetus*, for the period autumn 1980 through spring 1981. The objectives of our research are to obtain biological and ecological information necessary for determining the status of the western Arctic-Bering Sea bowhead population, and what effect, if any, the Eskimo hunt has on the recovery of the population.

In 1981, harvest monitoring, biological sampling and a population census were conducted by the Alaska Eskimo Whaling Commission (AEWC), under contract to the NMML. The AEWC subcontracted the field work to Arctic Technical Research (ATR), Fairbanks, Alaska.

Specific topics discussed in this report include: (1) Alaskan Eskimo whaling for bowheads during autumn 1980 and spring 1981, (2) summaries of completed or ongoing biological studies, and (3) information on the distribution of bowhead whales from aerial and vessel surveys and estimates of calf production derived from ice camp data during spring 1981. Analysis of the ice-based camp census data collected since 1978 were reported by Krogman *et al.* (1981).

ALASKAN ESKIMO WHALING

The objective of the harvest monitoring project is to determine the nature and number of the annual catch of bowhead whales, and to gather catch and stranding information on other cetaceans in Alaska. This includes recording relative whaling effort by each village and assessing the effect of removing whales from the population by direct kill or by animals being struck and lost. Sampling procedures and routine activities were described in Braham *et al.* (1979, 1980a) and Johnson *et al.* (1981).

Autumn 1980

During the spring 1980 hunt, Eskimo whalers took 15 bowheads and struck but lost another 16, striking a total of 31 whales. This exceeded the 1980 quota set by the IWC of 18 whales landed or 26 struck, whichever came first. The US Department of Commerce closed the 1980 whaling season on 29 May when 26 strikes had been verified; it was later determined that 5 additional strikes had occurred prior to the 29 May closure.

Despite the closure of whaling for 1980, Eskimos began hunting bowheads in the autumn during the first week of September. Autumn whaling was severely restricted because of inclement weather and an early freezeup, which occurred 2–3 weeks earlier than usual. Results of Eskimo whaling during 1980 were 16 bowheads landed and 18 struck but lost.

Kaktovik and Nuiqsut. Whaling began on 1 September at Kaktovik, Barter Island. Five crews actively whaled during the autumn season. Hunters from the village of Nuiqsut, because of unfavorable weather and ice conditions in the area, elected to join the Kaktovik whalers during the autumn hunt. A male bowhead estimated at 9.15–10.67 m in length was landed on 14 September. A second whale was struck but lost during the first week of October. A third whale was struck and killed on 4 October but could not be landed because of excessive ice. It was temporarily set adrift with floats attached to prevent sinking and to facilitate future recovery. When sea conditions permitted, the whalers attempted to relocate the animal but failed. Continued adverse weather made further whaling impossible at Kaktovik.

Barrow. No bowhead whales were struck by Barrow whalers in autumn 1980.

Other whale species

Landings by Alaskan Eskimos of whales other than bowheads during 1980 are listed in Table 1. A small gray whale, *Eschrichtius robustus,* and a minke whale, *Balaenoptera acutorostrata,* were landed by hunters from Savoonga. A gray whale calf was killed by hunters with rifle fire at Sheshalik, a seasonal Eskimo hunting site northwest of Kotzebue. During the autumn season, hunters from Kaktovik took 10 white whales (belukha), *Delphinapterus leucas*, in nearby Griffin Bay. Also during the autumn of 1980, residents of Toksook Bay, Nelson Island, shot and landed a sub-adult gray whale (R. Nelson, pers. comm.).

Table 1

Whales other than bowheads landed and utilized for food by Alaskan Eskimos during summer and autumn 1980

Species	Number landed	Date	Location	Length (m)
Gray	1	June/July	Savoonga	Small
Gray	1	2 July	Sheshalik	5.5
Gray	1	Autumn	Toksook Bay	10.67–12.19
Minke	1	Summer	Savoonga	—
Belukha	10	Sept/Oct	Kaktovik	—

Strandings

Ten cetacean strandings were reported during 1980: 3 bowheads, 6 gray whales, and 1 killer whale, *Orcinus orca* (Table 2). Two additional bowhead 'strandings' on Barter Island were reported, but these are believed to have been carcasses from the 1979 autumn hunt at Kaktovik. Ten other strandings of unidentified animals, only one of which was recent (summer 1980), were also reported along Alaskan shores north and south of Kotzebue Sound.

Spring 1981

AEWC/ATR biologists were stationed at five whaling villages during the 1981 spring season: Gambell and Savoonga on St Lawrence Island, and Point Hope, Wainwright, and Barrow on the mainland. Whaling activities at Wales and Kivalina were monitored by local AEWC representatives and by NMFS enforcement agents. Tables 3 and 4 summarize results of the spring 1981 hunt. The number of crews that actively whaled this year (93) was down slightly from spring 1980 (99).

Gambell. The hunt was monitored from 25 March to 25 April. Whales began passing the village during March, however whaling was delayed because of poor weather until 5 April when a bowhead was struck but lost. A second bowhead was struck and lost on 12 April. On 14 April a 15.5 m female was landed. Whaling stopped on that date because the village strike quota had been reached. During the 10-day whaling period the crews expended 868 hours of effort in hunting for whales. This compares with 605 hours in 1980 (1 whale landed, 3 struck and lost), and 706 hours in 1979 (no strikes).

Savoonga. The hunt was monitored from 30 March to 25 April at Powooiliak, Southwest Cape. Whaling took place 13–21 April. During this time the whalers struck but lost one bowhead on 13 April and landed two bowheads, one on 14 April and one on 21 April. Whales were still migrating past Powooiliak when whaling ended on 21 April. Numerous small bowheads were seen by the whalers early in the season. Favorable weather and sea conditions existed during the 9-day whaling period.

Table 2

Strandings of cetaceans on the Alaskan coast during 1980

Date[1]	Location	Latitude/Longitude	Length (m)	Condition of carcass[2]	Remarks
Bowhead whales					
30 June	45 km NE Savoonga	64°00′N, 170°20′W	13.70 est.	Recent	Cause of death unknown
3 July	Jeannette Island	70°22′N, 147°25′W	7.50 est.	Recent	Cause of death unknown
29 July	Ikpek Lagoon	65°54′N, 167°16′W	9.15 est.	Recent	Cause of death unknown
Gray whales					
May	Point Hope	68°21′N, 166°50′W	—	Old	Beached during winter
8 July	1.5 km N of Cape Krusenstern	67°09′N, 163°43′W	8.84	Recent	Flukes had been cut off, all baleen removed from mouth
24 July	Espenberg	66°36′N, 164°05′W	—	Recent	Baleen had been removed
18 July	9.5 km NE Gambell	63°47′N, 171°45′W	—	Recent	Killed by *Orcas*, muktuk salvaged by Eskimos
30 July	Shishmaref	66°15′N, 166°04′W	—	Recent	Flukes missing, Eskimos attempted to salvage, but lost it at sea
8–12 Sept	Point Lay	69°45′N, 163°03′W	—	Recent	Utilized by villages for food. Floats and a portion of 13 mm diameter steel cable were attached to the whale
Killer whale					
24 July	Kividlo	66°32′N, 164°46′W	6.25	Recent	All teeth missing

[1] Date first sighted, examined, or reported.

[2] Designated as recent if not observed and reported the previous year, and old if obviously dead for a year or more.

Wales. Three whaling crews began hunting at Wales on 17 April and continued until 31 May. No whales were struck. Whaling was hampered by unfavorable weather and ice conditions, as is frequently the case in the eastern part of the Bering Strait.

Kivalina. Four crews began hunting at Kivalina on about 15 April and continued until the village strike quota was filled on 26 April when two bowheads were struck and lost.

Point Hope. Whaling began later than usual at Point Hope because of persistent strong winds from the south and southwest that caused a considerable build-up of rough ice in the area. Although bowheads were first sighted about 1 April, a lead did not open south of the village until 29 April, when the whalers were able to reach open water about 8 km (4 nmi) offshore. The hunt was monitored from 15 April to 11 May. Whaling began on 30 April and ended on 4 May. Four whales were landed and a fifth was struck but lost, all on 4 May.

Wainwright. Whaling began at Wainwright on 18 April and continued through 12 June. A biologist was at the village from 1–30 May. Three large females (16.15, 16.46, and 17.68 m) were landed during May. An old whaling harpoon head approximately 13 cm in length and made of ivory with a steel blade was found in the largest whale taken (J. Cubbage, ATR biologist, pers. comm.). It was located following the discovery and investigation of two injuries, one old and one recent, just behind the head and dorsal to the flipper on the left side of the whale. The ivory harpoon head was located within the blubber and about 15 cm beneath the skin. The artifact was presented by the whaling captain to the AEWC on loan for study.

Barrow. Spring whaling began at Barrow on 15 April and continued through 12 June. Biologists were present in the village from 9 April until 5 June. Four whales were landed and five others struck but lost, two of which were reported to have been killed when lost.

Whales struck but lost

During the spring of 1981, 11 bowheads were struck and lost while 14 whales were landed (Table 3). During the years an annual catch quota has been in effect, the ratio of whales struck and lost to those landed was lower in 1981 (0.8:1) than in 1980 (1.1:1) and 1979 (2.1:1), but higher than in 1978 (0.5:1) (Table 5). The discovery of an old whaling harpoon head in the body of an adult whale landed at Wainwright the spring of 1981 is additional evidence that some strikes are of a minor nature and non-lethal for the whales. In the past four years three bowheads have been discovered to exhibit evidence of surviving previous strikes (Albert *et al.*, 1980; Johnson *et al.*, 1981).

Table 4

Date of capture, length and sex of bowhead whales landed by Alaskan Eskimos, spring 1981

Village	Date	Length of whales landed (cm) Female	Male
Gambell	14 Apr	1,550	—
Savoonga	14 Apr	1,676	—
	21 Apr	1,420	—
Point Hope	4 May	—	935
	4 May	1,200	—
	4 May	975[1]	—
	4 May	—	998
Wainwright	6 May	1,615	—
	18 May	1,768	—
	27 May	1,646[2]	—
Barrow	6 May	1,065	—
	22 May	797[3]	—
	25 May	840[3]	—
	30 May	—	870
Total no.		11	3

[1] Estimated length.
[2] Head was severed from carcass and each was measured separately.
[3] Designated *ingutuk* by Eskimo whalers.

One requisite for this year's cooperative research and management with the AEWC was a reporting of the nature of all strikes (i.e. circumstances and a description of the paraphanalia used, whether the bombs exploded, etc.) and the fate of the whales struck, including an estimate of whether a whale was likely to die from a particular strike. These data and estimates of mortality were reported to the Administrator, National Oceanic and Atmospheric Administration, US Department of Commerce, Washington DC, in July 1981 (Table 6). During the spring of 1981 the estimated mortality rate from whales struck but lost (only 2 of 11 whales struck were assumed to have lived) was 82%. Eskimo whalers are generally cautious hunters, not subject to missing a whale that they have approached with a great amount of care and effort. But on occasion, their hunting equipment, such as bombs fired from darting and shoulder guns, fail to explode, or even fail to enter an animal's vital organ cavity, thus reducing the likelihood

Table 3

Bowhead whaling activities by Alaskan Eskimos, spring 1981

Village	Number active crews	Whaling began[1]	Whaling ended	Whales landed	Struck and lost	Total struck	Village strike quota
Gambell	21	5 Apr	14 Apr	1	2	3	3
Savoonga	9	13 Apr	21 Apr	2	1	3	3
Wales	3	17 Apr	31 May	0	0	0	1
Kivalina	4	15 Apr	26 Apr	0	2	2	2
Point Hope	15	30 Apr	4 May	4	1	5	5
Wainwright	10	18 Apr	12 Jun	3	0	3	4
Barrow	31	15 Apr	12 Jun	4	5[2]	9	10
Totals	93			14	11	25[3]	28

[1] Date first boat reported to have entered water.
[2] Two whales are known to have been dead when lost.
[3] Five strikes remain for autumn whaling; 2 strikes remaining unused from spring are not transferable for use during autumn.

Table 5

Annual summary of Alaskan Eskimo spring hunt for bowhead whales 1973–81, showing status of whales struck, total number of crews actively whaling, and ratio of whales lost to whales landed. Data compiled from Marquette (1977, 1979), Braham *et al.* (1980a), Johnson *et al.* (1981), and unpublished NMFS records collected since 1973

	Status of whales hunted				
Year[1]	Landed[2]	Killed but lost	Struck but lost[4]	Number of whaling crews	Ratio of whales lost to whales landed
1973	31	0	10	65	0.3:1
1974	15	2	27	49	1.9:1
1975	15	2	26	75	1.9:1
1976	36	7	35	85	1.2:1
1977	26	3	79	90	3.1:1
1978[3]	10	0	5	82	0.5:1
1979	7	0	15	92	2.1:1
1980	15	2	14	99	1.1:1
1981	14	2	9	93	0.8:1

[1] Spring seasons only.
[2] Includes stinkers (Dauhvals).
[3] First year of annual IWC quota applied.
[4] Unknown if whales died.

that a whale will die from a strike. However, although a darting gun bomb and harpoon with line and floats attached are properly placed, results of this year indicated that most bowheads that were struck and lost died. It is not known whether this year's high struck and killed rate is similar to other years.

Former estimates of mortality rates for whales struck and lost prior to 1981 cannot be determined. The best evidence available to date is the data provided this spring by the AEWC; the value is less than the viewpoint of complete mortality of all struck and lost whales previously used as a cautionary management tool for this population (Braham *et al.*, 1979). It is, however, apparent that the death rate of struck and lost whales is significant and should be considered when estimating total removals from the population as a result of the Eskimo hunt.

BIOLOGICAL STUDIES: A SUMMARY OF CONTRACT RESULTS

Food and feeding of the bowhead whale

A study on the feeding and trophic relationships of bowhead whales in the Beaufort Sea was undertaken by Frost and Lowry (1981), Alaska Department of Fish and Game (ADF&G), under contract to the NMML. Their results incorporated an extensive literature search and analyses of stomach content data from bowhead whales, ringed seals, *Phoca hispida*, and arctic cod, *Boreogadus saida*, collected over the past six years by the ADF&G and the NMML. Field work conducted in the nearshore areas of the Alaskan Beaufort Sea during September of 1980, prior to freeze up, provided samples of zooplankton in the water column. The sampling design for the autumn field work considered the patchy distribution of marine organisms. An effort was made to integrate the sightings and distributions of higher order consumers with patches of their prey.

Although standing stock data on herbivores in the Beaufort Sea are not available, dominant organisms from the autumn 1980 work appeared to be copepods, *Calanus glacialis*, *C. hyperboreus*, and *Pseudocalanus* spp., and the euphausiid, *Thysanoessa raschii*. Only the copepods could be reliably sampled; their vertical distribution varied

Table 6

Bowhead whales struck and lost during the spring 1981 Alaskan Eskimo hunt, and evaluations of each made by the whalers describing the nature of each strike and assumed fate of the whale after being struck. Data from report by the Alaska Eskimo Whaling Commission[1]

Village	Date	Details of strike	Assumed fate of whale[2]
Gambell	5 April	Bomb exploded in whale but harpoon and floats came off when whale dived. Crew stated bomb was too close to harpoon.	Probably died
	12 April	Bomb exploded but the harpoon line came off. Crew could not approach whale again because of dangerous ice.	Probably died
Savoonga	13 April	Bomb exploded but the line came loose.	Probably died
Point Hope	4 May	Bomb exploded but no line attached[3].	Probably died
Kivalina	26 April	Bomb exploded but no line attached[3]. Crew could not approach whale again because of dangerous ice.	Probably died
	26 April	Bomb failed to explode after striking whale. A line was attached but crew could not follow whale because of dangerous ice.	Probably lived
Barrow	28 April	Bomb exploded but harpoon disengaged when float caught on the ice. Crew could not retrieve whale because of developing fog.	Definitely died
	1 May	Whale was struck by harpoon with line and float attached and shoulder gun was fired but bomb failed to explode. The line came loose when whale dived under ice.	Probably lived
	22 May	Bomb exploded and harpoon line was attached but crew forced to stop pursuit because of fog, snow and ice.	Probably died
	26 May	Bomb exploded but whale became entrapped within moving ice on far side of lead and could not be retrieved.	Definitely died
	26 May	Bomb fired from shoulder gun exploded but no harpoon line attached[3].	Probably died

[1] Alaska Eskimo Whaling Commission. 1981. Report on the spring 1981 bowhead whale hunt. Unpubl. report submitted by Alaska Eskimo Whaling Commission to National Oceanic and Atmospheric Administration in compliance with NOAA/AEWC Cooperative Agreement of 26 March 1981.
[2] Assumed fate of struck whales determined by Eskimo whalers.
[3] The AEWC will conduct hearings to determine circumstances of violations of AEWC Management Plan during the hunt of 1981.

geographically and temporally. They were sometimes found in very dense layers near the bottom. This could explain the observation reported on bottom feeding by bowhead whales (Würsig *et al.*, 1981).

Gastrointestinal contents of bowhead whales landed by Alaskan Eskimos revealed a varied diet (Table 7). A total of 46 prey species was found in 17 whales that contained identifiable food remains. With the exception of the three species each of molluscs and fishes, all identified prey were crustaceans. The distribution of prey species among the major groups of crustaceans was: gammarid amphipods (16); copepods (10); hyperiid amphipods (5); euphausiids, mysids, and shrimps (2 each); and isopods, cumaceans, and ostracods (1 each). The number of times each of the major prey groups occurred in the samples was: euphausiids (11); gammarid and hyperiid amphipods (10 each); copepods (9); mysids (6); shrimps (5); fishes (4); molluscs (3); and isopods, cumaceans, and ostracods (1 each). Of the individual prey species, the most frequently encountered was *T. raschii* (11 occurrences). All the remaining prey species occurred in fewer than five stomachs, while 37 species occurred in only one or two samples. Pebbles, generally about 1 cm in size, occurred in five samples.

Euphausiids (7) or copepods (6) were the dominant component in 13 of the 17 samples examined. Two of the remaining four samples were from colons and contained shrimp and bivalves. The other two contained a single amphipod and a single snail. Other prey groups, although they comprised many species and occurred quite frequently (e.g. gammarid amphipods), were never a major component of those samples which contained more than a few identifiable prey. In most of the samples, either *T. raschii* or *C. hyperboreus* was the dominant prey species. At Barrow, *T. raschii* was the dominant prey in whales taken in September, while in the few samples from spring, *T. raschii* was dominant in three and copepods (*C. hyperboreus, Euchaeta glacialis,* and *Metridia longa*) predominated in two. In samples from whales at Kaktovik, all of which were taken in late September and early October, copepods (principally *C. hyperboreus*) were dominant in four and *T. raschii* in two.

Although the available records do not permit a conclusive evaluation of feeding areas, it would seem that the migrating spring whales are not foraging extensively. Whale stomachs examined at Barrow and Kaktovik in the autumn usually contained substantial quantities of food.

Quantitative data on the composition of stomach contents collected from bowheads landed during autumn indicated that copepods and euphausiids comprised the bulk of the food eaten (Lowry and Burns, 1980). In stomachs of five whales landed at Kaktovik in autumn 1979, copepods and euphausiids comprised approximately 60% and 37% of the overall contents, respectively, while in the only two samples from whales landed at Barrow in the autumn copepods did not occur while euphausiids comprised about 92% of the samples.

If the prey composition data from whales landed at Barrow are combined with the data from the Kaktovik whales, the diet of bowhead whales in the Beaufort Sea has the following proportions: copepods 30%, euphausiids 65%, hyperiid amphipods 1%, and other organisms including primarily gammarid amphipods 4%.

The occasional occurrence of benthic organisms in bowhead stomachs has fostered a theory that the benthos may be an important food source (Mitchell, 1975; Griffiths, 1981). We believe the benthos contributes only a negligible portion of the dietary intake for two reasons. First, bowhead baleen with long, fine hairs is highly specialized to filter water column organisms in contrast to the sturdy baleen of gray whales specialized for bottom feeding. Experiments conducted by Braithwaite (1980) indicate bowhead baleen can filter *Artemia,* a pelagic organism, at 96–98% efficiency over a wide range of prey sizes and concentrations. It seems unlikely that a mechanism so adroit at filtering small water-column organisms could successfully strain benthic sediments. Secondly, since copepods appear to concentrate in dense layers near the bottom, whales foraging on these swarms could be expected to incidentally consume benthic fauna.

Estimates of consumption rates were generated for the major consumers in the eastern Alaskan Beaufort Sea which included bowhead whales, belukha whales, ringed seals, seabirds, and arctic cod to establish the relative importance of these foraging species. Of the calculated 1.3 million tons of zooplankton and nekton consumed annually, the distribution among predators was: seabirds 0.1%, bowhead whales 2.0%, ringed seals 2.1%, and arctic cod 95.8%.

The significance of these results to the stock of bowhead whales depends upon the yet unknown relationship between total annual production in the area and the consumption. In other words, if food is a limiting factor in the Beaufort Sea, then competition among the consumer species must occur. Certainly, arctic cod is the major consumer species; however, without more information regarding how the trophic system functions, it is not possible to determine whether competition for food is affecting the recovery of this stock of bowhead whales.

Estimating age: aspartic acid racemization method

Aspartic acid racemization has been used over the past decade to date fossils. More recent work expanded the utility of this technique to the ageing of mammals by using dentine (Helfman and Bada, 1976) and occular lens nuclei (Masters *et al.*, 1977).

In a preliminary study contracted to J. Bada, Scripps Institute of Oceanography, San Diego, California, we have investigated the possibility of using this technique to establish ages of bowhead whales landed by Alaskan Eskimos. Results of previous work on porpoise lenses yield an aspartic acid racemization rate (K_{asp}) of 7.0×10^{-3} (J. Bada, pers. comm.). Incorporating this rate into the kinetic expression for the racemization reaction allows us to extrapolate the age of the whale by using the equation:

$$t(\text{yrs}) = \frac{\ln\left(\frac{1 + D/L}{1 - D/L}\right) - 0.05}{7.0 + 10^{-3}}$$

where; D = dextrorotary and L = laevorotary isomers of aspartic acid.

Comparison of similar racemization analysis in porpoise with dentine lamination counts indicates that the accuracy of age estimates by the racemization method increases with age of the animal (J. Bada, pers. comm.).

Four bowhead whale lenses have been analyzed (Table 8). Based on their body lengths, we estimated 79B1 (bowhead whale specimen number) to be about a 1-year-old animal and 78G1 to be at least 3 years old. An age determination based on the length of the animals greater than 1,400 cm could not be generated (e.g. for 78WW1 and 78WW2).

Table 7

Prey identified from samples collected from gastrointestinal tracts of bowhead whales. Samples were collected from stomachs unless otherwise indicated. Dominant prey species in each sample are indicated by ××. (From Frost and Lowry, 1981).

Prey species	Barrow								Kaktovik						Other areas		
	4388^1 May 1969	76-B-6F 10 Sept 1976	76-B-7F 20 Sept 1976	77-B-5 5 May 1977	79-B-3^2 27 May 1979	80-B-3 25 May 1980	80-B-5 25 May 1980	80-B-9 27 May 1980	79-KK-1 20 Sept 1979	79-KK-2 6 Oct 1979	79-KK-3 8 Oct 1979	79-KK-4 10 Oct 1979	79-KK-5 11 Oct 1979	80-KK-1^3 14 Sept 1980	78-H-2 Point Hope 4 May 1978	79-H-3 Point Hope 6 May 1979	80-SH-1^2 Shaktoolik 9 May 1980
Copepods														××			
Calanus cristatus						×											
Calanus finmarchicus												×					
Calanus glacialis				×				×									
Calanus hyperboreus						××		×	××	××	×	××	×				
Calanus sp.						×				×		×					
Chiridius obtusifrons						×		×				×					
Euchaeta glacialis				×		××											
Heterorhabdus sp.										×		×					
Metridia longa				××													
Metridia lucens										×		×					
Pseudocalanus sp.				×													
Euphausiids																	
Thysanoessa inermis	××					×		×					×				
Thysanoessa raschii	××	××	××	×		×	××	××		×	××	×	××				
Mysids																	
Mysis litoralis								×		×	×		×				
Neomysis rayi						×	×	×									
Hyperiid Amphipods																	
Hyperia galba						×		×									
Hyperia medusarum								×									
Hyperia sp.										×							
Hyperoche medusarum								×	×								
Parathemisto abyssorum				×							×						
Parathemisto libellula		×	×						×	×	×	×	×				

Prey Species	4388[1] May 1969	76-B-6F 10 Sept 1976	76-B-7F 20 Sept 1976	77-B-5 5 May 1977	79-B-3[2] 27 May 1979	80-B-3 25 May 1980	80-B-5 25 May 1980	80-B-9 27 May 1980	79-KK-1 20 Sept 1979	79-KK-2 6 Oct 1979	79-KK-3 8 Oct 1979	79-KK-4 10 Oct 1979	79-KK-5 11 Oct 1979	80-KK-1[3] 14 Sept 1980	78-H-2 Point Hope 4 May 1978	79-H-3 Point Hope 6 May 1979	80-SH-1[2] Shaktoolik 9 May 1980
Gammarid amphipods																	
Acanthostepheia behringiensis			×								×		×				
Acanthostepheia incarinata										×							
Ampelisca macrocephala															×		
Anonyx nugax								×									
Apherusa glacialis												×					
Atylus carinatus											×		×				
Gammaracanthus loricatus											×		×				
Gammarus zaddachi			×														
Gammarus sp.										×							
Monoculoides zernovi			×														
Monoculoides c.f. *M. schneideri*											×	×					
Munnopsis c.f. *M. typica*											×						
Onisimus glacialis										×							
Onisimus litoralis									×								
Rozinante fragilis		×	×									×					
Weyprechtia heulgini												×	×				
Weyprechtia pinguis														×			
Family Lysianassidae									×								
Isopods																	
Saduria entomon													×				
Shrimp			×							×							×
Eualus gaimardii												×					
Sabinea septemcarinata												×					
Family Crangonidae									×								
Cumaceans																	
Diastylis sp.												×					
Ostracods				×													
Molluscs																	
Limacina helicina				×													
Natica clausa																×	
Nuculana sp.					×												
Fishes				×													
Boreogadus saida										×			×				
Myoxocephalus quadricornis											×		×				
Pungitius pungitius													×				
Pebbles		×				×	×		×			×					

[1] Sample from Floyd Durham via F. H. Fay. Exact collection date and portion of gastrointestinal tract from which sample was collected are not known.
[2] Sample from colon.
[3] Sample probably from small intestine.

To evaluate the accuracy of the racemization analysis for baleen whales, we initiated a study to compare the ages generated by occular lens racemization and by ear plug laminations. The eye lenses and ear plugs of 24 fin whales, *Balaenoptera physalus*, were collected by Tony Martin, British Sea Mammal Unit, Cambridge, England, from animals taken in the Icelandic fishery. The ear plug laminations have been counted, however the corresponding results from the racemization analysis are not yet available.

Table 8

Age of bowhead whales calculated by the aspartic acid racemization method

Specimen number	Sex	Length (m)	D/L Aspartic acid	Calculated age[1]
79B1	M	8.74	0.0270	0.57
78G1	M	13.83	0.0513	7.50
78WW1	F	16.30	0.109	24.10
78WW2	M	15.16	0.178	44.26

[1] ± 10% (J. Bada, pers. comm.).

Electrophoretic evaluation of bowhead whale proteins

Over the past three years tissues from 24 bowhead whales were collected to address questions of biochemical variability in the population. In this study, conducted by D. Duffield, Portland State University, Portland, Oregon, 28 protein systems representing 40 loci were examined by electrophoretic techniques. Four of the 28 systems showed considerable variability (i.e. detectable protein polymorphism) in which heterozygosity could be clearly determined.

More than half of the proteins tested showed some variability. Since marine mammal stocks are ordinarily thought to be conservative, this seems to be a high degree of protein variation. There is, however, no obvious correlation of variants or unique alleles with any morphologically distinct type of bowhead whale. This finding further confirms the results reported by Braham *et al.* (1980b) on the apparent morph *ingutuk*. The four systems with clear heterozygosity provided an estimate of individual variability (polymorphic loci) of 12–14% within the sampled animals. This is within the range found in other mammalian populations. On a stock level, it is apparent that individuals with relatively normal levels of heterozygosity and those with higher expected levels are found in the samples.

DISTRIBUTION AND ANNUAL GROSS RECRUITMENT

US–USSR Cooperative Research Cruise, 1980

Scientists from the United States and the Soviet Union participated in a second research cruise in the Chukchi Sea in September 1980, under the aegis of the US–USSR Environmental Agreement, Marine Mammal Project. Again, a 64 m whale-catcher, the vessel *Rasyashchiy*, was made available by the Soviet Government for the joint cruise. The objective was to further describe the distribution of bowhead whales and other marine mammals in the western Chukchi Sea to shed further light on the bowheads' autumn migration.

The survey covered the period 17 September through 1 October, with US participation originating and terminating in Nome, Alaska. After proceeding directly from Nome through the Bering Strait, the cruise track generally followed the northern Siberian coast northwestward into the East Siberian Sea to approximately 174°08′E (Fig. 1). The planned cruise track was then to have been northeastward and to circle the western and northern sides of Wrangel Island; however, heavy pack ice forced a course around the southern part of Wrangel Island and then eastward to Herald Island and Herald Shoals. Because of heavy seas and bad weather, marine mammal sighting became increasingly difficult as the ship passed Herald Island, and impossible near the area of Herald Shoals and thereafter to the south.

Bowheads were first seen just north of Cape Serdtse-Kamen (67°06′N latitude, 171°50′W longitude) with numerous small to large groups observed northwestward along the Siberian coast to about 179°E. In all, over 280 bowheads were sighted. Gray whales were sighted along the Siberian Coast between 170°20′W and 174°08′E. The last sighting, in the East Siberian Sea, was the furthest west gray whales have ever been reported in the Arctic Ocean.

A notable difference in whale distribution between 1980 and 1979 was that in 1979, north of Bering Strait, gray whales were not seen along the Soviet coast but only well offshore and well away from any bowheads (Johnson *et al.*, 1981). The 1980 gray whale sightings were interspersed with bowhead sightings; while there was no intermixing, the two species alternated along the coast, probably in relation to differences in food availability.

Small biopsies of skin and blubber tissue were collected from two bowhead whales in the same manner as in 1979 (i.e. by means of a small coring tube fitted to a crossbow arrow). Results of the biopsy sampling have thus far been disappointing. Only one of the six samples collected has responded to the culturing process that necessarily precedes chromosome and biochemical analysis. Several possible reasons and remedies for this have been suggested, mostly bearing on initial treatment of the samples. The overall procedure still appears to be a viable one.

Zooplankton samples, pipe-dredge bottom samples, salinity, temperature and water samples for measurement of organic carbon and chlorophyll-a were taken daily when sea conditions permitted. Gross examination of pipe-dredge samples revealed generally sandier bottom material and greater concentrations of cumacean crustaceans in areas of gray whale abundance.

As in 1979, no population estimations were attempted. Heavy seas, particularly in the second half of the cruise, caused considerable variation in sighting efficiency, and extensive meanderings to obtain biopsy samples made any systematic survey impossible.

The bowhead and gray whales observed appeared to be feeding but the ship could not remain with any particular group for a sufficient time period to establish migratory movement. Furthermore, the cruise again took place in the September–October period and, since no bowheads have been seen in the western Chukchi Sea prior to these months in recent years (Braham *et al.*, 1980d), we believe that the bowheads observed were probably returnees from the Beaufort Sea. Further study in August 1982 again will be attempted pending completion of arrangements with the Soviet government.

acceptable population estimate using the ice camp data was not possible for 1979, at least when compared to the 1978 estimate. The 1978 estimate of 1,783–2,865 is the best estimate to date (for five years of data, 1976–80) considered reliable, for reasons outlined by Braham *et al.* (1979) and in more detail by Krogman (1980). Further analysis of other years' estimates, especially 1980 and 1981, are covered in Krogman *et al.* (1981).

Continuation of aerial survey effort across the full width of the lead (and additional leads if present) where the census camps are located is important, especially when the lead is open beyond the observers' vision. The maximum effective distance observers on the ice can see is approximately 4–5 km depending upon the height of the observer's platform (Krogman, 1980). Aerial survey plays an important role during years when the observers on the ice can in fact remain near the lead throughout the season, with few hours of missed watch. The factors needed for successful use of the aerial survey frequency distribution data then are: (1) when the lead is open beyond the ice camp observers' viewing range, (2) if the lead remains open throughout the season, or (3) remains open at least during the time the ice camp observers can remain at the lead edge and count whales.

Theoretical considerations

The design of this year's experiment was to fly perpendicular transects across the lead as near the ice-camp census teams as possible and score by time (and thus position) whales sighted. Time begins at $t_o = 0.00$ at the edge of the shorefast ice and ends $(t_o + t_n)$ at the edge of the pack ice on the farside of the lead (or where ice coverage reaches 100%). Accumulated sightings from this procedure can then be arrayed into a spatial frequency distribution to determine the relative numbers of bowheads and their distance within and outside the range of view of the census observers.

Reilly (1981) provided us with the prerequisite design. To successfully carry out this test, a sample size of 150 whales was needed to provide a 90% level of confidence that the frequency of whales pooled into a three sample strata in the lead would reflect their true distribution, assuming a population size of 2,264. At the 95% level, a sample of 665 observations was needed; this was much greater than achievable.

Results and discussions

Using an *Aerocommander Shrike* (N9157N)[1], from 6 to 21 May we conducted approximately 20 hr of aerial survey covering just over 4,000 km of the pack ice and nearshore lead from northeast of Point Barrow to Point Lay. We also flew offshore on several occasions (approximately 5 hr and 1,000 km, 25% of area coverage) out to about 100 km off the coast to see if any whales were using offshore open water areas. Because of winds from the southwest and west much of the season, the nearshore lead near Barrow was closed for all but 4 days (6–7 and 20–21 May) of the 16 day period. On 20 and 21 May we ran systematic surveys across the lead, as designed, and on 6 and 7 May two flights were made over the nearshore lead at Point Barrow. Surveys were flown along the coast, and offshore as well, on 9, 12, 14–15 and 18 May to determine if bowheads were migrating through the area when the lead was closed, and to determine whether the animals were held up in open water areas south of Wainwright. On 14 May, a 6 m yearling bowhead was seen in heavy slush ice north of Point Barrow where the nearshore lead was closed. That was the only whale seen in slush or heavy ice near Barrow.

A total of 32 bowheads (in 19 'groups' or sightings) and over 1,449 white whales were seen (Table 9). Half of the total bowhead sightings were on 20 May, the first day the lead was open after being closed since 8 May. Five bowheads were seen between Icy Cape and Point Lay, and two were seen in the Beaufort Sea about 90 km ENE of Point Barrow. The remaining 25 whales were observed in the nearshore lead between Barrow and approximately 20 km north of Point Barrow. For 24 of these whales we had distance times or estimates which could be used for subsequent analysis for the sighting frequency distribution across the lead. After an evaluation of position and time of each observation, no duplicates resulted.

The lead was open to 20 km on 6 and 7 May, to 36 km on 20 May, and 20 km on 21 May at the survey site adjacent to Point Barrow. On 7 and 21 May, the lead was partially clogged with drifting ice north of the Point but not to the south, yet there was room for the whales to migrate among the ice floes and thus, the effective lead widths were, in our judgement, as reported above.

No bowhead whales were observed beyond the nearshore lead from Icy Cape to just north of Point Barrow, and out to 100 km offshore; 400 white whales were seen in small holes and cracks in the pack ice offshore during these same surveys. One bowhead was seen approximately 64 km WNW of Point Lay, but the animal was in the general vicinity of the fractured pack ice where the lead (or large polynya) characteristically forms (see Figs 2 and 3c in Braham *et al.*, 1980c). This propensity for bowheads to be nearer to shore than white whales was also evident in the nearshore lead. On the 4 days of survey when the lead was open 20–36 km wide, white whales were seen all across the lead to the pack ice whereas no bowheads were seen beyond 7 km from the shorefast ice edge. In 1979, no bowheads were sighted beyond 8 km of the shorefast ice, although the lead was greater than 10 km wide when open.

Although we were not able to achieve a sample size of 150 bowheads as desired for our frequency distribution experiment, the data collected provided some insight into the movement of whales past the census camps. The 24 bowheads scored had distance measurements taken ($n = 19$) or visual estimates of distance made ($n = 5$) which followed the distribution in Fig. 2. Again, we saw no bowheads beyond 7 km even when the lead was open to 36 km. Of those whales sighted, 70.8% (17) were seen within 2.2 km of the ice edge, and 95.8% (23) were within 5 km. These two distances are believed to be within the effective (2 km) and maximum (5 km) viewing distance of observers from the shorefast ice, depending upon the platform height. Comparable results were obtained in 1979 (2 km = 53.7%, 5 km = 91.9%; Braham *et al.*, 1980a).

A comparison of the sighting distribution using the ice camp and aerial survey data out to 5 km resulted in no significant difference (Table 10). This means that the ice camp sighting distribution across the lead is probably a close first approximation of the true distribution of whales. Unfortunately, we were unable to survey in April when the first group of bowheads went through, nor could we stay

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service.

Table 9

Marine mammals sighted during aerial surveys along the northwest coast of Alaska, 6–21 May 1981. Direction (e.g. W, NNE) are magnetic headings. Locations off Barrow or Point Barrow include the 5 km across the shorefast ice

Date	Time	Species obs.[1]	Number	Location
6 May	1225	*B. mysticetus*	2	18 km NW Pt. Barrow
7 May	1245	*B. mysticetus*	3	8 km W. Pt. Barrow
	1245	*D. leucas*	250+	9 to 27 km W. Pt. Barrow
9 May	1645	*D. leucas*	100	18 km W. Pt. Barrow
	1705	*U. maritimus*	1	45 km W. Barrow
	1711	*D. leucas*	2	36 km W. Pt. Barrow
	1725	*D. leucas*	29	54 km NNE Pt. Barrow
12 May	1104	*D. leucas*	1	36 km SW Icy Cape
	1114	*B. mysticetus*	4	22 km SW Icy Cape
	1130	*D. leucas*	6	73 km W. Icy Cape
	1710	*D. leucas*	1	18 km N. Pt. Barrow
14 May	1121	*D. leucas*	3	Midway Barrow–Wainwright
	1208	*D. leucas*	20	18 km offshore, 73 km SW Barrow
	1215	*U. maritimus*	2	36 km W. Barrow (sow, cub)
	1235	*D. leucas*	40	54 km N. Pt. Barrow
	1235	*B. mysticetus*	1	54 km N. Pt. Barrow
	1250	*D. leucas*	200+	54 km N. Pt. Barrow
15 May	1500	*U. maritimus*	1	45 km WSW Barrow
	1535	*D. leucas*	89	18 km W. Peard Bay
	1535	*D. leucas*	136	18 km W. Pt. Franklin
	1645	*B. mysticetus*	1	64 km WNW Pt. Lay
	1810	*D. leucas*	238	36 km NNW Wainwright
18 May	2000	*D. leucas*	95+	90 km ENE Pt. Barrow
	2010	*B. mysticetus*	2	90 km ENE Pt. Barrow
20 May	1507–1650	*B. mysticetus*	6	9 km W. Pt. Barrow
	1507–1650	*D. leucas*	104	9 km W. Pt. Barrow
	1700	*D. leucas*	1	73 km SW Barrow
	1720	*D. leucas*	10	46 km SW Barrow
	1725–1757	*B. mysticetus*	3	9 km W. Pt. Barrow
	1725–1757	*D. leucas*	60	9 to 18 km W. Pt. Barrow
	2230–2315	*B. mysticetus*	7	6 km W. Pt. Barrow
	2230–2315	*D. leucas*	14	6 to 18 km W. Pt. Barrow
21 May	1250–1320	*B. mysticetus*	3	11 km W. Pt. Barrow
	1250–1320	*D. leucas*	50	9 to 27 km W. Pt. Barrow
Totals		*B. mysticetus*	32	
		D. leucas	1,449+	
		U. maritimus	4	

[1] (*B. mysticetus*—bowhead; *D. leucas*—white whale or belukha; *Ursus maritimus*—polar bear).

beyond 21 May to determine if the distribution changed within the season.[2]

Because we think whales migrate closer to the nearshore lead ice edge at and north of Point Barrow than further south off the village of Barrow, we tested the distance estimates of individual whales observed across the lead south ($n = 8$) versus north and at the Point ($n = 8$). There was a slight difference (median distance off lead edge south = 1,850 m and north = 762 m) although this difference was not significant ($P = 0.3184$, Mann-Whitney test), probably a result of sample size.

The aerial surveys conducted this spring provided valuable information on the distribution of whales across the lead. Since the ice camp census crew was not able to operate a 24-hour watch throughout the spring migration (because the lead was closed during the middle portion of the season), no complete population estimate was possible. If the frequency distribution we obtained is an accurate reflection of the true distribution, then any estimate of the number of whales passing the ice camps includes most of the population (i.e. as much as 96%). Our sample size is too small, however, to use this with statistical reliability. The most important point is that bowhead whales migrated within the first third of the lead closest to the shorefast ice edge. As evidenced from the 1979 data, this may be a normal migration pattern off Point Barrow, Alaska.

Annual gross recruitment: calf counts

No bowhead calves were observed during the aerial surveys. There were 14 calves seen by the ice camp observers plus 4 duplicate sightings and 1 conditional. All 14 calves were seen between 16 April and 1 May. The method we have previously used to estimate the proportion of calves in the population (what we term production or annual gross recruitment, r_o), was to determine the sample space or area that calves were seen in near the ice camps, and then determine the percent of total (= all) whales within that space (Braham *et al.*, 1980a). This procedure was applied to the 1981 data.

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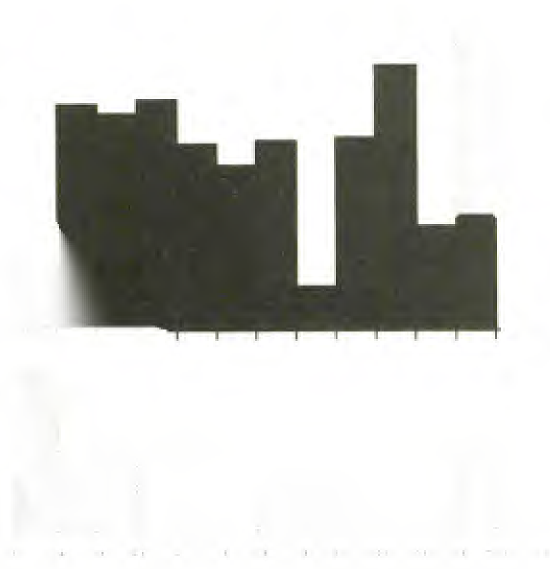
[2] Our experiment required that we fly near the ice camps. Eskimo whalers were situated next to the census camps, with increasing frequency since 1976. Our flying near Point Barrow on 20 and 21 May disturbed the Eskimos so we decided to terminate our experiment. Note: Of the 32 bowheads we observed, only 3 (9%) reacted in a negative manner to our plane's noise, even when we were forced by low fog to fly at an altitude of 75 m. Similar results were achieved above an altitude of 152 m in 1979 (Braham *et al.*, 1980a); however, additional work is needed on this topic to resolve the question of which combination of factors potentially contribute to 'disturbance' to whales by airplanes.



Cubbage, J. C. and Rugh, D. J. 1982. Bowhead whale length estimates and calf counts in the eastern Beaufort Sea, 1980. Paper SC/33/PS6 (published in this volume).

Frost, K. and Lowry, L. 1981. Feeding and trophic relationships of bowhead whales and other vertebrate consumers in the Beaufort Sea. Final Rep. to Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. 106 pp.

Griffiths, W. B. 1981. Characteristics of bowhead feeding areas. pp. 197–264. *In:* W. J. Richardson (ed.) *Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1980.* Rep. prepared for U.S. Bur. Land Manage. by LGL Ecol. Res. Assoc., Inc., Bryan, Texas.

Helfman, P. M. and Bada, J. 1976. Aspartic acid racemisation in dentine as a measure of ageing. *Nature* (Lond.) 262(5566): 279–81.

Johnson, J., Braham, H., Krogman, B., Marquette, W., Sonntag, R. and Rugh, D. 1981. Bowhead whale research: June 1979 to June 1980. *Rep. int. Whal. Commn* 31: 461–75.

Krogman, B. D. 1980. Sampling strategy for enumerating the western Arctic population of the bowhead whale. *Mar. Fish. Rev.* 42 (9–10): 30–6.

Krogman, B., Sonntag, R., Rugh, D., Grotefendt, R. and Priebe, G. 1981. Population estimation of the western Arctic stock of the bowhead whale. Paper SC/33/PS4 presented to the IWC Scientific Committee, Cambridge, June 1981.

Lowry, L. F. and Burns, J. J. 1980. Foods utilized by bowhead whales near Barter Island, Alaska, autumn 1979. *Mar. Fish. Rev.* 42 (9–10): 88–91.

Marquette, W. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973–76, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

Marquette, W. 1979. The 1977 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos. *Rep. int. Whal. Commn* 29: 281–9.

Masters, P. M., Bada, J. L. and Zigler, J. S. Jr. 1977. Aspartic acid racemisation in the human lens during ageing and in cataract formation. *Nature* (Lond.) 268 (5615): 71–3.

Mitchell, E. D. 1975. Trophic relationships and competition for food in Northwest Atlantic whales. pp. 123–33. *In:* M. D. Burt (ed.) *Proc. Canadian Soc. Zool. Ann. Meeting,* 2–5 June 1974.

Reilly, S. B. 1981. Aerial survey methods to verify the offshore distribution of migrating whales. Unpubl. manusc., 4 pp Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N. E., Seattle, WA 98115.

Wursig, B., Clark, C. W., Dorsey, E. M., Fraker, M. A. and Payne, R. S. 1981. Normal behavior of bowheads. pp. 21–90. *In:* W. J. Richardson (ed.) *Behavior, Disturbance Responses and Feeding of Bowhead Whales in the Beaufort Sea, 1980.* Rep. prepared for U.S. Bur. Land Manage. by LGL Ecol. Res. Assoc., Inc., Bryan, Texas.

SC/33/PS6

Bowhead Whale Length Estimates and Calf Counts in the Eastern Beaufort Sea, 1980

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ABSTRACT

Observations of bowhead whales (*Balaena mysticetus*) in the eastern Beaufort Sea August–September 1980 resulted in 9 calf sightings. Of 179 whales classified into length categories during aerial surveys, 6 (3.4%) were calves; of 191 seen from shipboard, 3 (1.6%) were calves. These percentages are consistent with values from similar studies on bowheads. However, our results tend to be lower for bowheads than production estimates based on reproductive data for other mysticete populations.

Information on bowhead whale (*Balaena mysticetus*) calf abundance and size class composition is needed to help determine recruitment into the population. In this regard we conducted vessel and aerial surveys for bowhead whales in August and September 1980 in the eastern Beaufort Sea off the northwestern coast of the Tuktoyaktuk Peninsula, Northwest Territories, Canada (69°30′–70°15′N, 130°–133°W). Aerial surveys were flown over the Canadian Beaufort Sea from Herschel Island to Banks Island (140°–123°W) and north to 72°N, concentrating on areas where we found high densities of whales. Whale sightings were recorded with regard to count, distance from observer, and lengths which were subjectively judged to be either large (over 15 m), medium (12–15 m), small (8–12 m), or a calf (less than 6 m).

A total of 100.5 hr of observation were made from two survey vessels: one an 18 m sailing ketch; the other a 16 m, 600 hp, diesel crewship; both with 3.6 m eyeheight. During the observation period, 489 bowhead sightings were logged of which only 191 were viewed adequately to be classified into size categories. Because these vessel surveys were run simultaneously, although in different locations, there may have been some duplication of sightings between vessels as well as between days within each vessel's log. Nine aerial surveys were flown totalling 37.5 hr during which 485 sightings occurred, 179 classified as to size. Assuming no duplication between sightings, 16% of the bowhead population was sampled, using 191 + 179 as the sample size and 2,264 as the population estimate (Braham *et al.*, 1979).

Bowhead whale length classifications are compared between surveys in Table 1. There is considerable variability in the data, especially between surveys. We found no linear relationship between length classification and survey altitude, so altitude alone could not explain differences between aerial and vessel results. The greatest discrepancies occurred in classifying small whales where frequencies ranged from 10 to 31% of the total sightings. Calf frequencies, on the other hand, were all within 4% of each other. Our data show no apparent differential geographic distribution of calves relative to adults; therefore, it is unlikely that the variability between surveys was due to sampling unrepresentative portions of the population.

Average distances from which the size of whales were judged was 0.54 km from survey vessels. Larger whales were generally recognized at greater distances than other whales. From one vessel, sighting distances to large animals was significantly greater ($p < 0.05$; t-Test) than sighting distances to medium-sized animals. Similarly, from another vessel, the sighting distances to large animals and calves was significantly greater than sighting distances to small animals ($p < 0.05$; t-Test). Three possible explanations are: (1) the closer a whale is, the smaller it appears to be to the observer, i.e. observer error which contradicts the optical illusion of size decreasing with distance; (2) large whales remained at greater distances from boats; or (3) small whales were attracted to boats.

Although there are inconsistencies between observers in identifying lengths of whales, identification of calves was

Table 1

Review of bowhead whale length estimates

Date	Platform	Total number whales	Percent (and count) of whales classified by size				
			Large	Medium	Small	Calf	Source
March 79	Aircraft	50	38 (19)	52 (26)	10 (5)	0	Unpubl. NMFS data
April–May 79	Aircraft	34	29 (10)	50 (17)	18 (6)	2.9 (1)	Braham *et al.*, 1980
May 80	Aircraft	98	— 71 (70) —		25 (25)	3.1 (3)	Johnson *et al.*, 1981
Aug–Sept 80	Aircraft	179	26 (46)	56 (100)	15 (27)	3.4 (6)	This study
Aug 80	Vessel	78	21 (16)	58 (45)	21 (16)	1.3 (1)	This study
Aug 80	Vessel	113	19 (22)	48 (54)	31 (35)	1.8 (2)	This study
			— 77 (425) —		21 (114)	2.4 (13)	Average

obvious enough to result in remarkably consistent data. Calves were generally lighter in color than mature whales and were one-third to a half of the length of adults. Calves of apparently different lengths were seen within a few days of each other, which supports the hypothesis that parturition is not restricted to a short time frame but may occur anytime between March and June (Braham, Krogman and Carroll, in press; Marquette, 1977).

Other researchers studying bowhead whales have attempted to count calves. Table 2 shows the number and percentage of calves seen from this and other studies. See Marquette *et al.* (1981) for additional analysis of National Marine Fisheries Service bowhead calf counts. There is very good agreement in percentage of calf sightings among all surveys (1.3–3.7%), and especially among aerial surveys (2.9–3.4%), with the exception of surveys in March, a time that may be prior to parturition (Marquette, 1977). Although aerial survey results are not significantly different from those for other methods, their consistency indicates that aerial surveys may be the best way to search for bowhead calves.

Although there is some agreement among all of these bowhead studies, resulting estimates of calf production seem low compared to other mysticetes. Based on analysis of life table information, Rice and Wolman (1971) reported a 13% annual gross production rate for gray whales (*Eschrichtius robustus*). Data from Mitchell (1974) yields a value of a gross annual reproduction rate for fin whales (*Balaenoptera physalus*) of 14% based on pregnancy rates of examined whales. For humpback whales (*Megaptera novaeangliae*), Scott and Winn (1980) estimated an annual gross reproduction rate of 11.8% to 21.6% using life table parameters.

Comparisons of calculated gross production of some other mysticetes with observed calf counts revealed that calf counts were below calculations. Rugh (unpublished data) counted gray whales on their egress from the Bering Sea in fall and found 4% were calves. This percentage is well below Rice and Wolman's (1971) calculated 13% but may be depressed in part because of calf mortality during the first nine months of life and in part because calves were weaned by the time they departed the Bering Sea; therefore, the calves were much larger than in the spring, decreasing the likelihood of their being recognized by onshore observers. For humpbacks, Scott and Winn (1980) found calf counts to be far lower than calculated reproduction rates. They offered several possible explanations: (1) high fetal mortality, (2) age of calf production greater than expected, or (3) estimates of calf production based on direct counts are biased.

Direct counts of bowhead calves may include some biases. If calves spend a greater percent of time underwater than adults, they may escape detection a greater proportion of the time. Although Carroll and Smithhisler (1980) reported bowhead adult-calf pairs remained underwater for less time than adults, Würsig *et al.* (1981), found time between blows of adult-calf pairs was significantly greater than other adults but no other significant differences between calf and adult dive behavior were found. To what degree calf-adult pairs may remain segregated from concentrations of whales is not known. The fact that, in this study and probably in most others, large concentrations of whales received more survey attention may introduce a bias. Calves might often be missed on a first pass during aerial surveys. For instance, while circling over one group of 22 bowheads, a calf was sighted after 15 minutes; a second calf was recognized after 60 minutes. However, if calf behavior allows an equal chance of sighting a calf as an adult, frequencies within size classes should not change significantly with the increased observation of a single pod.

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Table 2

Review of bowhead whale calf counts from different studies

Dates	Location	Observation platform	Number of sample whales	Number of calves	Percent calves	Calf production estimate[1]	Source
Aug–Sept 78	E. Canadian Arctic	Aircraft/land	83	3	3.6	—	Davis & Koski (1980) (Maximum estimate)
March 79	Bering Sea	Aircraft	50	0	0	0	Unpubl. NMFS data
April–May 79	Chukchi–W. Beaufort	Aircraft	34	1	2.9	3.0	Braham *et al.*, 1980
May 80	Bering Strait	Aircraft	98	3	3.1	3.2	Johnson *et al.*, 1981
Aug–Sept 80	E. Beaufort	Aircraft	179	6	3.4	3.5	This study
Aug–Sept 80	E. Beaufort	Aircraft	333	11	3.3	3.4	Würsig *et al.*, 1981
April–May 78	Pt. Barrow	Shore-fast ice	727	18	2.5	2.5	Braham *et al.*, 1979
April–May 79	Pt. Barrow	Shore-fast ice	170	6	3.5	3.7	Braham *et al.*, 1980
April–May 80	Pt. Barrow	Shore-fast ice	250	4	1.6	1.6	Johnson *et al.*, 1981
July–Aug 79	E. Beaufort	Ship	54	2	3.7	3.7	Hazard & Cubbage, 1980
Aug 80	E. Beaufort	Ship	78	1	1.3	1.3	This study
Aug 80	E. Beaufort	Ship	113	2	1.8	1.8	This study
	Totals:	Aircraft[2]	777	24	3.1	3.2	
		Shore-fast ice	1,147	28	2.4	2.5	
		Ship	245	5	2.0	2.1	
	Grand total average		2,169	57	2.6	2.7	

[1] Excluding calf sightings from denominator.

[2] Excluding the aerial survey in March when calves of the year presumably had not been born.

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REFERENCES

Braham, H., Krogman, B. and Carroll, G. In press. Population biology of the bowhead whale (*Balaena mysticetus*): migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution and life history of white whales (*Delphinapterus leucas*). U.S. Dep. Commer., NOAA Tech. Memo. NMFS, F/NWC.

Braham, H., Krogman, B., Johnson, J., Marquette, W., Rugh, D., Nerini, M., Sonntag, R., Bray, T., Brueggeman, J. Dahlheim, M., Savage, S. and Goebel, C. 1980. Population studies of the bowhead whale (*Balaena mysticetus*): results of the 1979 spring research season. *Rep. int. Whal. Commn* 30: 391–404.

Braham, H., Krogman, B., Leatherwood, S., Marquette, W., Rugh, D., Tillman, M., Johnson, J. and Carroll, G. 1979. Preliminary report of the 1978 spring bowhead whale research program results. *Rep. int. Whal. Commn* 29: 291–306.

Carroll, G. M. and Smithhisler, J. R. 1980. Observations of bowhead whales during spring migration. *Mar. Fish. Rev.* 42(9–10): 80–85.

Davis, R. A. and Koski, W. R. 1980. Recent observations of the bowhead whale in the Eastern Canadian High Arctic. *Rep. int. Whal. Commn* 30: 439–44.

Hazard, K. and Cubbage, J. 1980. Bowhead whale distribution and abundance in Amundsen Gulf, NWT, Canada, Summer, 1979. Paper SC/32/PS9 presented to the IWC Scientific Committee, Cambridge, June 1980.

Johnson, J. H., Braham, H. W., Krogman, B. D., Marquette, W. M., Sonntag, R. M. and Rugh, D. J. 1981. Bowhead whale research: June 1979 to June 1980. *Rep. int. Whal. Commn* 31: 461–75.

Marquette, W. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973–76 and a biological summary of the species. Processed rep. 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way, N. E. Seattle, WA 98115.

Marquette, W., Nerini, M., Braham, H. and Miller, R. 1981. Bowhead whale studies, autumn 1980–spring 1981: Harvest, biology and distribution. Paper SC/33/PS5 (published in this volume).

Mitchell, E. D. 1974. Present status of north Atlantic fin and other whale stocks. pp. 108–69. *In:* W. E. Schevill, (ed.) *The Whale Problem: a Status Report.* Harvard University Press, Cambridge, MA. 419 pp.

Rice, D. W. and Wolman, A. A. 1971. Life History and Ecology of the Gray Whale (*Eschrichtius robustus*). *Am. Soc. of Mammal., Spec. Publ.* 3: 142 pp.

Scott, G. P. and Winn, H. E. 1980. Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales (*Megaptera novaeangliae*). Final report to Marine Mammal Commission, Washington D.C., MMC-77/24. 100pp.

Würsig, B., Clark, C. W., Dorsey, E. M., Fraker, M. A. and Payne, R. S. 1981. Normal behavior of bowheads. pp. 22–90. *In:* W. J. Richardson (ed.) *Behavior, Disturbance Responses and Feeding of Bowhead Whales in the Beaufort Sea, 1980.* Rep. prepared for U. S. Bur. Land Manage. by LGL Ecol. Res. Assoc., Inc., Bryan, Texas.

SC/33/PS10

Investigations on Gray Whales Taken Off Chukotka in 1980

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(TINRO)

ABSTRACT

The catch of gray whales off Chukotka was examined from July–October 1980. As in 1979, most of the catch (71.4%) were females. The average length of males taken was 11.7 m while that of females was 12.0 m. More than half (63% of females and 68% of males) were immature. Over the 4 month period the ratio of pregnant:non pregnant animals was 1:1, although the proportions varied by month. Animals of similar physiological condition tend to remain together:pregnant females enter and leave the feeding grounds first.

INTRODUCTION

The gray whale is one of the best studied whale species, partly due to its coastal distribution and partly due to its long history of exploitation. Several detailed monographs have been written which have dealt in some detail with both its biology and exploitation (e.g. Scammon, 1874; Andrews, 1914; Tomilin, 1957; Rice and Wolman, 1971). The earliest information concerning the gray whales found off Chukotka (the California–Chukotka or Eastern stock) was a report of the 1933 operations of the Soviet factory ship, the *Aleut* (Zenkovich, 1934).

Gray whales were forbidden to be taken for commercial purposes by the International Whaling Commission (IWC) in 1946 although they continued to be taken in the subsistence fishery by Chukotkan native peoples and in 1969 a modern catcher boat, the *Zvezdny*, was chartered to take whales on their behalf (Ivashin and Mineev, 1981). The Magadan branch of TINRO began systematic observations of gray whales in 1965 and Zimushko has presented a series of reports on gray whale biology (1969a; b; 1970a; b; 1971). Since 1977 this work has been carried out by the Central Laboratory for Cetacean Research (TINRO), whose primary aim has been to assess the stock using materials collected from the Chukotka fishery. This paper presents the data obtained from the 1980 season and compares them with earlier results.

MATERIALS AND METHODS

Materials were collected at three villages; Lorino, Sireniki and Yanrakynnot. Between July and October, 99 whales were examined and their length, sex, physiological state, stomach content and blubber thickness determined; ear plugs were collected from 46 whales and the age of 35 whales determined; the species composition of the stomach contents was analysed for 38 whales; standard measurements (according to Tomilin, 1957) were taken (to the nearest 5 cm) for 64 adults and 12 foetuses; and data on three phenotypic characters were collected for 89 whales. Sexual maturity and the physiological state of females was determined by the presence of corpora lutea or albicantia or by the size of the uterus or presence of a foetus; where this was impossible whales of more than 12.0 m were considered mature; males of less than 11.5 m were considered immature (Zimushko, 1969b; Zimushko and Ivashin, 1980; and see Rice and Wolman, 1971).

RESULTS AND DISCUSSION

Sex ratio and length distribution

The largest number of whales (78) was examined at Lorino, of which 54 (73.8%) were females, although the proportion of females varied considerably from month to month and in August more males were taken than females (Table 1). At Sireniki, 12 (66.7%) of the 18 whales landed were females and at Yanrakynnot 4 of the 7 whales landed were females. Females also predominated in the catch in previous years (Table 2).

As in other baleen whale species, females are larger than males and it was once thought that the large number of females was due to the whalers' taking the largest whales (Zimushko and Ivashin, 1980, p. 242). However experiments (e.g. IWC, 1981, p. 134) including observations in 1980 have shown that this is not the main reason: mixed schools are common and the taking of the smaller animals does not necessarily mean that males are taken. This makes selective hunting almost impossible as males cannot be distinguished from females at sea. However, the 1980 data do appear to suggest that males are more abundant in August, whereas females are more abundant later in the season, but further information is needed to confirm this.

The range in lengths for the 1980 catch was 9.20–14.10 m for females and 10.25–13.00 m for males although most (74.3%) females were within the range 10.6–13.0 m (mean 11.99 m) and most (78.5%) males were within the range 11.1–12.5 m (mean 11.76 m). Length distributions are given in Fig. 1. Near Lorino, the smallest animals were taken in September and the largest in July and August. The smallest animals overall were those landed at Yanrakynnot (Table 1).

Time of year does appear to affect the size of whales taken: in September, strong winds and fog make it difficult for the whalers who tend to be less selective and take the first whales they come across. This also reinforces the view that taking smaller whales does not necessarily increase the proportion of males as almost 90% of the whales taken off Lorino in September were females.

There has been little change in the average lengths of whales caught since 1978 (Table 2).

Physiological state

Most (64.4% of the females and 84.2% of the males) of the whales taken at Lorino were mature. Over the 4 months of

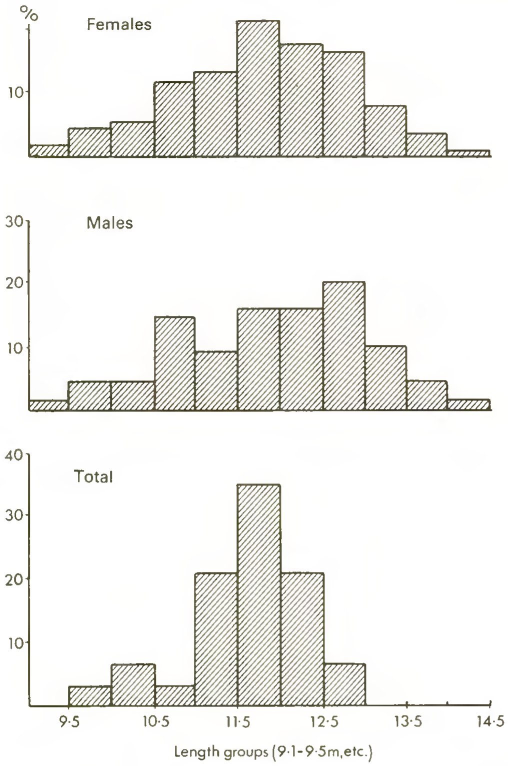

Fig. 1. Length composition of gray whales taken off Chukotka, 1980 (n = 99).

Table 2

Gray whale catch data, 1978–80

	1978	1979	1980
No. of whales taken	182	178	179
% females in the catch	74.0	65.0	71.4
Average length:			
Males	11.8	11.5	11.7
Females	11.9	11.9	12.0
% immature females in the examined catch	54.0	13.0	37.1
% pregnant females in the examined catch	30.0	84.0	52.3

the fishery the ratio of pregnant to non-pregnant (mature) females was about 1:1 but an examination of the data by month (Fig. 2) reveals a steady decline in the proportion pregnant from July to October (although sample sizes were small). At Sireniki, two of the seven mature females examined were pregnant and at Yanrakynnot both mature females examined were pregnant.

The smallest female with a corpus was 11.3 m while a 12.5 m female examined had no corpora. The largest number of corpora (11) was found in a 13.2 m female and the average number of corpora for the mature females examined was 5.1.

Rice and Wolman (1971) estimated the proportion of immature animals in the stock to be about 44%. However, it is to be expected that the proportion of immature animals in the catch will be less than this (24% in Rice and Wolman, 1971) due to the selection of larger animals by the whalers. We have already seen that weather conditions, which have the effect of reducing the selectivity of the whalers, results in a higher proportion of immatures in the catch.

Table 1

Some data on the catch of gray whales off Chukotka, 1980

								Reproductive condition									
								Females						Males			
	Catch							Mature									
	Females		Males		Average length, m			Pregnant		Not pregnant		Immature		Mature		Immature	
Month	n	%	n	%	Females	Males	b.a.	n	%	n	%	n	%	n	%	n	%
Lorino																	
July	16	72.7	6	27.3	12.2	11.75	11.99	9	90.0	1	10.0	6	37.5	4	66.6	2	33.4
August	10	47.1	11	52.9	12.0	11.9	11.96	5	71.4	2	28.6	3	30.0	11	100	—	—
September	17	88.9	2	11.1	11.76	11.25	11.7	4	40.0	6	60.0	7	41.2	1	50.0	1	50.0
October	11	100	—	—	12.18	—	—	1	12.5	7	87.5	3	27.3	—	—	—	—
July–October	54	73.9	19	26.1	11.99	11.79	11.93	19	57.1	16	42.9	19	36.2	16	84.2	3	15.8
Sireniki																	
4 July–16 October	12	66.7	6	33.3	12.1	11.6	11.93	2	28.5	5	71.5	5	41.7	3	50.0	3	50.0
Yanrakynnot																	
19 July–23 October	4	57.1	3	42.9	11.95	11.1	11.58	2	100	—	—	2	50.0	—	—	3	100
Total																	
July–October	70	71.4	28	28.6	12.0	11.68	11.9	23	52.3	21	47.7	26	37.1	19	67.9	9	32.1

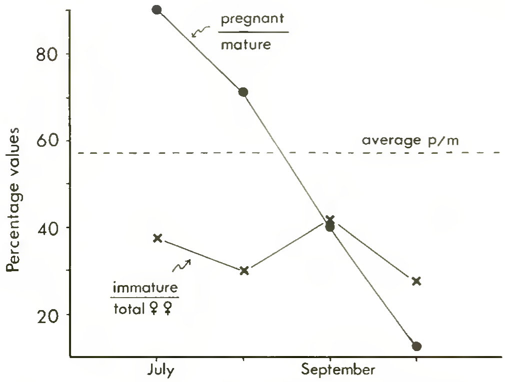

Fig. 2. Monthly trends of different physiological states (females) in the catch at Lorino.

In the past three years there has been considerable variation in the percentage of mature females pregnant (Table 2). Much of this can be explained with reference to the monthly trend shown in Fig. 2. In 1978 when the percentage was low, most of the catches were in the autumn; whereas in 1979 when the percentage was high, most of the catches were in the summer.

Rice and Wolman (1971) found that pregnant females were the first to begin the northerly migration and the first to arrive at the breeding grounds after the southerly migration. This is supported by the monthly pattern shown in Fig. 2 which suggests that the pregnant females are the first to arrive off Chukotka and the first to leave. Many of the non-pregnant females taken in October had large corpora and well developed mammaries and had probably just weaned their calves. Some of the females taken in October had large numbers of small (1–1.5 cm) ectoparasitic barnacles (*Cryptolepas rhachianecti*), as well as scars on their skin resulting from the adult barnacles. Zenkovich (1937) noted that whales found in estuaries (brackish/fresh water) do not possess ectoparasites. The above information suggests that the resting females taken in southern waters (estuarine) are those which have recently weaned their calves whereas those taken in July have probably not either given birth or conceived in the current year.

The data suggest that whales of a similar physiological state remain together in the summer habitat. The overall 1:1 pregnant: non-pregnant ratio supports the 2 year reproductive cycle proposed by Rice and Wolman (1971).

Age data

Of the 46 ear plugs collected, 6 were soft and damaged on removal. The smallest (1.8 cm) plug came from a 9.2 m female while the largest (21 cm) came from a 13.9 m female (Table 3). Although the sample size is small (Table 4) the data have been plotted in Fig. 3. The smallest number of growth layer groups (GLGs) seen was 3, in a 9.2 m female, while the largest number of GLGs (46) was from a 13.0 m female. A GLG comprises one light and one dark lamina. The number of GLGs found in whales of the same length varied considerably. The average number of GLGs for males was less than for females, and following Rice and

Table 4

The results of the estimation of the number of GLGs in the ear plugs of gray whales taken off Chukotka in 1980 (n = 35)

Number of GLGs	Length of whales (m)	
	Females	Males
3	9.2	—
4	—	11.6
5	10.5	10.4
6	10.8	11.2
7	11.6, 11.8	—
9	12.0 (2), 13.0, 13.2	—
12	12.5	11.5, 12.1
14	12.2, 12.5	12.0
15	—	12.3
16	12.2	—
17	—	12.1
23	12.5	—
24	13.1	—
25	—	11.4
26	12.9	—
27	13.9	—
29	13.2	12.0
31	13.9	—
32	—	12.4
35	—	11.6
44	—	13.0 (2)
45	—	11.9
48	13.0	—
Average number of layers	16	23
Average length (m)	12.6	11.9

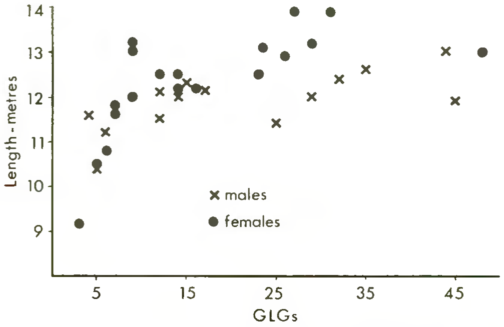

Fig. 3. Length and age (in GLGs) of 35 gray whales taken in 1980.

Table 3

Size of ear plugs and length of whales, 1980

Length of whale, m	9.2	10.6–11.0	11.1–11.5	11.6–12.0	12.1–12.5	12.6–13.0	13.1–13.5	13.6–14.0
Ear plugs:								
Average length, cm	1.8	5.0	5.0	8.0	12.2	13.4	14.0	18.0
Range, cm	—	3.0–6.0	—	4.0–11.0	7.0–15.0	5.0–18.0	13.0–15.0	15.0–21.0
Sample size	1	3	1	4	5	8	4	2

Table 5

Blubber thickness data from whales taken off Chukotka in 1980 (as a % of body length)

	July	August	September	October	July–October
Females, total:					
Average	1.06	1.05	1.02	1.01	1.04
Range	0.97–1.97	0.90–1.42	0.70–1.25	0.70–1.29	0.70–1.42
Sample size	5	10	13	11	39
♀, pregnant					
Average					1.18
Range					0.99–1.40
Sample size					11
♀, not pregnant					
Average					0.92
Range					0.70–1.23
Sample size					16
♀, immature					
Average					1.05
Range					0.97–1.26
Sample size					12
Males, total					
Average	1.09	1.07	1.11	—	1.08
Range	0.79–1.26	0.86–1.38	1.05–1.17	—	0.79–1.38
Sample size	3	10	2	—	15

Wolman (1971) we have taken the rate of GLG formation as one per year. Thus the average ages of animals in our sample was 22 for males and 16 for females.

Feeding

Of the 99 whales examined, 76% had full stomachs. The species composition of the stomach contents of 38 animals was examined. In agreement with previous work (e.g. Bogoslovskaya, Votrogov and Semenova, 1981), amphipods (35 species) were the most abundant prey and comprised an average of 90% of the stomach contents. *Pontoporeia femorata* which occurred in 68% of the samples was the most abundant species (62%). The high percentage of full stomachs testifies to the good food supply in the coastal waters of Chukotka.

Blubber thickness

Blubber thickness was found to vary with month and physiological condition (Table 5). Pregnant females had, as one might expect, the thickest blubber layers, as they arrive on the feeding grounds first and must be able to cope with the energetic demands of the remainder of gestation and lactation before they again return to the feeding grounds. The resting females had the thinnest blubber layer. Most of these were caught in the autumn (hence the declining monthly trend in female blubber thickness) and had just weaned their calves and only recently entered the feeding grounds.

Foetal data

Thirteen foetuses were taken and examined from pregnant females in 1980 (7 females and 6 males) and details are given in Appendices 1 and 2. The smallest foetus was 63 cm and the largest 285 cm.

Phenotypic data

Three phenotypic characters were examined: the shape of the fluke notch, the number of submaxillary folds and the number of prominences on the tail.

(a) *Shape of the fluke notch.* There are 5 types (Fig. 4) of which the first is the most common (58%).

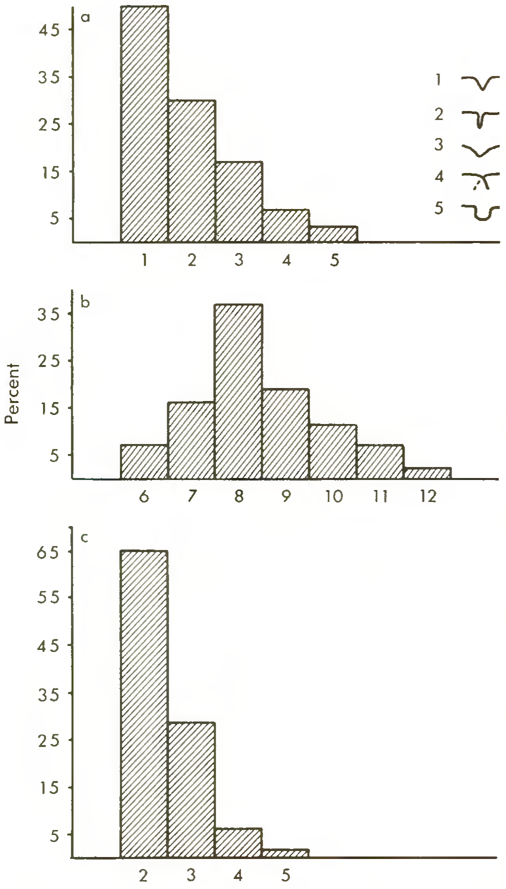

Fig. 4. Frequency of different phenetic characters: a: fluke notch shape; b: number of tail prominences; c: number of submaxillary folds.

Appendix 2

FOETAL MEASUREMENTS (AS A PERCENTAGE OF TOTAL LENGTH), 1980

Sex of foetus	♂	♂	♂	♀	♂	♀	♀	♂	♂	♀	♀	♀
Length of foetus (cm)	65	128	130	133	152	170	190	190	208	235	238	285
1. Snout tip to centre of eye	19.2	17.9	18.4	18.0	19.0	17.0	—	—	17.3	16.5	16.8	17.8
2. Snout tip to angle of mouth	18.4	19.5	20.0	19.5	19.0	19.4	18.4	—	18.2	17.8	18.4	19.6
3. Snout tip to ear	25.3	23.4	23.8	23.3	23.0	22.3	—	21.5	23.0	22.1	22.6	23.5
4. Snout tip to centre of melon	13.8	14.0	13.8	14.2	14.4	12.9	14.7	11.5	13.9	15.3	13.4	12.2
5. Snout tip to pectoral flipper	29.2	28.1	30.0	28.5	27.6	27.0	28.9	24.7	27.8	26.3	25.2	27.3
6. Anterior length	—	17.1	17.6	17.2	17.1	17.2	18.4	18.4	18.2	18.2	18.4	20.7
7. Posterior length	—	11.7	12.3	12.0	11.8	11.7	13.1	12.6	11.5	11.9	12.6	13.3
8. Maximum width	4.6	6.0	6.1	6.0	5.5	5.8	6.3	6.0	5.7	6.3	6.3	6.3
9. Fluke notch—anus	30.7	25.7	30.7	28.5	28.9	29.4	30.5	32.1	28.3	29.7	31.9	31.9
10. Anus—genital slit	39.2	35.9	40.0	31.5	38.8	32.3	33.6	38.4	37.5	32.7	34.8	35.0
11. Genital slit—umbilicus	46.1	44.5	48.4	44.3	47.3	43.5	45.2	47.8	45.1	46.3	48.3	48.4
12. Fluke notch—dorsal fin	32.3	32.8	32.3	33.8	32.8	30.5	—	31.5	29.8	32.7	34.4	36.4
13. Width tip to tip fluke	20.7	24.2	27.6	27.4	23.0	24.7	—	28.4	23.0	26.8	26.4	—
14. Maximum width of fluke	7.6	7.4	8.4	8.6	7.8	7.0	—	—	7.6	7.6	7.9	—
15. Immediately behind pectoral flipper	29.2	31.2	31.5	26.3	27.6	28.8	—	27.8	25.0	26.3	23.5	25.2

Appendix 3

BODY MEASUREMENTS (AS A PERCENTAGE OF TOTAL LENGTH) OF GRAY WHALES TAKEN IN 1980

	Females			Males		
Measurements	n	M	Range	n	M	Range
1. Snout tip to centre of eye	47	19.0	16.6–20.1	17	18.5	17.0–19.8
2. Snout tip to angle of mouth	46	19.5	17.9–20.6	17	19.5	17.7–21.3
3. Snout tip to ear	43	22.9	20.3–24.7	16	23.1	22.0–24.6
4. Snout tip to centre of melon	44	17.0	15.3–18.5	15	16.8	15.4–18.5
5. Snout tip to pectoral	43	27.6	25.0–31.5	15	27.2	26.8–28.1
6. Anterior length	42	17.9	16.0–19.4	15	18.2	16.1–19.3
7. Posterior length	39	13.3	11.0–14.9	16	13.3	11.8–14.5
8. Maximum width	41	6.4	5.9–6.8	17	6.6	6.1–7.4
9. Fluke notch	39	28.8	21.3–31.2	12	28.6	25.4–29.7
10. Anus–genital slit	39	3.2	2.5–3.8	12	9.8	8.5–11.5
11. Genital slit—umbilicus	34	16.7	12.2–19.4	11	10.2	8.9–11.6
12. Fluke notch—dorsal fin	33	31.8	28.7–33.9	11	31.6	30.4–34.1
13. Width tip to tip fluke	37	24.5	22.3–26.8	14	25.7	23.4–27.2
14. Maximum width of fluke	41	7.8	6.9–8.7	15	8.0	7.2–9.2
15. Immediately behind pectoral flipper	32	29.9	22.8–33.7	12	28.4	27.4–29.6

The northern boundary of the black right whale in the North Pacific is unknown. Some authors (e.g. Sleptsov, 1955) took the northern boundary to be along the Kommander and Aleutian Islands. Townsend (1935) reported catches along the western Bering Sea coast as far as 60°N (to the south of Mys Olutorskiy) and Clunin (1900) noted catches between Ostrov Karaginsky and Zaliv Korf. TINRO research vessels have seen no right whales in these waters since 1956.

Our observations in recent years suggest that they are now mainly found in the southeast Bering Sea with a northerly limit in a line joining the islands of Atkha, St Matthew and Nunivak, and between the Pribilov Islands and Bristol Bay. The most northerly recent sighting is 58°30′N although it is possible that they reached as far as St Lawrence Island (Tomilin, 1957). Apart from in the southeast, neither researchers or whalers have seen this species in the Bering Sea in recent years.

The largest historical concentrations of this species were in the western Gulf of Alaska, particularly near Kodiak Island (Scammon, 1874; Townsend, 1935). In 1963 TINRO vessels observed about 200 right whales at 51°N, 145°W. Occasional solitary animals have been seen by TINRO vessels in the eastern part of the Gulf of Chichagov Island.

Pike (1954) reported on occasional catches of right whales off Vancouver and Charlotte Islands, probably migrating animals. In the southern part of their range off this coast they have been reported in Californian waters (Bonnot, 1929). Scammon (1874) reported some whales taken (from February to April) as far south as 29°N (Sebastian Viscaino Bay) and Rice and Fiscus (1968) reviewed occasional recent sightings off the west US coast and Baja California.

In the open ocean, right whales were taken near Hawaii (Reindgart, 1866 *in* Tomilin, 1957). In January 1964 right whales were seen by a TINRO research vessel at 40°N 157°W. The southern boundary thus appears to vary from about 29°N off the North American coast to 20°N near Hawaii and 25°N of the Asian coast (Tomilin, 1957).

CONCLUSION

The North Pacific black right whale is severely depleted and probably numbers only a few hundred animals (Berzin and Yablokov, 1978), despite its long period of protection. Unfortunately relatively little work is currently being directed at obtaining reliable direct information on the present status of this stock, e.g. surveys in areas of historical abundance.

The bowhead whale, as a consequence of the continuing aboriginal fishery in Alaska, and the management problems associated with it, is by contrast much better studied, at least in the waters off Alaska. However there is still the need for more basic biological data, and particularly for information on the species in other areas of the North Pacific.

REFERENCES

Berzin, A. A. and Doroshenko, N. V. 1981. Right whales of the Okhotsk Sea. *Rep. int. Whal. Commn* 31: 451–5.

Berzin, A. A. and Yablokov, A. V. 1978. Abundance and population structure of important cetacean species of the world oceans. *Zool. Zh.* 7(12) 1771–85. (In Russian).

Bogoslovskaya, L. S., Votrogov, L. M. and Krupnik, I. I. 1982. The bowhead whale off Chukotka: migrations and aboriginal whaling. Paper SC/33/PS16 (published in this volume).

Bonnot, P. 1929. The whales of California. *Calif. Fish. Game* 15: 204–15.

Braham, H. W., Fraker, M. A. and Krogman, B. D. 1980. Spring migration of the western Arctic population of bowhead whales. *Mar. Fish. Rev.* 42(9–10): 36–46.

Clunin, N. V. 1900. Okhotskq-Kamchatski Krai 1(2): SPB (In Russian).

Doroshenko, N. V. 1979. Materials on the distribution and numbers of Greenland whales in the western part of the Chukchi Sea (the voyage of the R/V *Avangard* in the autumn of 1979). pp. 45–9. In: *Research Work on Marine Mammals of the northern part of the Pacific Ocean in 1978–79.* Project 02.05–61 'Marine mammals'. The Soviet-American agreement on cooperation in the sphere of environmental protection. Moscow. (In Russian).

International Whaling Commission. 1980. Report of the sub-committee on protected species and aboriginal whaling. *Rep. int. Whal. Commn* 30: 103–11

International Whaling Commission. 1981. Report of the sub-committee on other protected species and aboriginal whaling. *Rep. int. Whal. Commn* 31: 133–9.

International Whaling Commission. 1982. Report of the sub-committee on protected species and aboriginal whaling (published in this volume).

Johnson, J. H., Braham, H. W., Krogman, B. D., Marquette, W. M., Sonntag, R. M. and Rugh, D. J. 1981. Bowhead whale research, June 1979–June 1980. *Rep. int. Whal. Commn* 31: 461–75.

Klumov, S. K. 1962. Right whales of the Pacific Ocean. *Tr. IOAN SSSR.* 58: 202–98. (In Russian).

Omura, H. 1958. North Pacific right whale. *Sci. Rep. Whales Res. Inst., Tokyo.* 13: 1–52.

Rice, D. W. and Fiscus, C. 1968. Right whales in the southeastern North Pacific *Norsk Hvalfangsttid.* 57(5): 105–7.

Scammon, C. M. 1874. *The Marine Mammals of the Northwestern Coast of North America.* John H. Carmany and Co., San Francisco, 319 pp.

Sleptsov, M. M. 1955. *Cetacea of the Soviet Far East Seas,* Vladivostok, 161pp.

Sleptsov, M. M. 1961. Distribution of feeding grounds and Cetacea in the Okhotsk Sea. *Tr. IMZH* 34: 79–92 (In Russian).

Tomilin, A. G. 1957. pp. 14–756. In: *Animals of the USSR and Adjacent Countries. Cetacea.* Vol. 9. Academy of Sciences, USSR. (In Russian).

Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American Whaleships. *Sci Contr. New York Zool. Soc., Zoologica* 19(1): 1–50.

SC/33/PS15

Distribution and Feeding of Gray Whales Off Chukotka in the Summer and Autumn of 1980

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ABSTRACT

The distribution of whales by whaling areas, the total number of whales registered and peculiarities of their groupings are characterized. Specific composition of food samples of whales by areas is given; areas of complex composition of dominating amphipod species are found.

INTRODUCTION

In 1980 we continued our observations on the distribution, behaviour and feeding of gray whales in the summer feeding areas off eastern Chukotka. As before, observations were made from the catcher boat *Zvezdny* during whaling operations on behalf of the native people of Chukotka.

DISTRIBUTION OF WHALES IN 1980

A map and a brief description of the whaling areas have been given earlier (Votrogov and Bogoslovskaya, 1980; Bogoslovskaya, Votrogov and Semenova, 1981). A brief description of each Division in 1980 is given below.

Divisions 1, 2, 2a

These were passed by the catcher boat in June on the way to the more northerly latitudes where whaling operations are carried out, hence the relatively few sightings. In the last week in June, 43 gray whales were seen. Information from cargo vessels arriving in the villages of Khatyrka and Mainypyl'gino and from the shore observations of local citizens showed that as in previous years, gray whales kept close to the shore in these areas until September.

Division 3

This was less frequented by whales in 1978–80 than in the past. Whales (55) occurred only in July and August, about 30% of them in groups. One whale was taken. When the *Zvezdny* returned through this Division in September–October no animals were seen.

Division 4

This has become more important for whaling as the years have passed. In summer large, stable concentrations of large whales gathered there, remaining until October. A total of 181 animals was observed, about 69% in groups and 20 whales were taken. Most of the whales were seen in July after which their numbers decreased gradually. In early October we only saw two individuals and whales had left Division 4 by the middle of October.

Experimental tracking of whales revealed that they remained in this Division for some time. They moved to the south during the day turning to the west in the evening and then turning back to the north again late in the evening or at night. When leaving the southeastern part of the Division they usually moved at 4.5 miles per hour towards Bukhta Provideniya. Animals moved between 300–400 m to 1.5–2 miles from the shore as though orientating themselves with the capes of Mys Beringa, Mys Achchen and Mys Jakun.

As in 1979 the behaviour of whales was rather complicated, (Bogoslovskaya *et al.*, 1981). The whales were often quiet and spent much time at the surface blowing eight-eleven times before thrusting themselves out of the water and diving and turning, displaying the flippers and the tail. Groups of three and more animals suddenly would be divided into pairs by individuals. The *Zvezdny* observed such behaviour for four hours, only 500 m from four whales who paid her no attention at all. The pairs separated to distances of 800–1,000 m from each other.

Division 5

This was not a whaling area and was rarely visited by the catcher boat. In the 1980 season only eight whales were seen, far from the shore, of which two were taken. Hunters from Sireniki and Nunligran report that in the summer they sometimes see groups of 20–30 young animals as well as older whales 'bathing' in the fresh water near the Achchen lagoon.

Division 6

This was not a whaling area either and was rarely visited by the catcher boat. When arriving in this area in summer 1980, a concentration of small gray whales was observed 500–700 m from the shore near the outflow of fresh water from the River Kurupka.

Division 7

This is a new and important whaling area where in 1980, 426 gray whales were seen, 53% in groups, of which 30 were taken. Gray whales appeared there and near Sireniki by about 10 May and remained until mid-December.

The animals which fed there were usually small (9–11 m) but sometimes larger animals were present. There were constant replacement of animals in the area and regular daily movements: in the morning whales came to about 500–1300 m from the shore, moving from Mys Stoletiya to Mys Lysaya Golova, entered the bay and then returned in the evening. The whales remain in this Division for some time then leave it, moving at about 4.5 m.p.h. from Mys Lysaya Golova to Mys Chukotka. In this area most of the animals fed intensively. To the west and to the east of the area all of the observed whales were moving and this probably explains their more careful behaviour compared with the feeding whales which were quiet despite the considerable number of vessels arriving in and leaving Bukhta Provideniya.

Divisions 8 and 8a
These Divisions were mainly visited by gray whales in July. Only single individuals were observed in August, September and October. There were no large concentrations here where they have been observed in previous years. In total, 41 whales were seen of which 60% were in groups. Two whales were taken.

Division 9
This Division has become one of the main whaling areas in contrast with its past. Of the 218 whales observed there, a little above 50% were in groups; 22 whales were taken. Whales remained mainly in the north. When followed they escaped eastwards and south-eastwards. Animals of all sizes were present but whales of 12 m and longer predominated.

Division 10
This Division is very shallow with water not more than 15–35 m in depth. The weather conditions were very favourable as it is protected from winds and storms from the northeast, north, west and southwest. It had concentrations of walruses and small whales of nine–ten meters long, although larger animals sometimes came to the eastern and southern boundaries of the area. Whales fed actively and were peaceful, visiting the area from July to September. Of the 211 whales seen, 55% were in groups; 10 animals were taken.

Division 10/11
This Division was the transitional area between two important sectors. Of the 38 animals seen, 24 were in groups; two animals were taken. Whales were observed only in July and August.

Division 12/13
This Division was important as a whaling area this year. In August–October 109 whales were registered, about 60% in groups and 22 whales were taken. In September–October this area was suitable for whaling because like Division 10, it was protected by the coast from the northern winds predominant at that time of the year.

Division 11
This Division was visited more often by whales this year than last year. Of the 241 animals seen, about 60% were in groups; 24 animals were taken. The size of whale varied from 11.5 m to 13 m; no very small whales were observed and these probably gathered in Division 10. There were not very many whales there in summer but in October 133 whales were seen, having probably arrived from the Chukchi Sea. In late autumn the whales were as peaceful as in the summer thus enabling successful whaling despite the rough sea.

Division 11/12
This Division has been only occasionally visited in recent years because the whaling operations have been concentrated near to the villages. In October 1980, 220 animals were seen of which 63% were in groups; 3 animals were taken. This was an area of active feeding, where whales 'walked' well, i.e. dived for no more than two–three minutes.

Division 12
A small part of this area is an extremely important summer feeding ground for gray whales and most of that part of the stock which fed in the Bering Sea concentrated in this area. The whales migrated from this area to Mechigmanskiy Zaliv, then to the north into the Chukchi Sea and to the coasts of Alaska. In September–October 1980, 60 animals were sighted, of which 30% were in groups and nine were taken. Mainly larger animals were found there but young animals were quite common in this area. In previous years (apart from 1979) the western region of the area was a place where whales of different sizes congregated in summer (Votrogov and Bogoslovskaya, 1980)—from 200 to 400 animals could be seen at once.

Division 13
This Division was visited often by whales in previous years. In July–September 1980 only 40 whales were observed of which 50% were in groups and seven were taken.

Division 13/14
This Division was usually passed without any searching, whaling operations being carried out in other sectors. In July–August 21 animals were observed of which 50% were in groups and three were taken.

Division 14
In June–September 184 whales were observed, of which about 60% were in groups and 11 were taken. In October the *Zvezdny* only rarely passed this Division due to the strong northerly and northeasterly winds, but according to the available information whales were still there.

During all whaling seasons, including 1980, in summer and autumn large concentrations of gray whales suddenly appear in this Division as they do in Division 4, particularly near Mys Sery and Mys Litke. Although whales of varying sizes gathered close to the shore, animals of 10–10.5 m long dominated. Very large animals occurred five–ten miles to the east of the capes. Whales usually fed actively where they congregated. Sometimes the area became so deserted that searching throughout the day only resulted in one or two animals.

Division 16
Several whales were observed quite close to Mys Dezhneva and Uelen village this year.

Division 17
Of the 58 whales observed between June and September, 50% were in groups and seven animals were taken. Two whales were seen moving along the shore in the surf to the south of this Division.

Division 18
In July–August 1980, 47 whales were sighted, 60% in groups and three whales were taken.

Divisions 15, 20, 21
These Divisions were not visited by the *Zvezdny* in 1980. In the early 1970's we often studied these areas and constantly observed whales there.

At present, since the villages of Neshkan and Enurmino receive no whaling service, the searching time of the catcher boat in the Chukchi Sea has considerably decreased and we have visited these sectors very rarely. According to information received from hydrographic and research vessels *Avangard* and *Razayashi* (N. V. Doroshenko, pers. comm.) there was a considerable concentration of gray whales to the north of these areas which then went down to the Chukchi Sea and moved through the Bering Straits in autumn.

SOCIAL STRUCTURE

As shown in Table 1 over 45% were single animals, over 30% were pairs, about 15% were in groups of three, 7% in groups of four and only 2% and 1% in groups of five and six respectively.

The sex composition of the groups varied considerably: some pairs comprised a female and a male, others two females; two females and a male might constitute a group of three whales; in one case two whales were taken from a group of five animals and both were males.

Similarly the degree of attachment among the whales in groups varied. It was reasonably common for a second animal not to leave a harpooned one, and more often it was a male that did not leave a female. However, we did observe situations where a female would not leave another female. In 1979 during whaling operations in Division 14 we observed a whale which approached an attached whale, trying to hold it at the surface by putting his tail and head under it. Although it was thought to be a male it was later found that both these large animals were pregnant females. Sometimes two whales approached the third one that had been taken: on 7 September 1980, during whaling for three whales in Division 11, an 11.4 m male was taken; two females (13.4 m and 13 m) approached him. On 28 July a 12 m females was taken; the other two animals approached the female but seeing that she was dead turned and left rapidly.

Groups of more than three animals were usually not stable and easily dispersed during whaling or when being followed or driven. Thus, on 4 July the *Zvezdny* followed six whales; a 12.8 m female was taken; four of the whales left just after the shot but one whale approached the female and stayed beside her until she died.

According to our observations most of the single animals were females. Males occurred mainly in groups. Only about 20% of observed males in 1979–80 were single. The whaling data collected over the years gives the impression that females and young animals predominate near the Chukotkan coast and that males only appear in small numbers now and then.

FEEDING HABITS OF GRAY WHALES

As in 1979, food samples were taken alongside the catcher boat. The weight of the 132 samples collected varied from 22 kg to 200–300 g. The percentage composition of invertebrate species by weight was obtained. Species with an individual weight of less than 1% were considered as single. Species were identified according to Barnard (1969)

Table 1

Number of whales occurred and taken by whaling areas in 1980

	No. of individuals in the group						No. of whales occurring						
	1	2	3	4	5	6	VI	VII	VIII	IX	X	Total for the season	Taken during the season
	No. of groups						months						
1	10						10					10	
2	6	5	3			1	31					31	
2A		1					2					2	
3	38	5	1	1				42	12			55	1
4	74	30	7	4	2			118	46	14	3	181	20
5		1	1	1				6				6	2
6	9									9		9	0
7	239	60	15	4		1		39	119	205	63	426	30
8	2	1		1				5	3			8	1
8A	10	6			1	1		32		1		33	1
9	107	34	7	3	2			39	101	65	13	218	22
10	95	44	5	2	1			83	114	14		211	10
10/11	11	4	3		1			20	12	1		33	2
10/13	43	23	4	2					55	24	30	109	22
11	92	40	15	6				52	20	36	133	241	24
11/12	82	23	22	10							234	234	3
12	41	7	3					4		28	32	64	9
13	21	3	3	1				24	6	6	4	40	7
13/14	9	4	1						3	17		20	3
14	84	36	8	1			21	51	17	95		184	11
17	29	13	1				36	17		5		58	7
18	19	3	1	2	1	1		9	34	4		47	3
Total	1,021	343	99	38	8	4	100	542	542	524	512	2,220	179

Table 2

Characteristics of samples of stomach content of gray whales in June–October 1980

Area	No of samples	Date	Depth of feeding	Species in samples
3	1	28.VII	28 m	*P. femorata*—96%, *A. nugax*—1%; Polychaeta—3%; Algae
4	16	5.VII–26.VIII	37–54 m	*P. femorata*—98%, *A. nugax*—1%; *Rare: B. gaimardi, P. grandimana*; Polychaeta, Gastropoda, Bivalvia, Macrura; Algae
5	1	16.VII	44 m	*P. femorata*—100%
7	19	20.VIII–28.X	20–51 m	*P. femorata*—50–90%, *N. brueggeni*—4–30%, *A. nugax*—up single to 5–10%; *Rare: B. gaimardi, P. sinuata, E. cuspidatus, P. grandimana;* Hydroidea, Polychaeta, Gastropoda, Mysidacea, *E. gaimardi, H. coarctatus,* Holothurioidea, Ascidiacea, Synascidia; Algae
9	22	18.VII–3.X	15–64 m	*P. femorata*—up to 95%, *N. brueogeni*—up single to 100%, *B. gaimardi*—5–10%, *A. macrocephala*—up to 5%, *A. nugax*—up single to 3%; *Rare: Anonyx* sp., Lysianassidae g. sp., *S. inflatus, A. eschrichti, Ischyrocerus* sp.; *Sertularia* sp., Polychaeta, Gastropoda, Trochidae, *E. gaimardi, H. coarctatus,* Holothurioidea, Synascidia; Algae—up to 19%
10	6	2.VII–24.IX	17–32 m	*N. brueggeni*—84–99%, *P. femorata*—up single to 85%, *A. macrocephala*—3%, *B. gaimardi*—3%, *Rare: A. nugax, A. eschrichti,* Ampeliscidae g. sp.; Brachyura, Holothurioidea; Algae—up to 10%
10/11	2	25.VIII–28.VIII	31–45 m	*P. femorata*—60–99%; *Rare: A nugax, B. gaimardi, Nototropis* sp.; *Gastropoda*; Algae—up to 35%
10/13	17	2.VII–27.X	30–35 m	*P. femorata*—60–98%, *A. macrocephala*—10–25, *B. gaimardi*—up single to 10%; *Rare: A. nugax,* Lysianassidae g. sp., *M. diamesus, Nototropis* sp., *L. arcticus, P. grandimana, I. pachtusovi, Ischyrocerus* sp., *D. spinosissima,* Corophiidae g. sp.; Polychaeta, Polynoidae, Edwardsidae, Buccinidae, *H. coarctatus,* Holothurioidea; Algae
11	18	9.VII–26.X	31–45 m	*A. macrocephala*—65–80%, *A. eschrichti*—up single to 80%, H. laevis—40–60%, *P. femorata*—up single to 90%, *A. nugax*—25%, *L. acticus*—2%; *Rare: S. inflatus, B. gaimardi, H. sibirica. R. aculeata;* Polychaeta, Gastropoda, *H. coarctatus;* Algae
11/12	2	9.X	41 m	*A. macrocephala*—65%, *B. gaimardi*—30%, *H. sibirica*—10–30%; *Rare: A. nugax, A. eschrichti, Pontoporeia* sp., *L. arcticus*; Polychaeta, Gastropoda, *H. coarctatus;* Algae
12	5	21.VII–9.X	41–46 m	*A. macrocephala*—60–90%, *B. gaimardi*— 20–30%, *H. sibirica*—10%, *H. laevis*—1–3%, *L. arcticus*—3%, *A. nugax*—2%; *Rare: S. inflatus, A. eschrichti;* Actiniaria, Maldanidae, Neptunea, *Sipho* sp., Macrura, Brachyura, *Pelonaia corruyata*
13	8	18.VII–4.X	20–35 m	*P. femorata*—2–70–90%, *A. macrocephala*—20–60%, *L. arcticus*—25%, *A. nugax*—15%; *B. gaimardi*—2–3%, *A. eschrichti*—2%; *Rare: H. sibirica, P. grandimana;* Hydroidea, Polychaeta, Gastropoda, Macrura, *H. coarctatus,* Asteroidea, Holothurioidea, Ascidiacea; Algae
13/14	2	22.VII–7.VIII	35–38 m	*A. macrocephala*—66%, *A. nugax*—30%, *B. gaimardi*—2%; *L. arcticus*—1%; *Rare: P. femorata;* Algae
14	8	29.VI–16.IX	35–45 m	*A. macrocephala*—65–95%, *A. nugax*—10–60%, *B. gaimardi*—10–40%, *L. arcticus* (?)—15%; *Rare: P. femorata, I. pachtusovi* (?); Polychaeta, *H. coarctatus,* Holothurioidea; Algae
17	2	12.VII	42 m	*A. macrocephala*—45–88%, *A. nugax*—10–50%, *A. eschrichti*—3%; *Rare: B. gaimardi,* 1 *I. latipes;* Algae
18	2	18.VII	45–46 m	*A. macrocephala*—60%, *A. eschrichti*—38%, *Rare: Anonyx sp., B. gaimardi, P. femorata, A. nugax, L. arcticus, Ischyrocerus* sp.

and Gur'yanova (1951). Preliminary results of studies of test samples are given in Table 2. The distribution of the main food species by Division 5 is shown in Tables 3 and 4.

We plan to devote a special paper to the feeding habits of gray whales when the species composition of samples has been completed and we confine ourselves to only a few notes here. Differences in the predominant benthic amphipod species in the southern and northern whaling areas suggested last year and confirmed by this year's study, has enabled us to study migration. For example, on 18 September food sample N 127 in Division 18 consisted of two portions: highly digested remnants of *Pontoporeia femorata* and fresh individuals of *Ampelisca macrocephala* and *A. eschrichti*. This revealed that the whales had fed in Division 13 or further south not long ago.

It is now evident that whales migrate constantly from the south of the north and back, but it is not clear whether these migrations are connected with the difference in food species or by a more general regularity due to the structure of the stock. Individual marking of animals may help us to answer this and other questions arising from our observations on the behaviour of gray whales.

REFERENCES

Barnard, J. L. 1969. The families and genera of marine gammardiean Amphipoda. *Bull. U.S. Nat. Mus.*, 271: 1–535.

Bogoslovskaya, L. S., Votrogov, L. M. and Semenova, T. N. 1981. Feeding habits of gray whale off the Chukotka peninsula. *Rep. int. Whal. Commn* 31: 507–10.

Gur'yanova, E. F. 1951. *Amphipoda of the seas of the USSR and the adjacent waters.* M.-L., Akad. Sci. USSR (in Russian), 1,032pp.

Votrogov, L. M. and Bogoslovskaya, L. S. 1980. Gray whales off the Chukotka peninsula. *Rep. int. Whal. Commn* 30: 435–7.

Table 3

Distribution of the amphipods in areas in June–October 1979–80

Species	Divisions
1. *Anonyx nugax*	all Divisions: in 11—25%, 13—15%, 13/14—30%, 14—60%, 17—50%, in the others—
2. *Anonyx sp.*	9,18—rare
3. *Lysianassidae g. spp.*	9, 10/13—rare
4. *Stegocephalus inflatus*	9, 11, 12—rare
5. *Ampelisca macrocephala*	8, 10—3–5%, 10/13—25%, 11, 11/12, 12, 13, 13/14—65–80%, 14, 17, 18, 19—45–95%
6. *Ampelisca eschrichti*	9, 10, 11/12, 12, 13, I7—1–3%; II—up single to 80%; 18—38%
7. *Ampeliscidae g. sp.*	10—rare
8. *Byblis gaimardi*	4, 7, 8, 9, 10, 10/11, 10/13, 11, 13, 13/I4, 17, 18, 19—up single to 3–10%; 11/12, 12—20–30%; 14—10–40%
9. *Haploops sibirica*	11, 13—1–3%; 11/12, 12—10–30%
10. *Haploops laevis*	11—40–60%; 12—1–3%
11. *Haploops sp.*	14
12. *Pontoporeia femorata*	all Divisions: in 3–8, 9, 10, 10/11, 10/13, 12—50–100%; 8a–10%; 11—up single to 90%; in the others—rare
13. *Pontoporeia sinuata*	7—rare
14. *Pontoporeia sp.*	11/12—rare
15. *Arrhis luethkei*	8—rare
16. *Monoculodes diamesus*	10/13—rare
17. *Nototropis (=Atylus) brueggeni*	7–10—up single to 100%; 13—rare
18. *Nototropis atlasovi (?)*	8a—rare
19. *Nototropis sp.*	10/11, 10/13, 11/12—rare
20. *Rachotropis aculaeata*	11—rare
21. *Eusirus cuspidatus*	7—rare
22. *Anisogammarus (Spinulogammerus) subcarinatus*	8a, 9—rare
23. *Lembos arcticus*	10, 10/13, 11, 11/12, 12, 13/14, 17, 18—up single to 1–4%; 13, 14—10–25%
24. *Protomedeia grandimana*	4, 7, 10/13, 13—rare
25. *Ischyrocerus pachtusovi*	7/8, 9, 10/13, 14—rare
26. *Ischyrocerus latipes*	17, 18—rare
27. *Ischyrocerus sp.*	8a, 9, 10, 10/13, 18—rare
28. *Dulichia spinosissima*	10/13—rare
29. *Corophiidae g. sp.*	10/13, 19—rare
30. *s/o Caprellidea*	8a—rare

Table 4

Distribution of the other invertebrates in areas in June–October 1979–80

1. Hydroidea—7, 8a, 9 (Sertularia sp.), 13.
2. Actiniaria—10/13 (Edwardsiidae), 12.
3. Polychaeta—3, 4, 7, 7/8, 8a, 9, 10, 10/13, 11, 11/12, 13, 14—different tubes; 10/13—Polynoidae; 12—Maldanidae, Sedentaria.
4. Gastropoda (eggs, opercula, shell fragments)—4, 8a, 9 (Troichidae), 0, 10/11, 11, 11/12, 12 (Neptunea), 13; Buccinidae—7, 10/13, 11/12, 12 (Sipho sp.).
5. Bivalvia—4, 9 (Mytilidae).
6. Isopoda— 8a (Sphaeromidae).
7. Mysidacea—7.
8. Macrura—4, 7, 7/8, 8, 8a, 9—*Eualus gaimardi;* 4, 12, 13—g. sp.
9. Brachyura—7, 8, 9, 10, 10/13, 11, 11/12, 12, 13, 13/14, 14—*Hyas coarctatus;* 10, 12—g. sp.
10. Asteroidea—13.
11. Holothurioidea—7, 8, 9, 10, 10/13, 13, 14.
12. Ascidiacea—7, 8a, 10, 12 (*Pelonaia corruyata*), 13; 7, 9—*Synascidia*.

SC/33/PS16

The Bowhead Whale Off Chukotka: Migrations and Aboriginal Whaling

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INTRODUCTION

Bowhead whaling represents a peak in the development of the maritime culture of the Asiatic Eskimos and maritime Chukchis of Chukotka. For thousands of years the native hunters have successfully taken these animals using large walrus-skin boats and toggle-head harpoons made from bone and stone. During the long history of aboriginal whaling the local inhabitants inevitably gathered much information on the behaviour and migration paths of the whales. It is not an accident that all the main present and historic settlements of eastern Chukotka are in areas where the whales come close to the shore during their spring and autumn migrations. This paper is based not only on the available literature and our own data but also to a great extent on data provided by the native people of Chukotka who are predominantly hereditary sea hunters (see Acknowledgements).

Our own personal observations cover the period from mid-June to early November, 1969–80. In addition, in April 1980 (the traditional time of the seal and walrus hunt), two of the authors together with some Eskimos used a walrus-skin boat to examine the area off Sireniki.

Fig. 1 shows the positions of bowhead whale sightings in the East-Siberian, Chukchi and Bering Seas for 1970–79.

MIGRATIONS AND AREAS OF SUMMER AND WINTER HABITATS

The autumn and spring bowhead migrations off eastern Chukotka are equally well known but differ in both route and duration.

Spring migration

The spring migration along the coast of the northern Anadyr Gulf, the north-western Bering Sea and the Bering Straits is regularly observed by citizens of many villages from the Kresta Gulf to Mys Paak where Naukan, one of the centres of Eskimo whaling was situated before 1958. Whales move along this route for about two months from mid-April to late May–early June. The peak of the migration near the largest Eskimo whaling village, Sireniki, is usually between mid-April and early May.

The area from Sireniki to Zaliv Kresta is the third separate area from which migrations of whales wintering in the Sirenikovskaya polynya begins (Bogoslovskaya and Votrogov, 1981). The bulk of the Chukotka-Bering Sea population concentrates in the other two areas; off Southeast Cape and Southwest Cape, St Lawrence Island (Braham, Fraker and Krogman, 1980a). Many individuals from this population migrate along the coast of Chukotka evidently mixing with whales from the Sirenikovskaya polynya. There are probably other routes from the southern distribution of this population, as suggested by a sighting of three whales near Khatirka on 6 May 1979 (Fedoseev, 1979).

Many of the migrating animals come to within 100–200 m of the shore at definite points on the coast where they are available for observations and counts. It is in these places that the large whaling villages first appeared (e.g. Nunligran, Sireniki, Ungazik or Staroe Chaplino and Naukan).

Braham *et al.* (1980a) [and others] state that from the Bering Straits bowhead whales turn to the east to Alaska and then along the north Alaskan coast in the narrow passage of clear water between shore ice and pack ice. They believe that the usually complete ice cover north of Chukotka and the statement by Tomilin (1957) that no bowheads were hunted by Eskimos on the north Chukotkan coast means that it is unlikely that bowhead whales move northwestward into the western Chukchi Sea west of 169°30′W, in the spring, although they noted that some 'Eskimo whalers' (presumably Alaskan) suggested that a segment of the population did do this. However bowhead whales are quite regularly observed from Inchoun village (170°W) in early May and in May 1980 'very many whales' were reported by the villagers to be moving to the northwest in leads between the shore and pack ice (about 2–3 km from shore).

A comparison of spring hunting dates for villages in eastern Chukotka (see below) with those for St Lawrence Island and Alaska shows that the duration of the migration along the Chukotka coast is longer (up to early June) than on the American side. There the whales are found in the Bering Straits in late March–early April, appearing at Point Barrow in late April or early May (depending on ice conditions) and by mid-May some are already being seen in the Canadian Arctic near the mouth of the Mackenzie River and Banks Island (Braham and Krogman, 1977).

Bowhead whales are believed to migrate in 'waves' or 'pulses' (Braham *et al.*, 1980a) and according to Eskimo log-books for 1978, 'pulses' or migration peaks occurred near

Gambell (St Lawrence Island) between 14–21 April and 2 May near Point Hope between 1–3 May and Point Barrow from 29 April–2 May, these peaks may have been part of the same pulse (Braham *et al.*, 1980c). In the same year 'many' bowhead whales arrived at Sireniki on 25 May, one month later than at Gambell. Therefore the census of whales passing Point Barrow carried out between 15 April–30 May in 1978 (and which is considered to have provided the best estimate of the population size since the USA census programme began (IWC, 1982)), did not cover the total population; similar counts at Sireniki and other points along the coast of Chukotka would need to be added.

There are thought to be 2–3 migration waves (Braham and Krogman, 1977; Marquette, 1977), the first two comprising younger animals and the third comprising older animals and calves. Although calves were observed throughout the 1978 US census, Braham *et al.* (1980a) believe that as the hypothesis of sex-age segregation is so widely contended by Alaskan Eskimos, it probably has some basis in fact. Off Sireniki where we have most information and where animals are seen up to late May, the migration does appear to be intermittent, although segregation cannot clearly be shown. On 16 May 1979 A. Ankalyn observed a female with a calf 'the size of a large white whale'. Other hunters from Sireniki and Nunligran have seen females with calves in May in several years but all agreed that the greatest number of calves came in late March–early April; apparently showing the opposite trend to that thought to be found in Alaska. Further observations are clearly needed before sex-age segregation is confirmed or denied.

Autumn migration

The autumn migration begins towards the end of August and covers a much greater part of the Asiatic coast than the spring migration.

The most westerly coastal area approached by bowhead whales at the end of summer known to us at present is the area near Ostrov Ayon in the East Siberian Sea, although whales are not regularly observed there from the shore. In August 1976 local inhabitants saw two whales in open sea about 600–800 m from the shore. In the summer of the same year a dead bowhead calf was found on an ice block in the Malyy Chaunskiy Proliv.

Whales often arrive at Billings at the end of summer. More than once local inhabitants observed groups of whales varying in size from two-three to ten animals. In autumn 1977 a dead adult bowhead whale was found near the village.

Whales appear quite regularly in late August and early September near Mys Schmidta, according to local people. About 60 whales were observed there in pancake ice in the first half of October in 1970 (Fedoseev and Goltsev, 1975).

Neither the inhabitants of Wrangel Island or the scientists who work in the polar station and the sanctuary there have ever observed bowhead whales, but N. Galgaugwui, an Eskimo from Sireniki who lived on the northeastern coast of the island in 1971 and 1972 and who is familiar with bowhead whales, reported seeing some in the second half of October. This agrees with a report by Doroshenko (1979) who saw 12 bowhead whales between Wrangel and Herald Islands in October, 1979.

Bowhead whales are regularly seen to the west of Mys Vankarem in late summer and autumn. In the first half of October 1970, about 60 whales were seen near Mys Vankarem and similar numbers near Neshkan and Ostrov Idlydlya (Fedoseev and Goltsev, 1975). In August 1973 we observed a group of 20 large animals from the catcher boat *Zvezdny* to the west of the Mys Serdtse-Kamen'.

Bowhead whales are usually seen near to the coast in late October and particularly in early November, between Mys Serdtse-Kamen' and Uelen. This was a whaling area in the past and Uelen was the main hunting settlement. At the same time of year, large numbers of bowhead whales are seen along the Bering Strait and northwestern Bering Sea coasts from Naukan to Zaliv Kresta; an area where they are also seen during the spring migration.

It is interesting to note that in the autumn bowhead whales approach Ostrov Arakamchechen and enter Proliv Senyavina and the narrow channels which separate the islands. In November 1976, E. Paulin watched six–seven whales break fresh ice with their backs in the Straits, to the south of a small island, Ostrov Kynkai. Experienced hunters report that at one time bowhead whales entered Bukhta Providenya.

The autumn migration can be clearly observed from the Sireniki area and its vicinity, most of the animals arriving in the first half of November. At present the autumn migration thus begins around the end of August along the Chukchi Sea coast. There is very little information on the whales seen near Ostrov Ayon and Billings, e.g. whether they are feeding or breeding, or even if they belong to the Bering Sea Stock. As far as the more easterly points of the coast are concerned, whales commonly appear near Mys Vankarem towards late summer and early autumn. The easterly movement to the Bering Straits becomes more apparent from Mys Serdtse-Kamen' eastwards, especially near Inchoun and Uelen. From there southwards the autumn migration of whales is quicker than the spring. Although the influence of the wind, snow and temperature is less, migration is strongly connected with the arrival of the ice, and the exact timing varies from year to year depending on the ice conditions.

In some years large numbers of whales are found simultaneously near Uelen and Sireniki. For example, in 1977 the peak in whales passing Uelen was from 4 to 12 November while large numbers passed Sireniki throughout the first half of November and especially between 7 and 10 November. The migration speed of bowhead whales (Braham *et al.*, 1979) is such that only a small number of the 'Uelen' whales could have reached Sireniki within this time. A second migration wave reached Sireniki towards the end of November, and it seems likely that these were the 'Uelen' whales. One explanation is that there may be several northern areas which are the source for the autumn migration in the same way that there are three southern areas for the spring migration as discussed in the earlier section. Another is that this may be the result of either sex or age segregation.

Autumn and spring migration routes along the Chukotka coast in the Bering Straits and the northwestern Bering Sea therefore coincide although it is possible that these routes may be used by different subpopulations at different times of the year.

Summer areas

The 'Yankee' commercial whalers found that the best time for taking bowhead whales in the northern Bering Sea, the southern Chukchi Sea, the eastern Beaufort Sea and off Banks Island was July–September (Townsend, 1935). This and the late spring migration of some bowheads along

Table 1

Recorded observations of bowheads from villages, 1977–80.
The first figure represents the date, the figure in brackets the number of whales and other information.

Village	1977[1]	1978	1979	1980
Billings	Several times, groups of 2–3 whales appeared.	3 whales seen by end of *August*.		
Mys Schmidta	*Sept.*: 3rd (50 whales).			
Uelen and Inchoun	*Nov.*: 4–12, (many whales moving toward Bering Straits) on 12, ice appeared, movement stopped.	*Nov.*: early, rapid movement of whales as ice approached quickly.	*Oct.*: 12, early ice (2–3 whales); 20, ice driven offshore and 50 whales seen. *Nov.*: First half, main movements of whales.	*May*: early, 'many' whales passed Inchoun moving north in clear waters and polynyas, the pack ice.
Sireniki (incl. Imtuk, Angytykuk, and Kurupka)[2]	*Oct.*: 29 (3 whales, first of autumn). *Nov.*: 2 (3); 7 (very many); 10 (4 near shore, 'too many to count' offshore); 12 (1); 13 (2); 14 (2); 23 (5); 25 (~20); 26 (5–6); 27 (2); 29 (~5); 30 (3). *Dec.*: 1 (11); 2 (2 in morning, then 'very many'); 5 (1); 7 (0); 8 (2); 9 (4); 10–12 (0); 13 (2); 18 (5).	*Jan.*: 4 (1); 5–8 (0, storm): 9 (1); 10 (1); 11 (1); 15 (1) 17 (0). *Feb.*: 10 (1); 18 (0). *Mar.*: Observations not recorded. *Apr.*[3]: 3(1); 10(1); 20(1); 24(0). *May*: 3 (0); 7 (0); 15 (0); 17 (0); 18 (1); 20 (0); 25 ('so many whales, difficult for boats to avoid touching them'). *Nov.*: 2 (1); 15 (3); 21 (2); 22 (1); 25 ('several'); 25–27 (0, bad weather).	*May*: Early (many); 10 (several[4]); 11 (3); 12 (1); 14 (1); 15 (2[5]); 16 (2[6]); 17–19 (0, storm); 29 (0[7]); 30 (0). *June*: 1 (0). *Sept.*: Early (1). *Nov.*: 13–18 (0, storm); 19–23 (0); 24–30 (0, bad weather). *Dec.*: 1 (0); 4 (0); 5–7 (0, bad weather; 8 (1); 9–12 (0).	*Mar.*: 31 (2[5]). *Apr.*: 1 (2[8]); 4 (2); 5 (2[5]); 7 (1 calf); 10 (5); 12–14 (~30, see text); 15–26 (0). *Nov.*: Early (some whales); 12–12 *Dec.* (so many difficult for 1 observer to count).

[1] After late August. [2] Mainly recorded observations of A. Ankalyn; in winter from shore, in spring and autumn from a boat under good conditions.
[3] All 1 yr old animals. [4] Also some gray whales. [5] Including 1 calf. [6] Including calf 'size of large white whale'.
[7] Including one humpback whale. [8] Including 5 m calf.

The possibility of some whales feeding in the Chukchi and east Siberian Seas should be considered, taking into account the discussion in an earlier section of the possibility of some whales moving west after passing the Bering Straits and the observations of whales near Ostrov Ayon in August 1976. In the middle of the 19th century bowhead whales appeared annually off Mys Shelagskiy and even off Mys Bolshoy Baranov (Argentov, 1857). By the 1920s only occasional whales reached even Mys Yakan (Shnakenburg, 1933). This suggests that the range of the Chukotka-Bering Sea population was much greater in the past or even that it joined with another bowhead population from the east-Siberian Sea (although this latter supposition requires much more evidence, there is some background information to support it). Thus, in addition to the whales seen near the east Siberian Sea coast in summer, the possibility of the existence of large areas of ice-free water in winter, containing whales, for example near Ostrova Novosibirskiye and the Great Siberian Polynya should be at least considered.

Winter areas

In the waters off the southern coast of Chukotka near Sireniki, Nunligran, Enmelen and as far as the Kresta Gulf, bowhead whales occur regularly not only during the autumn migration but throughout the winter in the vast Sirenikovskaya Polynya. This polynya can be seen clearly in the satellite photograph in Braham *et al.* (1980a, Fig. 2).

Near the Sirenikovskaya polynya there is a larger one extending south-southeastwards to St Lawrence island. They are divided by a narrow dam of broken or fresh ice which is not a serious barrier for adult bowhead whales. These polynyas make it possible for the bowhead whales to remain in this area of the Bering Sea throughout the winter. In winter the Sirenikovskaya polynya and other smaller ones off the eastern Chukotka coast support large concentrations of marine mammals and birds (Bogoslovskaya and Votrogov, 1981).

In April 1980 we made an aerial observation of the Sirenikovskaya polynya and later investigated part of it using walrus-skin boats during the seal and walrus hunt. It turned out that the polynya was the wintering ground of a small population of bowhead whales and local Eskimos reported that calving occurred there. The hunters from Nunligran and Sireniki begin to see calves the size of 'two walruses' from late March and early April. The first calf was seen in 1981 near Sireniki on 16 March.

The following is a typical account of the initial stages of the spring migration. On 12 April 1980 at eight in the morning a group of seven adult whales with calves approached the village. One of the calves in the group remained alone, swimming and breaching until 2.00 p.m. when it entered Bukhta Providenya. By 5.00 p.m. there were 30 whales in the group (adults and calves) despite a strong northeasterly wind. Almost all the whales breached at one time during the day. The group 'stayed'[1] opposite Sireniki until 14 April then all the animals went towards Bukhta Providenya, i.e. along their migration route. After 14 April no whales were seen but in May hunters observed females with calves again.

Whales moved in the polynya in accordance with ice movements, sometimes gathering in specific places, e.g. in a shallow area near the ancient settlement of Angytykuk not far from Sireniki, where pairs of whales 'played' only 100–200 m from the shore. A. Ankalyn has seen whales there breaching and 'staying'[1]. Eskimos report that they have not heard the whistle of bowhead whales near Angytykuk.

INFORMATION ON BOWHEAD WHALES IN CHUKOTKA WATERS, 1977–80

To create a clearer picture of the seasonal distribution of bowhead whales in Chukotka waters, a brief summary of the available information from summer 1977 to the end of December 1981 is given in Table 1. Although the data are clearly incomplete they do give some idea of whale movements and show the importance of using certain points along the coast for observations and counts of bowhead whales.

OBSERVATION PROGRAMME FOR BOWHEADS

We have only included registered data received from the villages. Unfortunately much of the Chukchi Sea and Proliv Longa coasts and most of the coast from Bukhta Providenya to Uelen fell outside the view of the sea hunters. Many of the ancient whaling villages on the Bering Sea capes no longer exist and it is difficult to observe whales from the new villages which are on this coast, e.g. Novoe Chaplino, Providenya and Lavrentiya, as they are situated in bays which do not become free of ice until later or else are far from bowhead migration routes, e.g. Yanrakynnot and Lorino.

If a comprehensive observation programme is to be set up for the bowhead whale then it must clearly be based upon sites where whales are easily seen from the shore—which, as we have already mentioned, was a major factor in the original siting of Eskimo and Chukchi villages. An account of some potential sites is given below.

Sireniki village and the area of the Sirenikovskaya polynya

We have already seen that these are important and promising points for the study of both the spring and autumn migration of whales and their wintering and breeding.

Mys Chaplino

Oceanographic data (Coachman *et al.*, 1975) and observations of the native population suggest that the spring migration routes from St Lawrence Island and from Sirenikovskaya polynya meet near Mys Chaplino. The autumn migration is also known to pass Mys Chaplino—Eskimo hunters from the old village of Ungazik took whales twice a year. During commercial bowhead operations this was a favoured spot on the Asiatic coast of the Bering Sea.

Mys Paak

This is an extremely interesting point from which to examine the spring and autumn migrations. It appears to be near here that the spring migration path splits into two: the vast majority of whales moving northeastwards to Alaska, with the possibility of a smaller group moving to the southeastern part of the Chukchi Sea and certainly reaching at least Inchoun according to data from the hunters.

Mys Kygynin

This is another important cape for the waters near Ostrov Arakamchechen and Ostrov Ittygran. It was both an important habitat for bowhead whales and situated on the migration route, and was the centre of an active aboriginal fishery until the middle of the 19th century.

Uelen and Inchoun

These are excellent vantage points from which to view the autumn migration. In addition it is very important to collect further data on the spring migration to determine the extent of the possible split in the migration route.

ABORIGINAL WHALING FOR BOWHEAD WHALES

Bowhead whales have been taken by natives of Chukotka for at least two thousand years. There is considerable evidence of an active whale hunting culture in remains of settlements dating back to the first centuries A.D. (Rudenko, 1947; Arutyunov and Sergeev, 1969).

By the beginning of the second millenium A.D., bowhead whaling formed the basis of the aboriginal maritime culture on Chukotka. This is confirmed by numerous archaeological findings including the greatest Eskimo memorial found to date, constructed from the bones of some tens of bowhead whales, discovered recently on the Senyavin Strait Islands (Arutyunov, Krupnik and Chlenov, 1979; 1981).

From the type of whaling gear found, from rock paintings and from written accounts in the 18th and 19th centuries, it appears that bowhead whales were always taken in the open sea using multi-seater skin boats (baidars or umiaks) equipped with paddles, and later, with a rectangular sail. The inhabitants of Chukotka did not practise ice lead hunting in the spring as is the current practice of Alaskan Eskimos, due to the nature of the ice conditions off the Chukotkan coasts.

As whaling in the open sea is very difficult, especially with respect to bringing the animals back to shore, it seems likely that whaling must have been a collective enterprise, possibly even between communities, which dominated the economic organisation and the social and cultural life of Chukotka.

The first written information concerning Chukotkan aboriginal whaling relates to 1778 (James Cook spent some time in Nunyamo during his third voyage between 1776–80); the first detailed description of the whaling method comes from 1791 (Vdovin, 1978); a report of the first direct observation of the aboriginal bowhead hunt by Europeans was in 1856 (Heine, 1859). More or less regular information on Chukotkan whaling began around the 1850s and 1860s in the log-books of the American whalers operating in these waters according to Bockstoce and Marquette (1980). The numbers given in their paper allow an approximate assessment of the intensity of aboriginal whaling in the second half of the 19th century and even some idea of the take by the major villages. The period from 1910 to the 1940s is much more thoroughly described and documented and includes local economic data and reminiscences of the oldest inhabitants. By this time, the local hunters were already using American darting and shoulder guns and hunting was conducted not only from traditional walrus-skin boats, but, more often from the wooden whaleboats equipped with a triangular sail of the European type. Although seldom mentioned in the literature, gray and humpback whales were also taken in some

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[1] 'Staying' is typical of bowhead whales. The whale lies on the surface for most of the day only occasionally diving.

villages. Data on the take of whales for the period 1920–45 is summarised below for the main aboriginal whaling villages of Chukotka. This is an extension of earlier work by Krupnik (1979, 1980). Wherever possible both the local and most widely-used English name of the villages are given (Bockstoce and Batchelder, 1978), as well as the approximate population size and the number of crews for this period.

Uel'kal' is an Eskimo village on the western coast of Zaliv Kresta started in about 1920 by Eskimo emigrants from Mys Chaplino. It had 120–130 inhabitants and 4 well equipped and experienced whaling crews but there is not a single report of a kill for the period 1920 to 1945 (although one stinker was washed ashore in 1936). Great numbers of whale bones were found in the ancient dwellings not far from the village, which shows that active whaling had previously occurred there.

Enmelen (*Mys Beringa*) is a Chukot village of 120–130 inhabitants and 4–5 boat crews; by the early part of this century it was the most westerly point of aboriginal whaling on the Anadyr coast. The only registered kill during the period was a single whale in 1929.

Nunligran (*Bukhta Preobrazhenya*) is an old Chukot, and previously it appears, Eskimo, village; it had 130–140 inhabitants and 6 boat crews. Bogoraz reported (1901) that in the early 20th century the usual yield was 1–2 whales per year. However, we could only find records of the following kills: April 1901, 1 whale; early May 1933, 1 whale; 1934, 1 whale; 1943, 1 whale.

Sireniki (*Mys Ulyakhpen*) was in the early 20th century the centre of the Eskimo and in fact all aboriginal whaling in Chukotka. About 180–200 people lived there and in the neighbouring village of Imtuk (John Holland Bay) and there were 8–10 well equipped and experienced boat crews. There were two seasons per year; spring (late April–May) and autumn (November–early December), the latter being much more productive. According to oral tradition, the hunt was successful every year during the period from the 1920s to 1930s with an average of 2–3 whales per year, exclusively bowheads. Catches according to written sources are given in Table 2, and show a catch of 36 whales for the 17 years for which there are records.

Avan (East Head, Bald Head) is an Eskimo village of 60–90 people; it had 4–6 crews together with hunters from the neighbouring villages of Irirak (Plover Bay) and Urelik (Ugrylik, Emma Harbour). The seasons were in May and October–early November. According to the oldest inhabitants, no more than 5–6 whales were killed between 1920–1930, and one of these was a gray whale (about 1924–25). The others were bowhead whales (registered in documents of 1922, December 1930 and 1933). The bowhead whale killed in 1933 was the last one caught by local hunters with darting guns in this region.

Kiwak (*Mys Chukotskiy*) and *Chechen* (*Tassik, Tkachen Bay, Marcus Bay)* are two neighbouring villages with a mixed Eskimo–Chukchi population of about 120–130 persons and 5–6 boat crews. Again there were spring and autumn seasons. Three bowhead catches were recorded in November 1932, 1934 and 1936; the oldest inhabitants remember 2–3 whales more being killed in the 'twenties. The bowhead whale killed in 1936 was apparently the last one caught by traditional methods in Kiwak; only gray whales were later hunted there.

Chaplino (Ungazik, Mys Chaplino, Indian-Point) is the largest Eskimo village situated in Chukotka and in the early 20th century it had 450 inhabitants and 20–25 boat crews. After some people had moved to Uel'kal', the Chaplino population numbered 250–270 persons and 9–11 boat crews. The spring season, from May to early June was more productive than the autumn season from October to early November. The oldest local people remember 8–10 whales killed during the 1920s and 1930s, all bowheads except for 2 humpback whales. Documented catches are shown in Table 2. After 1941 only gray whales were taken.

Senyavin Strait Islands (*Ostrov Arakamchechen, Ostrov Ittygran)*. In the first ten years of the 20th century, there were some small Eskimo and Chukchi villages in the area including Siklyuk, Napakutaq, Meinygooq and Yarga. The total population was 120 persons. Only one boat crew operated (Napakutaq) and it moved each year for the spring whaling in Chaplino. In the late 1920s it took one bowhead whale which was towed to Chaplino. There were dim memories of a regular catch of whales by hunters from these island villages in the past. These are confirmed in the literature (Heine, 1859) and by the recently found bone memorials (bowhead, Ostrov Ittygran; gray, Ostrov Arakamchechen) reported by Arutyunov, Krupnik and Chlenov (1979; 1981) and Bogoslovskaya, Chelnov and Yurtsev (1979).

Mechigmenskiy Zaliv and Inlet. This is the only area of Chukotka besides Ostrov Arakamchechen where even from ancient times gray whales were the major harvested species. No data on the bowhead harvest are available for this area, although skulls and bones from bowheads have been found in the ruins of ancient traditional settlements.

Lavrentiya Zaliv (St Lawrence Bay). The first written records of the aboriginal bowhead hunt in Chukotka in the 18th and early 19th centuries related to this area. The three ancient villages of the maritime Chukchis situated in the bay were Nunyamo (North Head), at the northern entrance, Yandagai and Akkani (Mys Kriguygun, South Head); the total population was about 300 persons with 13–15 crews. Precise data for the area are sparse: 2 whales in 1869 (Bockstoce and Marquette, 1980), 2 animals in spring 1899 (Doty, 1900). No other data are available.

Naukan (Mys Dezhneva, East Cape). This was a large Eskimo village of 330–350 inhabitants (13–15 crews) to the south of Mys Dezhneva, near Mys Paak. During the spring season from May to June, the catch comprised mainly young bowhead whales while the autumn season, from late September to October was the most productive.

Even in the early 1930s Naukan was the only Asiatic Eskimo village to also regularly take gray whales during a summer season (as did the Chukchis of the Mechigmenskiy Zaliv coast). The old inhabitants of Naukan remember that between 1920 and 1940, bowhead whales were taken almost annually, usually one whale but occasionally two; gray whales were only caught in some years. Documented catches are shown in Table 2. For the 17 years for which there are records, 20 whales were taken. The last bowhead killed with darting guns in Naukan was in autumn 1946. Since then local hunters took only gray whales from whale boats.

Data for the late 19th and early 20th centuries are sparse. In addition to those given by Bockstoce and Marquette (1980), there is information on a catch of three whales (one adult and two 'little') in spring 1895 and 1 in spring 1899 (Gondatti, 1898; Doty, 1900).

Table 2

Recorded catches of bowhead whales from Sireniki, Chaplino and Naukan, 1920–45

Year	Catch	Year	Catch
		Sireniki	
1920	4[a]	1936	2
1928	2	1937	0
1929	1	1938	1[s]
1930	1	1941	1
1931	0	1942	2
1932	5	1943	1
1933	2[s], 4[a]	1944	0
1934	6[1]	1945	2[a]
1935	2	Total	36
		Chaplino	
1923–31	5	1937	1[a]
1932	1[a]	1941	1[s]
1933	1[s]	Total	9
		Naukan	
1920	1	1941	0
1923–32[2]	8	1942	1
1933	2[3]	1943	1
1934	2	1944	0
1935	0	1945	1
1936	3	[1946]	1
1938	1 calf	Total	21

[a] Autumn hunt. [s] Spring hunt. [1] Including 1 stinker.
[2] Including: 1927, 1; 1929, 1; 1932, 2. [3] Including 1 in early May.

Ostrova Diomida (*Diomede Islands*). The scattered information on catches by the Eskimos in this area (e.g. in 1905, 1910, 1916: Bockstoce and Marquette, 1980), relates, of course, to the inhabitants of both islands, i.e. it includes the former inhabitants of Ostrov Ratmanova (Big Diomede Island). There are many records of regular whaling by the inhabitants in the 18th century (Berg, 1935; Efimov, 1950; Vdovin, 1978), when at least 200 people lived on Ostrov Ratmanova. However by the beginning of the 20th century, the population had considerably decreased due to epidemics and migration to the neighbouring Ostrov Kruzenstern (Little Diomede Island). The whaling either ceased completely or was transferred to the latter island.

Uelen. This is the largest traditional village of the maritime Chukchis, with a population of 260–280 and 10–12 crews. During the first half of this century there was only an autumn (October–November) season for bowhead whales. In spring the Uelen hunters moved to Naukan, and whaled with their crews. Gray whales were taken as well as bowheads from at least the end of the 19th century. The hard weather conditions meant that aboriginal whaling here suffered a much greater loss rate than other villages.

The data for the 1920s–1940s are fragmentary. In autumn 1920, 27 whales were killed but only 10 were flensed (Sverdrup, 1930); in autumn 1929, 16 whales were killed and 4 used; in 1930, three whales were caught and one used. There are no data for the period after 1932, although it is known that no whales were killed between 1941 and 1945. Only gray whales were taken there in the post-war period.

Enurmino (Mys Serdtse-Kamen'). This is a Chukchi village with 120–150 inhabitants and 6-7 hunting boat crews. It represents the most northerly site of regular aboriginal whaling from the late 17th to the first half of the 20th century. There was one hunting season, usually from September to October, although in some years it lasted until December, while in others, the whales had already arrived in late June–early July (Shnakenburg, 1933). A total of 24 whales were taken there between 1902 and 1933 including 23 adult bowhead whales; of these 13 were caught in three successful years between 1923 and 1932. No whaling data were recorded after 1933 but it is known that the last bowhead whale was killed in 1938.

Other villages situated along the Arctic coast of Chukotka
The many whale bones found in the ancient ruined settlements of Inchoun, Uten, Chegytun', Neshkan, Ostrov Kolyuchin, Vankarem, Mys Schmidta etc. (Nordenskold, 1880; Dikov, 1977) and the discovery of baleen whale handicraft wares and remains of harpoons show that aboriginal whaling used to be conducted along the northern coast of Chukotka as far as Mys Schmidta (Severnyi, Rirkaipyi), while rock paintings of whaling scenes found in the valley of the Pegtygmel River testify to its existence as far west as Mys Billingsa.

Although bowhead whales still appeared annually near the coast as far as Mys Shelagsky and even Mys Bolshoy Baranov in the 19th century (Argentov, 1857), the maritime Chukchis along the coast did not whale. There is no information on their whaling between the 18th and early 20th centuries apart from one clearly erroneous report that in 1822 the inhabitants of Ostrov Kolyuchin killed 50(?) whales (Wrangel, 1948).

THE EXTENT OF CHUKOTKAN BOWHEAD WHALING IN THE LATE 19th AND EARLY 20th CENTURY

Thus, in the 1920s–1930s, regular aboriginal whaling for bowhead whales occurred in eight villages: Nunligran, Sireniki, Avan, Kiwak, Ungazik (Chaplino), Naukan, Uelen and Enurmino, i.e. in two isolated areas in the southeastern and northeastern extremities of the Peninsula. During the period, the total annual catch was about 5–15 animals (Krupnik, 1980); 10–15 animals were harvested during a 'successful' year, of which 2–3 whales would be from Sireniki and Imtuk, 1 from Ungazik, 1–2 from Naukan, 1 from Uelen, 1 from Enurmino, with perhaps 1 (irregularly) from Avan or Kiwak, and 1 (irregularly) from the area around Bukhta Preobrazhenya and near Bukhta Lavrentiya. This level of catch can be considered as an 'ideal' reconstruction for the 1910s; in the 1920s it would in fact have been lower due to unfavourable weather conditions and low availability, while in the 1930s it increased again due to improved weather conditions and availability.

It is possible to approximately assess the likely intensity of aboriginal whaling between 1880 and the 1900s based on data from American whalers log-books (Bockstoce and Marquette, 1980), some fragmentary written information and, in some cases, the local oral tradition. There are grounds to believe that during this period whaling was more intense in Ungazik and Naukan (where, apparently, several whales were taken per year) as well as in Nunligran, Kiwak (or Chechen) and especially in Avan. An annual catch of 3–5 whales was quite usual for some aboriginal villages at that time (see Bockstoce and Marquette, 1980).

From this information the total annual aboriginal catch may have been as high as 16–20 animals in Chukotka in the latter half of the 19th century: 2–3 whales from Ungazik; 2–3 from Naukan; 1–3 from Sireniki and Imtuk; 1–2 from

Avan; 1–2 from Uelen; 1–2 from Enurmino and 1 from each of Nunligran, Kiwak, Bukhta Laventiya and the villages lying along the Arctic coast (Krupnik, 1979, 1980). One reason for the higher level of catches in the last quarter of the 19th century in both Chukotka and Alaska was the tremendous demand for baleen by American whalers and merchants.

Bockstoce (1977) believes that before the beginning of commercial whaling (i.e. up to the mid 19th century), the annual catch of bowhead whales by Alaskan Eskimos was 4 times higher than at the beginning of the 20th century; about 40–50 animals per 2,500 coastal inhabitants. However, we have no reason to believe that the same is true for Chukotka; the spring catch of bowheads in the narrow ice leads near Point Hope or Point Barrow will always have been much more productive than hunting in open water as carried out from Chukotka. The size of the ancient villages, number of bones found there, folk-lore and the memories of the local inhabitants do not suggest that the level of precontact whaling for bowheads in Chukotka was much greater than the level in the 1870s and 1880s; it may even have been lower. In the earlier years whaling was mainly centred on young individuals and calves, as confirmed by the whaling legends found in old underground dwellings and memorials that their ancestors hunted ‘small bowhead whales’.*

THE POSSIBILITY OF MODERN ABORIGINAL WHALING FOR BOWHEADS

There was an aboriginal bowhead whale harvest in Chukotka for many millennia: it ceased in most of the villages in the 1940s and 1950s for various reasons, and was replaced by a gray whale catch. Bowhead whaling persisted longest in Sireniki, where regular hunting remained until 1960 and where the last whale was killed in the early 1970s using traditional methods. The last bowhead whale killed from Nunligran was in the late 1960s.

However, time has shown that none of the marine mammals currently taken (including the gray whale) can substitute for the meat and skin (mantaq) of the bowhead whale for the Chukotkan aboriginal population. Even now they feel the cessation of bowhead whaling very keenly and in many areas, particularly Sireniki, express their desire to begin again as soon as possible.

For many centuries, bowhead whaling formed the basis of the culture of both the Asiatic Eskimos and the maritime Chukchis, irrespective of the size of the catch. That it is still very important to the national self-consciousness and the conservation of their cultural and linguistic traditions is well appreciated by all of them.

Information given in this paper shows that the ‘best’ estimate (2,264 range, 1,723–2,865) of the bowhead population, from the Point Barrow census (Braham *et al.*, 1979; IWC, 1982) did not include animals found off Chukotka at that time. Thus the real size of the population will be higher and it is probably not a single population but includes at least two parts, which have different winter and summer habitats and migratory routes.

For these reasons, we suggest that the possibility of a renewed harvest of a limited number of bowhead whales by local hunters in some Chukotkan villages should be considered by the IWC. Our data show that on a historical basis the most reasonable thing would be to allow a catch of one bowhead whale from Sireniki, Nunligran and Uelen, where experienced hunters still remain.

We do not believe that such limited hunting if strictly controlled will cause damage to or prevent an increase in the population. Delay in making such a decision will lower the number of experienced hunters and prevent their passing on their knowledge to the next generation.

Much of the recent progress in bowhead whale studies by American biologists is due to the fact that their investigations have been started and are performed with the cooperation of Alaskan Eskimo whaling operations. Similar collaboration could occur in Chukotka, utilising the accumulated experience of the whalers, which would increase our knowledge of the biology of little known whale species.

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REFERENCES

Argentov, A. 1857. A description of Nicholas Tchaun parish. *Zap. Sibirskogo otdela Russ. Geograph. Obtchestva* 4. (In Russian).

Arutyunov, S. A., Krupnik, I. I. and Chlenov, M. A. 1982. *The Whalebone Allee. Antiquities of Senyavin Strait Islands.* Nauka, Moscow, 174 pp. (In Russian).

Arutyunov, S. A., Krupnik, I. I. and Chlenov, M. A. 1979. The Whalebone Allee – Ancient Eskimo Memorial on Ittygran Island. *Sovetskaya Ethnographia* 4: 12–28. (In Russian).

Arutyunov, S. A. and Sergeev, D.A . 1969. *Ancient Cultures of the Asiatic Eskimos. The Uelen Cemetery.* Nauka, Moscow. 202 pp. (In Russian).

Berg, L. S. 1935. The Kamchatka Discovery and Expedition of V. Bering: 1725–1742. Glavsevmorpoot, Leningrad, 412 pp. (In Russian).

Bockstoce, J. R. and Batchelder, C. 1978. A gazetter of whalers’ place names for the Bering Strait region and the western Arctic. *Names* 26(3): 258–70.

Bogoraz, W. 1901. *A diary of the journey to and stay at Uniin.* Arkhiv Acad. of Sci., Leningrad. (In Russian).

Bogoslovskaya, L. S., Chlenov, M. A. and Yurtsev, B. A. 1979. The islands of Senyavin Strait – a unique natural and cultural complex. *Priroda* 9: 91–7. (In Russian).

Bogoslovskaya, L. S. and Votrogov, L. M. 1981. Mass wintering of birds and whales in polynyas of the Bering Sea. *Priroda* 11: 42–3. (In Russian).

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* Asiatic Eskimos call these ‘ingutuk’, as in Alaska and do not consider it as a separate species.

Braham, H. W. and Krogman, B. D. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga whale (*Delphinapterus leucas*) in the Bering, Chukchi and Beaufort Seas. Processed Rep., U.S. Dep . Commer., Natl. Oceanic Atm. Admin., Natl. Mar. Fish. Serv., Northwest Alaska Fish. Cent., Mar Mammal Div., Seattle, Wash., 28 pp.

Braham, H. W., Krogman, B., Leatherwood, S., Marquete, Rugh, D., Tillman, M., Johnson, J., and Kerroll, J. 1979. Preliminary report of the 1978 spring bowhead whale research program results. *Rep. int. Whal. Commn* 29: 291–306.

Braham, H. W., Fraker, M. A. and Krogman, B. D. 1980a. Spring migration of the western Arctic population of bowhead whales. *Mar. Fish. Rev.* 42(9–10): 36–46.

Braham, H. W., Krogman, B. D., Johnson, J., Marquette, W., Rugh, D., Nerini, M. and Sonntag, R. 1980b. Population studies of the bowhead whale (*Balaena mysticetus*): Results of the 1979 spring research season. *Rep. int. Whal. Commn* 30: 391–404.

Braham, H. W., Krogman, B., Nerini, M., Rugh, D., Marquette, W. and Johnson, J. 1980c. Research on bowhead whales, June–December 1978. *Rep. int. Whal. Commn* 30: 405–13.

Coachman, L. K., Aagaard, K. and Tripp, R. B. 1975. *Bering Strait.* Univ. Wash. Press, Seattle and London.

Dikov, N. N. 1977. *Archaeological monuments of Kamchatka, Chukotka and Upper Colyma. Asia joint to America in Antiquity. Nauka, Novosibirsk, 391 pp.* (In Russian).

Doroshenko, N. V. 1979. Data on the distribution and number of bowheads in the west part of the Chukchi Sea, pp. 45–9. *In. Nauchno-issled. raboty po morskym mlekopit. Severnoy chasty Tikhogo okeana v 1978/79. VNIRO, Moscow.* (In Russian).

Doty, W. 1900. Log Book, St. Lawrence Island. pp. 224–56. *9th Annual Report on Introduction of Domestic Reindeer into Alaska.* Washington.

Efimov, A. V. 1950. *The History of the Great Russian Geographic Discoveries in the Arctic and Pacific oceans in the 17th and first half of the 18th centuries.* Geographgiz, Moscow, 318pp. (In Russian).

Fedoseev, G. A. 1979. Data on aerovisual observations for the distribution and number of ice seals, walrus and migrations of the whales in ice of the Bering Sea in spring 1979. pp. 17–44. *In: Nauchno-issled. raboty po morskym mlekopit. Severnoy chasty Tikhogo okeana v 1978/79.* VNIRO, Moscow. (In Russian).

Fedoseev, G. A. and Goltsev, V. N. 1975. New data on the distribution and number of marine mammals in the Bering and Chukchi Seas. pp. 144–6. *In: Marine Mammals,* pt 2, Naukova dumka, Kiev. (In Russian).

Gondatti, N. L. 1898. Voyage from Markovo village on the Anadyr River to Providenya Bay. *Zap. Priamurskogo otdela Russ. Geograph. Obtchestva* 4(1): 7–33+XXV. (In Russian).

Heine, W. 1859. *Die Expedition in die Seen von China, Japan und Okhotsk.* Leipzig, Bd. 2.

International Whaling Commission. 1982. Report of the Scientific Committee. Annex G, the Report of the sub-committee on protected species and aboriginal whaling (published in this volume).

Kotzebue, O. 1821. *Voyage of "Ruryk" into the South Sea and Bering's Strait.* Vol. 1., Saint-Petersbourg. 108 pp. (In Russian).

Krupnik, I. I. 1979. Aboriginal Asiatic Eskimo Whaling in the 1920s–1930s. *XIV Pacific Sci. Congress. Khabarovsk. Committee F., Section Fiii:* 145–8.

Krupnik, I. I. 1980. Asiatic Eskimo sea-mammal hunting in the 1920s–1930s. p. 66–79. In: V. Zemsky (ed.) *Morskye mlekopitayutchye*, Moscow. (In Russian).

Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973–1976, and a biological summary of the species. Processed Rep., US Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest Alaska Fish. Cent., Mar Mammal Div., Seattle, Wash., 80pp

Marquette, W. M., Bockstoce, J. R. 1980. Historical shore-based catch of bowhead whales in the Bering, Chukchi and Beaufort Seas. *Mar. Fish. Rev.* 42(9–10): 5–19.

Nordenskold, A. 1880. *Swedish Arctic Expedition of 1878–1879. The Discovery of North-East Passage* St. Petersbourg. (In Russian).

Rudenko, S. I. 1947. Ancient culture of the Bering Sea and the Eskimos' problem. M.-L. 207 pp. (In Russian).

Shnakenburg, N. B. 1933. *Whaling in Chukotka.* Tikhokeanskaya zvezda (Khabarovsk) N 259, 3. (In Russian).

Sverdrup, G. U. 1930. *Voyage of the Vessel "Mod" in Laptev and East-Siberian Seas.* Leningrad, 440 pp. (In Russian).

Townsend, C. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica,* 19(1): 3–50.

Vdovin, I. S. (ed.) 1978. *Ethnographic materials of the North-East Geographic Expedition: 1785–1795.* Magadan, Publ. House, Magadan, 176 pp. (In Russian).

Wrangel, F. 1948. *Journey along the Northern Coasts of Siberia and in The Arctic Ocean.* Glavsevmorpoot, Moscow–Leningrad, 454 pp. (In Russian).

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Humpback Whale Censuses in the West Indies

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ABSTRACT

Shipboard censuses and surveys for humpback whales in the West Indies were conducted from the research vessel *Regina Maris* in 1977, 1978, 1980 and 1981. The number of whales in this breeding population is estimated to be not less than 2,000 individuals. Most of the breeding population occurs on Silver and Navidad Banks north of the Dominican Republic each winter, with peak abundance observed in February. There is significant variation in estimates from the same area from year to year, which may be due to environmental conditions. The relationship of this breeding population to feeding populations at higher latitudes in the western North Atlantic is discussed.

INTRODUCTION

Humpback whales (*Megaptera novaeangliae*) in the western North Atlantic have been exploited throughout their range since the 16th century (Mitchell and Reeves, 1982) to the point that they were considered depleted by the 1920s (Sergeant, 1966). Several attempts have been made recently to estimate the present size of this population based upon censuses conducted in the West Indies (Mitchell, 1973; Winn, Edel, and Taruski, 1975; Balcomb and Nichols, 1978; and Whitehead, 1982), where the whales spend the midwinter months in relatively shallow waters near islands and offshore banks. While most of these estimates are in agreement that the population numbers in the low thousands, there is significant variation in the actual number estimated. This may be attributable to the census method and platform, or to the seasonal timing of the census effort. In order to examine the seasonal variation in whale occupancy of the habitat and develop census methods which yield accurate estimates of population, the research vessel *Regina Maris* conducted whale surveys in the West Indies during the winter months of 1977, 1978, 1980 and 1981. This paper reports upon the findings of the 1980 and 1981 surveys and describes a computer assisted method of estimating whale abundance at sea.

MATERIALS AND METHODS

The research platform

The research vessel *Regina Maris* is a 144 ft three-masted barquentine with accommodation for 36 people, including crew, students and scientific staff. The ship's endurance and seaworthiness permit extended voyages to all oceans for studies of living whales. For whale census work, two to five observers visually search an approximately 3.5 nm strip on each side of the ship from a deckhouse lookout where the height of eye is 19 ft. An additional one to three observers visually search the same area from a lookout on the foremast where the height of eye is up to 80 ft.

Types of data collected

During a census the ship maintained constant speed and heading and observers logged information about each whale sighted. Due to navigation considerations, the censuses were of unequal length. The data gathered for each sighting event are: (1) time of sighting; (2) sighting cue; (3) group size, if determined; (4) radial distance and angle of sighting; (5) meteorological and sea state information; (6) remarks. In 1981, following the recommendation of the IWC Workshop on the Design of Sightings Surveys (IWC, 1982), the name of the observer first noting the sighting was included in remarks. The foremast and deckhouse censuses were conducted independently, with the intention that the foremast results could be used to evaluate the missed whale rate of the deckhouse lookouts. In this report only the data from the deckhouse are used for population estimates because they were consistently gathered by one of us (Balcomb) during all years.

Methods of data management

Prior to 1980, the sighting data from each census were manually plotted and whale densities were calculated based upon the number of whales which were seen within two and three nautical miles of the ship's track (Balcomb and Nichols, 1978). In 1980 and 1981 the sighting data were entered into a shipboard 48K *Apple* mini-computer at the time of census or soon thereafter, and a visual plot was maintained on a video monitor. This procedure not only minimized data entry errors, but it also facilitated evaluation of repeat sightings of whales in a time frame the observers could remember. The computer method also facilitated subsequent analysis of sighting data and correlations with environmental information, etc. The data for 1980 contain information concerning 3,421 sighting events that have been sorted according to environmental conditions, visual cue, bearing angle, and range at first sighting. The sorted data were first examined to determine whether significant differences occurred in sightability of different cues, at different ranges, and under various environmental conditions. The sorted data were then tabulated and examined in increments of 0.25 nm to determine the range at which the number of sightings diminished. This range was then taken to be the strip width on either side of the ship's track during the census surveys for purposes of calculating whale density.

abundant to conduct meaningful censuses. The only concentrations of humpback whales that we found feasible to census in 1981 were on Silver and Navidad Banks north of the Dominican Republic.

Habitat area censused

The area of habitat censused was initially determined using US nautical charts of Silver, Navidad, and Mouchoir banks and a graphics tablet and program for the shipboard mini-computer. Navidad Bank comprises an area of approximately 154 nm^2, all of which is navigable and used in extrapolation of whale density values for population estimation. Silver Bank is less accurately charted, however, and it is not safely navigable over its entire area. The charted area is approximately 840 nm^2, a figure which was used by both Winn *et al.* (1975) and Balcomb and Nichols (1978) for previous extrapolations to population estimates. Our recent experience on Silver Bank indicates that it is not as large as charted, so we have recalculated the area using a NASA LANDSAT photograph taken on 1 February 1979 and the graphics tablet and program already mentioned. The resultant area of Silver Bank was 607 nm^2, 366 of which were determined by our surveys to be both safely navigable and utilized habitat for humpback whales. Due to extreme hazard of navigating the remaining 241 nm^2 of Silver Bank, that area was not censused and our population estimate does not include whales which no doubt occurred there. Due to differences in observed density in different areas of Silver Bank, the entire area was stratified into seven subareas (Fig. 1), five of which were sampled by census. These subareas we designated northwest (nw), west central (wc), east central (ec), southwest (sw), and southeast (se). Censuses sampling two subareas were geographically described using the abbreviation for both (e.g. ewc for east and west central). The area of Mouchoir Bank was calculated to be 280 nm^2, most of which was safely navigable. Scarcity of whales on that bank, however, renders extrapolation of census results suspect.

Temporal considerations

The migrations of populations of humpback whales are not en masse, but are instead flows of animals which gradually increase in number to a peak and diminish again as the season progresses (Chittleborough, 1965). On a breeding ground such as Silver Bank, this phenomenon is quite perceptible and it can significantly affect one's estimate of population. In order to estimate the peak number of whales utilizing the breeding habitat, we have temporally stratified our census results into approximately one week periods, and for population estimates have chosen the week in which the highest densities of whales were present. Because these peaks were in different weeks on different banks, we have cautiously selected a one week window in mid-February 1980 for our population estimate in that year. We have selected a similar one week window in late February 1981 for our population estimate on Silver Bank in that year.

Population estimation

A population estimate for each stratified area and time period was made by multiplying the average density of whales sighted by the area of habitat in which the censuses were taken. The population estimates for the stratified areas were summed for each time period to derive a total population estimate for humpback whales utilizing the breeding habitat at that time. The number thus derived is conservative in that it: (1) refers only to the banks north of the Dominican Republic; (2) does not include areas of Silver Bank which could not be safely surveyed; and (3) does not account for whales which may have already left or not yet arrived on the banks, i.e. there is no correction for transient occupancy, which may be very significant.

RESULTS

Sightability of whales

The sighting data for 1980 were first examined to see if there was any difference in the overall sighting range when whitecaps were present and when they were absent. The average sighting range for 2,271 events when whitecaps were present was 1.48 nm, and for 1,150 events when whitecaps were absent was 1.49 nm, indicating remarkably little difference in average sighting range for those conditions. The data were then examined for average sighting range under different wind conditions (Table 1).

Table 1

Wind velocity and sighting range

Wind velocity	No. of observations	Average sighting range
0 to 5 knots	82	1.48 nm
6 to 10 knots	245	1.70 nm
11 to 15 knots	1,546	1.52 nm
16 to 20 knots	971	1.50 nm
21 to 25 knots	567	1.26 nm
26 to 30 knots	10	1.19 nm

This indicates that there was little difference in average sighting range with wind velocities up to 20 knots, but above that velocity average sighting range decreases.

The data were then examined to determine the average sighting range for several sighting cues (Table 2).

Table 2

Sighting cue and sighting range

Sighting cue	No. of observations	Average sighting range
Blow	1,638	1.11 nm
Breaches, etc.	976	1.83 nm
Back	161	0.77 nm
Flukes	28	0.95 nm

These results indicate a preponderance of initial sightings were of 'blow' and 'breaches, etc.' (i.e. breaches, splashes, flipper and lobtail) with the latter being noticed at significantly greater range than the other sighting cues.

In order to examine this important aspect of sightability of various sighting cues at differing ranges, the data were sorted by cue in increments of 0.25 nm range out to 2.25 nm (Table 3).

Table 3

Sighting cue in increments of 0.25 nautical mile

Range	Blow	Splash	Breach	Flipper	Lobtail	Back	Other	Total
0–0.25	239	19	21	9	3	60	8	359
0.26–0.50	284	24	24	11	3	28	4	378
0.51–0.75	253	38	18	13	7	29	3	361
0.76–1.00	290	38	35	7	7	28	4	409
1.01–1.25	100	26	6	6	2	3	2	145
1.26–1.50	269	66	31	13	5	16	5	405
1.51–1.75	83	28	18	14	0	2	0	145
1.76–2.00	205	62	34	13	2	8	0	324
2.01–2.25	6	4	0	0	3	1	0	14

Several things are apparent from these sorted data: (1) 'blow' is the predominant sighting cue at all ranges; (2) there is an apparent observer bias to log sightings in increments of 0.5 nm at ranges of one nm and beyond; (3) except for sighting cue 'back' there is little difference in sightability of a given cue out to a range of one nm; and (4) beyond one nm the sightability of all sighting cues decreases. Assuming the real distribution of whales outside one nm is the same as within one nm, one might conclude that approximately 9% of possible sightings would be missed if the strip width were 1.5 nm, and 16% missed within 2 nm. From this we deduce that one nm may be the range within which all possible sighting events are seen. By this we mean if a whale came to the surface within one nm of the ship during a census it would have been seen. After that, it is a separate question in which whale behavior, ship's speed, etc. must be taken into account to estimate how many whales might be missed because they do not come to the surface during the time that the ship passes.

The visual bearing to each whale at initial sighting was examined for 1,742 sighting events in which a hand compass was used to determine the angle of sighting off ship's track. These data were sorted in increments of 5° from the centerline of ship's track (Table 4).

Table 4

Tabular presentation of number of initial sightings along bearing angles in five degree increments

Deg.	No.	Deg.	No.	Deg.	No.	Deg.	No.
0	18	21–25	113	46–50	96	71–75	83
1–5	102	26–30	117	51–55	89	76–80	62
6–10	93	31–35	105	56–60	81	81–85	53
11–15	103	36–40	91	61–65	82	86–90	67
16–20	102	41–45	98	66–70	78	91+	109

These data indicate very little difference in the number of initial sightings for all visual angles between 0° and 75° and only a slight decrease thereafter (i.e. the visual horizon was effectively covered).

Among the 3,421 sighting events recorded, there were 179 definite repeat sightings (i.e. 5.2% of total) of identified whales after a prolonged dive interval, as well as 125 other possible or probable repeat sightings (3.6% of total). The average dive interval was determined for 96 of the definite repeat sightings in which the whale(s) submerged for more than one minute. The average dive interval (5.44 minutes) and a standard deviation (3.64 minutes) were calculated to derive an approximate maximum dive interval of 12.72 minutes (average + two standard deviations) for most whales. Assuming that the diving behavior of resighted whales is the same as the behavior of all whales and that there is no significant difference in movements of whales toward or away from the ship during a census (the sighting data stratified by range suggest there is no difference), 95% of the whales within one nm of the ship would surface and be seen if the ship's speed were 4.72 knots (1 nm/12.72 minutes × 60). The ship's speed was usually about 6 knots during each census, which causes us to estimate that some whales are missed during a census due simply to their not coming to the surface within the strip width during the time that the ship passes. The result of whales missed during a census is that our density estimates will be conservative.

Population estimation

Based upon the assumption that in wind conditions of 20 knots or less all potential sighting events within one nm of the ship's track are seen and recorded, we derive a density estimate for each census conducted (Table 5).

From these data it can be seen that in 1980 the peak densities of whales occurred on Navidad Bank on 28 and 29 January and they occurred about two weeks later, 7 to 13 February, on Silver Bank. We found no whales on Mouchoir Bank until mid-March. The density peaks suggest an east to west progression in the movements of whales. Being conservative in our total population estimate and assuming that whales may have been moving from bank to bank, we derive population estimates for each bank by multiplying whale density times habitat area (Table 6).

The first calf that we sighted was on 24 January 1980 in the northwest sector of Silver Bank. The proportion of calves increased gradually through February and March until early April when they represented about 30% of the population (i.e. most sightings were cow/calf/escort). Most of the unaccompanied adult whales had left by that time, however, and the total population on Silver Bank was probably fewer than two hundred whales. From this we may deduce that about sixty calves were present and an unknown number had migrated north.

Similarly derived whale densities and population estimates for 1981 are presented in Tables 7 and 8.

Since our 1981 research objective was to survey most of the habitat available to humpback whales in the West Indies, and the whales were scarce in most of those habitats, we have fewer complete censuses than in 1980 and cannot compare the Navidad and Silver Bank censuses during the approximately same one week period. Nevertheless, the total number of whales estimated for those two banks in 1981 is 1,177, which is in marked contrast to the 1,923 estimated using similar procedures in 1980.

Table 5

Whale density estimates from each census in 1980

Census no.	Date	Whales	Density	Sector
Navidad Bank				
7	16 Jan.	23	0.88	
8	16 Jan.	12	1.10	
9	17 Jan.	22	1.45	
20	28 Jan.	147	7.22	
21	29 Jan.	159	6.23	
38	14 Feb.	83	2.87	
39	14 Feb.	44	1.79	
41	1 Mar.	60	1.99	
57	21 Mar.	27	0.79	
58	21 Mar.	25	0.73	
69	5 Apr.	0	0.00	
Silver Bank				
1	13 Jan.	8	0.47	nw
2	13 Jan.	7	0.37	sw
4	14 Jan.	4	0.23	nm
5	15 Jan.	22	0.82	nw
6	15 Jan.	17	0.78	wc
12	18 Jan.	23	1.06	se
14	18 Jan.	12	0.47	sw
15	18 Jan.	13	0.64	nw
16	19 Jan.	27	1.06	wc
17	24 Jan.	23	1.60	nw
18	27 Jan.	89	3.98	wc
22	30 Jan.	11	1.47	se
23	30 Jan.	11	0.40	sw
24	30 Jan.	49	1.78	sw
25	2 Feb.	72	2.22	wc
27	7 Feb.	30	1.97	sw
28	7 Feb.	45	2.27	sw
29	8 Feb.	138	7.66	wc
30	11 Feb.	134	6.30	wc
31	11 Feb.	56	2.19	wc
32	11 Feb.	27	1.01	sw
33	12 Feb.	110	5.29	se
34	12 Feb.	24	3.80	ec
35	13 Feb.	69	7.37	wc
36	13 Feb.	138	8.68	wc
37	13 Feb.	57	3.26	nw
42	3 Mar.	76	3.84	ec
43	3 Mar.	17	1.52	wc
44	3 Mar.	55	2.54	ec
45	5 Mar.	18	1.58	ec
46	5 Mar.	12	1.21	ec
47	5 Mar.	47	2.34	wc
48	8 Mar.	121	4.34	wc
49	8 Mar.	13	0.54	sw
50	12 Mar.	40	2.22	nw
51	14 Mar.	97	2.27	wc
53	19 Mar.	36	1.79	wc
54	20 Mar.	32	2.13	wc
55	20 Mar.	59	2.29	ewc
56	20 Mar.	18	1.12	ec
59	22 Mar.	34	1.70	ec
60	22 Mar.	50	2.13	ewc
61	22 Mar.	7	1.85	wc
62	26 Mar.	34	1.41	wc
63	30 Mar.	28	1.26	wc
65	30 Mar.	5	0.28	wc
66	2 Apr.	5	0.35	wc
67	4 Apr.	19	0.81	wc
68	4 Apr.	17	1.22	wc
Mouchoir Bank				
26	6 Feb.	9	0.18	

Table 6

Population estimates for 1980

Sector	Area (nm sq.)	Density	Population
Silver Bank 7 to 13 February 1980			
nw	68	3.26	221
wc	111	6.13	680
ec	60	3.80	228
sw	104	1.75	182
se	23	5.29	121
		Total	1,432
Navidad Bank 14 February 1980			
Entire bank	154	2.87	441
Mouchoir Bank 6 February 1980			
Entire bank	280	0.18	50
Total all banks 6 to 14 February 1980			1,923

Table 7

Whale densities for each census in 1981

Census no.	Date	Whales	Density	Sector
Navidad Bank				
1	31 Jan.	42	1.39	
Silver Bank				
2	4 Feb.	21	0.42	nw
3	4 Feb.	16	0.61	sw
4	5 Feb.	57	1.90	se
5	5 Feb.	31	0.64	ec
6	6 Feb.	28	1.16	wc
7	8 Feb.	28	0.60	nw
9	14 Feb.	13	0.65	nw
10	16 Feb.	93	2.47	wc
11	21 Feb.	47	1.17	wc
12	21 Feb.	59	2.62	sw
13	22 Feb.	95	3.52	se
14	22 Feb.	110	4.23	ec
15	22 Feb.	105	4.45	wc
16	5 Mar.	38	1.62	nw
Mouchoir Bank				
Mouchoir Bank was visited twice in February 1981, but both times the weather conditions precluded conducting a useful census. Several whales were seen on the westernmost (leeward) edge of the bank.				

Table 8

Population estimates for 1981

Sector	Area (nm sq.)	Density	Population
Silver Bank 14 to 22 February 1981			
nw	68	0.65	44
wc	111	2.70	299
sw	60	2.62	157
se	104	3.52	366
ec	23	4.23	97
		Total	963
Navidad Bank 31 January 1981			
Entire bank	154	1.39	214

DISCUSSION

Winn *et al.* (1975) estimated 754 humpback whales present on Silver Bank in February 1973; Balcomb and Nichols (1978) estimated 809 whales on Silver Bank in early March 1977 (plus 96 on Navidad); and Whitehead (1981) estimated a peak total population of 3,000 humpback whales on Silver, Navidad, and Mouchoir Banks during the winter of 1977/78. Now we have two more years in which estimates are available for the number of humpback whales utilizing the breeding/calving banks north of the Dominican Republic: 1,923 in 1980, and 1,177 in 1981.

Aside from differences in methodology or assumptions which may account for the extreme differences in these estimates, one is still left with significant differences for between year estimates using the same methods, or using adjusted figures reported by the different authors. For example, we are confident that we sampled the peak population of humpback whales utilizing Silver Bank in February 1980, and in February 1981, yet the numbers of whales estimated are significantly different (1,432 and 963, respectively). Likewise, the late January estimates for Navidad Bank in the two years are drastically different (1,034 and 214, respectively). These differences cannot be reasonably explained by a corresponding decrease in the population. A more likely explanation is that the differences are due to different timing and perhaps different subgroups and destinations in the migrations of the whales in different years. They may even be due to differences in environmental conditions in different years. This is suggested by the fact that on Silver Bank the distribution of whales on the bank was significantly different in the two years, with the highest density of whales in 1980 being in the west central area of the bank (leeward of extensive reef when relatively mild northeast trade winds prevailed), and the highest density in 1981 was in the southeast area of the bank (leeward of extensive reef and coral heads when unusually strong northwesterly winds prevailed). The wintering whales may be seeking the protection from seas and swells which the banks and reefs have to offer. The Navidad data tend to support this supposition in that it has no reef protection at all, and in the windier year had drastically fewer whales. Matilla (pers. comm.) indicated that there were more whales along the coast of Puerto Rico in February 1981 than he had seen at any time in the previous three years. Perhaps this abundance can be explained by a general movement of whales from the banks to the greater protection of bays and the lee shores of large islands. Whatever the explanation, it is clear that the numbers of whales estimated by survey in principally occupied habitats in any given year are bound to be conservative simply because the migratory phenomenon is so flexible.

An alternate method of population estimation suggested by us in 1977 (Balcomb and Nichols, 1978) and valiantly attempted by Whitehead (1981) is some application of the Petersen method of mark-and-recapture using individuals which are photo-identified. Katona, Harcourt, Perkins, and Kraus (1980) have published a catalogue of 1,010 photo-identified individual humpback whales from the western North Atlantic in which 120 significant resightings were known as of the date of publication. Ten of these resightings were of Silver/Navidad/Puerto Rico whales that were seen in feeding areas in New England and Newfoundland/Labrador or vice versa. To those we can add at least 14 more breeding area/feeding area resightings of individual whales in 1980/81 which unequivocally document that the population of whales we are censusing in the West Indies breeding and calving grounds is the same as that found on feeding grounds at high latitudes in the western North Atlantic. We believe that population contains no fewer than about 2,000 whales as of this writing. We anticipate that within the next few years the photo-identification method will yield more detailed information about western North Atlantic humpback whales than is known for any other species of large cetacean.

ACKNOWLEDGEMENTS

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REFERENCES

Balcomb, K. C. and Nichols, G. Jr. 1978. Western North Atlantic humpback whales. *Rep. int. Whal. Commn* 28: 159–64.

Chittleborough, R. C. 1965. Dynamics of two populations of the humpback whale (*Megaptera novaeangliae* (Borowski)), *Aust. J. Mar. Freshw. Res.* 16: 33–128.

Katona, S. K., Harcourt, P., Perkins, J. S. and Kraus, S. D. 1980. Humpback whales, a catalogue of individuals identified by fluke photographs. College of the Atlantic, Bar Harbor, Maine 04609.

Mitchell, E. D. 1973. Draft report on humpback whales taken under special scientific permit by Eastern Canadian land stations, 1969–71. *Rep. int. Whal. Commn* 23: 138–54.

Mitchell, E. and Reeves, R. R. 1982. Catch history, abundance and present status of Northwest Atlantic humpback whales. *Rep. int. Whal. Commn* (special issue 5).

Sergeant, D. E. 1966. Population of large whale species in the western North Atlantic with special reference to the fin whale. Fish. Res. Bd Can. Circular No. 9, 1–13 + 9 tables and 9 figs.

International Whaling Commission. 1982. Report of the workshop on the design of sightings surveys (published in this volume).

Whitehead, H. 1982. Populations of humpback whales in the Northwest Atlantic. Paper SC/33/PS2 (published in this volume).

Winn, H. E., Edel, R. K. and Taruski, A. G. 1975. Population estimate of the humpback whale (*Megaptera novaeangliae*) in the West Indies by visual and acoustic techniques. *J. Fish. Res. Bd Can.* 32: 499–506.

SC/33/PS19

Preliminary Notes on the Occurrence of the North Atlantic Right Whale, *Eubalaena glacialis*, in the Bay of Fundy

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INTRODUCTION

In 1980, the New England Aquarium conducted aerial and shipboard surveys to determine the distribution and abundance of cetaceans in the lower Bay of Fundy, Canada, and the Eastport, Maine, region. The surveys yielded a substantial amount of information on the US endangered whales species, the finback (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), and north Atlantic right whale (*Eubalaena glacialis*) that seasonally inhabit the region. Finback and humpback whales were regularly observed in the region, but the occurrence and extended duration of stay of a significant number of right whales, including cow/calf pairs, as well as observations of mating behavior provided new information about this endangered species.

The study area in the Bay of Fundy encompasses approximately 1,600 square miles (Fig. 1). Aerial surveys were conducted at an altitude of 750 ft, with two observers, a recorder, and a pilot in a *Cessna* 185. Both random and stratified surveys were flown on 12 days at intervals throughout the summer and fall. Data recorded on cetaceans observed during surveys included species, location, sea state, wind direction, and limited behavioral information. Four one-day boat cruises in the western section of the study area were made. In addition, small craft were opportunistically used on 23 days to examine the behavior and social interactions of right whales near the Wolves Islands, N.B. Additional observations were made on other cetaceans, but efforts were primarily directed toward *E. glacialis*.

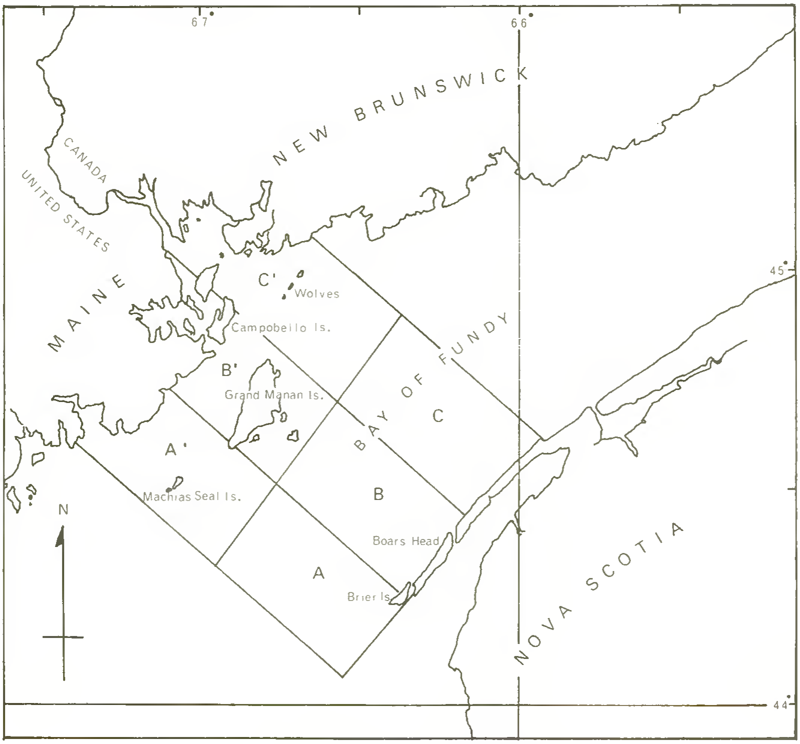

Fig. 1. 1980 Aerial survey areas in the Bay of Fundy.

RESULTS

Right whales were first observed in the lower Bay of Fundy on 10 July, and were present at least until 30 October 1980. During this period, observers recorded 131 sightings of *E. glacialis*. Separate sightings do not represent the number of animals present, since identifiable individuals were frequently resighted from day to day. On 13 August, a single aerial survey in the Grand Manan Island and the Wolves area observed 19 whales. Eight to 12 right whales were repeatedly observed in the Wolves Island area during the first two weeks of September. During this time, there were no opportunities to survey the area east of Grand Manan Island where right whales had been observed frequently in July and August. Photographic identification utilizing head callosity patterns on the right whales (Payne *et al.*, 1981) provided identification of 26 individuals. Since all animals seen were not photographed, and some photographs could not be used for individual identification, the local population of right whales probably exceeded 26.

Right whale sightings in the Bay of Fundy during the summer and fall of 1980 revealed a restricted spatial and temporal distribution (Fig. 2). Right whales were first observed in the southern section (Areas A and B) in mid-July; they appeared in the central portion (Area B′) of the Bay of Fundy by the first of August; and were restricted to a narrow strip bounded by the entrance of Passamaquoddy Bay, the western and southwestern margins of the Grand Manan Basin and the eastern side of Grand Manan Island (Area B′ and C′) in mid-August. This distribution pattern continued until at least 30 August. Outside the Bay of Fundy, a University of Rhode Island, CETAP survey flight recorded over 40 right whales north of Browns Bank, N.S. (42°45′N, 65°30′W) during the third week of August (H. Winn, pers. commn.; Stone and Perkins, 1980). Fishermen's reports to M. Barto (*in litt.* to R. Reeves, Nov. 1980) indicated that eight or nine right whales were observed about 12 miles east of Grand Manan Island between 6 and 15 October. The 30 October aerial survey covered the Wolves Island area, as well as the western and southern portions of the Grand Manan Basin, but right whales were found only on the east side of Grand Manan Island.

Cow/calf pairs

Between 10 July and 9 September 1980, 19 sightings of cow/calf pairs were made. Except for the three sightings on 10 July, 1 August and 5 August, all cow/calf observations were in the area defined on the east by the Wolves, a short chain of low lying islands, on the north by mainland New Brunswick, and on the west by Deer and Campobello Islands (Fig. 3). This area is generally smooth bottomed with depths ranging from 20 to 45 fathoms, and no marked dropoffs or ridges. All sightings of cow/calf pairs were confined to this area after 5 August, in agreement with observations from the other parts of the world and the suggestion that there is a cow/calf preference for inshore waters (Donnelly, 1969; Payne, 1976; Castello and Pinedo, 1979; Mermoz, 1980).

Cow/calf pairs were frequently resighted. Three identified cow/calf pairs were seen on 7 September, and another cow/calf pair was sighted 8 September, 1980. Examination of aerial survey photographs provided identification of four cow/calf pairs sighted from 10 July to 9 September 1980. Of these eight individual whales, four cows and three calves have been identified.

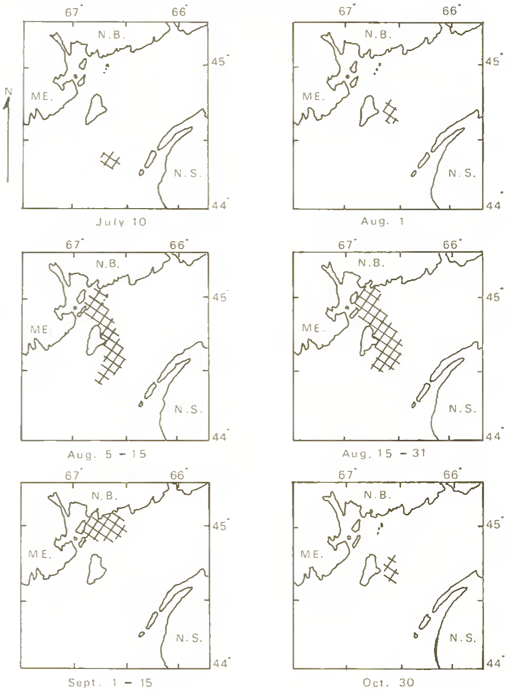

Fig. 2. Distribution of right whales, *E. glacialis*, in the Lower Bay of Fundy during the Summer and Fall of 1980.

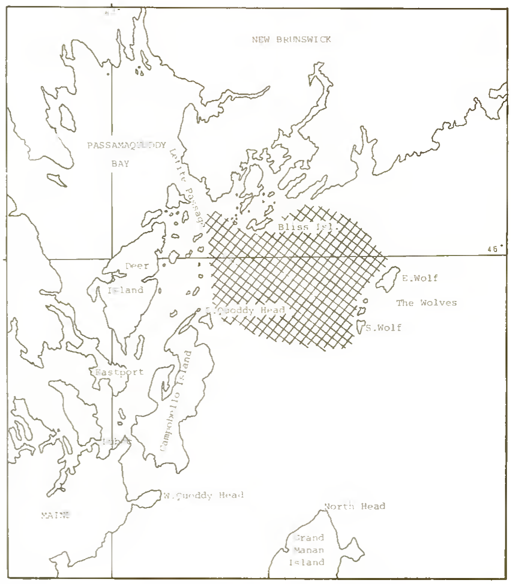

Fig. 3. Right Whale Cow/Calf Distribution Area in the Bay of Fundy during 1980.

In reviewing this local population and the significance of cow/calf sightings, an analysis of year class has been attempted. Since W. Watkins and W. Schevill (pers. comm.) have observed a calf stay with a cow for at least two years, it was not safe to assume that each cow/calf pair represented a newborn calf, first year class, even though weaning may occur within five to six months of birth (Klumov, 1962; Gaskin, 1972). To estimate the age of the calves we examined the allometric characteristics of three cow/calf pairs using the techniques described by Whitehead and Payne (1981). Photographs of the fourth identified cow/calf pair could not be used because the calf is underwater. Relative measurements of the cow/calf pairs seen on 10 July, 5 August, 30 August and 9 September were taken from clear 35 mm aerial photographs. One cow/calf pair was seen on 5 August and 9 September, and analyses from both sightings are included here.

Three sets of measurements are used in this analysis. Total relative length of the calf (L_c) was compared with the total relative length of the mother (L_m), to develop a growth curve for the calves seen, and to estimate an approximate date of birth (Fig. 4). The snout to blowhole distance (nose length) of the calves (N_c) and of their mothers (N_m) was also compared since photographs occasionally only show the heads of the cow/calf pairs. These ratios are expressed as (N_c/N_m) (Fig. 4). As a calf approaches adulthood, total length (L_c) and nose length (N_c) approach that of the mother's, and approach one. Applying Whitehead and Payne's (1981) mean cow length (13.66 m) to the (L_c/L_m) ratios, a calf length was estimated. Calf lengths were then compared with the *E. australis* age/length growth curve to compare and estimate calf age (Fig. 5). The results of these analyses are presented in Table 1.

Table 1

Estimate calf length and age

Date	L_c/L_m	N_c/N_m	Estimated calf length[1]	Estimated calf age[2]
10 July	0.5698	0.4807	7.78 m	2.5 ± 5 months
5 Aug.	0.6939	0.5431	9.43 m	5.0 ± 1 months
30 Aug.	0.6865	0.6269	9.38 m	5.0 ± 1 months
9 Sept.	0.7258	0.6400	9.97 m	6.0 ± 1 months

[1] Based on mean cow length of 13.66 m (From *E. australis*, Whitehead and Payne, 1981).

[2] Estimated from Whitehead and Payne's (1981) growth curve for first six months of *E. australis* (Fig. 5).

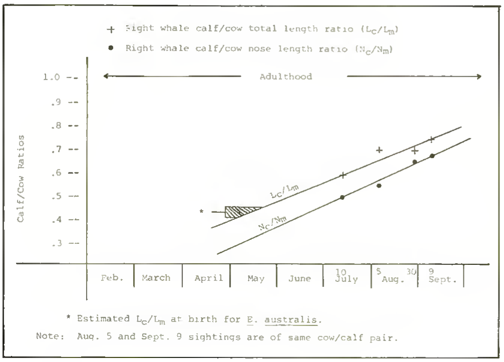

Fig. 4. Allometric ratios of right whale (*E. glacialis*) calf/cow pairs in the Bay of Fundy—1980.

Whitehead and Payne's (1981) growth curve for the first four months of *E. australis* in Fig. 5 has been extrapolated to six months and the estimated calf lengths plotted. These data, combined with a nearly straight line fit for the N_c/N_m ratio, support the hypothesis that the identified calves were probably young of the year, born in March or April. This supports the Schevill, Moore and Watkins (1981) observations of newborn and very small calves in Cape Cod Bay from March to May.

Two caveats must be considered with this interpretation of the data. First, with so few data points it is impossible to estimate statistical accuracy. Second, the use of Whitehead and Payne's (1981) growth curves derived from the south Atlantic species *E. australis* to age *E. glacialis* must be viewed cautiously. Nevertheless, because no north Atlantic right whale data are available, data from *E. australis*, a close relative, have been utilized to provide a hint of the vital biological parameters.

Baleen whales are generally considered to have a recruitment rate of 4% to 6% (Allen, 1974), though there has been speculation that the rate for the genus *Balaena* may be lower. Davis and Koski (1980) report birth rates as low as 2.2% from surveys of *B. mysticetus* in the eastern Canadian Arctic. The presence of four calves less than one year old is significant, particularly if the north Atlantic right whale population is as low as 100 (Winn *et al.*, 1981).

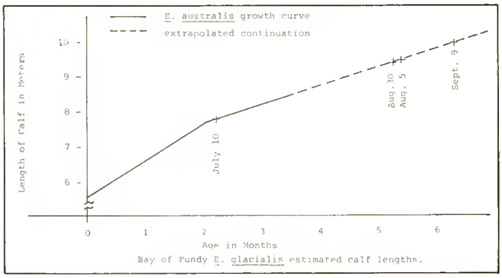

Fig. 5. Three Bay of Fundy calves plotted on growth curve for *E. australis* (from Whitehead and Payne, 1981).

Social behavior

Schevill, Moore and Watkins (1981) describe apparent courtship and other social behaviors by *E. glacialis* in the southern Gulf of Maine which were observed mostly during the spring. The 1980 Bay of Fundy observations indicate that these behavior patterns and activities continue through the summer into fall. Apparent courtship and mating behavior was observed from aircraft and ships on eleven occasions from 13 August to 30 October. These agree with descriptions of right whale behavior in other areas (Payne, 1976; Donnelly, 1967; 1969), although the seasonal pattern is out of phase. Donnelly (1969) and Best (1970) reported two distinct right whale arrival times along the coast of South Africa: cows to give birth and nurse in June and July (the austral winter), and adult bulls and cows to mate in August, September and October (early austral spring). Donnelly (1969) notes that during the second period no cow/calf pairs are seen. Best (1970) hypothesized an inshore southerly migration of cows and calves during the spring, and an offshore northerly migration of all right whales in the fall. On the other hand, Payne (1976) reported cow/calf pairs and mating groups at the same time June to October (austral winter and early spring), for the

Argentinian population of *E. australis*, though adults appeared to leave breeding and calving grounds before cow/calf pairs. From these observations one might expect similar trends in *E. glacialis* of the North Alantic, but seasonally reversed.

Winter sightings of northern right whales from the southern portion of the northwest Atlantic include several calves (reviewed by Reeves *et al.*, 1978). However, sightings from Florida were not abundant, and it is not clear that they represent the southern end of a migration or define a specific calving area. Schevill *et al.* (1981), report apparently new-born calves in April and May at the same time they observed 'presumable courtship and sexual routines' in Cape Cod Bay. Unlike the specific birthing times and places observed for *E. australis*, it appears that the North Atlantic right whale gives birth from late winter through late spring, possibly throughout its range. Mating activity also seems to be prolonged, apparently occurring in the early spring and continuing at least until the end of October (Kraus and Prescott, 1981). The apparently prolonged breeding period and the coincidence of shifted breeding activities stand in contrast to the patterns in southern right whale populations. Whether this pattern is historic, or a response to severely reduced numbers and/or a loss of site and time specific breeding habitat, remains to be determined.

Feeding

Watkins and Schevill (1976; 1979) described feeding behavior of *E. glacialis* from observations in Cape Cod Bay made during the past twenty years. Observations of feeding right whales in the Bay of Fundy during 1980 were made only on 10 July 1980 on two animals at or within 5 m of the surface. Bay of Fundy waters are murky and frequently observed long-duration (15 minutes or more) dives by single animals were probably episodes of feeding at depths. Previous reports for the region indicate a year-round abundance of euphausiids (Kulka and Iles, 1972). Observers noted an apparent 'preference' by the whales for 'murky' waters, and reporting basking sharks (also filter feeders) in the same area on 30 August and 9 September.

DISCUSSION

E. glacialis has been previously recorded in the lower Bay of Fundy. Neave and Wright (1968; see Schevill, 1968) reported a group of 15 in August of 1966 from the ferry that crosses the Gulf of Maine between Bar Harbor, Me., and Yarmouth, N.S. Arnold and Gaskin (1972) sighted at least five right whales in the entrances to Passamaquoddy Bay between 22 August and 29 August 1971. Local fishermen noted that whales 'with bumps on heads' have occurred nearly every year since 1966, and even report they occasionally saw them as late as January. Two right whales were reported present on 5 November 1968, in Letite Passage, between Deer Island and the mainland (M. Barto, pers. comm., with photos). Reeves *et al.* (1978) summarized the sightings in the northern Gulf of Maine for the period 1973 to 1977. One of us (S. Kraus) observed a pair of right whales in the Grand Manan Basin (at 44°34′N, 66°32′W) on 23 August 1978.

These records suggest a consistent summer and fall right whale distribution in the lower Bay of Fundy. Prior to the 1980 surveys, no systematic effort was made to examine the Grand Manan region of the Bay of Fundy for large cetaceans. The small numbers of sightings most likely reflect the lack of effort and not the absence of whales in the region. The relatively large numbers (a minimum of 26 animals) and long-term residence of the right whales in the Bay of Fundy observed in 1980 substantiates earlier sightings. Because of the extremely small size (est. 100–150) of the North Atlantic population (Winn *et al.*, 1981; Mitchell, 1973, 1974) and pessimistic views by some (Reeves *et al.*, 1978; Mitchell, 1975) as to its chances for recovery, the presence of four identified cow/calf pairs in the region is significant. Mating activity was observed among many of the adults, from 13 August to at least 30 October.

Examination of other right whale mating and calving areas reveals that the common denominator appears to be the seasonal use of shallow well-protected bays. In the northwest Atlantic, early shore whalers hunted right whales along the mid-Atlantic coast, and seasonally killed large numbers in the Delaware and Chesapeake Bays, Long Island Sound, and Cape Cod Bay (Lipton, 1975; Reeves *et al.*, 1978). It seems likely that these bays, and perhaps others, were mating and calving areas. The killing of these right whales during the 16th and 17th centuries may have exterminated a segment of the population using these bays for breeding and calving grounds.

Allen (1974) notes that for gray whales, congregating in specific areas probably 'assist(s) the species in maintaining its reproductive efficiency, since it would improve the chances of encounters between animals at very low population levels'. The two locations where right whales have been seen most recently, Cape Cod Bay and the western Bay of Fundy, appear similar in many respects to other reported right whale mating areas.

In conclusion, the long duration of residence by *E. glacialis* in the lower Bay of Fundy during 1980 suggests that the area is important to a significant portion of the population. The presence of four cow/calf pairs in the western inshore portions of the Bay, and observations of feeding and courtship behavior and apparent mating add substantially to the importance of the habitat.

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REFERENCES

Allen, K. R. 1974. Recruitment to whale stocks, pp. 352–8. *In:* Schevill, W. E. (ed.), *The Whale Problem: a status report.* Harvard University Press, Cambridge, Mass. 419 pp.

Arnold, P. W. and Gaskin, D. E. 1972. Sight records of right whales (*Eubalaena glacialis*) and finback whales (*Balaenoptera physalus*) from the lower Bay of Fundy. *J. Fish. Res. Bd Can.* 29: 1477–8.

Best, P. B. 1970. Exploitation and recovery of right whales (*Eubalaena australis*) off the Cape Province. *Investl. Rep. Div. Sea Fish. S. Afr.* 80: 1–20.

Castello, H. P. and Pinedo, M. C. 1979. Southern right whales (*Eubalaena australis*) along the southern Brazilian coast. *J. Mamm.* 60(2): 429–30.

Davis, R. A. and Koski, W. A. 1980. Recent observations of the bowhead whale in the eastern Canadian high Arctic. *Rep. int. Whal. Commn* 30: 439–44.

Donnelly, B. G. 1967. Observations on the mating behaviour of the southern right whale *Eubalaena australis*. *S. Afr. J. Sci.* 63(5): 176–81.

Donnelly, B. G. 1969. Further observations on the southern right whale, *Eubalaena australis*, in South African waters. *J. Reprod. Fert. Suppl.* 6: 347–52.

Gaskin, D. E. 1972. *Whales, Dolphins and Seals*. St Martin's Press, New York, NY. 200 pp.

Klumov, S. K. 1962. Gladkie (yaponskie) kity Tichogo Okeana [(Japanese) right whales in the Pacific Ocean.] *Tr. Inst. Okeanol.* 58: 202–97.

Kraus, S. D. and Prescott, J. H. 1981. Large cetaceans of the Bay of Fundy. Rep. to U.S. Dept. of Comm., Nat. Mar. Fish. Serv. (Unpublished manuscript.)

Kulka, D. W. and Iles, T. D. 1975. Populations of euphausiid species in the Bay of Fundy and their seasonal movements. ICES document C.M. 1975/L:25. (Unpublished manuscript)

Lipton, B. 1975. Whaling days in New Jersey. *Newark Mus. Quart.* 26(2–3): 72 pp.

Mermoz, J. F. 1980. Preliminary report on the southern right whale in the southwestern Atlantic. *Rep. int. Whal. Commn* 30: 183–6.

Mitchell, E. D. 1973. The status of the world's whales. *Nature Canada* 2(4): 9–27.

Mitchell, E. D. 1974. Present status of northwest Atlantic fin and other whale stocks. Chapter 5, pp. 108–69, *In:* W. E. Schevill (ed) *The Whale Problem: a status report*. Harvard University Press, Cambridge, Mass, 419 pp.

Mitchell, E. D. 1975. Trophic relationships and competition for food in northwest Atlantic whales. *Proc. Canad. Soc. Zool. Ann. Mtg.*: 123–33.

Neave, D. J. and Wright, B. S. 1968. Seasonal migrations of the harbor porpoise (*Phocoena phocoena*) and other Cetacea in the Bay of Fundy. *J. Mamm.* 49(2): 259–64.

Payne, R. 1976. At home with right whales. *Nat. Geog.* 149(3): 322–39.

Payne, R. O., Brazier, O., Dorsey, E., Perkins, J., Rowntree, V. and Titus, A. 1981. External features in southern right whales (*Eubalaena australis*) and their use in identifying individuals. U.S.D.C. NTIS PB81-161093. 77 p.

Reeves, R. R., Mead, J. G. and Katona, S. K. 1978. The right whale, *Eubalaena glacialis*, in the western north Atlantic. *Rep. int. Whal. Commn* 28: 303–12.

Schevill, W. E. 1968. Sight records of *Phocoena* and of cetaceans in general. *J. Mamm.* 49: 794–6.

Schevill, W. E., Moore, K. E. and Watkins, W. A. 1981. Right whale (*Eubalaena glacialis*) sightings in Cape Cod waters. Woods Hole Oceanog. Inst. Tech. Rept. WHOI-81-50. 16 p.

Stone, G. and Perkins, P. 1980. CETAP Flight Rept. Nova Scotia Right Whale Survey, August 1980. Unpubl. manuscript, Univ. Rhode Island.

Watkins, W. A. and Schevill, W. E. 1976. Right whale feeding and baleen rattle. *J. Mamm.* 57(1): 58–66.

Watkins, W. A. and Schevill, W. E. 1979. Aerial observation of feeding behavior in four Baleen whales: *Eubalaena glacialis*, *Balaenoptera borealis*, *Megaptera novaeangliae*, and *Balaenoptera physalus*. *J. Mamm.* 60(1): 155–63.

Whitehead, H. and Payne, R. 1981. New techniques for measuring whales from the air. U.S.D.C. NTIS PB81-161143. 36 pp.

Winn, H. E., Goodale, O. E., Hyman, M. A. M., Kenney, R. D., Price, C. A. and Scott, G. 1981. Right whale sightings and the right whale minimum count. Chapter VI *In: A Characterization of Marine Mammals and Turtles in the mid- and north-Atlantic Areas of the U.S. Outer Continental Shelf*. Annual Report for 1979 to the Bureau of Land Management by CETAP at the University of Rhode Island, 37 pp.

SC/33/SM2

Peculiarities of White Whale Distribution and Population Dynamics in the White Sea

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ABSTRACT

The results of studies on white whale distribution and population dynamics in the White Sea are given. Fluctuations in numbers and density are shown for the northern and southern areas of the Sea. A correlation between different types of groupings and number of animals is shown. The intraspecific structure is analysed. The authors consider there to be no grounds to consider the southern White Sea white whales as a separate subspecies.

There are few data in the literature concerning the number and distribution of the white whale (*Delphinapterus leucas*) in the White Sea, despite the fact that it is hunted in this area. The first attempt to determine the numbers of white whales in the southern White Sea was made in 1933 by Klumov (1939), who believed that a special form of white whale lived in this area. He concluded that there were up to 6,000–8,000 animals and that the maximum sustainable yield was 500–700 annually. Until now, these data have been used to support the view that white whale hunting is on such a small scale that it has little effect on the population (Heptner *et al.*, 1976).

From 1970 to 1980, boats and aircraft have been used to collect data on white whale distribution, numbers and group structure. Between 1970 and 1972, a method to estimate numbers from aircraft was developed (Potelov, 1973) and a brief outline of the method is given below.

(a) The number of encounters with white whales (independently of the number of animals in a grouping) is taken as the data base for estimating population size.
(b) The percentage of observation squares containing white whales is determined from the total number of observation squares.
(c) The average number of encounters per observation square where at least one encounter has occurred is determined.
(d) The average number of white whales per encounter (grouping) is determined.

$$\bar{X}_g = \frac{(S.1) + (G.x_1) + (Y.x_2) + (K.x_3)}{100}$$

$\bar{X}_g$ = average no. animals per encounter
S = singles
G = groups
Y = yuros
K = kosyak
(S, G, Y, K: see p. 417)
x_1 = no. animals in group
x_2 = no. animals in yuro
x_3 = no. animals in kosyak

(e) Data obtained using variation statistics are then extrapolated to the whole distribution area.

The accurate determination of the track width is difficult when counting marine mammals. A standard value dependent on the limit of visibility of the animal is used by the majority of terrestrial animal investigators.

Of course the distance that white whales can be seen varies with prevailing conditions, e.g. light, time of day, weather conditions, height of the flight, grouping size etc. Thus, the maximum distance from the plane to a white whale was not more than 10 km and from the vessel not more than 5 km in calm weather. When the sea state deteriorated to 2, the distance of course decreased: to 1.0 km from the plane and to 0.5 km from the vessel.

At sea state 3 or more it is difficult to find white whales. There is also some relationship between sightability and grouping size with, as one might expect, the greater the number in a grouping, the easier it can be seen.

To determine the distance simultaneously with recording the sighting a stopwatch was used and the distance calculated from the time and the known velocity of the plane. The results are further given in Table 1. The apparent regularities revealed need to be further studied but even now it seems that a standard track width cannot be determined for the counting of white whales. We believe that the visibility limit must be calculated based on the maximum distance to a sighted animal or to an 'imitation' (e.g. white floats, drifting logs). Average values of the visibility limit can only be related to areas with similar weather conditions.

Double values of this distance were taken as the track width which was thus from 2.0 km–4.4 km in calm weather (average 3.1 km), from 1.0 km–3.0 km with light rippling (average 1.9 km), from 0.6 km–1.6 km at sea state 1–2 (average 1.0 km) and only 0.2 km–0.6 km at sea states of 3 or more.

The size of the observation squares had to be constant otherwise difficulties are inevitable when examining the data using variation statistics. The value chosen cannot be arbitrary as it affects not only the values of the final results, but also the reliability. The dependence of the accuracy of white whale counts against the size of the observation squares can really only be based on experimental results. We were not able to carry out such experiments and we therefore took a value of 40 km² which although arrived at without any mathematical basis, was chosen for the following reasons:

(a) The observed track width was on the average 3.0 km while counting groupings, at 180 km per hour at a height of 300 m above the sea (Table 1) and thus an area of about 40 km² was examined every 4 minutes.

Table 1

The distance between the plane and the sea, which allows a white whale to be seen under different sea conditions (flight height—300 m, velocity—180 km/hour)

Sea state	Single animals	Groupings	'Imitations' (logs or white floats etc.)
1. Calm	1080(1000–1250) 3	1930(1000–2475) 12	1466(832–2000) 11
2. Ripples	1000(500–1500) 4	750(500–1000) 2	1100(1000–1200) 2
3. 1–2	300 2	500 3	850 1
4. 3–5	150 2	300 1	—

Note: The mean distance (in metres) and the range are given in the numerator; and the number of measurements in the denominator.

(b) In the repeated process of investigating the same section of any area, the results of counting are statistically more accurate for small squares. We do not believe that it is sensible to shorten the duration of observations to less than 4 minutes, for, as can happen, counting conditions may improve and increase the visibility limit, thus, the distance covered will be shorter as well as the time of observation.

(c) The smaller the width of area investigated, the longer is the observation time. The principle of the random selection of information should be adhered to in the design of the survey. There are many suggestions as to how this can be achieved in the selection of areas to be examined. Aksutina (1968) proposed that the overall area be divided into a number of squares, 2–3 times the number of 'stations' planned and the position of the stations then determined by random numbers.

Unfortunately it is very difficult to keep strictly to this principle when counting white whales by plane. Table 2 shows that the animals are encountered more often within 2 km of the shore (58.4% of the total number), while 22.0% white whales were found at a distance of 2–5 km from the coast, 16.7% 5–10 km from the coast and 2.9% at distances of more than 10 km.

Table 2

Distribution of white whales and the distance from the coast, White Sea, 1971–75

Distance from the coast (km)	Number encountered	Percent
Up to 1	717	38.80
1–2	363	19.64
2–3	218	11.80
3–4	168	9.09
4–5	20	1.08
5–6	112	6.06
6–7	101	5.46
7–8	39	2.11
8–9	35	1.90
9–10	21	1.14
10+	54	2.92

The only exception to this fall in density with increasing distance from the coast is for the shallow waters in the northern part of the Sea where the whales stay further from the coast where the water depth allows free movement. These differences enabled us to divide the area into coastal (<10 km from the coast) and marine (>10 km) zones.

Table 3

Numbers of white whales in the White Sea, 1971–80

Areas	1971	1972	1975	1979	1980
Southern part	476	1,170	201	135	271
Onezhsky Gulf	345	870	150	44	174
Dvinsky Gulf	42	123	21	29	67
Kandalakhsky Gulf	26	54	0	59	30
Bassin	63	123	30	3	0
Northern part	1,094	400–800*	116	97	376
White Sea	1,570 ±18.7%	1,500–2,000 ±20.0%	317 ±18.2%	232 ±19.8%	647 ±20.0%

* No counts: the estimated number was calculated.

Table 3 shows that in summer the white whale is found throughout the southern White Sea, but its density varies in different areas; being most common in the Onezhsky Gulf and the southern part of the Dvinsky Gulf, and less common in the Bassin area and the Kandalakshsky Gulf.

Data on the density of animals within the inshore zone of different areas of the Sea are given in Table, 4, which shows that the number of animals is greatest near the coasts of the Onezhsky and Dvinsky Gulfs, and that there are between 2–4 times more whales in the southern part of the Sea compared with the northern part.

Table 4

Distribution of white whales in the coastal zone of the White Sea from 1971 to 1980 (animals/100 km^2)

Areas	1971	1972	1975	1979	1980
Southern part	7.8	17.6	0.9	2.1	3.7
Onezhsky Gulf	12.5	31.5	1.5	1.6	4.8
Dvinsky Gulf	3.8	11.2	0.5	4.0	6.1
Kandalakshsky Gulf	1.8	3.6	0	2.6	2.0
Bassin	8.3	3.9	1.2	0.4	0
Northern part of the Sea	1.6	4(?)	0.3	2.0	1.0
Mezensky Gulf	1.25	?	0.1	2.3	0
Gorlo	4.3	?	0.5	1.3	4.8
Voronka	1.25	?	0.9	1.7	1.9
White Sea	4.1	8.5	0.5	2.0	2.1

(?) In 1972, the white whales were not counted in the White Sea; the mean density was therefore estimated for this area and the Sea as a whole.

Table 4 shows the clear fluctuations in density between areas and between years. For example in the southern area density varied from 0.9 animals/100 km^2 to 17.6 animals/100 km^2. Similarly annual values for the whole area vary considerably from 135 (1979) to 1,170 (1972).

These results are much lower than those of Klumov (1939) yet during the last 50 years, the white whale harvest only reached the 'limit' of 500–700 animals on five occasions. In the other years the numbers were much less than 500 animals (average 258). It seems safe to conclude that the large difference between our data and his cannot be explained by over-exploitation and that in fact the difference is due to (a) imperfections in Klumov's estimation technique; (b) migrations of white whales from the Barents Sea to the White Sea during these years.

STOCK IDENTITY

Over the years there have been a wide range of views on the stock identity of the white whales found in the White Sea. Heptner (1930) believed that they form an independent stock; Ostroumov (1935) believed there to be a southern White Sea form and a western form; Klumov (1935; 1939) believed that there were southern White Sea and Kara Sea forms, while Tomilin (1957) thought that the White Sea white whales were a geographical race. Kleinenberg *et al.* (1964) examined the available data and concluded that the morphological differences Klumov used to distinguish independent forms of white whale in the White Sea were not representative. Nevertheless, Heptner *et al.* (1976) considered that there may be two sub-species: in the southern White Sea and the Kara Sea.

White whales may be found in the White Sea at any time of the year, but they are generally rare in autumn and winter. Thus, the results of the white whale counting for the period from 1970–80 showed that in September–October (before the ice) the animals were 5 times less common than in the summer period (June–July). In spring, white whales were approximately 2.5 times more common than in autumn. The increase in white whales in spring is connected with their migration from the Barents Sea along the Tersky coast. The animals continue to arrive in summer. In June, we often observed groupings of up to 50 animals in the area of Boronka, Gorlo and even in the northern part of the Onezhsky Gulf; these groupings were generally moving from north to south. Towards the end of June–beginning of July, the white whales move north to the Barents Sea. The main migratory route is along the western coast of the Kanin Peninsula, where it is regularly harvested. Ognetov (1981) concluded that the available morphological data revealed no differences between animals from the White and Kara Seas.

Data given in Tables 3 and 4 show that the annual fluctuations in white whale numbers are synchronous for the southern and northern parts of the Sea, i.e. when the number of animals was high in the southern areas, it was also high in the northern areas. In addition the annual fluctuations noted in the southern part of the Sea coincided with harvesting results to the north of the Kanin Peninsula (Ognetov and Potelov, 1978) strongly suggesting that the southern White Sea animals are not separate from the northern animals. These annual fluctuations in animal numbers are correlated with the mean air temperatures to the north of Ostrov Vaygach in May, i.e. the lower the air temperature the higher their numbers. It is known (Antonov, 1980) that in May–June the fluctuations in air temperature to the south of Novaya Zemlya, Point Dixon and other places in the southern Kara Sea depend on the ice conditions in the Barents and Kara Seas. Thus it appears that the number of white whales found in the southern part of the White Sea is dependent on the ice conditions in the Barents and Kara Seas; therefore the more intense is the ice formation then the greater the number of animals in the White Sea. This further supports the view of Ogentov (1981) that the white whales of the White and Kara Seas are from the same stock.

SOCIAL ORGANISATION

Ognetov and Potelov (1978) and Ognetov (1981) divided white whale groupings into the following four categories: (a) singles, (b) groups (2–10 whales), (c) yuros (11–100 whales), and (d) kosyaks (more than 100 animals). We have followed the same method for white whale data from the White Sea for the period 1971–80 (Tables 5 and 6). Table 5 shows that the occurrence of singles and groups is similar in both the southern and northern areas of the Sea.

Table 5

Types of white whale groupings in the southern and northern areas of the White Sea, 1971–80 (percent)

Areas	Number of groupings	Singles	Groups	Yuros	Kosyaks
Southern	146	43.8	50.0	5.5	0.7
Northern	71	35.2	49.3	11.3	4.2

However the larger groupings are encountered more often in the northern area. Table 6 shows that the total number of animals entering as singles or groups has varied insignificantly by year, whereas the number of animals in yuros and kosyaks varied considerably which resulted in the large yearly fluctuations in total number of animals in the whole sea.

Unfortunately, we have very little data on the morphology and ecology of the animals entering in the different groupings. Nevertheless, the singles and small individual groups (2–5 animals) consist mainly of adult (i.e. white) animals. Singles and groups are found throughout the White Sea and may be encountered in the Barents and Kara Seas.

Table 6

Number of counted animals in different groupings (the White Sea, 1971–80)

Years	Number of animals	Singles and groups	Yuros and kosyaks
1971	1,570	184	1,386
1972	1,170	208	962
1975	317	287	30
1979	232	232	0
1980	647	327	302

It is difficult to distinguish small, dark coloured calves from an aircraft or even a vessel. Therefore, the fact that in 1979–80 small calves were found in 24 of the 48 groups investigated suggests that many groups contain pregnant and post-partum females, as well as mature males.

CONCLUSION

(1) White whale numbers in the White Sea can vary considerably by year (200–1,000+) and appear to be correlated with ice conditions in the Barents and Kara Seas. This further supports the view that these white whales do not constitute an independent stock.

(2) It appears that sometimes, perhaps once in 10–12 years, an extremely large number of white whales migrates from the Barents to the White Sea.

(3) The extent of the migration into the White Sea also varies, some groupings reaching the southern areas of the Sea, some others reaching the Mezensky Gulf, while others only enter the northern areas adjacent to the Barents Sea.

(4) Although white whales are generally found in the White Sea from May to July (Ognetov and Potelov, 1978) the duration of stay of individual groupings may vary: some animals remain there throughout the year, some stay for 1–2 months, while others stay for only a few days. This makes it very difficult to determine precisely the number of white whales found in the White Sea during a year;

(5) It appears from the numbers of encounters that singles and groups remain in the White Sea for the longest period, although the reasons for this are not clear.

REFERENCES

Aksutina, Z. M. 1968. *Elements of the Mathematical Assessment of the Results of Observations in Biological and Fishery Investigations.* Pischevaya Promyshlennest, Moscow, 288 pp. (In Russian.)

Antonov, V. S. 1980. Long-term fluctuations of some elements of the hydrometeorological regime of the Arctic Region. pp 13–19. In: *Collection of Articles on Problems of the Arctic and Antarctic Regions*, Volume 53 (In Russian.)

Heptner, V. G. 1930. Data on the geographical distribution and biology of the beluga. *Tr. Nauchno-Issled. Int. Zool.* 4(2): 7–100. (In Russian.)

Heptner, V. G., Chapsky, K. R., Arsenyev, V. A. and Sokolov, V. E. 1976. *Mammals of the Soviet Union,* Vol. 2, Vysshaya shkola, Moscow. (In Russian.)

Kleinenberg, S. E., Yablokov, A. V., Belkovich, V. M. and Tarasevich, M. N. 1964. *Beluga – Investigation of the Species.*Nauka, Moscow, 455 pp. [Translated from Russian. Israel Prog. for Scient. Transl., Jerusalem. No. 1923, 376 pp. 1969].

Klumov, S. K. 1935. New form of the white whale. *Rybn. Khoz.* 7: 26–8 (In Russian.)

Klumov, S. K. 1939. White whale of the Soviet North. *Tr. VNIRO.* 12: 3–78 (In Russian.)

Ognetov, G. N. 1981. Studies on the ecology and the taxonomy of the white whale (*Delphinapterus leucas* Pall., 1776) inhabiting the Soviet Arctic. *Rep. int. Whal. Commn* 31: 515–20.

Ognetov, G. N. and Potelov, V. A. 1978. The dynamics of the white whale approached to the White Sea. *Ekologya* 4: 78–85. (In Russian.)

Ostroumov, N. A. 1935. On the systematics and distribution of the white whale of Northern Europe and the Kara Sea. *Zh. Rybn. Indust. Sevia* 11: 28–35. (In Russian.)

Potelov, V. A. 1973. White whale numbers in the White Sea. In: *Rare Cetacean Species of the USSR and Their Protection.* Nauka, Moscow, 100 pp. (In Russian.)

Tomilin, A. G. 1957. *The Animals of the USSR and Adjacent Countries.* Vol. 9. Cetaceans. USSR Acad. Sci. Moscow. 756 pp. (In Russian.)

SC/33/SM3

Dolphin Mortality in the Eastern Tropical Pacific Incidental to Purse Seining for Yellowfin Tuna, 1980

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ABSTRACT

Estimates of dolphin mortality incidental to purse seining for yellowfin tuna in the eastern Pacific have been made from data collected by scientific technicians aboard seiners of the international fleet. Roughly 30% of all sets on tuna associated with dolphins were observed in 1980. The estimated total number of dolphins killed was approximately 44,000, primarily spotted dolphins and whitebelly spinner dolphins.

INTRODUCTION

In 1976, the Inter-American Tropical Tuna Commission (IATTC) recognized that it had a responsibility to concern itself with the problem of dolphin mortality associated with the purse seine fishery for yellowfin tuna in the eastern tropical Pacific Ocean. In 1979 an observer program was started in which trained observers are placed on board seiners of both member and non-member countries to record data for estimating population size and incidental mortality. The National Marine Fisheries Service of the United States (NMFS) has been conducting a similar program on American seiners since 1971.

METHODS

In this paper, 1980 data from both the IATTC and NMFS programs have been used including observed trips aboard seiners from Costa Rica (3), New Zealand (1), Panama (2), the USA (98), and Venezuela (2). During the year, seiners from Bermuda, British Cayman Islands, Costa Rica, Ecuador, Republic of Korea, Mexico, Netherlands Antilles, New Zealand, Panama, Senegal, Spain, the USA, and Venezuela made sets on dolphins in the eastern Pacific Ocean and the total number of dolphin sets from these boats has been used for making estimates of mortality.

Because of the differences in sampling intensity, and because of more stringent regulations for seiners from the USA than for other countries, the data were split into two groups, the first for the USA and the second for the other countries. In the latter group only four countries agreed to participate in the sampling program. These countries accounted for about 30% of the sets on dolphins which were made by non-USA seiners. Thus the estimates given for non-USA seiners are made by extrapolation from the results from seiners in the sampled fleets to all international fleets.

In making the estimates, only animals which were known to have been killed were used from both the IATTC and the NMFS data. It is possible that some of the animals which were injured during the set died later. There are differences in the definitions used by NMFS and IATTC of what constitutes a fishing trip. These differences cause the number of sample trips for seiners from the USA to be undercounted by up to two trips. This does not affect the estimates of mortality, but means that the estimates of standard errors for the USA were overestimated by about 2%.

Table 1 gives a summary of the data divided into four strata classified by: USA, non-USA; successful sets (in which at least ½ ton of yellowfin and/or skipjack tuna was captured), and unsuccessful sets.

The distribution of dolphin mortality is badly skewed and confidence intervals based on normal distributions are unlikely to be accurate. To obtain an estimate of the sampling distribution of the mortality estimates a Monte-Carlo simulation was carried out by repeatedly sampling from a population consisting of 167 trips with successful sets which were observed by IATTC and NMFS technicians during 1979 and 1980. This population was midway in size between the populations for the USA and non-USA seiners in 1980. Samples of 8 and 55 trips were randomly selected for spotted and common dolphins. This process was repeated 100,000 times and sampling distributions calculated for mortality estimates.

RESULTS

All the successful and unsuccessful dolphin sets that were made during a trip are treated as a cluster sample (Cockran, 1953). Letting s_i be the number of sets in the ith sampled trip ($i = 1, \ldots n$), k_{ij} the number of species j killed in trip i, S_0 the estimated total sets made on dolphin schools, and N the estimated total number of trips during which sets were made on dolphins, the estimated kill per set of species j is:

$$\hat{R}_j = \frac{\sum_{i=1}^{n} k_{ij}}{\sum_{i=1}^{n} s_i}$$

and the ratio estimate of the total number of the species j killed is

$$\hat{K}_j = S_0 \hat{R}_j$$

with variance

$$\mathrm{var}(\hat{K}_j) = \frac{N(N-n)}{n(n-1)} \left(\sum_{i=1}^{n} k_{ij}^2 + \hat{R}_j^2 \sum_{i=1}^{n} s_i^2 - 2\hat{R}_j \sum_{i=1}^{n} k_{ij} s_i \right).$$

In addition to stratifying by country and fishing success, the trips were also stratified by the number of sets per trip to examine the effect of variation in the number of

Table 1

Observed dolphin mortality, 1980

	Total trips with sets on dolphins	Sampled trips with sets on dolphins	Sampled sets on dolphin	Spotted dolphin	Eastern Spinner dolphin	White-belly Spinner dolphin	Unidentified Spinner dolphin	Common dolphin	Striped dolphin	Others and Unidentified dolphin
USA (1)	226	97	1,894	4,535	283	1,555	56	139	20	119
USA (2)	149	76	239	155	2	61	0	25	17	12
Non-USA (1)	151	8	78	379	34	292	0	39	3	0
Non-USA (2)	124	6	32	50	23	0	1	230	18	0

(1) = Successful sets.
(2) = Unsuccessful sets.
Note that a fishing trip can have both successful and unsuccessful sets.

Table 2

Effects of stratification by number of sets

Number of strata	Number of trips per strata	Estimated total US kill from successful sets	Standard error of total kill
1	97	16,702	2,473
2	48, 49	16,514	2,405
3	33, 33, 31	16,192	2,265
4	25, 25, 23, 24	15,531	2,064
5	16, 19, 18, 20, 24	16,465	2,419

observations per cluster which could cause biased estimates. Several stratifications were tried and the effects of these are shown for the kill of all species combined for successful USA sets in Table 2. This table shows that there is little effect on the estimates but that the stratification does reduce the standard error. For each of the four original groups a stratification was chosen which minimized the variance of the total kill. Thus, the estimate of total kill for successful USA sets was chosen as 15,531 with standard error 2,064 (Table 2, line 4). The resulting estimates and standard errors for all strata are shown in Tables 3 and 4.

Table 5 shows the Monte-Carlo estimates of bias in the standard error, and the 95% confidence intervals. The estimates of the standard errors are biased downwards and

Table 3

Estimated incidental mortality, 1980

	Spotted dolphin	Eastern Spinner dolphin	Whitebelly Spinner dolphin	Unidentified Spinner dolphin	Common dolphin	Striped dolphin	Others and Unidentified dolphin
USA (1)	10,629	678	3,403	135	350	44	292
USA (2)	303	4	114	0	50	31	22
Non-USA (1)	10,804	1,096	9,402	0	909	53	0
Non-USA (2)	833	370	0	16	3,712	289	0
Total	22,569	2,148	12,919	151	5,021	417	314

(1) = Successful sets.
(2) = Unsuccessful sets.

Table 4

Standard errors of mortality estimates, 1980

	Spotted dolphin	Eastern Spinner dolphin	Whitebelly Spinner dolphin	Unidentified Spinner dolphin	Common dolphin	Striped dolphin	Others and Unidentified dolphin
USA (1)	1,529	104	903	42	128	21	146
USA (2)	101	3	49	0	23	23	15
Non-USA (1)	2,232	555	2,730	0	513	68	0
Non-USA (2)	364	374	0	12	3,370	215	0
Total	2,732	677	2,876	43	3,411	227	147

(1) = Successful sets.
(2) = Unsuccessful sets.

the confidence intervals are asymetrical and wider than plus or minus two standard errors. These characteristics are much more marked for small samples than for large samples, and for common dolphins than for spotted dolphins. For estimates for common dolphins using samples of 8, 11% of the estimates of kill were zero and thus there was no lower 95% lower confidence limit.

Table 5

Ratio of average estimate of standard error to population standard error (bias) and 95% confidence limits as a multiple of average estimated standard error from the mean for estimated total kill based on a sampling population of 167 trips

	Sample size (trips)	Bias in estimated standard error ($\bar{s}$)	Empirical confidence limits	
			Lower	Upper
Spotted dolphin	8	0.77	$-1.7\bar{s}$	$+3.5\bar{s}$
Spotted dolphin	55	0.96	$-1.9\bar{s}$	$+2.1\bar{s}$
Common dolphin	8	0.57	—	$+4.9\bar{s}$
Common dolphin	55	0.91	$-1.8\bar{s}$	$+2.3\bar{s}$

DISCUSSION

The estimates of dolphin mortality incidental to purse seining in the eastern Pacific presented in this paper are of mixed quality. For seiners from the USA fleet, about 40% of the trips which contributed to dolphin mortality were sampled. For spotted dolphins this sample gives an estimated coefficient of variation of 14% and approximate 95% confidence limits of about ±30% of the estimate. For common dolphins the coefficient of variation is 37% giving approximate 95% confidence limits of ±75% of the estimate, which is less satisfactory. For the non-USA fleet only 5% of the population of trips was sampled. The Monte-Carlo results suggest that for samples of this size the symmetrical confidence limits are no longer useful. Using the empirical intervals for samples of 8 trips the 95% intervals for combined successful and unsuccessful sets would be (8,000–20,000) and (0–21,000) for spotted and common dolphins respectively. These are only good enough for rough estimates of mortality. The USA and non-USA fleet are now of roughly equal importance in causing dolphin mortality and it is clear that more trips must be sampled from the non-USA portion of the fleet if precise estimates of total mortality are to be obtained.

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REFERENCE

Cockran, W. G. 1953. *Sampling Techniques*. John Wiley and Sons.

SC/33/SM4

A Preliminary Analysis of the British Stranding Records of the Harbour Porpoise (*Phocoena phocoena*)

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ABSTRACT

The records of strandings of the harbour porpoise (*Phocoena phocoena*) on British coasts were analysed for the period 1913–1979. No significant upward or downward trend was found for the record as a whole, but there are significant fluctuations. 1940–43 may represent a particularly low period and 1932–39 a particularly high period. Different seasonal patterns were found on west and east coasts: the Cumberland and South Wales records showing a late summer peak, while the east England records showed a different pattern, possibly a north-south movement. The regional record over the whole period shows that the Cumberland records were not evident for the first 20 years and that the east England records were most numerous during the same period. In discussing these findings the importance of resolving various problems, including identification, observer changes and environmental changes is emphasised before statements can be made with authority about possible trends in the records. Further work is then necessary before any trends can be related to the population alive at sea.

INTRODUCTION

Concern has been expressed in recent years about the status of the North Sea and Baltic Sea populations of the harbour porpoise (*Phocoena phocoena*) (Andersen, 1975; Duguy, 1977; Evans, 1980; IWC, 1980; Mitchell, 1975; Smit and Wijngaarden, 1976; Van Bree, 1977). While it is clear from catch records and recent sightings that at the least a major change in migration habits has occurred over the past 150 years near the island of Funen in the Danish Baltic (Andersen, 1975), the situation in the North Sea is not so clear.

The data available for the North Sea consist of strandings recorded for the British Isles from 1913, less complete strandings records for the Netherlands from 1931, some recent strandings records from France and sightings records from the last twenty years for the British Isles (Harmer, 1914; 1915; 1916; 1917; 1918; 1919; 1921; 1923; 1925 and 1927; Fraser, 1934; 1946; 1953 and 1974; Sheldrick, 1976 and 1979; Evans, 1980; Duguy, 1977; Van Bree, 1977).

It is unfortunate that the longest series of records are of strandings, since the exact relationship between these and the living population has not yet been elucidated (and may not be one of direct proportion). Nevertheless, as these are the records on which much of the comment is based, it is not unreasonable to subject them, as they stand, to statistical analysis, particularly as this has not previously been performed in detail.

This study is confined to the British records since they are the most comprehensive. It attempts to answer the following questions:

1. Has the rate of stranding changed significantly over the 67 years of records available and/or have there been any periods where the rate of stranding has been particularly low or high?
2. Does the pattern of strandings around the coastline change significantly either with season or from year to year?

MATERIAL AND METHODS

Details of strandings (originating mainly from Coastguard reports) have been published by the British Museum (Natural History) (Harmer, 1914; 1915; 1916; 1917; 1918; 1919; 1921; 1923; 1925 and 1927; Fraser, 1943; 1946; 1953 and 1974). The more recent records (1967–79) were kindly made available by the Museum.

The records were used as they stand except that all Irish records have been omitted because of the major differences in recording routine over the period, as have the few records where exact dates cannot be given. Each stranding is regarded as a single event, even when more than one animal was involved. This species, however, tends to strand singly and only a very few records refer to pairs or more animals.

RESULTS

Long-term trends

From 1913 to 1979 a total of 723 strandings records was used. Fig. 1 shows the variation in the frequency per year over this period. Mean frequency was 10.8 with a standard deviation of 5.7. A standard linear regression analysis gives an estimated trend of −0.058 per year and gives the following analyses of variance:

	DF	Sum of squares	Mean square	F
Regression	1	83.905	83.905	2.646
Residual	65	2,061.169	31.710	

The F ratio, 2.646, is not significant at 90% on an $F_{1,65}$ distribution. We therefore accept the hypothesis that there is no significant downward (or upward) trend in the level of strandings over the period.

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Clearly there are, however, some periods with very high levels of strandings (e.g. 1932–39) and some very low periods (1940–46). To test whether there are significant fluctuations, the records were grouped (1913, 1914–15, . . . 1978–79) and a one sample chi square test with 33 degrees of freedom performed. This was significant at the 99.9% level, confirming that the record is not uniform. In particular 1940–43 (and to a lesser extent 1944–53) are low periods with 1932–39 (and 1954–61 to a lesser extent) high periods.

Geographical and seasonal variations

Figs 2–9 inclusive indicate the density of strandings around the British Coast. The coast (excluding Ireland and the Channel Islands) has been divided into 40 sections, as shown in Table 1. The coast lengths are taken from Fraser (1974).

The value given for each section is the number of strandings per 100 miles of coast. The drawings were constructed by plotting the relevant figures towards the centre from the section number and joining the points. They are therefore not easily read in a quantitative manner but are intended to illustrate the geographical and temporal changes in a manner not easily achieved by tables. Fig. 2 gives the overall distribution of strandings. These are divided mainly into a large group along the east and southeast coast of England, a much lower number along the south coast and in Wales, a large group in Cumberland (section 32) and very few in Scotland. The small number of records from Scotland in partly due to a difference in reporting requirements resulting in smaller species, such as the porpoise, being under-recorded (Sheldrick, 1976).

Figs 3–6 indicate the variation in strandings over the year. The association between month of stranding and region of stranding was assessed by grouping the coastal sections into five areas, to produce a reasonable number of observations in each cell and performing a chi square test with 44 degrees of freedom. The areas were Shetland to Berwick, Northumberland to London, Kent to Cornwall, Somerset to Cumberland and Dumfries to Hebrides. The test result was significant at 95%; that is, the seasonal variation is not uniform along the coastline. In particular, the records for Cumberland (and to a lesser extent those in South Wales) appear abruptly in late summer, fall away towards the end of the year and are very sparse in the first half of the year. The east England records, on the other hand, do not show this pattern.

An attempt was made to determine whether the east England records showed any positional changes with season. The totals for each of four geographical groupings (obtained by grouping pairs of sections from Northumberland to London) and for each of four three-month periods were compared using a chi squared test with nine degrees of freedom. The result was significant at the 95% level, again showing that seasonal variation is not uniform. This appears to be because of a shift in strandings southwards during April to June and northwards during July to September.

Figs 7–9 indicate the changes in the geographical distribution of strandings over the years of observation. Groups of five years were used except for 1973–79. Again a chi square test (with 48 degrees of freedom)

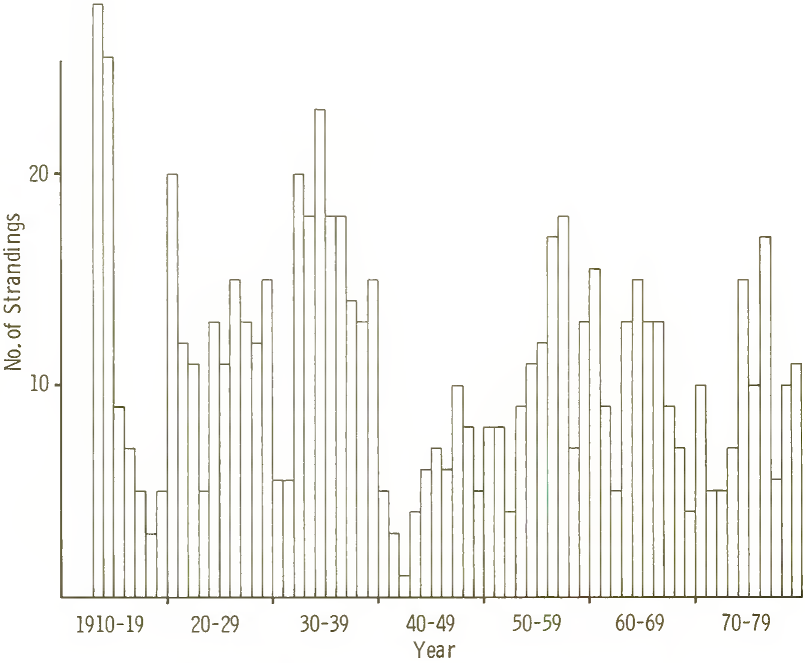


Fig. 1. Incidence of strandings 1913—79 for British coasts, excluding the Irish coasts. The number of records for each year is shown.

explores associations between year of stranding and region of stranding. The statistic is significant at 95%. This is a reflection of the fact that the Cumberland group was not evident over the first 20 years and that the east England group was particularly prominent during the same period.

DISCUSSION

The records of strandings show no overall trend, although there are significant fluctuations. The main low period appears to be from 1940–43 while 1932–39 is particularly high. Lesser low and high periods may be observed between 1944–53 and 1954–61 respectively.

Some interesting seasonal patterns appear with differences between the west and east coasts. The Cumberland and South Wales groups show a late summer peak, while the east England records show a different pattern, which appears to be a north-south movement. The regional record over the whole period shows that the Cumberland group was not evident over the first 20 years and that the east England records were more numerous over the same period.

Table 1

Key to sections shown in Figs 2–9[1]

No.	Coastal section	Coast length (miles)
1	Shetland Islands	980
2	Orkney Islands	601
3	Caithness	96
4	Sutherland	286
5	Ross and Cromarty	436.5
6	Nairn, Moray, Banff	99
7	Aberdeen, Kincardine	99.5
8	Angus, Perth	80
9	Fife	101.5
10	Clackmannan, Stirling, Lothian, Berwick	105.5
11	Northumberland, Durham	129
12	Yorkshire	149.5
13	Lincolnshire	102
14	Norfolk	103
15	Suffolk	53
16	Essex, London	109
17	Kent	162.5
18	Sussex	89
19	Hampshire, Isle of Wight	130
20	Dorset	113
21	Devon	176
22	Cornwall, Scilly Isles	311
23	Somerset, Gloucestershire, Monmouth	129.5
24	Glamorgan, Carmarthen	151.5
25	Pembrokeshire	184.5
26	Cardigan, Merioneth	96
27	Carnarvon	126
28	Anglesey	115
29	Denbigh, Flint, Cheshire	60.5
30	Lancashire	152
31	Isle of Man	85
32	Westmorland, Cumberland	100
33	Dumfries, Kircudbright	110.5
34	Wigtownshire	128
35	Ayrshire	77.5
36	Buteshire	132
37	Renfrew, Dumbarton	81
38	Argyllshire	119.7
39	Invernesshire	547
40	Outer Hebrides	860

[1] The old county names have been used throughout and recent records converted to this system. Coast lengths are taken from Fraser (1974).

This analysis does not therefore support statements made on the basis of graphical analysis of the same data, that strandings have declined in recent years for this species (Evans, 1980). Sheldrick's (1976) remarks on the subject refer only to the final quinquennium (1968–72) then available, although they have often been misinterpreted to refer to a longer period. From Fig. 1 it can be seen that this period only represents one of the minor fluctuations in the record. The analysis agrees with Sheldrick's (1976) observation that strandings records were particularly high in the 1930s.

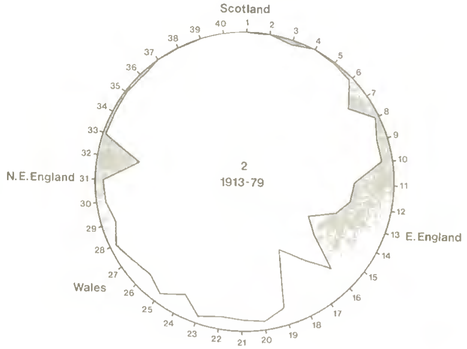
The seasonal patterns for the west coast, particularly the Cumberland group, have been described before (Fraser, 1943; 1946; 1953; 1974; Harrison, 1970), with peaks in late summer and very few records from January to March. It has not previously been noted that the east coast records show a different pattern. The possibility of north-south movements should be explored further when corrected records are available. The regional differences over the whole period have not previously been noted and are impossible to assess in isolation. Why should so many strandings suddenly appear on the Cumberland coast from about 1930? The same applies to the high level of records for east England in the first twenty years compared to the fairly steady levels thereafter.

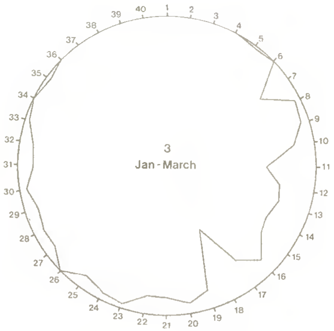
Looking at the record as a whole, however, it is difficult to believe that observer changes have not played some part in the production of the pattern. The two histories of the Coastguard service (Webb, 1976; Bowen, 1927) reveal considerable changes in numbers and organisation over the period as well as showing differences in coverage on different parts of the coast. For example, during the first ten years or so of the period, the Coastguard were under Admiralty control and were a naval reserve for times of war; in 1914 the majority were mobilised at very short notice to the naval ports. Most of the smaller stations were abandoned entirely by the Coastguard service and the buildings taken over by the Army, others had skeleton crews only. In many cases the families of the absent Coastguards and local sea scouts took on some of the duties (Bowen, 1927).

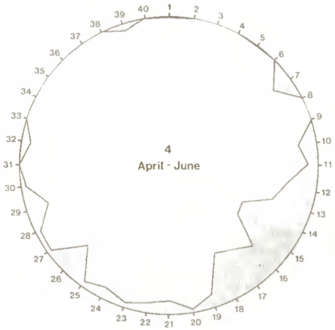
There appear always to have been far more stations on the east and south coasts, perhaps increasing the chances that stranded animals will be found, while the rough coastline and long distances between stations in the north and west must reduce the probability, even if the Coastguards were to devote all their time to this task. Webb (1976) quotes from a review of the service in 1922 a formidable list of peacetime duties for ten different government departments and other authorities—reporting strandings is not a separate item. Indeed from this list it is clear that the Coastguards have provided a remarkable quantity of information over the years, given their other responsibilities.

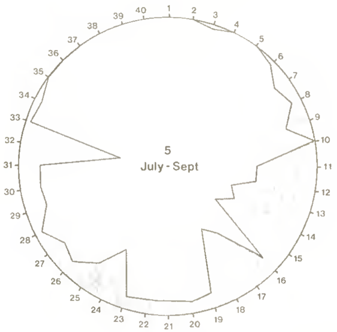
The Receivers of Wreck, who are sometimes also Coastguards, have played their part in the production of the records, as have many individuals and other organisations. Allowance also must be made for changes here, although these are not well documented.

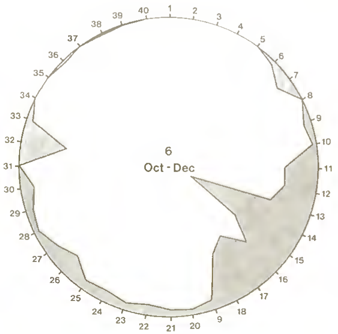
It should be possible to devise at least a rough correction to account for the differential distribution of Coastguard stations and for such changes over the period, but quantification of the effects of the wars on recordings will be very difficult. If patterns in the full record are to be compared, however, some effort needs to be made in this area.

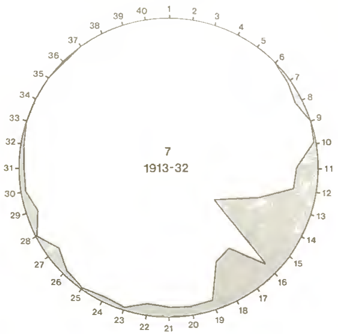


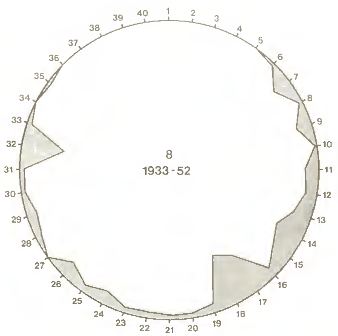


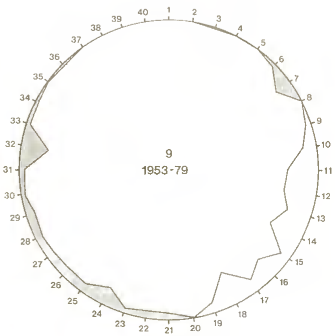












Figs 2–9. The circular diagrams indicate the density of strandings records around the coast, which has been divided into 40 sections. The key to the section numbers is given in Table 1, but general indications of area are given on the diagrams. The drawings were constructed by plotting the relevant figures (strandings per 100 miles of section) towards the centre from the section number and joining the points. They are therefore not exact quantitative representations, but do facilitate comparisons between sections and show seasonal movements particularly well.

Fig. 2. This shows all strandings records over the period 1913–79 by section.

Figs 3–6. These show seasonal changes over the whole period. Fig. 3 shows strandings records from January to March, Fig. 4 from April to June, Fig. 5 from July to September and Fig. 6 from October to December. Note the abrupt appearance of records in Cumberland (section 32) and Wales in summer in contrast to the different movement on the east coast.

Figs 7–9. These show sectional distribution of strandings in three periods. Fig. 7 from 1913–32, Fig. 8 from 1933–52 and Fig. 9 from 1953–79. Note that the last period is longer than the other two by seven years, in this grouping of the records. The sudden appearances of the Cumberland records (section 32) after the first grouping and the high number of records in the eastern area in the first grouping are discussed in the text.

One aspect of the present analysis, the contrast between the seasonal patterns on the east and west coasts, may be a 'real' reflection of the behaviour of the porpoise, since it is hardly plausible that the coast watchers display any such seasonal behaviour.

Throughout we have emphasised that the records have been analysed as they stand, with the two exceptions mentioned. This is the same method used by other workers, but the records listed under *Phocoena phocoena* include, in the early years (at least until 1932), undetermined specimens up to 5 ft 11 in in length. In the 1913–26 list, for example, of 178 records, 108 were either determined on the evidence of some part of the animal or were unidentified specimens up to 3 ft 2 in in length. The other 70 were undetermined specimens between 3 ft 3 in and 5 ft 11 in (Harmer, 1927)—quite a large proportion of the total, although Harmer does give good reasons for these assumptions. The only remedy here is to check the entire file of original reports at the Museum. (The report of a 48 ft 4 in specimen 1956.19 on p. 8 of Fraser (1974) is a misprint and the correct length is given as 4 ft 4 in on p. 25.)

Thus, before any firm conclusions can be drawn from such analyses, it is firstly necessary to exclude all records where species identification is doubtful. Secondly, the distribution and reporting patterns of the Coastguard and other coast watching organisations and individuals need to be taken into account and thirdly, the exact legal requirements for reporting and their possible influence need more detailed attention (Fraser, 1974). Environmental changes, both natural (Southward, 1980; Sheldrick, 1976) and those resulting from human activity (Evans, 1980; Sheldrick, 1976; Van Bree, 1977), are obviously important too. In short a great deal of work is necessary before these valuable records can yield any reliable information on strandings patterns and only then will it be feasible to begin work on the possibility of relating strandings records to live populations at sea.

FINAL NOTES

In our original manuscript we explored the possibility of significant fluctuations in the whole record and seasonal movements on the east coast using the Rank Sum Test. Ms Shaw has pointed out that this use of the statistic is not strictly correct. We have therefore substituted chi square tests. In consequence, some of the details of our present conclusions on these matters differ from those on which the committee reports were based.

ACKNOWLEDGEMENTS

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REFERENCES

Andersen, S. H. 1975. Change of migratory behaviour in the harbour porpoise, *Phocoena phocoena*, illustrated by catch statistics from 1834–44. Paper ACMRR/MM/EC/32. FAO Advisory Committee on Marine Resources Research.

Bowen, F. C. 1927. *His Majesty's Coastguard.* Hutchinson and Co., London. 288 pp.

Duguy, R. 1977. Notes on the small cetaceans off the coasts of France. *Rep. int. Whal. Commn* 27: 500–501.

Evans, P. G. H. 1980. Cetaceans in British waters. *Mamm. Rev.* 10: 1–52.

Fraser, F. C. 1934. Report on Cetacea stranded on the British coasts from 1927–32. 11: *British Museum (Natural History), London.*

Fraser, F. C. 1946. Report on Cetacea stranded on the British coasts from 1933–37. 12: *British Museum (Natural History), London.*

Fraser, F. C. 1953. Report on Cetacea stranded on the British coasts from 1938–47. 13: *British Museum (Natural History), London.*

Fraser, F. C. 1974. Report on Cetacea stranded on the British coasts from 1948–66. 14: *British Museum (Natural History), London.*

Harmer, S. F. 1914. Report on Cetacea stranded on the British coasts during 1913. 1: *British Museum (Natural History), London.*

Harmer, S. F. 1915. Report on Cetacea stranded on the British coasts during 1914. 2: *British Museum (Natural History), London.*

Harmer, S. F. 1916. Report on Cetacea stranded on the British coasts during 1915. 3: *British Museum (Natural History), London.*

Harmer, S. F. 1917. Report on Cetacea stranded on the British coasts during 1916. 4: *British Museum (Natural History), London.*

Harmer, S. F. 1918. Report on Cetacea stranded on the British coasts during 1917. 5: *British Museum (Natural History), London.*

Harmer, S. F. 1919. Report on Cetacea stranded on the British coasts during 1918. 6: *British Museum (Natural History), London.*

Harmer, S. F. 1921. Report on Cetacea stranded on the British coasts during 1919 and 1920. 7: *British Museum (Natural History), London.*

Harmer, S. F. 1923. Report on Cetacea stranded on the British coasts during 1921 and 1922. 8: *British Museum (Natural History), London.*

Harmer, S. F. 1925. Report on Cetacea stranded on the British coasts during 1923 and 1924. 9: *British Museum (Natural History), London.*

Harmer, S. F. 1927. Report on Cetacea stranded on the British coasts from 1913 to 1926. 10: *British Museum (Natural History), London.*

Harrison, R. J. 1970. The life of the common porpoise (*Phocoena phocoena*). *Proc. Roy. Inst. Great Britain.* 44: 113–33.

International Whaling Commission 1980. Report of the Scientific Committee. Section 6.2.2. *Rep. int. Whal. Commn* 30: 117.

Mitchell, E. D. (Ed) 1975. Review of the biology and fisheries for smaller cetaceans. Report of the Meeting on Smaller Cetaceans, Montreal April 1–11, 1974. *J. Fish. Res. Board Can.* 32: 875–1,240.

Sheldrick, M. C. 1976. Trends in the strandings of Cetacea on the British coasts 1913–72. *Mamm. Rev.* 6: 15–23.

Sheldrick, M. C. 1979. Cetacean strandings along the coasts of the British Isles 1913–77. *In:* J. R. Geraci and D. J. St Aubin (Eds) *Biology of Marine Mammals: Insights Through Strandings.* U.S. Marine Mammal Commission. Report No. MMC-77/13.

Smit, C. J. and Van Wijngaarden, A. 1976. *Threatened mammals in Europe.* European Committee for the Conservation of Nature and Natural Resources, Council of Europe, Netherlands.

Southward, A. J. 1980. The western English Channel—an inconstant ecosystem? *Nature (London)* 285: 361–6.

Van Bree, P. J. H. 1977. On former and recent strandings of cetaceans on the coasts of the Netherlands. *Z. Säugetierkunde.* 42: 101–7.

Webb, W. 1976. *Coastguard: An official history of H.M. Coastguard.* HMSO, London. 196 pp.

SC/33/SM6

Time/Area Distribution and Composition of the Incidental Kill of Dolphins and Small Whales in the U.S. Purse-Seine Fishery for Tuna in the Eastern Tropical Pacific, 1979–80

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ABSTRACT

Data are presented for 4,642 spotted dolphins, *Stenella attenuata;* 1,745 spinner dolphins, *S. longirostris;* 99 striped dolphins, *S. coeruleoalba;* 1,535 common dolphins, *Delphinus delphis;* two bottlenose dolphins, *Tursiops truncatus;* one Pacific white-sided dolphin, *Lagenorhynchus obliquidens,* and one false killer whale, *Pseudorca crassidens.* Possible source of biases in the samples are discussed.

INTRODUCTION

Data on composition of the U.S. incidental purse-seine kill of small cetaceans have been presented and analyzed in a series of publications (Perrin, Coe and Zweifel, 1976; Perrin, Holts and Miller, 1977; Perrin, Miller and Sloan, 1977; Perrin and Henderson, 1979; Smith, 1979; and Henderson, Perrin and Miller, 1980). Recent studies have shown that the data may be subject to biases, of several kinds. The purpose of this paper is to present the data for 1979 and 1980 and to discuss the biases affecting them.

METHODS

The kill data and the life-history specimens from which the data on reproductive condition were derived were collected by fishery technicians employed by the U.S. National Marine Fisheries Service (NMFS) and the Inter-American Tropical Tuna Commission (IATTC) aboard commercial purse-seiners. Data on kill by time and area reported here were collected only by the NMFS technicians. Data on sex composition, reproductive condition and length frequencies of the kill were collected by IATTC and NMFS technicians. NMFS technicians collected data on 62 cruises in 1979 and 41 cruises in 1980. IATTC technicians collected data on 25 cruises in 1979 and 38 in 1980. The sampling scheme is described in Smith (1979), and copies of the forms used are included here as Appendices 1 and 2. Laboratory procedures for processing the specimens and criteria for sexual maturity were as described in Perrin *et al.* (1975 and 1977). The management units used here are defined in Smith (1979). Dolphins not identified to species are not included in the data presented here. The NMFS observed-kill data are presented by 5°-square areas (Fig. 1). The computer programs used to summarize data on reproductive condition were described by Henderson and Perrin (1980).

RESULTS

Incidental kill data by area and month are presented for 8,026 small cetaceans in Tables 1–5. Sex data for 3,408 dolphins, by area and quarter, are presented in Tables 6–10. Length-frequency data for 3,455 specimens are presented in Tables 11–13 and reproductive-condition data for 1,850 females in Tables 14–16. The tables can be found on pp. 000–00.

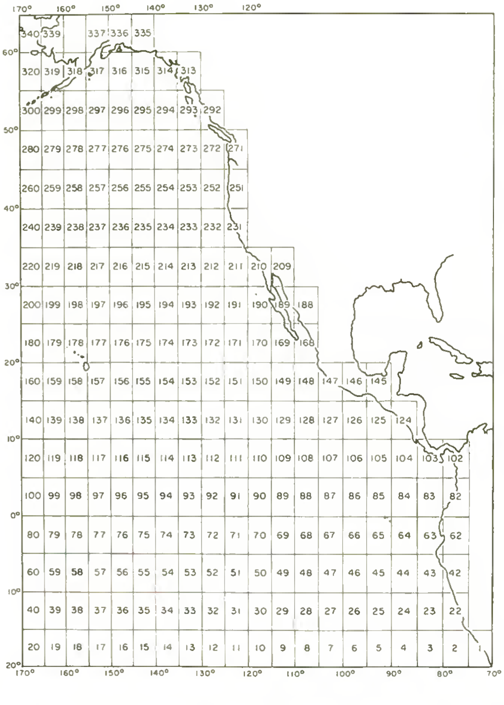
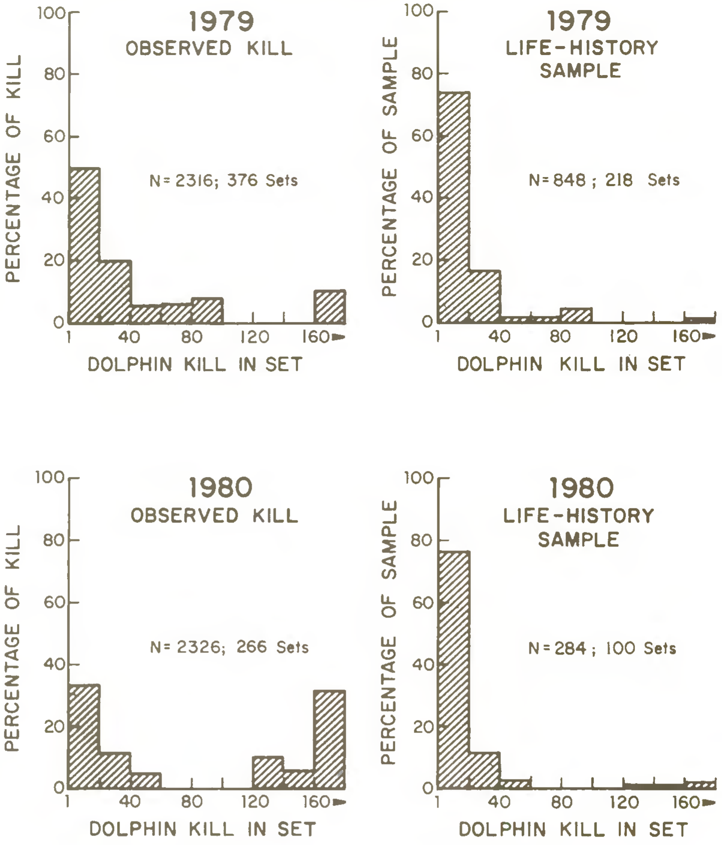


Fig. 1. Statistical reporting blocks (5-degree squares) for eastern tropical Pacific. Dashed line includes usual area of operation of US tropical-tuna purse-seine fishery (area of consideration for this paper). Solid line includes blocks in which data reported here were collected in 1979 and 1980.



	Spinner dolphin		Common dolphin		Striped dolphin	
	Overall kill	Life-history sample	Overall kill	Life-history sample	Overall kill	Life-history sample
Total sets	285	149	83	47	13	8
Total dolphins	1,745	389	1,535	289	99	30
	(% of kill)	(% of sample)	(% of kill)	(% of sample)	(% of kill)	(% of sample)
Kill in set:						
1–19	42.7	86.6	22.9	57.4	73.7	93.3
20–39	10.7	6.7	10.0	12.8	26.3	6.7
40–59	2.9	2.8	15.1	21.8		
60–79	6.9		4.6			
80–99	5.1	1.3	11.5	1.7		
100–119			7.4	6.2		
120–139						
140–159						
> 160	31.7	2.6	28.5			
Total	100.0	100.0	100.0	100.0	100.0	100.0

Fig. 2. Comparisons of kill-size structures of observed kills with those of subsamples from which life-history data and specimens were collected; for spotted dolphin, *Stenella attenuata*, in 1979 and 1980. Includes only data collected by NMFS technicians. The table compares kill-size structures of observed kill with those of subsamples for which life-history data and specimens were collected (same analysis as in Fig.): for spinner dolphins, *Stenella longirostris*; common dolphin, *Delphinus delphis*; and striped dolphin, *S. coeruleoalba*: 1979 and 1980 combined. Includes only data collected by NMFS observers.

Appendix 2

FORM USED BY NMFS AND IATTC FIELD AND LABORATORY TECHNICIANS TO COLLECT LIFE-HISTORY DATA ON DOLPHINS KILLED IN THE TUNA PURSE-SEINE FISHERY

NOAA FORM 88-129
NMFS 11/80

PORPOISE LIFE HISTORY FORM

NOAA
U. S. DEPT. OF COMM.

CARD 1 (12)

CR. # ______ 1–4

SPECIMEN # ______ 5–12

SPECIES/STOCK ______ 13 14

SEX ______ 15

DATE (YR/MO/DAY) ______ 16–21

SET # ______ 22–24

POSITION (LAT/LONG) ______ 25–33

QUAD ______ 34

TOTAL LENGTH (cm.) ______ 35–38

COLORATION ______ 39

LACTATING ? ______ 40

FETUS: SEX ______ 41

LENGTH (cm.) ______ 42–45

COLLECTED ?: TEETH ______ 46

TESTIS ______ 47

OVARIES & UTERUS ______ 48

FETUS ______ 49

STOMACH ______ 50

HEAD ______ 51

CARCASS ______ 52

PHOTOS ? ______ 53

ROLL # ______

FRAME(S) # ______

COLOR PATTERN
& DORSAL FIN:

BASIS FOR STOCK ID.:

______
(OBSERVER'S NAME)

IN FIELD ↑

NOTE: IF FETUS< 25 CM., LEAVE IN UTERUS & PRESERVE (do not sex & measure in field)

IN LAB ↓

54 TOTAL WEIGHT (gm) | 61 Lt. GONAD (gm) 67 | 68 Rt. GONAD (gm) 74 | 75 Ln (mm), S.G., E — RIGHT TESTIS | 80 BL

CARD 2

1 REPEAT COLS. 1–11, CARD 1 11 | 12 | 13 LAYERS 15 | 16 C.L. | 17 1, 19 2, 21 3 — C.L. DIAMS. (mm) | 23 CA (L) | 25 CA (R)

27 FOLL. DIAM. (mm) | 30 1, 32 2, 34 3, 36 4, 38 5, 40 6 — C.A. IN LEFT OVARY | 42 1, 44 2, 46 3, 48 4, 50 5, 52 6 — C.A. IN RIGHT OVARY | 54 Total CORP. (C.A.+C.L.)

56 TUBULE DIAM. (mm) | 59 FETUS WEIGHT (gm) | 66 READING STATUS | 68 READER CODE

C. A. diams. (mm), by Type

1	2	3	4	5	6

NOTES (Uterus, Etc.):

DISPOSITION OF MATERIALS:

Appendix 1

FORM USED BY NMFS TECHNICIANS TO COLLECT INCIDENTAL-KILL DATA ABOARD COMMERCIAL TUNA PURSE-SEINERS

NOAA FORM 88-124
FSW 34 11-78

1979 MARINE MAMMAL SET LOG TALLY SHEET

CRUISE # ________ NOAA - U.S. DEPT. OF COMM.
SET # ________

Page 5

SYMBOLS TO USE:
√ = DEAD
+ = ESCAPED OR RELEASED ALIVE
⊕ = ESCAPED OR RELEASED ALIVE BUT INJURED
? = STATUS UNDETERMINED
?⃝ = STATUS UNDETERMINED BUT INJURED

NOTE: "INJURED" MEANS
1) BLEEDING
2) HAVING OBVIOUSLY BROKEN BONES
3) HAVING GONE THROUGH THE POWER BLOCK

	SPOTTED																SPINNERS									OTHER SPECIES (1)			OTHER SPECIES (2)			UNID
	NEONATE			TWO-TONE			SPECKLED			MOTTLED			ADULT			AGE UNK	EASTERN			WHITEBELLY			OTHER OR UNID									
	M	F	?	M	F	?	M	F	?	M	F	?	M	F	?		M	F	?	M	F	?	M	F	?	M	F	?	M	F	?	
ANIMALS DUMPED																																
ANIMALS PROCESSED																																
SUBTOTALS √																																
+																																
⊕																																
?																																
?⃝																																

Spotted Stock Name ________ Other Spinner Name ________ Other Species/Stock (1) Name ________ Other Species/Stock (2) Name ________

DISCUSSION

Several potential sources of bias have been identified and are discussed below. For some, adjustment procedures have been developed; others have not yet been so addressed.

Effects of size of kill

Powers and Barlow (1979) examined the age structure of kill samples in relation to the size of the kill in the purse-seine set from which the samples came. They found that for the spotted dolphin, *Stenella attenuata*, samples from small-kill sets contained proportionately more calves than did those from large-kill sets. This has been interpreted to mean that calves are more vulnerable to death in the purse-seine operation than are adults, and therefore when only a few animals are killed, they tend to be calves. This would mean that the large-kill samples are more representative of the populations at large (or, at least, the animals captured) than are the small-kill samples. The most recent analyses of data for *S. attenuata* to estimate reproductive rates have taken this presumed effect into account by including only samples from net sets in which 40 or more spotted dolphins were killed (Henderson, Perrin and Miller, 1980). Powers and Barlow (1979) did not find a similar effect for the spinner dolphin, *S. longirostris,* and analyses for that species have been based on all samples regardless of kill size (Perrin and Henderson, 1979). The data for other species (*S. coeruleoalba* and *Delphinus delphis*) have not been examined for the presence of a kill-size effect.

An aspect of the kill-size effect that has not been taken into account relates to the fact that the technicians at sea do not process all dead animals that pass across the deck; they are limited to 30–40 dolphins by constraints of time and space. This means that the animals from small-kill (less than 30–40 sets) are usually all examined, whereas only a subsample of the animals from large-kill sets are examined, amplifying the bias caused by the kill-size effect for *S. attenuata* and possibly for *S. coeruleoalba* and *D. delphinus*. The under-representation of animals from large-kill sets in the life-history samples is shown in Fig. 2.

Effect of seasonality

Perrin *et al.* (1976) and Perrin *et al.* (1977) described diffuse seasonality in breeding of spotted and spinner dolphins in the eastern tropical Pacific, with two or more peak periods during the year. Because of the multiple peaks, the diffuseness, and the fact that the length of gestation is nearly a year (11.5 months in *S. attenuata* and 10.6 months in *S. longirostris*), the effect of seasonal sampling bias (as can be seen in Tables 1–5) on estimates of reproductive rates cannot be large. Barlow (1979) examined the effect of seasonality and developed a method to adjust for it. He found a maximum effect on pregnancy-rate estimates of 4% (for eastern spinner dolphins). Barlow also described variation in seasonal breeding peaks between sub-areas of what have been assumed to be areas containing single interbreeding populations. He concluded that the effect of seasonal-sampling bias on estimates of reproductive rates is probably more than the maximum 4% that he found because of this confounding of breeding units in the analyses. Stuntz (1980) also found areal variation in seasonality, within putative interbreeding populations of the spotted dolphin. This confounding of populations, of course, has other implications for assessment and management. As fishing effort is not evenly distributed by area, the various cryptic subpopulations may differ from each other in status and production.

Other biasing effects

Stuntz (1980) found differences in the age structure of spotted dolphin samples with size of the dolphin school (more calves in smaller schools), tons of yellowfin tuna captured (fewer calves with larger tuna catches) and length of the chasing and corralling phase (see Perrin, 1969, for description of fishing operation) (fewer calves after longer chases) as well as with area and time of year. He pointed out that there are alternative explanations for the observed trends and noted that definitive analyses of the biases must be carried out before the structural (and reproductive) dynamics of the populations can be modeled with any confidence.

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R. B. Miller and V. L. Cass processed the specimens in the laboratory and prepared the data for analysis. M. S. Lowry and T. C. Foster reviewed the final tables. K. S. Raymond prepared the figures, and V. Hostler typed the manuscript.

LITERATURE CITED

Barlow, J. 1979. Reproductive seasonality in pelagic dolphins of the eastern tropical Pacific. Paper SOPS/79/26 presented to Status of Porpoise Stocks Workshop, 27–31 August 1979, La Jolla, California, 22 pp.

Henderson, J. R., Perrin, W. F. and Miller, R. B. 1980. Rate of gross annual production in dolphin populations (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific, 1973–1978. *Southwest Fisheries Center Admin. Rep.* LJ-80-02, 51 pp.

Perrin, W. F. 1969. Using porpoise to catch tuna. *World Fishing* 18(6): 42–5.

Perrin, W. F., Coe, J. M. and Zweifel, J. R. 1976. Growth and reproduction of the spotted porpoise, *Stenella attenuata*, in the eastern tropical Pacific. *Fish. Bull.* 74: 229–69.

Perrin, W. F., Holts, D. B., and Miller, R. B. 1977. Growth and reproduction of the eastern spinner dolphin, a geographical form of *Stenella longirostris* in the eastern tropical Pacific. *Fish. Bull.* 75: 725–50.

Perrin, W. F., Miller, R. B. and Sloan, P. A. 1977. Reproductive parameters of the offshore spotted dolphin, a geographical form of *Stenella attenuata*, in the eastern tropical Pacific, 1973–75. *Fish. Bull.* 75: 629–33.

Perrin, W. F., and Henderson, J. R. 1979. Growth and reproductive rates in two populations of spinner dolphins, *Stenella longirostris,* with different histories of exploitation. *Southwest Fisheries Center Admin. Rep.* LJ-79-29, 37 pp.

Powers, J. E. and Barlow, J. 1979. Biases in the tuna-net sampling of dolphins in the eastern tropical Pacific. Paper SOPS/79/31 presented to Status of Porpoise Stocks Workshop, 27–31 August 1979, La Jolla, California, 7 pp.

Smith, T. D. (ed.) 1979. Report of the Status of Porpoise Stocks Workshop (August 27–31, 1979, La Jolla, California). *Southwest Fisheries Center Admin. Rep.* LJ-79-41, 120 pp.

Stuntz, W. E. 1980. Variation in age structure of the incidental kill of spotted dolphins, *Stenella attenuata*, in the U.S. tropical purse-seine fishery. *Southwest Fisheries Center Admin. Rep.* LJ-80-06.

Table 1

Kill data for spotted dolphin, *Stenella attenuata*, in observed kill, 1979 and 1980; by stock, five-degree square and month of the year; data collected by NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
SPOTTED DOLPHIN:														
Northern Offshore														
	83	0	0	0	1	0	0	0	0	0	0	0	0	1
1979	84	13	0	6	2	0	0	0	0	0	0	0	0	21
	85	24	13	0	0	0	0	0	0	0	0	0	0	37
	86	0	0	0	0	0	0	0	0	0	4	0	0	4
	87	0	0	0	0	0	0	0	0	0	1	0	0	1
	88	0	0	0	0	0	0	0	0	11	0	2	0	13
	90	0	0	0	0	4	0	0	0	0	0	0	0	4
	103	0	1	0	0	0	0	0	0	0	0	0	0	1
	104	40	0	0	4	0	0	0	0	0	0	0	0	44
	105	5	1	0	5	3	0	0	0	0	0	0	0	14
	106	40	1	16	0	0	0	0	0	0	6	0	0	63
	107	30	1	10	0	0	0	0	8	0	265	0	0	314
	108	4	0	0	0	0	0	0	7	0	10	12	0	33
	109	0	0	0	0	0	0	0	0	0	3	0	0	3
	110	0	0	0	0	7	0	0	3	0	0	1	0	11
	111	0	0	0	0	0	3	1	5	1	0	0	0	10
	112	0	0	0	12	80	2	39	0	0	0	0	0	133
	113	0	0	0	0	4	13	6	4	0	0	0	0	27
	114	0	0	0	0	0	72	2	0	0	0	0	0	74
	125	0	4	7	13	62	0	0	0	0	0	0	0	86
	126	20	29	30	1	0	0	2	0	0	0	0	0	82
	127	6	12	13	7	0	0	0	0	0	6	0	0	44
	128	69	4	16	5	4	1	0	2	15	47	0	0	163
	129	0	0	0	1	4	0	0	0	0	0	1	0	6
	130	0	0	0	3	0	0	0	1	0	0	2	0	6
	131	0	0	0	0	0	0	0	27	0	0	0	0	27
	132	0	0	0	0	0	0	12	5	0	0	0	0	17
	133	0	0	0	0	0	1	13	72	3	0	0	0	89
	134	0	0	0	0	0	30	45	2	1	0	0	0	78
	146	0	0	1	2	0	0	0	0	0	0	0	0	3
	147	0	1	0	2	2	0	30	0	1	0	0	0	36
	148	13	18	0	0	0	7	0	0	2	0	1	0	41
	149	23	0	4	6	1	3	3	0	2	2	3	0	47
	150	0	0	0	0	2	0	1	0	0	0	0	0	3
	151	0	0	0	0	20	0	0	0	0	0	0	0	20
	168	0	0	0	0	0	1	0	0	0	0	2	0	3
	170	0	0	0	0	0	0	1	0	0	0	0	0	1
	Total	287	85	103	64	193	133	155	136	36	344	24	0	1560
1980	83	1	0	0	0	0	0	0	0	0	0	0	0	1
	84	0	0	0	0	0	0	0	0	0	6	18	0	24
	85	0	0	0	0	0	0	0	0	0	0	1	0	1
	86	0	7	0	0	0	0	0	0	0	0	0	0	7
	88	0	0	0	0	0	0	0	0	0	3	0	0	3
	89	0	0	0	0	0	0	0	0	0	6	0	0	6
	90	0	0	0	0	0	0	0	0	43	20	0	0	63
	91	0	0	0	0	0	0	0	0	2	13	0	0	15
	104	0	0	248	6	0	0	0	0	0	0	0	0	254
	105	0	0	2	1	8	0	0	0	0	0	2	15	28
	106	125	9	0	0	0	0	0	0	3	0	13	35	185
	107	10	54	3	1	0	0	0	0	0	144	3	0	215
	108	0	0	0	0	0	0	0	2	3	10	9	0	24
	109	0	0	0	0	1	0	0	0	1	0	32	0	34
	110	0	0	0	0	0	0	0	0	0	0	0	1	1
	111	0	0	0	0	0	0	0	0	0	1	0	0	1
	112	0	0	0	0	0	12	11	16	0	0	0	0	39
	113	0	0	0	0	0	8	12	1	0	0	0	0	21
	114	0	0	0	0	0	2	72	3	0	6	0	0	83
	125	5	0	0	0	0	0	0	0	0	0	0	0	5
	126	0	13	1	0	3	0	0	0	0	0	0	0	17
	127	0	4	0	0	0	0	0	0	1	0	0	0	5
	128	1	0	15	42	17	0	0	10	2	0	0	0	87
	129	2	0	15	11	0	1	0	27	1	32	8	0	97
	130	0	0	0	0	0	0	10	0	6	1	0	0	17
	131	0	0	0	0	0	0	2	17	0	8	0	0	27
	132	0	0	0	0	0	4	4	0	0	0	0	0	8
	133	0	0	0	0	0	1	0	0	4	21	0	0	26
	134	0	0	0	0	0	0	4	1	0	0	0	0	5
	147	0	2	0	0	0	0	0	0	0	0	0	0	2
	149	0	0	1	55	0	0	29	10	0	0	0	0	95
	150	0	0	0	0	1	4	2	0	40	0	0	0	47
	168	1	0	0	0	0	0	0	0	0	0	0	0	1
	169	1	0	0	0	0	0	0	0	0	0	0	0	1
	Total	146	89	285	116	30	32	146	87	106	271	86	51	1445
Southern Offshore														
1979	23	2	0	0	0	0	0	0	0	0	0	0	0	2
	24	57	0	0	0	2	0	0	0	0	0	0	0	59
	25	0	0	0	0	0	0	0	0	0	0	0	3	3
	43	9	0	0	0	0	0	0	0	0	0	0	0	9
	44	220	0	0	3	350	1	0	0	0	0	0	0	574
	45	1	0	0	0	0	0	0	0	0	0	0	17	18
	64	1	0	0	0	0	0	0	0	0	0	0	0	1
	65	4	0	0	0	0	0	0	0	0	0	0	0	4
	66	0	36	0	0	0	0	0	0	0	0	0	0	36
	Total	294	36	0	3	352	1	0	0	0	0	0	20	706
1980	23	12	9	0	0	0	0	0	0	0	0	0	0	21
	24	1	2	0	0	0	0	0	0	0	0	0	10	13
	43	165	2	1	0	0	0	0	0	0	0	0	0	168
	44	4	55	2	0	0	0	0	0	0	568	0	0	629
	45	40	0	0	0	0	0	0	0	0	0	0	0	40
	66	1	0	0	0	0	0	0	0	0	0	0	0	1
	Total	223	68	3	0	0	0	0	0	0	568	0	10	872

Table 1—*continued*

Species and Stock	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
Coastal														
1979	168	0	0	0	40	0	0	0	0	0	0	0	0	40
Unidentified to Stock														
1979	148	0	0	0	0	0	0	0	10	0	0	0	0	10
1980	84	0	0	0	0	0	0	0	0	0	0	0	1	1
	104	0	0	0	0	0	0	0	0	0	0	0	8	8
	Total	0	0	0	0	0	0	0	0	0	0	0	9	9
All Stocks														
1979	Total	581	121	103	107	545	134	155	146	36	344	24	20	2316
1980	Total	369	157	288	116	30	32	146	87	106	839	86	70	2326

Table 2

Kill data for spinner dolphin, *Stenella longirostris*, in observed kill, 1979 and 1980; by stock, five-degree square and month of the year; data collected by NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
SPINNER DOLPHIN:														
Northern Whitebelly														
1979	85	6	7	0	0	0	0	0	0	0	0	0	0	13
	86	0	0	0	0	0	0	0	0	0	1	1	0	2
	87	0	0	0	0	0	0	0	0	0	3	0	0	3
	88	0	0	0	1	0	0	0	0	0	0	0	0	1
	89	0	0	0	0	0	0	0	1	0	0	0	0	1
	90	0	0	0	0	1	0	0	0	0	0	0	0	1
	91	0	0	0	1	0	0	0	0	0	0	0	0	1
	106	0	0	4	0	0	0	0	0	0	0	0	0	4
	107	1	0	0	0	0	0	0	0	0	0	0	0	1
	108	2	0	0	3	0	0	0	0	0	2	0	0	7
	109	0	0	0	0	0	0	0	0	0	2	0	0	2
	111	0	0	0	0	0	1	2	2	0	0	0	0	5
	112	0	0	0	0	10	0	0	4	0	0	0	0	14
	113	0	0	0	0	0	2	0	7	0	0	0	0	9
	114	0	0	0	0	0	40	2	0	0	0	0	0	42
	128	1	0	0	0	0	0	0	0	2	0	0	0	3
	131	0	0	0	0	1	0	0	4	0	0	0	0	5
	132	0	0	0	0	0	0	1	3	0	0	0	0	4
	133	0	0	0	0	0	0	9	35	30	0	0	0	74
	134	0	0	0	0	0	12	267	0	0	0	0	0	279
	150	0	0	0	0	0	2	0	0	0	0	0	0	2
	151	0	0	0	0	2	0	0	0	0	0	0	0	2
	Total	10	7	4	5	14	57	281	56	32	8	1	0	475
1980	86	0	14	0	0	0	0	0	0	0	0	0	0	14
	89	0	0	0	0	0	0	0	0	0	2	0	0	2
	90	0	0	0	0	0	0	0	0	2	1	0	0	3
	91	0	0	0	0	0	0	0	0	2	1	0	0	3
	105	0	0	0	0	0	0	0	0	0	0	0	2	2
	107	7	12	0	3	0	0	0	0	0	0	0	0	22
	108	0	0	0	0	0	0	0	0	0	0	1	0	1
	109	0	0	0	0	0	0	0	0	1	0	0	0	1
	111	0	0	0	0	0	0	0	0	0	2	0	0	2
	112	0	0	0	0	0	1	2	9	0	0	0	0	12
	113	0	0	0	0	0	2	2	2	0	1	0	0	7
	114	0	0	0	0	0	2	105	0	0	11	0	0	118
	129	0	0	0	0	0	0	0	0	0	0	7	0	7
	130	0	0	0	0	0	0	4	0	0	0	0	0	4
	131	0	0	0	0	0	2	0	11	0	6	0	0	19
	132	0	0	0	0	0	0	9	0	0	0	0	0	9
	133	0	0	0	0	0	0	0	0	2	2	0	0	4
	134	0	0	0	0	0	0	0	4	0	0	0	0	4
	149	0	0	0	0	0	0	7	0	0	0	0	0	7
	150	0	0	0	0	0	0	0	0	1	0	0	0	1
	Total	7	26	0	3	0	7	129	26	8	26	8	2	242

Table 2—*continued*

Species and Stock	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
Southern Whitebelly														
1979	24	11	0	0	0	0	0	0	0	0	0	0	0	11
	44	62	0	0	3	116	5	0	0	0	0	0	0	186
	45	9	0	0	0	0	0	0	0	0	0	0	0	9
	46	0	0	0	0	0	0	0	0	0	0	1	0	1
	65	8	0	0	0	0	0	0	0	0	0	0	0	8
	Total	90	0	0	3	116	5	0	0	0	0	1	0	215
1980	23	4	1	0	0	0	0	0	0	0	0	0	0	5
	43	4	0	0	0	0	0	0	0	0	0	0	0	4
	44	1	22	0	0	0	0	0	0	0	286	0	0	309
	Total	9	23	0	0	0	0	0	0	0	286	0	0	318
Eastern														
1979	107	0	0	1	0	0	0	0	0	0	0	0	0	1
	108	0	0	0	0	0	0	0	0	0	6	0	0	6
	109	0	0	0	0	0	0	0	0	0	1	0	0	1
	125	0	2	7	0	0	0	0	0	0	0	0	0	9
	126	1	10	39	0	0	0	26	0	0	0	0	0	76
	127	4	3	94	1	4	0	0	0	0	0	0	0	106
	128	11	2	0	2	1	2	0	0	20	5	0	0	43
	129	0	0	0	0	0	0	0	0	0	0	1	0	1
	133	0	0	0	0	0	0	0	1	0	0	0	0	1
	147	0	1	0	0	0	0	12	0	0	0	0	0	13
	149	0	0	0	1	0	0	0	0	0	0	0	0	1
	150	0	0	0	1	0	0	0	0	0	0	0	0	1
	Total	16	18	141	5	5	2	38	1	20	12	1	0	259
1980	86	0	5	0	0	0	0	0	0	0	0	0	0	5
	125	0	1	9	0	0	0	0	0	0	0	0	0	10
	126	0	1	1	0	3	0	0	0	0	0	0	0	5
	127	0	1	0	0	0	0	0	0	2	0	0	0	3
	128	8	0	17	3	1	0	0	8	0	0	0	0	37
	129	0	0	3	2	1	0	0	0	0	4	16	0	26
	130	0	0	0	0	0	0	0	0	4	0	0	0	4
	131	0	0	0	0	0	0	0	3	0	6	0	0	9
	147	0	3	0	0	0	0	0	0	0	0	0	0	3
	149	0	0	0	0	0	0	0	0	7	1	0	0	8
	Total	8	11	30	5	5	0	0	11	13	11	16	0	110
Unidentified to Stock														
1979	107	3	0	0	0	0	0	0	0	0	0	0	0	3
	108	0	0	0	0	0	0	0	0	0	1	0	0	1
	113	0	0	0	0	0	1	0	0	0	0	0	0	1
	114	0	0	0	0	0	2	0	0	0	0	0	0	2
	126	0	0	1	0	0	0	0	0	0	0	0	0	1
	128	0	0	0	0	0	0	0	0	64	1	0	0	65
	133	0	0	0	0	0	0	1	0	0	0	0	0	1
	148	0	0	0	0	0	0	0	0	0	0	3	0	3
	168	0	0	0	0	0	0	0	0	0	0	1	0	1
	Total	3	0	1	0	0	3	1	0	64	2	4	0	78
1980	114	0	0	0	0	0	0	3	0	0	0	0	0	3
	128	0	0	0	0	0	0	0	2	0	0	0	0	2
	129	0	0	0	0	0	0	0	2	0	5	21	0	28
	130	0	0	0	0	0	0	1	0	0	0	0	0	1
	131	0	0	0	0	0	0	0	5	0	4	0	0	9
	132	0	0	0	0	0	2	2	0	0	0	0	0	4
	150	0	0	0	0	0	0	0	0	1	0	0	0	1
	Total	0	0	0	0	0	2	6	9	1	9	21	0	48
All Stocks														
1979	Total	119	25	146	13	135	67	320	57	116	22	7	0	1027
1980	Total	24	60	30	8	5	9	135	46	22	332	45	2	718

Table 3

Kill data for common dolphin, *Delphinus delphis*, in observed kill, 1979 and 1980; by stock, five-degree square and month of the year; data collected by NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
Baja Neritic														
1979	168	0	0	147	490	0	0	0	0	0	0	0	0	637
	169	0	0	0	35	0	0	0	0	0	0	0	0	35
	Total	0	0	147	525	0	0	0	0	0	0	0	0	672
1980	169	13	0	0	0	0	0	0	0	0	0	0	0	13
	189	0	0	0	0	1	0	0	0	0	0	0	0	1
	Total	13	0	0	0	1	0	0	0	0	0	0	0	14
Northern Tropical														
1979	168	2	7	130	13	0	0	0	0	0	0	0	0	152
	169	3	0	0	0	0	0	0	0	0	0	0	0	3
	Total	5	7	130	13	0	0	0	0	0	0	0	0	155
1980	168	6	0	0	0	0	0	0	0	0	0	0	0	6
Central Tropical														
1979	103	14	0	0	0	96	0	0	0	0	0	0	0	110
	104	39	127	178	89	0	0	0	0	0	0	0	0	433
	105	3	0	25	0	0	0	0	0	0	0	0	0	28
	106	0	5	16	0	0	0	0	0	0	0	0	0	21
	125	0	23	0	0	4	0	0	0	0	0	0	0	27
	126	0	9	0	0	0	0	0	0	0	0	0	0	9
	134	0	0	0	0	0	16	0	0	0	0	0	0	16
	Total	56	164	219	89	100	16	0	0	0	0	0	0	644
1980	104	0	0	0	1	0	0	0	0	0	0	0	0	1
	105	0	0	0	0	18	0	0	0	22	2	0	0	42
	Total	0	0	0	1	18	0	0	0	22	2	0	0	43
Southern Tropical														
1979	44	0	0	0	0	1	0	0	0	0	0	0	0	1
All Stocks														
1979	Total	61	171	496	627	101	16	0	0	0	0	0	0	1472
1980	Total	19	0	0	1	19	0	0	0	22	2	0	0	63

Table 4

Kill data for striped dolphin, *Stenella coeruleoalba*, in observed kill, 1979 and 1980; by stock, five-degree square and month of the year; data collected by NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
Northern Tropical														
1979	168	0	0	55	2	0	0	0	0	0	0	0	0	57
1980	168	17	0	0	0	0	0	0	0	0	0	0	0	17
Central Tropical														
1979	124	0	0	0	0	0	0	0	0	0	7	0	0	7
	125	0	0	0	18	0	0	0	0	0	0	0	0	18
	Total	0	0	0	18	0	0	0	0	0	7	0	0	25
All Stocks														
1979	Total	0	0	55	20	0	0	0	0	0	7	0	0	82
1980	Total	17	0	0	0	0	0	0	0	0	0	0	0	17

Table 5

Kill data for bottlenose dolphin, *Tursiops truncatus*, Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, and false killer whale, *Pseudorca crassidens*, in observed kill, 1979 and 1980; by five-degree square and month of the year; data collected by NMFS observers on U.S.-registered vessels.

Species	5-DEG SQUARE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ALL MONTHS
Bottlenosed dolphin														
1979	126	0	1	0	0	0	0	0	0	0	0	0	0	1
	107	0	0	0	0	0	0	0	0	0	1	0	0	1
	Total	0	1	0	0	0	0	0	0	0	1	0	0	2
Pacific white-sided dolphin														
1979	189	0	0	0	0	0	0	0	1	0	0	0	0	1
False killer whale														
1980	126	0	1	0	0	0	0	0	0	0	0	0	0	1

Table 6

Sex data for spotted dolphin, *Stenella attenuata*, in observed kill, 1979 and 1980; by stock, five-degree square and quarter of the year; data collected by IATTC and NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG	QUARTER 1			QUARTER 2			QUARTER 3			QUARTER 4			ALL QUARTERS		
	SQUARE	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
Northern Offshore																
	66	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
1979	82	0	0	0	0	0	0	7	9	16	0	0	0	7	9	16
	85	4	9	13	0	0	0	0	0	0	0	0	0	4	9	13
	86	0	0	0	0	0	0	1	0	1	7	16	23	8	16	24
	87	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	88	0	0	0	0	0	0	4	4	8	0	1	1	4	5	9
	90	0	0	0	3	0	3	0	1	1	0	0	0	3	1	4
	104	0	1	1	4	0	4	0	0	0	0	0	0	4	1	5
	105	2	4	6	1	6	7	0	0	0	0	0	0	3	10	13
	106	5	19	24	0	0	0	5	5	10	3	2	5	13	26	39
	107	11	10	21	0	0	0	2	4	6	35	55	90	48	69	117
	108	1	3	4	0	0	0	0	0	0	18	27	45	19	30	49
	109	1	8	9	0	0	0	0	0	0	1	1	2	2	9	11
	110	0	0	0	2	0	2	2	1	3	2	5	7	6	6	12
	111	0	0	0	1	0	1	1	0	1	0	0	0	2	0	2
	112	0	0	0	7	12	19	7	11	18	5	5	10	19	28	47
	113	0	0	0	2	5	7	7	8	15	6	2	8	15	15	30
	114	0	0	0	22	26	48	2	1	3	2	9	11	26	36	62
	125	5	5	10	34	29	63	1	0	1	0	0	0	40	34	74
	126	14	23	37	0	1	1	8	3	11	0	0	0	22	27	49
	127	15	27	42	2	3	5	0	0	0	0	3	3	17	33	50
	128	30	28	58	7	23	30	2	3	5	10	18	28	49	72	121
	129	0	0	0	0	4	4	0	0	0	2	7	9	2	11	13
	130	0	0	0	0	0	0	0	0	0	6	10	16	6	10	16
	131	0	0	0	0	0	0	0	0	0	3	0	3	3	0	3
	132	0	0	0	0	0	0	9	9	18	0	8	8	9	17	26
	133	0	0	0	0	0	0	18	29	47	1	2	3	19	31	50
	134	0	0	0	9	18	27	3	5	8	0	0	0	12	23	35
	146	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	147	0	0	0	1	1	2	0	0	0	0	0	0	1	1	2
	148	4	8	12	0	3	3	6	6	12	0	1	1	10	18	28
	149	2	3	5	6	7	13	3	0	3	0	5	5	11	15	26
	150	0	0	0	1	1	2	0	1	1	4	1	5	5	3	8
	151	0	0	0	3	8	11	0	0	0	0	0	0	3	8	11
	168	0	0	0	0	0	0	0	0	0	4	2	6	4	2	6
	Total	94	149	243	105	147	252	89	100	189	109	181	290	397	577	974
1980	66	1	1	2	0	0	0	0	0	0	0	0	0	1	1	2
	83	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	85	1	0	1	3	1	4	0	1	1	14	10	24	18	12	30
	86	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	87	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	88	10	12	22	0	0	0	0	0	0	0	0	0	10	12	22
	89	2	5	7	0	0	0	0	0	0	2	2	4	4	7	11
	90	4	0	4	0	0	0	3	4	7	5	12	17	12	16	28
	91	2	0	2	0	0	0	0	0	0	6	4	10	8	4	12
	104	15	15	30	4	2	6	0	0	0	0	0	0	19	17	36
	105	3	2	5	0	1	1	0	0	0	4	8	12	7	11	18
	106	13	19	32	0	0	0	0	0	0	7	12	19	20	31	51
	107	11	20	31	1	0	1	2	1	3	24	24	48	38	45	83
	108	1	0	1	0	0	0	10	22	32	3	5	8	14	27	41
	109	0	0	0	0	0	0	0	1	1	1	12	13	1	13	14
	111	0	0	0	0	0	0	1	6	7	1	3	4	2	9	11
	112	0	0	0	4	9	13	21	38	59	0	0	0	25	47	72
	113	0	0	0	3	3	6	10	11	21	1	3	4	14	17	31
	114	0	0	0	3	0	3	2	6	8	2	2	4	7	8	15
	125	7	7	14	2	3	5	0	0	0	0	0	0	9	10	19
	126	1	6	7	0	0	0	0	0	0	0	0	0	1	6	7
	127	1	3	4	9	3	12	0	0	0	0	0	0	10	6	16
	128	3	10	13	24	27	51	8	11	19	0	0	0	35	48	83
	129	7	7	14	2	3	5	8	13	21	6	12	18	23	35	58
	130	0	0	0	0	0	0	12	22	34	1	1	2	13	23	36
	131	0	0	0	0	0	0	13	6	19	0	0	0	13	6	19
	132	0	0	0	1	0	1	16	12	28	0	1	1	17	13	30
	133	0	0	0	1	0	1	4	9	13	3	1	4	8	10	18
	134	0	0	0	0	0	0	1	1	2	0	0	0	1	1	2
	148	0	0	0	0	7	7	0	0	0	0	0	0	0	7	7
	149	0	0	0	17	19	36	1	2	3	0	0	0	18	21	39
	150	0	0	0	1	0	1	2	7	9	0	0	0	3	7	10
	169	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	Total	82	109	191	75	78	153	115	173	288	80	113	193	352	473	825
Southern Offshore																
1979	23	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	24	9	10	19	1	1	2	0	0	0	0	0	0	10	11	21
	25	0	0	0	0	0	0	0	0	0	2	1	3	2	1	3
	43	6	5	11	0	0	0	0	0	0	0	0	0	6	5	11
	44	36	27	63	80	90	170	4	2	6	2	2	4	122	121	243
	45	0	0	0	0	0	0	0	0	0	1	4	5	1	4	5
	64	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	66	13	15	28	0	0	0	0	0	0	0	0	0	13	15	28
	Total	64	58	122	81	91	172	4	2	6	5	8	13	154	159	313
1980	23	2	4	6	0	0	0	0	0	0	0	0	0	2	4	6
	24	0	1	1	0	0	0	0	0	0	4	3	7	4	4	8
	43	19	11	30	0	0	0	0	0	0	0	0	0	19	11	30
	44	8	11	19	0	0	0	0	0	0	5	1	6	13	12	25
	45	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	67	19	26	45	0	0	0	0	0	0	0	0	0	19	26	45
	Total	48	54	102	0	0	0	0	0	0	9	4	13	57	58	115
Coastal																
1979	147	0	0	0	2	5	7	0	0	0	0	0	0	2	5	7
	168	0	0	0	4	8	12	0	0	0	0	0	0	4	8	12
	Total	0	0	0	6	13	19	0	0	0	0	0	0	6	13	19
All Stocks																
1979	Total	158	207	365	192	251	443	93	102	195	114	189	303	557	749	1306
1980	Total	130	163	293	75	78	153	115	173	288	89	117	206	409	531	940

Table 7

Sex data for spinner dolphin, *Stenella longirostris*, in observed kill, 1979 and 1980; by stock, five-degree square and quarter of the year; data collected by IATTC and NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG	QUARTER 1			QUARTER 2			QUARTER 3			QUARTER 4			ALL QUARTERS		
	SQUARE	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
Northern Whitebelly																
1979	85	3	1	4	0	0	0	0	0	0	0	0	0	3	1	4
	86	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2
	91	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
	106	2	2	4	0	0	0	0	0	0	0	0	0	2	2	4
	108	2	0	2	1	1	2	0	0	0	1	3	4	4	4	8
	110	0	0	0	0	0	0	0	0	0	1	2	3	1	2	3
	111	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
	112	0	0	0	0	0	0	2	2	4	0	0	0	2	2	4
	113	0	0	0	0	1	1	3	4	7	0	0	0	3	5	8
	114	0	0	0	18	18	36	0	2	2	1	0	1	19	20	39
	126	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2
	128	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	132	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
	133	0	0	0	0	0	0	20	18	38	0	0	0	20	18	38
	134	0	0	0	4	7	11	0	0	0	0	0	0	4	7	11
	150	0	0	0	0	2	2	0	0	0	0	0	0	0	2	2
	Total	7	6	13	24	30	54	25	27	52	4	6	10	60	69	129
1980	85	0	0	0	0	0	0	2	0	2	31	49	80	33	49	82
	88	3	2	5	0	0	0	0	0	0	0	0	0	3	2	5
	89	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	90	0	0	0	0	0	0	1	0	1	0	1	1	1	1	2
	91	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	107	2	6	8	1	0	1	0	0	0	0	0	0	3	6	9
	108	0	0	0	0	0	0	3	1	4	0	0	0	3	1	4
	109	0	0	0	0	0	0	0	1	1	1	1	2	1	2	3
	111	0	0	0	0	0	0	3	2	5	1	0	1	4	2	6
	112	0	0	0	2	0	2	3	3	6	0	0	0	5	3	8
	113	0	0	0	0	1	1	1	4	5	0	0	0	1	5	6
	114	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	128	2	0	2	0	0	0	0	0	0	0	0	0	2	0	2
	129	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	130	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	131	0	0	0	0	2	2	5	3	8	0	0	0	5	5	10
	132	0	0	0	0	0	0	5	5	10	0	0	0	5	5	10
	133	0	0	0	0	0	0	6	10	16	0	0	0	6	10	16
	134	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	Total	7	8	15	3	3	6	32	29	61	33	54	87	75	94	169
Southern Whitebelly																
1979	24	4	3	7	0	0	0	0	0	0	0	0	0	4	3	7
	44	12	10	22	19	13	32	0	0	0	2	0	2	33	23	56
	45	2	3	5	0	0	0	0	0	0	0	0	0	2	3	5
	Total	18	16	34	19	13	32	0	0	0	2	0	2	39	29	68
1980	23	17	12	29	0	0	0	0	0	0	0	0	0	17	12	29
	43	1	1	2	0	0	0	0	0	0	0	0	0	1	1	2
	44	5	3	8	0	0	0	0	0	0	6	4	10	11	7	18
	66	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
	67	2	1	3	0	0	0	0	0	0	0	0	0	2	1	3
	Total	26	17	43	0	0	0	0	0	0	6	4	10	32	21	53
Eastern																
1979	106	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	107	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
	108	0	0	0	0	0	0	0	0	0	1	8	9	1	8	9
	109	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
	110	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2
	125	5	6	11	0	1	1	0	0	0	0	0	0	5	7	12
	126	13	16	29	0	0	0	6	4	10	0	0	0	19	20	39
	127	33	25	58	0	2	2	5	1	6	0	0	0	38	28	66
	128	11	12	23	2	1	3	3	5	8	4	5	9	20	23	43
	130	0	0	0	0	0	0	0	0	0	7	5	12	7	5	12
	131	5	8	13	0	0	0	1	0	1	1	0	1	7	8	15
	132	0	0	0	0	0	0	0	0	0	3	6	9	3	6	9
	133	0	0	0	0	0	0	1	0	1	1	1	2	2	1	3
	146	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	Total	67	68	135	2	4	6	18	10	28	19	26	45	106	108	214
1980	109	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
	125	3	3	6	0	0	0	0	0	0	0	0	0	3	3	6
	126	5	2	7	2	0	2	0	0	0	0	0	0	7	2	9
	127	0	3	3	0	1	1	0	0	0	0	0	0	0	4	4
	128	3	10	13	1	1	2	6	6	12	0	0	0	10	17	27
	129	0	1	1	2	2	4	0	0	0	6	4	10	8	7	15
	130	0	0	0	0	0	0	3	5	8	1	1	2	4	6	10
	131	0	0	0	0	0	0	3	0	3	0	0	0	3	0	3
	132	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
	133	0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
	149	0	0	0	0	0	0	3	2	5	0	0	0	3	2	5
	Total	11	19	30	5	4	9	17	14	31	8	5	13	41	42	83

Table 7—*continued*

Species and Stock	5-DEG	QUARTER 1			QUARTER 2			QUARTER 3			QUARTER 4			ALL QUARTERS		
	SQUARE	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
Unidentified to Stock																
1979	107	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	130	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2
	132	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2
	133	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
	168	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
	Total	0	0	0	0	0	0	0	0	0	2	5	7	2	5	7
1980	128	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
	129	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
	131	0	0	0	0	0	0	2	3	5	0	1	1	2	4	6
	132	0	0	0	0	0	0	2	0	2	0	0	0	2	0	2
	133	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
	Total	0	0	0	0	1	1	5	3	8	1	1	2	6	5	11
All Stocks																
1979	Total	92	90	182	45	47	92	43	37	80	27	37	64	207	211	418
1980	Total	44	44	88	8	8	16	54	46	100	48	64	112	154	162	316

Table 8

Sex data for common dolphin, *Delphinus delphis*, in observed kill, 1979 and 1980; by stock, five-degree square and quarter of the year; data collected by NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG	QUARTER 1			QUARTER 2			QUARTER 3			QUARTER 4			ALL QUARTERS		
	SQUARE	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
COMMON DOLPHIN:																
Baja Neritic																
1979	168	4	9	13	16	21	37	0	0	0	0	0	0	20	30	50
1980	169	2	4	6	0	0	0	0	0	0	0	0	0	2	4	6
Northern Tropical																
1979	168	30	28	58	5	3	8	0	0	0	0	0	0	35	31	66
	169	1	1	2	0	0	0	0	0	0	0	0	0	1	1	2
	Total	31	29	60	5	3	8	0	0	0	0	0	0	36	32	68
1980	168	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
	169	6	6	12	0	0	0	0	0	0	0	0	0	6	6	12
	Total	7	6	13	0	0	0	0	0	0	0	0	0	7	6	13
Central Tropical																
1979	103	10	4	14	3	3	6	0	0	0	0	0	0	13	7	20
	104	20	27	47	37	45	82	0	0	0	0	0	0	57	72	129
	105	0	3	3	0	0	0	0	0	0	0	0	0	0	3	3
	106	6	7	13	0	2	2	0	0	0	0	0	0	6	9	15
	125	3	3	6	7	11	18	0	0	0	0	0	0	10	14	24
	126	7	2	9	0	0	0	0	0	0	0	0	0	7	2	9
	134	0	0	0	1	2	3	0	0	0	0	0	0	1	2	3
	Total	46	46	92	48	63	111	0	0	0	0	0	0	94	109	203
1980	104	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1
	105	0	0	0	4	11	15	0	0	0	0	0	0	4	11	15
	Total	0	0	0	5	11	16	0	0	0	0	0	0	5	11	16
Southern Tropical																
1979	64	3	4	7	0	0	0	0	0	0	0	0	0	3	4	7
All Stocks																
1979	Total	84	88	172	69	87	156	0	0	0	0	0	0	153	175	328
1980	Total	9	10	19	5	11	16	0	0	0	0	0	0	14	21	35

Table 9

Sex data for striped dolphin, *Stenella coeruleoalba*, in observed kill, 1979 and 1980; by stock, five-degree square and quarter of the year; data collected by NMFS observers on U.S.-registered vessels.

Species and Stock	5-DEG SQUARE	QUARTER 1			QUARTER 2			QUARTER 3			QUARTER 4			ALL QUARTERS		
		M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
Northern Tropical																
1979	168	14	12	26	1	5	6	0	0	0	0	0	0	15	17	32
1980	149	0	0	0	11	4	15	0	0	0	0	0	0	11	4	15
	168	1	8	9	0	0	0	0	0	0	0	0	0	1	8	9
	Total	1	8	9	11	4	15	0	0	0	0	0	0	12	12	24
Central Tropical																
1979	124	0	0	0	0	1	1	0	0	0	1	2	3	1	3	4
	125	0	0	0	5	0	5	0	0	0	0	0	0	5	0	5
	Total	0	0	0	5	1	6	0	0	0	1	2	3	6	3	9
All Stocks																
1979	Total	14	12	26	6	6	12	0	0	0	1	2	3	21	20	41
1980	Total	1	8	9	11	4	15	0	0	0	0	0	0	12	12	24

Table 10

Sex data for bottlenose dolphin, *Tursiops truncatus*, Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, rough-toothed dolphin, *Steno bredanensis*, and false killer whale, *Pseudorca crassidens*, in observed kill, 1979 and 1980; by five-degree square and quarter of the year, data collected by IATTC and NMFS observers on U.S.-registered vessels.

Species	5-DEG SQUARE	QUARTER 1			QUARTER 2			QUARTER 3			QUARTER 4			ALL QUARTERS		
		M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
Bottlenosed dolphin																
1979	107	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
	126	1	1	2	0	0	0	0	0	0	0	0	0	1	1	2
	Total	1	1	2	0	0	0	0	0	0	1	0	1	2	1	3
Rough-toothed dolphin																
1979	124	0	0	0	0	0	0	1	3	4	0	0	0	1	3	4
Pacific white-sided dolphin																
1979	189	0	0	0	0	0	0	1	1	2	0	0	0	1	1	2
False killer whale																
1980	126	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1

Table 11

Length frequencies for spotted dolphins, *Stenella attenuata*, and striped dolphins, *Stenella coeruleoalba*, in observed kill, 1979 and 1980; by stock, year, and sex; data collected by IATTC and NMFS observers on U.S.-registered vessels.

	Spotted dolphins										Striped dolphins					
Length (cm)	Northern Offshore				Southern Offshore				Coastal		Central Tropical		Northern Tropical			
	1979		1980		1979		1980		1979		1979		1979		1980	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
75-79		1														
80-84	3					1										
85-89	3	3		3	3	1										
90-94	4	3	2		4	7			1							
95-99	2	8	4	4	4	3		1	1	1						
100-104	2	2		3	3		1			1						
105-109	1	5	5	5		2										
110-114	1	2	2	3	2									1		
115-119	3	2	3	2		1		1								
120-124	5	3	2	2			1					1				
125-129	3	4	5	5	3	2	1									
130-134	4	3	4	3	3		1									
135-139	6	12	8	5	2	1										
140-144	7	11	6	5	2	4										
145-149	8	12	11	5	4	3	1	1								1
150-154	7	18	16	8	6	3	1	2	1							
155-159	24	13	24	20	10	8	2	2								
160-164	36	34	31	31	12	7	2	3						1		
165-169	30	36	32	37	8	9	5	2								
170-174	35	32	23	35	8	18	5	3	1							
175-179	23	50	29	37	18	11	4	5	1				1	2		
180-184	23	69	18	54	11	25	10	5				1	1	1	1	
185-189	22	96	23	75	9	25	7	16			1		1	1	1	
190-194	23	91	30	81	9	15	5	11			1			1	1	3
195-199	42	50	29	44	8	7	4	5	1	1	1		1	3	2	2
200-204	26	16	21	14	13	2	6	1		2		1	3	3	4	3
205-209	28	2	19	2	5	1	1	1					2	2	2	2
210-214	18	1	9	2	5	1					1		3	2	1	1
215-219	7		7	2			1			1	1					
220-224	2		3	1	1					1	1		2			
225-229	2		2										1			
230-234										1						
235-239																
240-244										1						
Total	400	579	368	488	153	157	58	59	6	9	6	3	15	17	12	12

Table 12

Length frequencies for spinner dolphins *Stenella longirostris*, in the observed kill, 1979 and 1980; by stock, year, and sex; data collected by IATTC and NMFS observers on U.S.-registered vessels.

Length (cm)	Northern Whitebelly				Southern Whitebelly				Eastern				Unidentified			
	1979		1980		1979		1980		1979		1980		1979		1980	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
75-79																
80-84	1	1		1												
85-89					2	1				1						
90-94														1		
95-99							2				1					
100-104									1					1		
105-109				1				1				1	1			1
110-114									1	2						
115-119					4				2		1					
120-124	2	2	3	1					4	3		2				
125-129		2	1	2			1		2	3		1				
130-134	4	2	2				1	1		2						1
135-139	1		2	5	2				5	3	1	1				1
140-144	1		1		1			1	3	5		2			1	
145-149	4	2	3	1			2		7	5	2				1	
150-154	3	2	4	6	3		1	1	10	8	5	5		2		
155-159	4	2	3	5		3			13	11	3	5	1	1	2	2
160-164	3	13	2	7	4	2	3	1	13	12	5	4				
165-169	2	6	9	13	1	4	2	4	7	15	6	4				
170-174	5	11	13	20	3	5	7	2	16	18	6	6			1	
175-179	13	12	16	17	5	6	3	4	10	14	7	9			1	
180-184	8	7	10	13	11	4	2		13	9	1	2				
185-189	4	4	7	5	2	4	6	3	4		2					
190-194	5	2	2		1			3			1					
195-199		1					2									
200-204			1													
205-209							1									
210-214																
215-219																
220-224																
225-229																
230-234																
235-239							1									
Total	60	69	79	97	39	29	34	21	111	111	41	42	2	5	6	5

Table 13

Length frequencies for common dolphin, *Delphinus delphis*, in the observed kill, 1979 and 1980; by stock, year and sex; data collected by IATTC and NMFS observers on U.S.-registered vessels.

Length (cm)	Baja Neritic				Northern Tropical				Southern Tropical		Central Tropical			
	1979		1980		1979		1980		1979		1979		1980	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
75-79														
80-84														
85-89														
90-94											2	1		
95-99														
100-104											1	1		1
105-109														
110-114														
115-119														1
120-124													1	
125-129														
130-134												1		
135-139					1				1					
140-144												1		
145-149					2	2					1			
150-154	1			1		1					2			
155-159	2	1			1				1		4	2		1
160-164		1			2	4			1		1	5		1
165-169	1	1				1	1	1		1	5	5		
170-174	2	5			1	2	1	1		1	6	11		1
175-179	2	11		2	1	7	3	1			4	7		
180-184	4	4			3	8		2		2	8	5		
185-189	2	5			9	3					10	9	1	
190-194	2	2	1	1	6	4					10	20		3
195-199	2		1		7		1				9	20		1
200-204	2				3		1				7	10	1	2
205-209											9	7	1	
210-214											9	2		
215-219											5			
220-224											3		1	
225-229														
230-234														
235-239														
Total	20	30	2	4	36	32	7	5	3	4	94	109	5	11

Table 14

Reproductive condition for 1,276 female spotted dolphins, *Stenella attenuata*, and 17 female striped dolphins, *Stenella coeruleoalba*, in the observed kill, 1979 and 1980; by stock and year; data collected by IATTC and NMFS observers on U.S.-registered vessels.

	Spotted								Striped	
	Northern Offshore				Southern Offshore				Northern Tropical	
	1979		1980		1979		1980		1979	
	N	%	N	%	N	%	N	%	N	%
Maturity undetermined	247	42.8	237	49.2	81	51.7	35	60.4	2	11.8
Sexually immature	123	21.2	105	21.8	17	10.8	6	10.3	8	47.0
Sexually mature:										
Condition undetermined	2	0.3	1	0.2	0	0.0	0	0.0	0	0.0
Pregnant only	42	7.3	30	6.2	9	5.7	6	10.3	0	0.0
Pregnant and lactating	17	2.9	9	1.9	1	0.6	0	0.0	0	0.0
Lactating only	117	20.2	75	15.6	28	17.8	8	13.8	3	17.6
"Resting"										
With corpus luteum	7	1.2	6	1.2	10	6.4	0	0.0	0	0.0
Without corpus luteum	21	3.6	19	3.9	10	6.4	3	5.2	4	23.6
Post-reproductive	3	0.5	0	0.0	1	0.6	0	0.0	0	0.0
Total	579	100.0	482	100.0	157	100.0	58	100.0	17	100.0

Table 15

Reproductive condition for 369 female spinner dolphins, *Stenella longirostris*, in the observed kill, 1979 and 1980; by stock and year; data collected by IATTC and NMFS observers on U.S.-registered vessels.

	Eastern				Whitebelly							
					Northern				Southern			
	1979		1980		1979		1980		1979		1980	
	N	%	N	%	N	%	N	%	N	%	N	%
Maturity undetermined	43	38.8	21	50.0	18	26.1	61	62.9	18	62.1	14	66.6
Sexually immature	36	32.4	12	28.6	20	29.1	19	19.6	6	20.7	3	14.3
Sexually mature:												
Condition undetermined	0	0.0	0	0.0	1	1.4	0	0.0	0	0.0	1	4.8
Pregnant only	14	12.6	4	9.5	4	5.8	2	2.1	3	10.3	0	0.0
Pregnant and lactating	0	0.0	0	0.0	1	1.4	1	1.0	0	0.0	0	0.0
Lactating only	15	13.5	5	11.9	12	17.4	10	10.3	2	6.9	3	14.3
"Resting"												
With corpus luteum	0	0.0	0	0.0	6	8.7	0	0.0	0	0.0	0	0.0
Without corpus luteum	3	2.7	0	0.0	7	10.1	4	4.1	0	0.0	0	0.0
Post-reproductive	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	111	100.0	42	100.0	69	100.0	97	100.0	29	100.0	21	100.0

Table 16

Reproductive condition for 188 female common dolphins, *Delphinus delphis*, in the observed kill, 1979 and 1980; by stock and year; data collected by IATTC and NMFS observers on U.S.-registered vessels.

	Baja Neritic		Northern Tropical		Southern Tropical				Central Tropical			
	1979		1979		1979		1980		1979		1980	
	N	%	N	%	N	%	N	%	N	%	N	%
Maturity undetermined	20	66.7	20	62.6	0	0.0	0	0.0	33	30.9	0	0.0
Sexually immature	2	6.7	3	9.4	2	50.0	2	50.0	31	29.0	5	45.4
Sexually mature:												
Condition undetermined	0	0.0	0	0.0	0	0.0	0	0.0	1	0.9	0	0.0
Pregnant only	2	6.7	1	3.1	0	0.0	0	0.0	7	6.5	1	9.1
Pregnant and lactating	0	0.0	1	3.1	0	0.0	0	0.0	4	3.7	0	0.0
Lactating only	4	13.3	6	18.7	2	50.0	2	50.0	22	20.6	4	36.4
"Resting"												
With corpus luteum	1	3.3	1	3.1	0	0.0	0	0.0	3	2.8	0	0.0
Without corpus luteum	1	3.3	0	0.0	0	0.0	0	0.0	6	5.6	1	9.1
Post-reproductive	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	30	100.0	32	100.0	4	100.0	4	100.0	107	100.0	11	100.0

SC/33/SM7

The Beluga (*Delphinapterus leucas*); Growth at Age Based on a Captive Specimen and a Discussion of Factors Affecting Natural Mortality Estimates

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ABSTRACT

Length at age as well as colour change data, obtained from a captive beluga (*Delphinapterus leucas*) over a thirteen year period, are in close agreement with those from wild specimens only if it is assumed that two growth layer groups are annual tooth deposits. Reasons for a double annual tooth lamination rate are discussed. The frequency and significance of ice entrapment as a factor in natural mortality of beluga is also considered.

INTRODUCTION

Studies of beluga (*Delphinapterus leucas*) population dynamics have been confounded by problems in both age determination and estimation of natural mortality rate. Much of the difficulty in quantifying these parameters may be attributed to the habitat; seasonally isolated regions of the Arctic and sub-Arctic where solid or drifting ice predominates much of the year and where the year itself is divided into seasons of darkness and light. Because of these conditions the beluga habitat could be considered atypical when compared with those of odontocetes from lower latitudes and its growth patterns correspondingly unique.

AGE DETERMINATION

The determination of age using tooth laminae has been a controversial subject for two reasons: first, that tooth erosion beyond adulthood results in under-representation of dentine and cementum layering and, second, the long debated problem of interpretation; one or two growth layer groups per year (IWC, 1980 p. 119). The difficulty with the latter has been the inability to collect samples throughout the year or, ideally, to obtain comparative data from beluga of known age.

On 27 July 1980 a male beluga, captive since 1967, died in the Vancouver Public Aquarium. Dr Newman, Director, kindly provided length at age data gathered during the early years of captivity and upon death (see Table). Teeth had been extracted after death, however the layering is difficult to define in longitudinal thin sections. This is not surprising since the animal had spent almost its entire life in captivity and, it should be noted, at a lower latitude, both of these possibly influencing tooth metabolism. In addition, the teeth appear to have been exposed to abnormal wear, probably attributable to intensified social interactions with other beluga and odontocetes during captivity. Taking into account the above, it is apparent that tooth lamination cannot be used here with any confidence for comparison with teeth from wild specimens.

Table 1

Length at age data for captive beluga

Date	Length (cm)	Comments
26 September 1967	227	Capture (Alaska)
October 1968	263	Vancouver Aquarium
May 1969	279	Vancouver Aquarium
October 1970	310	Vancouver Aquarium
February 1979	427	Vancouver Aquarium
27 July 1980	427	Died

While it is acknowledged that the captive beluga was hand fed for most of its life, it would be useful to compare length at age with data from wild populations. In Fig. 1, lengths are shown plotted against growth curves of Cumberland Sound beluga (from Brodie, 1971). For comparison, two curves are plotted for the captive beluga based upon tooth lamination rates of one and two growth layer groups per year. The captive beluga had been taken in Alaskan waters (26 September 1967) where, according to Seaman and Burns (1981), the peak of calving is in July. Based on Brodie (1971) the calf was probably 14 months old, however, an error of several months either way at this point would not greatly alter the growth curve.

The plotted growth for the Alaskan beluga is in very close agreement with that for males from Cumberland Sound, here assumed to deposit two dentinal growth layer groups per annum. Included in the figure is a growth curve (dotted line) for the Alaskan beluga, if it is assumed that one growth layer group is deposited per annum. It is apparent that there is greater conformity when assuming that two growth layer groups are deposited annually.

Since tooth lamination cannot be used here for direct comparison the only remaining age-related characteristic for which we have data from both wild and captive specimens, is epidermal colour change. The ages at which Cumberland Sound beluga became noticeably white, expressed in tooth layers were estimated at 12 and 14 growth layer groups for females and males respectively, assumed by Brodie (1971) to represent 6 and 7 years respectively. According to Dr Newman (pers. comm.) the captive beluga became white in 1972 (presumed here to be age 6) and was estimated to be near full body length.

It would appear that growth, on a body length basis, was not markedly altered by the conditions of captivity and that the timing of pigmentation change was consistent with that

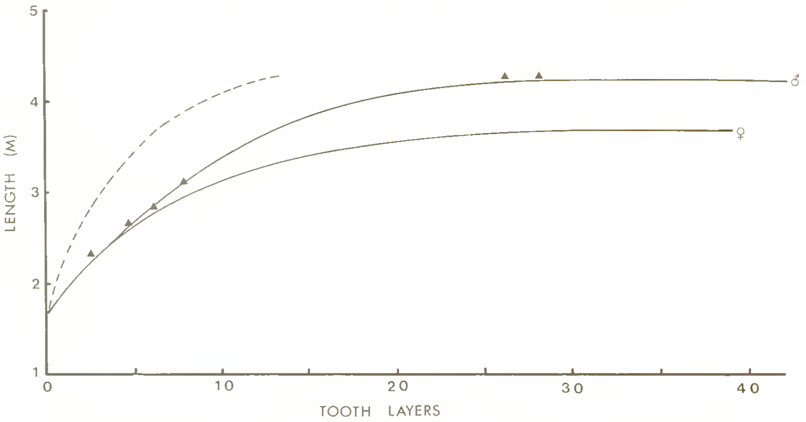

Fig. 1. Length at age for the captive beluga (triangles) plotted against growth curves for female and male beluga from Cumberland Sound, after Brodie (1971). The triangles are plotted assuming two dentinal growth layer groups per annum with the dotted line indicating the growth curve if single growth layers are annual.

presumed for wild specimens. It seems highly improbable that the rate of growth and pigmentation change could have proceeded at twice the natural rate in captivity, thus appearing to be consistent with that of wild beluga if we assume a tooth lamination rate of one growth layer per year.

Field evidence necessary to resolve the question of single or double, annual tooth layering is difficult to obtain, due partly to the limited availability of beluga during the restricted summer and their isolation in offshore areas of pack ice during the winter. One might speculate as to the causes for the partitioning of tooth mineralization into half-year cycles. A period of reduced feeding or forced migration during mid-January to mid-March could effect changes in tooth metabolism, resulting in a poorly mineralized layer six months out of phase with the July calving season, during which time tooth mineralization seems to be reduced (Brodie, 1969).

While the hypothesis of single, annual growth layer groups in beluga teeth would permit conformity with what is now presumed for odontocetes in general, it is not clearly supported by field observations nor has it been substantiated by a known age, captive specimen. It is acknowledged that this argument is based on data from one specimen, however its significance is further underlined by the fact that data were gathered over a 13 year period and on two parameters. The annual deposition of two growth layer groups in the teeth continues to be an attractive hypothesis for *Delphinapterus leucas*.

ESTIMATING NATURAL MORTALITY FROM ICE ENTRAPMENT

The incidence of recorded ice entrapment of beluga and narwhal (*Monodon monoceros*) has been well documented (Mitchell and Reeves, 1981), however what requires further consideration is the frequency of such entrapments, in particular those that may have gone undiscovered in isolated regions of the Arctic. In attempting to estimate the undiscovered ice entrapments we must first understand the original distribution of human habitation in the Arctic. The Inuit communities, hunting camps and travel patterns evolved in relation to the availability of terrestrial and marine resources, including the migration routes and summering habitats of beluga and narwhal. Included in the travel pattern were, no doubt, sites where there was greater potential for ice entrapment, such information being passed on through generations of hunters. Thus, the pattern of human distribution and travel demonstrates a bias, typical of a successful predator, with the result that ice entrapment of whales was more frequent near inhabited or travelled areas.

In hunting societies these 'off season' discoveries of trapped whales were, and are still considered, valuable supplies of 'captive' animals providing fresh food with minimal hunting effort, sometimes supplying a community throughout the winter. As potential resource areas these 'savssats' were sought out by hunters who were capable of detecting such open water at long range.

In addition to human predation, polar bears (*Thalarctos maritimus*) could take advantage of the situation and either prey upon the confined whales or feed upon the remains left by hunters. The point to be made here is that trapped whales were utilized and in recent years have been included in the catch statistics, thus the mortality from predation and ice entrapment were not always from separate events. What portion of entrapped whales that died undiscovered is unknown but it is likely to be small and it is interesting that, despite the enormous increase in aerial traffic and environmental surveys associated with mineral exploration, no significant numbers of entrapped whales have been reported in the uninhabited Arctic regions.

There is a tendency (apparently inversely related to field experience) to assume that the Arctic marine habitat is characterized by a high natural mortality. This includes the impression that the Arctic is hostile to marine mammals when, in fact, they are morphologically and behaviourally adapted. For example, the absence of back fins facilitates navigation in forming ice by Arctic whales, while blubber stores, often exceeding 40% of total body weight provide heavy insulation as well as energy reserves and permit extended isolation from prey resources (Sergeant and Brodie, 1969; Brodie, 1981). Beluga and narwhal can often be sighted in ice conditions that would at first be interpreted as a possibly fatal entrapment, yet they demonstrate a remarkable ability to navigate in pack ice and narrow leads. The beluga, in particular, not only demonstrates an ability to negotiate pack ice but spends many weeks each year in the confines of very shallow river mouths and estuaries. Such abilities are necessary adaptations to an Arctic, marine habitat yet are sometimes not appreciated by researchers with experience limited to more southerly, pelagic Cetacea.

REFERENCES

Brodie, P. F. 1969. Mandibular layering in *Delphinapterus leucas* and age determination. *Nature* 221: 956–8.

Brodie, P. F. 1971. A reconsideration of aspects of growth, reproduction and behaviour of the white whale (*Delphinapterus leucas*) with reference to the Cumberland Sound, Baffin Island, population. *J. Fish. Res. Bd Canada* 28: 1,309–18.

Brodie, P. F. 1981. A preliminary investigation of the energetics of the bowhead whale (*Balaena mysticetus, L.*) *Rep. int. Whal. Commn* 31: 501–2.

Mitchell, E. and Reeves, R. R. 1981. Catch history and cumulative catch estimates of initial population size of cetaceans in the eastern Canadian Arctic. *Rep. int. Whal. Commn* 31: 645–82.

Seaman, G. A. and Burns, J. J. 1981. Preliminary results of recent studies of Belukhas in Alaskan waters. *Rep. int. Whal. Commn* 31: 567–74.

Sergeant, D. E. and Brodie, P. F. 1969. Body size in white whales, *Delphinapterus leucas. J. Fish. Res. Bd Canada* 26: 2,561–80.

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The 1979 Hunt for Narwhals (*Monodon monoceros*) and an Examination of Harpoon Gun Technology Near Pond Inlet, Northern Baffin Island

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ABSTRACT

About 150 narwhals were killed during the Pond Inlet narwhal hunt in 1979; most (73%) of these were adults and 44% were females. Seven (39%) of 18 mature females were pregnant. Loss rates were lower in 1979 than in 1978 but many narwhals received superficial wounds; 23% of the landed catch had old bullet scars. Hunters exhibited considerable variability in their selectivity of males and females. The introduction of harpoon gun technology proved ineffective in improving hunting efficiency. The narwhal hunt is a long tradition in Pond Inlet but now appears more intensive with modern technology; in 1979 the tusk trade brought $46,000 to the hunters.

INTRODUCTION

In a symposium on Canada's threatened species, Land (1977) brought attention to the narwhal hunt in the communities of Pond Inlet and Arctic Bay, Baffin Island. Land contended that, because of the high market value for tusks, narwhals were being slaughtered at an unprecedented rate. He noted that present hunting methods were inadequate and that losses due to wounding and sinkage were very high. Land recommended a total ban on trading and trafficking of narwhal tusks until reliable information on the abundance, distribution and population dynamics of the narwhal became available. Such data are needed to determine, reliably, how many narwhals can be killed without harming the population.

A quota system to regulate the catch of narwhals was instituted in 1976 as 'an appropriate way of handling the problem' (Mansfield, Smith and Beck, 1975); however, Davis, Finley and Richardson (1980) stated that present knowledge of population size, reproductive biology and kill statistics was still inadequate for assessing sustainable yield of narwhals. Loss and wounding rates continue to be very high and the landed catch greatly exceeded the quota of 100 narwhals in Pond Inlet during 1978 (Finley, Davis and Silverman, 1980). Finley *et al.* (1980) suggested that improved hunting methods would be an effective way of reducing the overall kill of narwhals and that Inuit must become involved in all levels of programs aimed toward conservation of the narwhal.

Thus in the summer of 1979, with the support of the Pond Inlet Hunters' and Trappers' Association, we attended the narwhal hunt in order to (1) assess more completely the problems inherent in the present hunting practices; (2) introduce some alternate hunting techniques, particularly the use of a harpoon gun, in an attempt to reduce hunting losses and wounding; (3) monitor total kill, losses and wounding associated with present and introduced hunting technology; and (4) discuss with the hunters the possibility of developing appropriate and acceptable hunting practices to ensure the long-term protection of the narwhal.

In this report we describe the 1979 hunt and compare the 1978 and 1979 hunts. We describe the use of the harpoon gun and the feasibility of adapting it to the narwhal hunt. Some aspects of the socio-economics and technology of the narwhal hunt are discussed.

MATERIALS AND METHODS

From mid June to mid September 1979, we accompanied hunters during narwhal hunts in Pond Inlet and Eclipse Sound (Fig. 1). We recorded the physical, biological and technological aspects of each hunting event. When possible a hunting event was observed from initial encounter with the narwhal to the final outcome of the hunt. When the hunter and prey were clearly visible to the observer the outcome of the hunting event was classified as (1) narwhal killed and secured, (2) narwhal killed and sank, (3) narwhal mortally wounded and (4) narwhal superficially wounded, and (5) narwhal not struck by bullets.

It was not always possible to assess the severity of wounding and a judgement by the observer was sometimes necessary. Animals that were considered mortally wounded were usually struck at close range (within 20 m) and at a critical angle. A mortally wounded narwhal often thrashed about in an uncontrolled manner before it dived and occasionally an animal escaped but was not expected to survive due to the severity of the wounds. Narwhals that were considered superficially wounded were usually struck on the back from long range (beyond 20 m) and/or a low angle. An oil slick provided evidence of a hit in many cases.

Narwhals that were killed and secured were examined for bullet scarring from previous encounters. The distinctive white scars are almost invariably found on the back just behind the head—the vital area for which most hunters aim. Bullet scars were measured and, when possible, photographed. The extent and nature of the damage caused by the lethal bullet was also examined when possible. Whenever possible during this study and other concurrent studies, an attempt was made to assess the degree of bullet scarring in free-ranging narwhals. During September and October 1979, narwhals were observed with 7× binoculars as they migrated past Cape Adair (220 m above sea level) on the east coast of Baffin Island (71°30′N, 71°35′W). Animals that were clearly visible were assessed for the presence of bullet scars.

Standard measurements were taken from most specimens and the reproductive condition was examined. Measurements and reproductive data were used to differentiate adult and immature whales. Mature males were generally >390 cm in length, had tusks >100 cm, and a single testicle weight >400 g. Mature females were >340 cm in length and had ovulated.

Two types of hand-held harpoon guns, *Greener* Light Model and *Kongsberg* M 52, were introduced to the narwhal hunt. The harpoons, attached to 30 m lines, were driven by 7.5 mm (*Greener*) or 12 mm (*Kongsberg*) blank cartridges. Wire (1/16 inch) or nylon (3/8 inch) harpoon lines, wound on a release frame mounted on the gun, were attached to inflatable buoys (diameter 60 cm). Several modifications and variations of the basic design were tried by the hunters. In addition, two types of hard-point ammunition, 150 grain .303 calibre and 180 grain 30-06 calibre, were provided to the hunters to test the effectiveness of this ammunition.

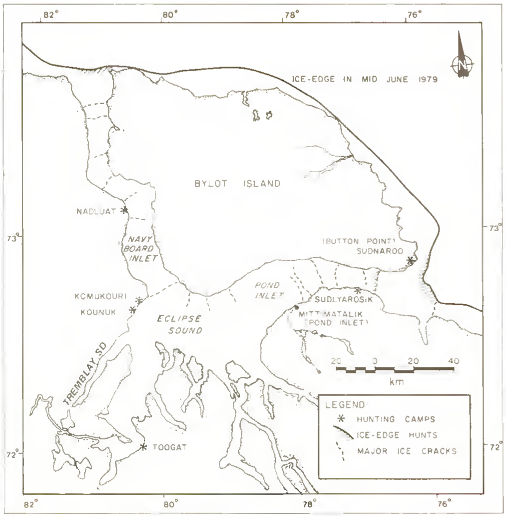

Fig. 1. Pond Inlet area showing positions of ice-edges and hunting areas in 1979.

RESULTS

Ice conditions and timing of the 1979 hunt

Ice conditions strongly affect the timing, duration and success of the narwhal hunt (Finley *et al.*, 1980). Because of much breaking and refreezing during March and April 1979, the Pond Inlet ice-edge extended deeper into the inlet and the fast-ice along the edge was much thinner (40–70 cm in mid-June) in 1979 than the previous year when the ice remained solid and thick (150–175 cm) throughout June and early July. Ice conditions became treacherous along the ice-edge by late June; in some areas it became difficult to approach the edge. Pack-ice frequently was blown against the ice-edge during June and early July. Because of these conditions there were fewer hunters at the Pond Inlet ice-edge than during the previous year and several hunters made the long (200 km) trip to the Navy Board Inlet ice-edge (Fig. 1) where no one had hunted in 1978. Camps at the Pond Inlet ice-edge had to be moved frequently due to the breaking of the fast-ice. Most of the hunters eventually camped at Button Point and commuted to the ice-edge by snowmobile until 8 July when the ice-edge began to disintegrate quickly.

The ice-edge receded to the narrows of Pond Inlet by 10 July (Fig. 1) and the hunt continued from there until 15 July. By then the ice had deteriorated so much that many of the hunters retreated to a land-based camp, Sudlyarosik, on the south side of the inlet. The ice-crack phase of the 1979 hunt was, as usual, of short duration (16–19 July), after which the hunters returned by skidoo, boat or foot to Pond Inlet.

During late July and early August, little hunting was conducted while the hunters waited for the ice to clear from Eclipse Sound in order that they could travel by boat to the summer hunting camps to the west of Pond Inlet. An intensive narwhal hunt was conducted from 10 August to the end of the month, primarily from the camps (Kounuk, Komukouri, Nadluat) in the vicinity of Navy Board Inlet. Although we were not present at Pond Inlet during most of September, it was reported that little hunting for narwhals was conducted then.

Analysis of kill and hunter effort

The seasonal distribution and composition of the 1979 narwhal catch is shown in Table 1. These statistics are derived from carcasses that we personally examined (55), from material evidence of tusks (27), and from reliable reports by hunters (30). Since females rarely possess tusks, statistics based on evidence of tusks would bias estimates of the composition of the catch toward males. Thus in the following account the composition of the narwhal catch is determined only from carcasses that we personally examined.

The ice-edge hunt

The first narwhal, an adult female, was taken at the Pond Inlet ice-edge on 4 June. It was reported that another female had been taken at the Navy Board Inlet ice-edge about two weeks previously. About five hunters remained at the Navy Board ice-edge until mid to late June and we received reports that at least seven more narwhals were taken there.

There had been little hunting activity at the Pond Inlet ice-edge before our arrival on 16 June, and no camps had been established along the ice-edge. Very few hunters appeared at the ice-edge until 27 June when several hunters arrived, some of them from the Navy Board Inlet ice-edge. On 30 June there were six encampments consisting of approximately 14 hunters scattered along about 40 km of ice-edge. This ice-edge was abandoned by 6 July. Most of the hunters then retreated to the position of the new ice-edge at Sudlyarosik where, on 13 July, there were nine encampments consisting of approximately 25 hunters along 13 km of ice-edge. An intensive hunt took place at this ice-edge until 16 July when the ice had

Table 1

Composition of the observed and reported 1979 narwhal catch in the Pond Inlet area. Numbers in parentheses represent carcasses that we personally examined

	Type of hunt			
	Ice Edge[1] (4 June–15 July)	Ice Crack (16–19 July)	Open Water (24 July–late Sept.[4])	All hunts
Males[2]				
Adult	12 (10)	7 (2)	22 (8)	41 (20)
Immature	7 (6)		6 (5)	13 (11)
Unclassified	4	4	8	16
Females[3]				
Adult	10 (9)	1 (1)	10 (10)	21 (20)
Immature	1 (1)		3 (3)	4 (4)
Unclassified	5		5	10
Unknown sex	1	1	5	7
Total[5]	40 (26)	13 (3)	59 (26)	112 (55)

[1] Includes some reports of kills at Navy Board Inlet ice edge.

[2] Mature males were generally over 390 cm in length, with tusks >100 cm in length, light and mottled pigmentation, and testical weight >400 g.

[3] Mature female were generally over 340 cm in length and had ovulated.

[4] Most narwhal hunting was finished by the end of August and there were no reports of narwhals being taken during September.

[5] See 'Discussion' for an estimate of the actual number secured.

deteriorated to such a degree that travel by snowmobile became almost impossible.

During the ice-edge hunt which lasted about 43 days, 40 narwhals (36% of the total 1979 catch) were landed. Of the narwhals that we personally examined, 16 (62%) were males (Table 1). Most of the catch (73% of those we examined) consisted of adults.

The ice-crack hunt

As the ice in the narrows of Pond Inlet deteriorated rapidly on 15 July many hunters returned to Pond Inlet. However, about 8–10 hunters moved to the land-based camp, Sudlyarosik, to wait for the narwhals to penetrate through the ice cracks and enlarged seal holes. Three encampments remained on the ice as late as 18 July.

At least 13 narwhals (12% of the total catch) were taken as they penetrated into the deteriorating fast ice. It is probable that others were taken but because of the difficulty of travelling we were unable to visit other encampments. We saw only three carcasses of which two were adult males and the other an adult female (Table 1).

The open-water hunt

The first narwhals had appeared near the settlement of Pond Inlet on 18 July and were reported from Eclipse Sound a few days later. The pack-ice in Eclipse Sound had dispersed in early August and on the weekend beginning 10 August many hunters departed by boat to hunt narwhals. Many narwhals were taken on that weekend and during three subsequent weeks from the camps (Kounuk, Komukouri and Nadluat) in the Eclipse Sound—Navy Board Inlet area. When we arrived at Kounuk on 20 August about 17 hunters were involved in the hunt but by 29 August most had returned to Pond Inlet. Some who remained in camp until 15 September reported that few whales were seen after the end of August and none were taken. We were at Kounuk from 10–15 September and at that time there were only about six hunters in the region and no whales were taken.

During the last three weeks of August at least 59 narwhals (53% of the total catch) were landed. Of the 26 narwhals that we personally examined, 13 (50%) were males (Table 1). Most of the catch (69%) consisted of adults.

Scarring, wounding and loss rates

A narwhal lying at the surface of the water exposes only a small area of its back (Fig. 2). In order to kill a narwhal a hunter must have a rifle with sufficient power to penetrate thick blubber and the shot must be directed downward in order to strike a vital area. Most hunters use a .303 calibre rifle with hard-point ammunition and they aim for a position just behind the blowhole of the whale. Experienced hunters shoot just before the whale begins to dive when it rises farthest out of the water. Most whales are killed at a range of less than 20 m with a single shot. When possible, hunters take advantage of any elevation afforded by the shooting site, such as an ice ridge at the floe edge or rock outcroppings along a shoreline, in order to obtain a critical angle from which to shoot. Without the advantage of elevation, narwhals beyond 20 m range are difficult or impossible to kill and many receive bullet wounds across their backs (Fig. 3). The distinctive white scars that result from such wounds are easily seen from the ground and during aerial surveys (Fig. 4).

Scarring rates

The locations of 6 bullet scars on 4 narwhals taken in 1979 ranged from 30 to 80 cm (average 46.8) behind the blowhole (Fig. 2). In most cases the scars (Fig. 4) were roughly perpendicular to the long axis of the whale and usually were found on the centre of the back along a line

Fig. 2. Resting position of a narwhal at the surface. Location of bullet scars (slashes) and lethal hits (X) were measured relative to the blowhole.

Table 2

Incidence of bullet scarring on narwhals taken in the Pond Inlet area, 1977–79

	1977[1]	1978[1]	1979	Total
Number examined	17	31	30	78
Number with scars				
Adult male	2	10	4	16
Immature male	0	0	0	0
Adult female	4	3	3	10
Immature female	1	0	0	1
Number without scars				
Adult male	1	10	10	21
Immature male	2	3	4	9
Adult female	4	5	8	17
Immature female	3	0	1	4

[1] Scarring information from 1977 and 1978 hunts provided by Helen Silverman.

wounded and lost. In one other case a narwhal may have been mortally wounded, but since we were uncertain it is listed as a superficial wounding in Table 3. However, the incidence of superficial wounding was very high during the 1979 ice-edge hunt; 16 of 39 hunting events resulted in animals being struck but not mortally wounded. In the other 22 hunting events that we witnessed, the hunters missed their prey.

As in 1978, it was sometimes difficult to ascertain whether an animal had been struck. However, in at least 6 of 16 cases of superficial wounding, an oil slick provided clear evidence of a hit (Table 3). Most of the superficial wounding occurred when animals were beyond a range of about 20 m. In fact, during the period of 13–15 July when there were many hunters at the ice-edge, narwhals were seldom allowed to closely approach the ice-edge and hunters frequently shot at narwhals from extreme ranges (75–150 m). This type of shooting probably causes most of the long grazing scars found on narwhals. The positions of the scars on the back (Fig. 2) suggest that the shots were fired from long ranges and low elevations—conditions common to many of the shots we observed at the 1979 ice-edge hunt.

On two occasions we observed hunters using small calibre rifles (17 cal. and .222) and soft-point ammunition. In both cases the rifles were ineffective and resulted in wounding of narwhals (Table 3).

Because of the dispersed nature of the brief ice-crack hunt during 1979, only one hunting event was fully observed. As two narwhals briefly surfaced in a melt-hole within 15 m of a hunter, they were shot at and one animal was struck in the side with a 50 grain, .222 projectile. The narwhal was not considered mortally wounded. About one hour earlier, an adult male narwhal was killed and secured as it surfaced in a melt-hole. Besides an old bullet scar just posterior to the blowhole, the narwhal was also found to have a more recent bullet wound on its right side. The wound, which penetrated into the dorsal muscle, appeared to have been inflicted within the previous week.

Thus in 17 hunting events in which we observed narwhals being struck by a bullet during the ice-edge hunt, only one or possibly two were mortally wounded and none were secured. These statistics are very different than those from the 1978 ice-edge hunt, when 16 narwhals were killed in 21 hunting events, and only 5 of the 16 were secured.

Wounding and loss rates, open water hunt

Observations of the narwhal hunt were conducted primarily from camps (Kounuk and Komukouri) in Eclipse Sound, during the period of 20 August to 15 September (Fig. 1). Little pack-ice was present in Eclipse Sound during this period but the generally windy weather and rough seas discouraged hunting from boats. Hunters often shot at passing narwhals from the beach, or from an elevation afforded by outcroppings near the water. Boats were put into the water to retrieve dead whales or to pursue wounded whales.

Table 3

Observations of hunting incidents resulting in wounding of narwhals during the 1979 hunt

Date	Type of hunt	Hunter	Calibre of rifle	Ammunition Grain	Ammunition Point	Number shots	Range (m)	Group size	(S) (M)	Outcome; superficial or mortal wound
16 June	ice-edge	S	.303	180	HP[1]	1	20	6	S	oil slick formed
16 June	ice-edge	S	.303	180	HP	1	20	1	M	oil slick formed
25 June	ice-edge	P	.303	180	HP	1	60	1	S	
25 June	ice-edge	D	17 cal.	50	SP[2]	1	—	—	S	
25 June	ice-edge	D	17 cal.	50	SP	1	50–60	2	S	
25 June	ice-edge	D	17 cal.	50	SP	1	30	4	S	
25 June	ice-edge	P	.303	180	HP	1	20	1	S	oil slick formed
25 June	ice-edge	D	17 cal.	50	SP	1	30	1	S	oil slick formed
28 June	ice-edge	I + I	.303	180	HP	2	5	1	S	2 tusks; hit twice
5 July	ice-edge	I	.303	180	HP	1	15	3	S	
5 July	ice-edge	C	.303	180	HP	1	20	10–15	S	
13 July	ice-edge	I	.303	180	HP	1	25	1	S	oil slick formed
13 July	ice-edge	I + S	.303	180	HP	2	70	1	S	oil slick formed
13 July	ice-edge	J + S	.303	180	HP	2	25	1	S	
13 July	ice-edge	I	.303	180	HP	1	25	1	S	
15 July	ice-edge	J + P	.303	180	HP	2	75	2	S	oil slick formed
15 July	ice-edge	P + S	.303	180	HP	2	100	2	S	
17 July	ice-crack	N	.222	50	SP	1	15	2	S	
23 August	open-water[3]	P + J	.303	180	HP	2	20	4	M	
26 August	open-water[3]	P	.303	180	HP	1	20	4	S	

[1] HP = Hard Point.

[2] SP = Soft Point.

[3] These hunts were conducted from the shore.

During calm weather, narwhals can sometimes be herded toward shore by boat. On one occasion three hunters in a single boat forced a group of narwhals into shallow water by shooting into the water. In the shallow water the narwhals could be followed easily. Whenever the narwhals surfaced the hunters were within easy range (5–10 m) and could easily select the animals with larger tusks. When the narwhals changed direction or attempted to escape into deep water they were re-directed with shots into the water. In three hours, the hunters took seven males with large tusks. No losses were observed although we were unable to devote our full attention to the outcome of the hunt because of priorities in testing the harpoon gun.

Little other information about loss rates and wounding was obtained during the open-water hunt because (a) the hunt was carried on over a large area, (b) it was not always possible to accompany hunters in their boats, and (c) priority was given to testing the harpoon gun. In two cases in which hunting was conducted from the shore the whales were wounded, one mortally and one superficially. In another instance two severely (probably mortally) wounded narwhals were observed from shore, swimming away from hunters in a boat. The hunters were attempting to secure a third wounded whale that they had harpooned, and either did not know where the other two wounded whales were, or were unable to pursue them at the time.

Although narwhals are available to the hunters from Pond Inlet throughout the summer season, the hunters from Clyde River (400 km south of Pond Inlet) may expect to see narwhals only briefly, if at all, during their southerly migration along the east coast of Baffin Island. We were in Clyde River when the first narwhals arrived in the early afternoon of 22 September 1979. Within one-half hour of the first sighting of the whales, 13 canoes had been launched. Eventually a small group of 5 narwhals were herded into shallow water near the village and 6 canoes with 18 hunters became involved in the chase. Many shots (at least 69) were fired into the water in order to herd the narwhals. A male narwhal was eventually secured while the others in the group escaped during the confusion. The hunt continued until dark and two more males were secured, one or two sank and a few were wounded. No other narwhals were taken by the hunters in Clyde during the remainder of the season.

Introduction and effectiveness of harpoon gun technology

Both the *Greener* and *Kongsberg* harpoon guns were tested for their range and accuracy by hunters at Pond Inlet before they were tested for practical application. The effective range for both guns appeared to be less than 20 m and was even less with lines thicker than 3/16 inch.

The *Greener* harpoon gun was first tried on 19 June when a hunter attempted to retrieve a wounded whale that was swimming within 3 m of the ice-edge. The wire harpoon line broke as soon as the harpoon was fired and it was necessary to retrieve the whale with a hand-thrown harpoon. The harpoon line was strengthened at the point of attachment to the harpoon, and on the following day two hunters successfully employed the harpoon gun in retrieving a wounded bearded seal (*Erignathus barbatus*). A nylon harpoon line broke on a subsequent occasion when the gun was fired at close range at a group of whales along the ice-edge.

On 21 June, two hunters, each armed with a *Kongsberg* gun, attempted to harpoon an immature beluga (*Delphinapterus leucas*) from a range of 10 m as it swam along the ice-edge. One cartridge failed to fire but the whale was struck with a harpoon from the other rifle. The whale dove but the resistance of the float caused the harpoon head to part from the shaft.

On 25 June, a group of 6 or 7 narwhals was encountered resting along the ice-edge. One hunter used the *Kongsberg* gun to harpoon one of the whales from a range of 5 m. This animal dove beneath the ice-edge and took the large (60 cm) float with it. The animal (and float) resurfaced 11 minutes later 200 m off the ice-edge and it continued to move slowly offshore. After a delay of 6 min, a 5 m boat was dispatched with a malfunctioning 20 hp motor. The whale was closely approached but instead of shooting it outright the hunters decided to attach another harpoon and float. Meanwhile the whale dove and remained submerged for another 7 mins. When it surfaced it was struck with the hand-thrown harpoon and it dove for another minute. It was shot in the head at close range with a .303 rifle when it surfaced. The whale appeared to be dead. The outboard engine was stopped and the harpoon lines were being drawn in when the whale began to thrash violently. At one point it breached near the boat, endangering the four occupants of the boat; then it dove taking both floats with it. Twenty-one minutes later the whale floated to the surface, dead.

Much of the remainder of the ice-edge hunt was conducted in such a manner that the harpoon guns could not be tested. It was often difficult to approach the ice-edge as the ice became unstable and hunters began shooting at whales at distances far greater than the range of the harpoon guns.

Both harpoon guns proved to be frail and unwieldy and under the circumstances of the ice-edge hunt in 1979. The line-release frames were too frail to withstand the rigorous methods of transport on komatiks and skidoos, and constantly required re-adjustments. Also the hunters, who are accustomed to carrying compact .303 rifles strapped over their shoulders, found the harpoon gun with the attached float too unwieldy at times when rapid mobility was deemed essential.

The harpoon guns proved to be even more unmanageable during the open-water hunt from boats. Aiming the guns was difficult in rough seas from a moving boat, and a spent line became twisted and impossible to replace quickly on the line-release frame. During one chase the line became fouled in the boat's propeller and the narwhals escaped. In the frenzied pace of a hunt from a boat, hunters were unwilling to take the considerable time and patience required to retrieve the harpoon line, and to properly re-rig and reload the gun. In fact, a handthrown harpoon with a strong sealskin line is a more effective way of securing a narwhal from a boat, particularly when the animal has been wounded and exhausted.

The *Kongsberg* harpoon gun has been introduced to Greenland hunters for the purpose of hunting belugas, but hunters have encountered similar problems and are reluctant to use it (Finn Kapel, pers. comm.). Furthermore, Kapel notes that the *Kongsberg* gun is no longer manufactured and that the high price of harpoons and ammunition will prevent the introduction of harpoon guns for general use in Greenland. The failure of some cartridges in the present study probably relates to the antiquity of the supplies. The *Greener* harpoon gun is also not manufactured at present.

Both types of harpoon guns are inadequate for effective use on animals as large as narwhals. Heavier lines greatly reduced the range of the harpoon and line breakage continued to be a problem with the *Greener* gun. Modifications were necessary to strengthen the *Kongsberg* harpoons but weaknesses were still a problem. In addition, light harpoon gun technology does not meet humane standards of killing.

In Alaska, harpoon gun technology is employed by the Inuit in taking the large bowhead whale (*Balaena mysticetus*) during the annual ice-edge hunt. The weaponry is more complex than that employed during the present study and involves the use of time-delayed explosives. This technology was introduced by the American whalers in the early 1900s. Again, a significant fraction of the whales that are struck are lost (Marquette, 1979).

DISCUSSION

Kill statistics

Kill statistics, based in part on the number of tusks brought in, do not represent the total catch of females. Since the Pond Inlet quota of 100 is controlled primarily through issuing of tags for the tusks of males, females are not likely to be reported. In 1979, 87 tags were issued for tusks, only two of which were from females. Only 7 tags were issued for females although we were aware of at least 35 that were taken (Table 1). Furthermore if we assume that the proportion of females (44%) in the catch that we personally examined is representative of the entire catch, then in addition to the 85 tagged males, 67 females were taken. Therefore a total landed catch of 152 narwhals is estimated for 1979.

In addition to the landed catch, a number of narwhals are lost to sinkage and others are mortally wounded and die later. This problem was particularly severe in 1978; however in 1979 we saw only two cases in which narwhals were mortally wounded but not retrieved. Occasionally a hunter finds a narwhal that has died from mortal wounds. For example, on 30 June 1979 a hunter retrieved a tusk from a large male narwhal that he found floating along the ice edge. In August 1979, the carcass of a male narwhal was found along the north coast of Bylot Island and another male was found along the south coast of Devon Island. Due to their decomposed state it was not ascertained whether they had died of bullet wounds.

It is not possible to calculate a loss rate for the 1979 hunt but we believe that losses from sinking or mortally wounding were lower compared to 1978 when we observed a loss rate of 69% at the ice-edge hunt (cf. Finley *et al.*, 1980). In 1979, ice conditions were very different than in 1978; it was often difficult to approach the ice edge in 1979 and there was no vantage point (i.e. an ice ridge) from which shots could be directed downward at a critical angle toward narwhals that were moving along the ice edge. Also, fewer narwhals appeared to be present in 1979. Often they did not closely approach the ice edge, and when they did competition among the hunters was so intense that they began shooting from long ranges. On 13–14 July hundreds of rounds of ammunition were expended on narwhals at ranges up to 100 m; only a few animals were taken and many received superficial wounds. Such circumstances explain the high rate (23% in 1979; 42% in 1978) of scarring found on narwhals.

In 1978 our estimates of hunting losses and wounding were derived primarily from the activities of three hunters who had considerable hunting experience and who we considered to be average to good hunters. In 1979 we continued our work with two of these hunters and we attempted to include several other hunters in our observations. The hunters encompassed a wide range of experience, selectivity and efficiency in their hunting techniques. One of these hunters appeared to be very careful to select males, particularly males with large tusks. During the 1979 season he was able to take 16 males; he killed only two females that we were aware of, and one of these had a tusk. On the other hand, a less discriminating hunter took 12 narwhals of which 8 were females.

During 1979 we were unable to follow through any hunting encounters that, according to our criteria, resulted in the killing and securing of a narwhal. We were often in the immediate area when a narwhal was killed and secured but were never able to observe the event from start to finish and thus we excluded the observations from our assessment of loss rates. We did observe two hunting events that resulted in mortal wounding and saw at least two other mortally wounded whales that were excluded from consideration by our criteria. We did not observe any cases involving losses due to sinkage of dead whales (which we had seen in 1978), although we had reliable reports of a few such cases. It appeared that loss rates were not as high in 1979 as in 1978, but it is not possible to attempt an estimate of total kill from our limited data on loss rates. It is important that the various circumstances of the hunt must be taken into account before attempting to estimate a total kill that includes loss rates.

Composition of kill

Statistics on the sex composition of the total kill reported for 1978 (Finley *et al.*, 1980) and for 1979 (Table 1) are derived from carcasses that we personally examined, from tusks brought in, and from reliable reports from hunters. As noted previously these statistics combined tend to be biased toward over representation of males. This was not taken into account by Finley *et al.* (1980). When we consider the 1978 data for only those animals that were personally examined ($n = 74$), the female composition of the total catch is estimated at 40%. In 1979, females comprised 44% of the total (personally examined) catch. In the following discussion of seasonal distribution of the 1978 and 1979 kills, composition is derived only from specimens that were personally examined.

Typically, a large number of females are taken during the ice-edge hunt. In 1978, 62% ($n = 37$) of the narwhal catch from the hunt consisted of females; in 1979, 38% ($n = 26$) were females ($\chi^2 = 3.44$, $p > 0.05$). During the spring, females and their calves are often seen close to the ice edge and present a tempting target to the hunter. Also, hunters may be less selective early in the season when fresh muktuk is in demand.

As the fast ice begins to disintegrate in July, narwhals penetrate westward toward Eclipse Sound. The large males tend to precede the females, moving through enlarged seal holes and ice cracks. The hunters anticipate this situation in which the narwhals are vulnerable and the males with large tusks are easy to select. In 1978 the ice-crack hunt was particularly successful and 56 narwhals were taken. Of the 26 that we personally examined, 20 (77%) were males; 90% of those were adults with large tusks (Finley *et al.*, 1980). In 1979 the ice-crack hunt was brief and few whales (13) were taken. We saw only three carcasses of which two were adult males and the other a pregnant female. From the evidence of tusks that we saw and from the reports from hunters, we suspect that the composition of the catch from the 1979 ice-crack hunt was mostly males, as in 1978.

The proportion of females taken during the open-water hunt was much higher in 1979 (50% of 26 personally examined specimens) than in 1978 (9% of 11); ($\chi^2 = 5.50$, $p < 0.02$). In 1978 hunters were aware that they had almost exceeded the quota of 100 before the open-water hunt had even begun and they probably exercised some restraint in killing narwhals, particularly females. In 1979 the ice-edge and ice-crack hunts were much less successful than during 1978, and many hunters continued to hunt during the open water season since the quota had not been met. It appeared that hunters were less selective than during the previous year. During 23–24 August 1979, when there were almost no males in the groups of narwhals passing the camps, some hunters continued to take whales. Two hunters working together took five females in one morning. Another hunter reported that during his stay at Kounuk he took four whales, all females.

It appears that the year-to-year variability in the female composition of the kill is largely due to the discrimination of the hunters and the seasonal emphasis and success of the various phases of the hunt. Also it is apparent that different hunters exercise variable degrees of selectivity and contribute disproportionately to the female composition of the kill.

A large portion of the 1979 narwhal catch consisted of adults; of the animals personally examined by us, 83% of the females and 65% of the males were adults. It is easy to distinguish the dark immatures from the light-mottled adults, and it appears that hunters select adults over immatures with the hope that the animal will possess a tusk. The higher proportion of immature males than of immature females was not statistically significant ($\chi^2 = 2.41$, $p > 0.05$), but may reflect the tendency of hunters to select animals with tusks, even when they are small. Immatures are sometimes taken for their muktuk, which is considered more palatable than that of the adults.

Adult females taken during the summer may possess either full-term fetuses conceived over one year earlier or small developing fetuses conceived during the previous spring (around April–May). Many adult females are accompanied by calves. Of the 18 mature females for which we have reproductive data, 7 (39%) were in an early stage of pregnancy. This proportion of females in early pregnancy is almost identical to that found by K. Hay (pers. comm.; 38% of 79 examined). Some of the females taken during the 1979 hunt were probably accompanied by suckling calves since we found that at least 4 of the 18 mature females were lactating. Starvation of preweaning calves after their mothers are killed in the hunt is not taken into account in any analysis of hunting losses.

Socio-economics of the narwhal hunt

The skin or muktuk of the narwhal, particularly young animals, is considered a delicacy by most people in the eastern Canadian Arctic. Muktuk from old animals is often considered unpalatable and only choicer cuts from flukes and flippers may be taken or, in some cases, nothing is taken. At one time the meat was stored for dog food but now there are few dogs and the meat is discarded or used for bait in fox traps. In NW Greenland, it is said that most of the narwhal meat is consumed by the people (Durham, 1979).

Muktuk may be eaten fresh or occasionally it is boiled. Much of the large surplus obtained during the summer in Pond Inlet is stored under rocks for consumption after it has aged. Polar bears destroyed large caches of muktuk at Sudlyarosik in September 1979. Some of the surplus (750 kg) in 1979 was purchased at $3 per kg by the Hunters' and Trappers' Association (HTA) and was shipped to Frobisher Bay where local muktuk is not available. Also later in the winter, HTA purchased some of the cached muktuk from the hunters and sold it for local consumption.

The muktuk comprises about 10% of the body weight of the narwhal (Mansfield *et al.*, 1975); thus from a large female (900 kg) or a large male (1600 kg) a hunter could obtain 90–160 kg of muktuk. Assuming an average yield of about 120 kg per adult narwhal, a quota of 100 narwhals might supply about 12,000 kg of muktuk to the community of Pond Inlet. The yield is undoubtedly lower since not all of the muktuk is removed from each whale and not all of the whales are adults. Also foxes and polar bears frequently destroy the caches of muktuk.

The commercial value of the narwhal tusk is a major incentive for the killing of a narwhal. In 1979, the Hudson's Bay Company purchased tusks from hunters for $45 per lb ($99 per kg) for unbroken tusks and $15 per lb for damaged tusks. In September, the ivory stockroom contained 56 tusks valued at $26,000. The average value for an entire tusk (average 5.36 kg) was $531.90 and the largest tusk (10.52 kg) commanded a price of $1,043.55. In addition the local Inuit cooperative had purchased 16 tusks as of the end of September and displayed small hand-crafted tusks in their souvenir shop.

One fortunate hunter obtained $5,000.00 for an extraordinary double-tusked narwhal in 1978. The rewards for obtaining a rare double-tusked narwhal provide considerable incentive to the hunter. In 1979 a double-tusked narwhal was sighted along the ice edge and in the ensuing excitement it was struck twice by bullets but managed to escape. Because of the strong selective hunting pressure for double-tusked narwhals, the frequency of their occurrence in the population would be over-represented in the statistics from hunter kills.

About 20% of the tusks purchased by the Hudson's Bay Company have broken tips that considerably decrease their market value. If the dentinal canal is not exposed, some of the broken tusks can be filed by the hunter and sold at or near top price. Some of the smaller tusks are hand crafted and sold at higher prices as souvenir items. Assuming an annual take of about 100 tusks, as in 1978, and a frequency of about 20% for broken tips, the cash flow to the community of Pond Inlet could be about $46,000 per year. Treude (1977) estimated without reliable data that in 1972, the theoretical cash return to Pond Inlet hunters from narwhal tusks was $3,840 or only about 7% of the total cash return from all hunting. This statistic is clearly outdated; in 1979 the sale of narwhal ivory accounted for a substantial proportion of the income from hunting and trapping.

Although many hunters are involved in the narwhal hunt, most of them are tied to a wage economy in Pond Inlet and are only able to hunt on weekends or during holidays that coincide with the hunting season for narwhals. Each of these hunters may obtain a few tusks during the course of the summer. Only a few hunters seriously pursue narwhals throughout the season and they may take a large portion of the total kill. In 1978, two hunters accounted for about one-third of the quota. In

1979, one of these hunters was able to take 16 tusks worth about $8,500.00. For hunters who still depend primarily on hunting and trapping for their livelihood, the cash income from narwhal tusks figures very importantly as a dependable means of supporting themselves during a time when prices for sealskins are low (Wenzel, 1978), the local quota for polar bears is limited to 13 (Stirling, Schweinsburg, Calvert and Kiliaan, 1977), and the market value for fox skins is highly variable (Treude, 1977).

A large portion of a hunter's income is spent on snowmobiles, boats, outboard motors, gasoline and ammunition. For the subsistence hunter, these requirements for a modern hunting lifestyle are available only through an exchange economy. The cash from four or five narwhal tusks can buy one snowmobile (worth $2,400 in 1979) that may last only a year under normal driving conditions. It is becoming increasingly difficult for the subsistence hunter to purchase the equipment necessary for modern hunting. The alternative is involvement in the wage economy system.

Traditions and technology of the narwhal hunt

The narwhal hunt is a long-standing tradition with the people of north Baffin Island. Some of the earliest accounts indicate that narwhal tusks were a fairly prominent item in the first contact with an exchange economy involving the European whalers of the 1800s (Markham, 1874; Tremblay, 1921). Trading often occurred between whaling ships and the ice-edge camps of the Inuit. Button Point was an important meeting place for trade contact and the Inuit often travelled long distances to trade there when the whaling fleet arrived in June and July. On 27 July 1858, M'Clintock (1859) met two Inuit at Button Point; they had been left to barter with the whalers. At the time the ice-edge in Pond Inlet was in an advanced stage of deterioration and M'Clintock found that most of the hunters had retreated further up the inlet. M'Clintock (1859, p. 140) observed that 'In their bartering with us, saws were most eagerly sought for in exchange for narwhal's horns'.

As the commercial bowhead whaling era came to a close in the early 1900s, some entrepreneurs saw potential for a lucrative trade with the Inuit of the Pond Inlet area. Independent traders established posts at Button Point and near the present site of Pond Inlet (Mittimatalik), and a competitive trade for furs and narwhal tusks developed (Bernier, 1911; Munn, 1932). In 1922, the Hudson's Bay Company established a trading post at the present site of Pond Inlet and continued the trade in narwhal tusks. Alex Smith, a Hudson's Bay Company trader who was posted at Pond Inlet in 1928, recalls that narwhal skins were also purchased and marketed in the south as 'porpoise leather' (pers. commn).

Peter Freuchen, a member of the Fifth Thule Expedition, commented upon his arrival at Pond Inlet in June 1924: 'I entered one of the regions where narwhal hunting is of utmost importance to the Eskimos and assembles them at certain places in certain seasons when this animal makes its appearance' (Degerbøl and Freuchen, 1925, p. 258). 'I found that all the Eskimos and some of the whites had moved out to Button Point to receive the narwhals when they arrived there'. The seasonal hunting pattern observed by Freuchen appears to have been very similar to that observed in recent years. On 1 July, Freuchen observed many narwhals among the pack ice just off the ice edge. By 5 July, 'several hundreds' penetrated through cracks into the rotting ice and the hunters killed 27 during the day. Even then there appeared to be a problem with losses: on 8 July 'Twelve were killed, but only four brought ashore. They were all males with tusks, but among the others were females with their young' (Degerbøl and Freuchen, 1935, p. 259). He noted that the narwhals passed Pond Inlet 'on July 16 at 7 p.m., the very same day and time as last year'; this date is only two days earlier than that in 1979. Freuchen recorded that at least 47 narwhals were killed during the ice-edge hunt although he later claimed (Freuchen and Salomonsen 1958, p. 216) that 'several hundred narwhals are usually killed by the natives every year'.

Many changes have affected the people of northern Baffin Island as they have shifted from a subsistence exchange economy and life in dispersed camps to a wage economy and life in one of the eastern Arctic's larger settlements, Mittimatalik – Pond Inlet (Treude, 1977). The changes have accelerated rapidly in the past two decades. The hunting system has been profoundly influenced by the interaction with and dependence on a monetary economy, rapid technological changes in hunting equipment (snowmobiles, outboard motors etc.), rapid increases in population, and the partial acceptance of southern life styles. Certainly some of the new technologies have been beneficial to the hunter. However, the overall effect has been a decline in the availability of game from some combination of overkilling, movement out of the area of disturbance, or increased wariness of the hunted species (Beaubier, 1970). Several of the hunters in Pond Inlet claimed that narwhals often avoid areas where boat traffic is intensive, particularly in narrow fiords (e.g. Tremblay Sound) where they cannot easily escape the noise. Appaq stated in an interview, 'They're very wary; while they're underwater they flee from the slightest sounds. Before canoes and ships were being used, when people just used paddles for travelling on water, there being no noise to scare the narwhals, they seemed to be greater in number.'

The introduction of modern technology has contributed to wasteful and inefficient hunting by the Inuit. Dunbar (1956) noted that 'the introduction of the rifle has, amongst other things, had the effect of making increasing numbers of Eskimos "trigger-happy" especially since Government relief to families and family allowances, have made cartridge-thrift less important'. Indeed, we were surprised by the amount of .303 ammunition expended by some hunters, particularly the younger ones who often shot at almost anything that passed by. At Grise Fiord, one of us accompanied a young hunter in a boat in pursuit of a group of about 25 harp seals. During the course of the chase, 64 rounds of .303 ammunition were expended, one animal was killed and sank outright, and another was mortally wounded but abandoned while the hunter continued pursuit of the herd. One and possibly two additional animals in the group had received wounds before the chase was abandoned. Riewe (in Riewe and Amsden, 1979) commented on the large expenditure of ammunition in the hunt for harp seals at Grise Fiord: 'on one particular hunt three men expended $43 in ammunition in five and a half hours of harp seal hunting and managed to kill nine seals but retrieved only three'. In fact, .303 hard-point ammunition (360 rounds per year) is supplied free to members of the 'Northern Rangers' from the Department of National Defence. The hunters may feel obligated to make use of this ammunition before a new supply arrives, thus explaining the indiscriminate use of this ammunition. It is ironic that hard-point ammunition has been banned for general hunting use yet it is the only type of projectile capable of penetrating the thick blubber of the narwhal and is available only as army surplus.

Obviously there is a need for improvement of hunting methods, as has been pointed out by several of the older hunters. Appaq commented 'As Inuit who wish to have meat available in the future, we must carefully consider our hunting. As men, we must undertake to tell our children about the hunt so they will be better able to follow us. When I was a lad of your age trying to hunt, or my son learning to hunt, I'd want to get the animal so badly. Before it came into range, in my excitement I might lose or wound the animal. Either way its meat would not be used. We must tell our children not to waste meat in the hunt, and to consider that this meat can be used later. By being constantly reminded they develop good habits.' Many older hunters lamented that changes had occurred so rapidly that traditions had broken down and there was little respect for the older ways. Older hunters from Grise Fiord commented respectfully on the hunting skills of the people from Thule, NW Greenland.

In Thule, there is considerable pride in the maintenance of traditional hunting skill, particularly in the narwhal hunt (Durham, 1979). Kayaks and hand-thrown harpoons are still used for taking narwhals. Boats with outboard motors are prohibited in the hunting of narwhals. In fact there is a conscious effort by the local people to limit the use of modern hunting technology for the exploitation of marine mammals (Kapel and Petersen, 1982).

Present status of the narwhal

In the summer a large proportion of the world population of narwhals gather in Admiralty Inlet and the Pond Inlet – Eclipse Sound area of northern Baffin Island and here they are hunted intensively by the people of Pond Inlet and Arctic Bay. Elsewhere in the eastern Canadian Arctic, small numbers of narwhals may be taken by some settlements but the occurrence of narwhals is irregular. Narwhals regularly are found during the summer off NW Greenland and small numbers are taken by the people of Thule (Vibe, 1950; Mansfield *et al.*, 1975; Durham, 1979). Outside the waters of the eastern Canadian Arctic and West Greenland (essentially Baffin Bay – Davis Strait) narwhals occur irregularly and in small numbers (Reeves and Tracey, 1979). Observations of the narwhal in Soviet Arctic waters are 'extremely rare' (Yablokov, 1979). Thus the management and protection of the narwhal is primarily a Canadian concern and also a very local problem.

For purposes of management and establishment of a quota system, the population of narwhals in the eastern Canadian Arctic and NW Greenland was conservatively estimated by Mansfield *et al.* (1975) to be 10,000. The reproductive rate of the narwhal was assumed to be similar to belugas (birth rate of 9% of the population) (Mansfield *et al.*, 1975). Davis *et al.* (1980) considered this information to be inadequate for attempting to manage the species, particularly when there was a lack of reliable harvest data as pointed out by Smith and Taylor (1977).

Davis, Richardson, Johnson and Renaud (1978), using a series of extrapolations from aerial surveys and shore based watches, estimated that 20,000 to 30,000 narwhals entered Lancaster Sound in 1976, but they and Davis *et al.* (1980) cautioned that the estimate was vague and needed to be verified.

Studies of the reproductive biology of the narwhal were initiated in 1963–65 by Mansfield *et al.* (1975) and were continued in 1974–76 by K. Hay as part of a thesis for McGill University, Montreal. Results from this study are not yet available but Hay (pers. commn) reports that the narwhal has a reproductive cycle similar to that of the beluga, as assumed by Mansfield *et al.* (1975). However, Hay suggests that the birth rate of the beluga is lower than the rate (0.09) previously calculated. Also, nothing is known of the age-specific mortality of the narwhal population and it is, therefore, impossible to derive a reliable estimate of the sustainable yield. Sergeant (1979) assumed a safe yield of about 5% annually, provided the catch was two-thirds males. This figure cannot be translated into an allowable harvest (quota) without reliable information on the population size and hunting loss rates.

Management considerations

Although the narwhal hunt represents a significant cultural tradition in the lives of the people of Mittimatalik (Pond Inlet), the economic value of narwhal ivory now obscures the cultural significance and is resulting in commercial exploitation of this species. In 1978 the quota was exceeded by about 50 whales (Finley *et al.*, 1980). In 1979 the quota was again exceeded by at least 20 and probably about 50. This does not include those that were lost from sinking, those that were mortally wounded and escaped, or dependent calves that starved after death of their mothers. The high incidence of bullet scarring (35% of a sample of those taken near Pond Inlet in 1977–79) is evidence of the degree of hunting to which the narwhal population, or at least the Pond Inlet segment of the population, is subjected.

Recently there has been much concern that the present rate of kill may be too high (Mansfield *et al.*, 1975; Schweinsburg, 1976; Land, 1977; Reeves, 1977). While the Canadian government recognizes the right of native people to take whales for subsistence purposes, more attention is becoming focused on the commercial aspect of the hunt (Brynaert, 1980). It has been suggested that the elimination of the trade in narwhal tusks would have the effect of reducing the hunt to a subsistence level. However, it should be noted that the trade of narwhal tusks traditionally has been encouraged from the earliest development of an exchange economy, and attempts to control the hunt through a ban on the tusk trade may be viewed with considerable resentment. Such a step could jeopardize future attempts to foster a cooperative approach to wildlife management.

Increasing pressure has been brought to bear on the hunting activities of northern natives. In the past decade controls or quotas have been established on the hunting of polar bears, walruses, bowhead whales, and narwhals. The imposition of regulatory policies on native hunters is often viewed with considerable resentment and non-compliance, particularly at a time when the hunters have become more politically sophisticated and ethnically self-aware. In Alaska, where socio-economic changes have been more rapid than in the Canadian Arctic, attempts at imposition of hunting controls have met with outright hostility and wildlife has become a political issue (Burns, 1980). In our discussions with hunters we have also found considerable misunderstanding and resentment about the implementation of controls on hunting. To date, wildlife enforcement has not been rigorously imposed on the Inuit of the Canadian Arctic and enforcement officers have taken a tolerant view toward infractions of marine mammal regulations. However, in the summer of 1979, some hunters from Pangnirtung chose to ignore the quota on narwhals and were charged and tried for exceeding the quota. This case marks one of the first such confrontations over marine mammal regulations in the Canadian Arctic.

Enforcement by itself will not create positive attitudes toward conservation objectives; rather it tends to generate resentment and non-compliance. Attempts at communication are often thwarted by the language barrier. Although we found that there is often misunderstanding and resentment about implementation of hunting regulations, there is also a recognition of the need for conservation measures. During our many hours of discussions with the hunters we learned much about the local natural history of animals and the problems of hunting them, while the hunters were very interested to hear of our knowledge of animals in a larger geographical context. Our communication was greatly facilitated by the use of illustrations and maps. This exchange of ideas, partly through illustrative techniques, holds promise for the development of a cooperative approach to conservation of the narwhal.

Conservation education would be useful in illustrating the relationship between regulatory policy and local self-interest, and in developing a broader understanding of the geographical scope of conservation policy. Policies are more likely to be accepted if the reasons for them are presented in terms that are precise, concrete and unambiguous. It is important that conservation education be delivered not from an authoritarian standpoint but in a manner that emphasizes common goals and encourages mutual respect.

After completing our field work in 1979, we prepared a concise document in Inuktitut that outlined the problems of the narwhal hunt, indicated that the hunters should assume responsibility for improving hunting practices, and presented some possible approaches for controlling the hunt. The document was distributed to the Hunters' and Trappers' Association of Pond Inlet and was followed up with a meeting to discuss their views. The response of the HTA was positive and the following recommendations were considered for future initiation:

1. Improved hunting methods. Rifles of a suitable calibre and hardpoint ammunition should be used in hunting narwhals. Harpoons with floats should be carried by hunters to retrieve dead and wounded narwhals. Under most circumstances boats should also be accessible in order to retrieve wounded animals.

2. Discourage hunting from the ice-edge. Since loss rates are likely to be high and females with their calves are likely to be killed, the emphasis of the hunt should be shifted to the ice-crack or open-water phase where losses are not as severe and where it is possible to select for males.

3. Discourage the killing or harassing of females, especially those with calves. Females that are killed should be included as part of the quota. Hunters should be discouraged from using outboard motors to pursue narwhals in certain areas, such as Tremblay Sound, that are frequented by females with their calves.

4. Involvement of older and experienced hunters in decision making and hunter education. Young hunters could gain much from the experience and knowledge of some of the older hunters.

5. Quotas. Present kills of narwhals in Pond Inlet are more than adequate to meet the community needs for muktuk. There is presently no need to exceed the quota. Personal quotas may be desirable if it is considered that the large portion of the kill by a few individuals limits the opportunities of other hunters.

6. Patrolling the hunt. A local Inuk could be employed to monitor the hunt and to determine when the quota (including male and females) is nearly filled.

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REFERENCES

Beaubier, P. H. 1970. The hunting pattern of the Igluligmiut: with emphasis on the marine environment. Unpubl. MA thesis, McGill University, Montreal. 248 pp.

Bernier, J. E. 1911. *Report of the Dominion Government Expedition to the Northern Waters and Arctic Archipelago of the D.G.S. 'Arctic' in 1910.* Kings Printer, Ottawa. 161 pp.

Brynaert, K. A. 1980. Report on beluga and narwhal. *International Wildlife.* 10: 24.

Burns, J. J. 1965. The walrus in Alaska: its ecology and management. Unpubl. Rep. Alaska Dept. Fish and Game, Juneau. 48 pp.

Burns, J. J. 1980. Marine mammal management in Alaska—an update. Alaska Seas and Coasts. University of Alaska, Vol. 7: 1–4.

Davis, R. A., Finley, K. J. and Richardson, W. J. 1980. The present status and future management of Arctic marine mammals in Canada. *Sci. Advis. Board N.W.T. Rep. No. 3.* Yellowknife, N.W.T. 93 pp.

Davis, R. A., Richardson, W. J., Johnson, S. R. and Renaud, W. E. 1978. Status of the Lancaster Sound narwhal population in 1976. *Rep. int. Whal. Commn* 28: 209–215.

Degerbøl, M. and Freuchen, P. 1935. Mammals. *Report Fifth Thule Expedition, 1921–24.* Vol. 2: No. 4–5.

Dunbar, M. J. 1956. The status of the Atlantic walrus *Odobenus rosmarus* (L.) in Canada. pp. 59–61. *In: Proc. 5th Tech. Meet. Int. Union for the Protection of Nature.*

Durham, F. E. 1979. Aboriginal narwhal hunting in northwest Greenland in 1976. Unpubl. MS presented to IWC meeting on Aboriginal-Subsistence Whaling, 5–9 February 1979, Seattle, Washington. 16 pp.

Finley, K. J., Davis, R. A. and Silverman, H. B. 1980. Aspects of the narwhal hunt in the eastern Canadian Arctic. *Rep. int. Whal. Commn* 30: 459–64.

Freuchen, P. and Salmonsen, F. 1958. *The Arctic Year.* G. P. Putnams Sons, New York. 438 pp.

Kapel, F. O. and Petersen, R. 1982. Subsistence hunting—the Greenwood case. *Rep. int. Whal. Commn* (special issue 4).

Land, E. M. 1977. The narwhal and the walrus; a problem of ivory. pp. 79–81. *In:* T. Mosquin and C. Suchal (eds), *Canada's Threatened Species and Habitats.* Spec. Publ. 6, Can. Nature Fed. Ottawa.

Mansfield, A. W., Smith, T. G. and Beck, B. 1975. The narwhal, *Monodon monoceros*, in eastern Canadian waters. *J. Fish. Res. Bd Can.* 32: 1041–6.

Markham, A. H. 1874. *Whaling Cruise to Baffin's Bay and the Gulf of Boothia.* Sampson Low, Marston, Low and Searle, London. 300 pp.

Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973–1975, and a biological summary of the species. Unpubl. Rep., National Marine Fisheries Service, Seattle, Washington. 80 pp.

M'Clintock, F. L. 1859. *The Voyage of the 'Fox' in the Arctic Seas. A Narrative of the Discovery of the Fate of Sir John Franklin and his Companions.* John Murray, London. 375 pp.

Munn, H. T. 1932. *Prairie Trails and Arctic By-Ways.* Hurst and Blackett Ltd, London. 275 pp.

Reeves, R. R. 1976. Narwhals; another endangered species. *Can. Geogr., J.* 92: 12–19.

Reeves, R. R. and Tracey, S. 1979. *Monodon monoceros.* American Society of Mammalogists, Mammalian Species No. 122. 28 pp.

Riewe, R. R. and Amsden, C. W. 1979. *Harvesting and Utilization of Pinnipeds by Inuit Hunters in Canada's Eastern High Arctic.* Mercury Series, Archaeological Survey of Canada, Ottawa. 30 pp.

Schweinsburg, R. E. 1976. Work report polar bear research in and around Admiralty Inlet, July–August 1975. Unpubl. Rep., Northwest Territories Fish and Wildlife Service, Yellowknife, N.W.T. 72 pp.

Sergeant, D. E. 1979. On permissible exploitation rates of Monodontidae. *Rep. int. Whal. Commn* 31: 583–8.

Smith, T. G. and Taylor, D. 1977. Notes on marine mammal, fox and polar bear harvests in the Northwest Territories, 1940 to 1972. *Environ. Can. Fish. and Mar. Serv. Tech. Rep.* 694. 37 pp.

Stirling, I. 1978. A review of population ecology studies of polar bears conducted in the western Canadian Arctic from 1971 through 1977, for the purpose of evaluating management practises. Unpubl. Rep. by Canadian Wildl. Serv. Edmonton, to Northwest Territories Fish and Wildl. Serv., Yellowknife. 68 pp.

Stirling, I., Schweinsburg, R. E., Calvert, W. and Kiliaan, H. P. L. 1977. Population ecology of the polar bear along the proposed Arctic Islands Gas Pipeline route. Unpubl. Rep. Department of Environment, Edmonton. 69 pp.

Treude, E. 1977. Pond Inlet, northern Baffin Island: the structure of an Eskimo resource area. *Polar Geog.* 1: 95–122

Tremblay, A. 1921. *Cruise of the 'Minnie Maud', Arctic Seas and Hudson Bay 1910–11 and 1912–13.* Arctic Exchange and Publishing Ltd. Quebec. 250 pp.

Vibe, C. 1950. The marine mammals and the marine fauna in the Thule District (northwest Greenland) with observations on ice conditions in 1939–41. *Medd. om Grønland* 150: 1–117.

Wenzel, G. 1978. The harp seal controversy and the Inuit economy. *Arctic* 31: 2–6.

Yablokov, A. V. 1979. History of Soviet exploitation of narwhals (*Monodon monoceros*), and white whales, *Delphinapterus leucas*, and approximate population estimates for Soviet waters. Paper SC/31/SM13 presented to the IWC Scientific Committee Cambridge, June 1979.

SC/33/SM11

Occasional Captures of Delphinids in the Northeast Atlantic

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ABSTRACT

Incidental catches by fishing gear on the French coasts of the Channel and the Atlantic show that six species of Delphinidae are involved: *Stenella coeruleoalba, Delphinus delphis, Tursiops truncatus, Grampus griseus, Globicephala melaena,* and *Phocoena phocoena.* Harpooning by fishermen in the open sea continues to supply food for consumption on board, but the effect on populations of Delphinidae cannot be exactly measured.

INTRODUCTION

The search for and capture of fish as a food resource places the dolphin and man in the same position as predators. The resultant conflict is aggravated by the fact that man uses fishing gear which inflicts a certain mortality on the dolphins, who, in turn, can do harm to the fishery by damaging nets.

On the French Atlantic and Channel coasts, notably in southern Brittany, this conflict reached its peak about 30 years ago. At that time, a systematic destruction of dolphins was undertaken, with the aid of the National Navy, without spectacular results.

These operations did not continue in the years following World War II, but dolphins continued to be captured by commercial fishermen. While it is impossible to give an estimate of the number of animals involved, some of the available information suggests that the take by the fisheries was not negligible. For example, in the year 1963, 250 dolphins were sold by a single fish dealer in Lorient.

However, these captures were entirely opportunistic and did not result in the development of a specialized fishery for dolphins. About two-thirds of the dolphins were harpooned; the others were accidentally captured in fishing nets, or, more rarely, shot with rifles. The available data for the coast of Brittany show that the capture of dolphins before 1970 was quite variable from port to port. At Lesconil, for example, the number of captures was 3 or 4 annually, by 40 boats. Lorient and Concarneau were two ports at which the fishery for dolphins was regularly practised whereas it was rare at the ports of Douarnenez and Penmarc'h.

In 1970, a law was enacted protecting dolphins against capture or pursuit in French waters. Because of this, it became impossible to sell dolphins, even those taken accidentally. However, the practise of capturing dolphins for consumption at sea did not cease entirely.

ENTANGLEMENTS IN FISHING GEAR

This law also requires that dolphins captured accidentally must be reported. We have therefore been able to assemble the known data for the French Atlantic and Channel coasts for 1971 to 1981. These observations, presented in Table 1, show that 6 species are captured in fishing gear, mainly by trawl (bottom and midwater) and gillnets. Most captures occur in autumn and spring (Fig. 1). However, it should be noted that the simultaneous capture of 7 *D. delphis* in March and again in September accounts for most of the variation in the histogram.

A comparison of the monthly frequencies of capture and those of strandings indicates a similar seasonal distribution. The summer minimum suggests that these species are out in the open sea at that time. This could be related to two factors: the first concerning the breeding season, of which we have evidence for *Delphinus delphis* (Collet, 1981); the second, having to do with feeding, remains hypothetical in our current state of knowledge.

A comparison can also be made between relative frequencies of the species in captures and in strandings (Table 2). These figures, (not statistically significant), indicate that for two species, differences can be seen which may be interpreted as indices of relative vulnerability if it is assumed (although there is little evidence to support this) that the number of stranded animals is directly proportional to the size of the population in the sea. On this basis the long-finned pilot whale (*G. melaena*) is the least vulnerable, and the harbour porpoise (*P. phocoena*) the most vulnerable to capture in fishing gear.

Fig. 1. Seasonal distribution of incidental capture by fishing gear on the Channel and Atlantic coasts of France, 1971–81. (*Stenella coeruleoalba + Delphinus delphis* (shaded), *Tursiops truncatus, Grampus griseus, Globicephala melaena* and *Phocoena phocoena.*)

Table 1

Capture of delphinids on the Channel and Atlantic Coast of France, 1971–81 (o? = sex unknown).

Fishing gear	*Stenella coeruleoalba*	*Delphinus delphis*	*Tursiops truncatus*	*Grampus griseus*	*Globicephala melaena*	*Phocoena phocoena*
Trawl (bottom or midwater)		♀ (9.3.75) ♀ (14.10.75) o? (–.1.77) ♂ (25.1.77) o? (7.2.78) 2♂, 4♀, 1o? (5.3.78) ♀ (22.2.79) ♀ (7.12.79) ♂ (6.11.80)	♀ (5.10.75) o? (–.8.76) o? (17.4.78)		♀ (4.1.71) o? (15.10.72) ♀ (29.6.77)	
Gillnets	♂ (3.10.77) ♂ (5.2.79)	o? (1.5.72) 3♂, 3♀, 1o? (6.9.80)		o? (9.9.77) o?(9.10.77)	o? (16.8.78) o? (3.2.79)	o? (5.7.72) ♀ (11.4.76) ♀ (20.12.77) ♀ (13.1.79) ♂ (15.10.79) ♀ (29.12.80)
Shark Longlines		♂ and ♀ (17.12.77)				
Total = 43	2 (4.6%)	25 (58.2%)	3 (7.0%)	2 (4.6%)	5 (11.6%)	6 (14.0%)

DIRECT TAKE

The other effect of fishing activities on the small odontocetes, i.e. a directed take using harpoons, is mainly carried out by the fishing boat crews to obtain meat for consumption at sea. It is therefore an opportunistic fishery, dependent on the time available to the crew, and varying from vessel to vessel. In general, it can be assumed that it is carried out on all tuna vessels. A quantitative estimate of this capture is impossible, but all the evidence suggests that it is of a different order from the accidental capture in nets. In the period 1971–81, the latter amounted to no more than 43, while the number of dolphins harpooned must have been on the order of several thousand. Almost all of these were *Delphinus delphis* or *Stenella coeruleoalba*.

Table 2

Relative frequencies of strandings and captures of delphinids on the Channel and Atlantic coasts of France, 1971–81

Species	Strandings	Captures
Stenella coeruleoalba	6.5%	4.6%
Delphinus delphis	49.0%	58.2%
Tursiops truncatus	10.0%	7.0%
Grampus griseus	1.9%	4.6%
Globicephala melaena	26.4%	11.6%
Phocoena phocoena	6.2%	14.0%
Total	(322) 100.0%	(43) 100.0%

Human predation on these two species, given the existence of large fisheries, would be very difficult to stop by law because it is practiced in international waters. One approach however would be to warn the fishermen of the dangers of eating dolphins because of the high levels of contamination by organochlorides and heavy metals.

REFERENCE

Collet, A. 1981. Biologie du dauphin commun, *Delphinus delphis* L., en Atlantique Nord-Est. Thèse Doct. zeme cycle, Université de Poitiers. 156 pp.

SC/33/O 1

Reanalysis of Spanish Sperm, Fin and Sei Whale Catch Data (1957–1980)*

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INTRODUCTION

A previous study (Aguilar and Lens, 1981) examined whaling activities in the Spanish area since the beginning of the century. At that time, however, a reliable analysis of catch and effort data was not possible, as detailed information was not available, although an approximate appraisal was discussed in Anon. (1981).

The present study is based on catch and effort statistics provided by the Spanish Fishing Authorities and includes whaling activities carried out by Spanish land stations between 1957–80.

Unfortunately, although total catch statistics are available length and sex data are not always given, particularly for the period 1957–65. For this reason, and in order to achieve a statistically acceptable figure for the examination of the development of the fin whale fishery, it was thought reasonable in some cases to pool the data of the first eight years (1957–64) instead of, as in the rest of the series, pooling groups of five years or from year to year.

The opening and closing date of the season has not been taken into account regarding length and sex. It has been seen, however, that both the fin and the sperm whale follow a sequential migration, and thus starting the season early in any particular year may produce an increase in the average length of the catch that year. This aspect will be examined in further detail in a later study.

Another problem concerns the identification of the species. In a preliminary report (Aguilar and Lens, 1981), the confusion existing in identifying the '*ballena de pintas*' or '*gubarte*' which, on account of its size and description without doubt refers to the sei whale or the Bryde's whale, was discussed. Although the situation is not completely clear, it seems that this refers mainly to the sei whale although the possibility of a Bryde's whale being caught cannot be completely ruled out.

It is also possible that some of the youngest component of the 'fin whale' catches may in fact be sei whales, as misclassification has been shown in a few cases. This might explain the greater representativity which appears in some years around the 14–15 m size (Figs 7 and 8).

The present whaling season from the two factories in northwest Spain lasts from April to December, with a peak in catches between July and August. Fig. 1 shows the distribution of the cumulative catches from 1957–80 of the three main species (fin, sperm and sei whales) by ten day period.

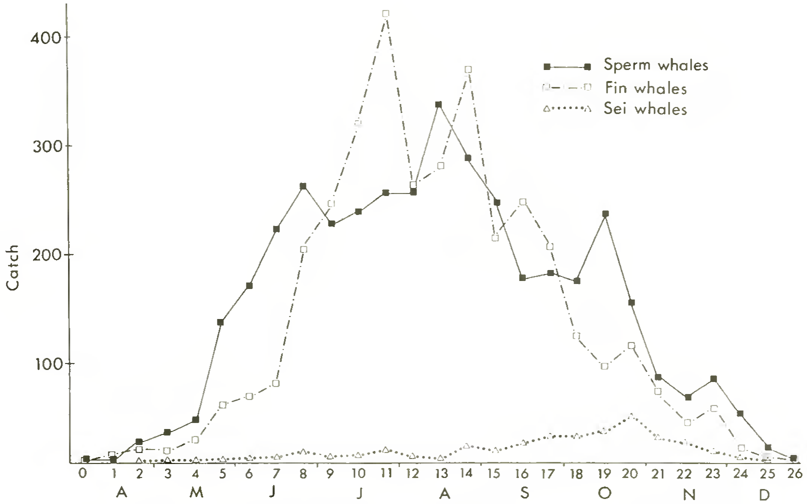

Fig. 1. Distribution of catches throughout the season (cumulative data, 1957–80).

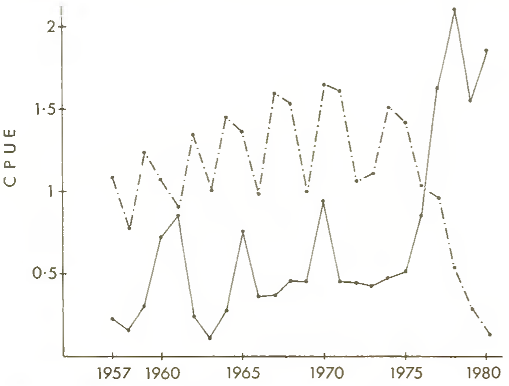

Fig. 2. Corrected CPUE, –·–·–: sperm whales; ——: fin whales.

Fin whales are mainly caught between the second fortnight of June and the end of September, with a very clear peak in July and August. A less pronounced peak in the middle of the season is also found in sperm whale catches but the May and October catches are still important. By contrast the frequency of capture of sei whales appears to increase as the season progresses, peaking at the end of October.

The catch per unit effort (CPUE) data has been recalculated taking into account the new data, on a catcher's day work (CDW) basis corrected for tonnage following Aguilar and Lens (1981).

No other kind of correction has been made, and it has been assumed that factors such as the weather, the variation of the day's length or the time wasted at the harbour due to breakdowns or servicing of engines, have remained constant from year to year.

It is hoped that the recent introduction of logbooks in the IWC format will make it possible to refine CPUE calculations in the near future.

SPERM WHALES, *Physeter catodon* Linnaeus 1758

There has been intensive exploitation of the sperm whale in the North Atlantic since at least the beginning of the century. The catch figures (some of which may, however, be inaccurate) show a slow increase which reaches a peak of nearly a thousand animals in 1956, from where they decrease to the present levels (IWC. 1981a).

The catches have been mainly from land stations in different areas of the Atlantic coast, but a few episodes of pelagic whaling have also taken place. The sperm whale is now hunted from only four points: Iceland, Azores, Madeira and northwest Spain.

Research programmes on the stock identity of sperm whales in the North Atlantic are being developed but at present the assumption of a single population is based on relatively little data. Nevertheless, a mark fired into a sperm whale off Nova Scotia was recovered seven years later at one of the Spanish factories.

Length data

Due to the fact that it is at the moment managed as a single population, it has been thought convenient to make a comparison between the length data of the Spanish and Icelandic fishery.

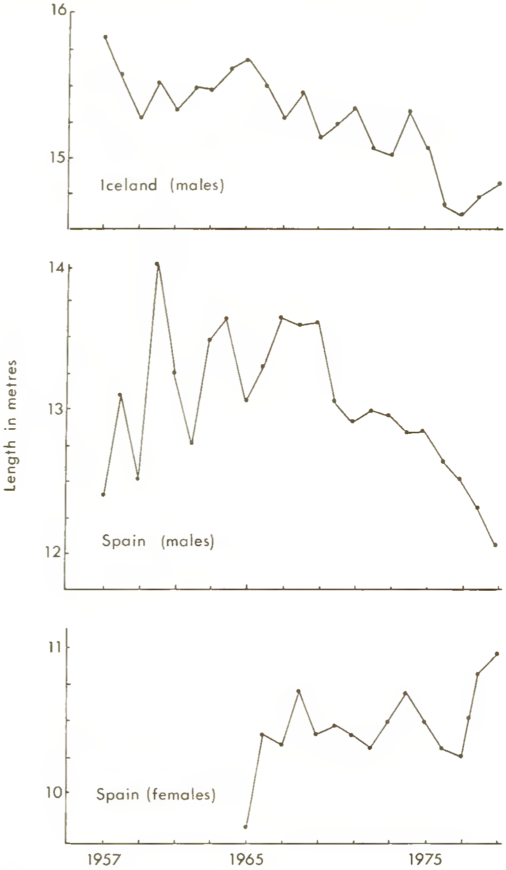

Fig. 3. Average lengths of sperm whales from Spain and Iceland.

However, the comparison has to be made with care, because in different areas of the Atlantic different components of the population are being exploited. In the Azores and Madeira females and young males are killed (Clarke, 1956). In Spain, as will be seen below, the female proportion is smaller and adult and young males are captured. Finally, in Iceland the catch is only directed to males, usually adult (Martin, 1980). Something similar happens in the distribution of pelagic catches in other areas, where a gradient of sizes with latitude has also been observed (Allen, 1980; Gulland, 1974).

Fig. 3 shows the yearly variation in the average length of sperm whales taken off Spain and Iceland by sex. The Icelandic values are those corrected for the date and position of kill given by Martin (1981). With respect to the Spanish data, it should be remembered that until 1964 only a limited number of animals were sexed and measured resulting in the fluctuations seen in the earlier years. The 1980 data have not been included as only 13 sperm whales were caught.

The male average lengths in both areas, taking into account that they belong to different population components, reveal a decreasing trend, especially since 1967. The females, however, seem to have maintained a stable average length.

Fig. 4 shows the length distribution of male sperm whales from Spain and Iceland by five-year groups.

The Icelandic catch is characterized by a clear modal value, especially in the former years of the series. In the Spanish case, however, as one might expect as the components of the population exploited are of more variable size, the situation is less pronounced.

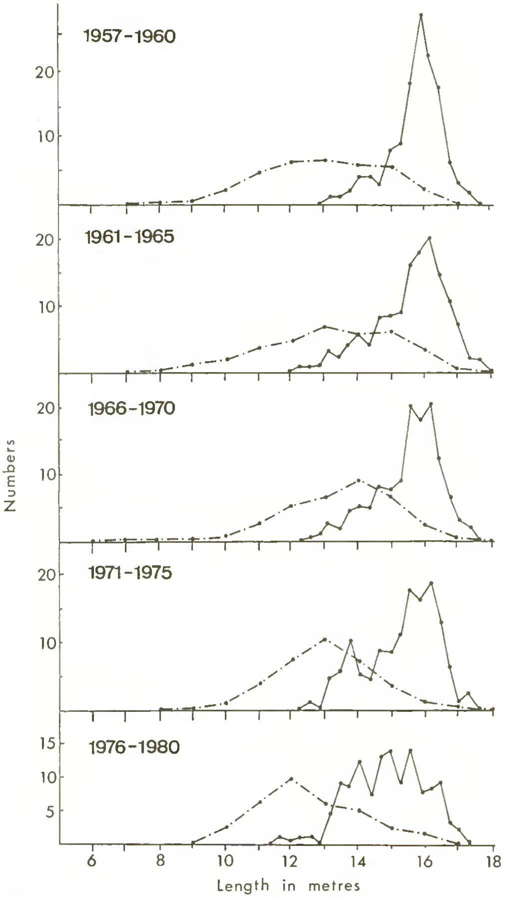

Fig. 4. Length distributions of male sperm whales, ——: Iceland; —·—·—: Spain.

The modal value during the period 1956–70 remains fairly constant, both for Spain (13–14 m) and for Iceland (nearly 16 m). In the period 1971–75 the component of males between 13 and 15 increases in Iceland, and the distribution is a little displaced to the smaller lengths in Spain. During recent years (1976–80) the Icelandic modal value has been lost and the catch has been directed to the younger components of the population; in Spain, the maximum frequency of catches has decreased by nearly one metre in comparison with former years.

Such changes in the length distributions reflect changes in the component of the population exploited. The sperm whales have a slow growth curve compared with the other large whales and reach physical maturity at a later age, somewhat over the age of first recruitment. Even so the variability in growth rates between individuals will still be great.

Despite this, and although factors such as changes in selectivity or in the migratory routes cannot be ruled out, we can assume that the length distribution reflects approximately, in stable conditions, the age composition of the population.

Martin (1981) and Holt (1981) concluded on this basis with the Icelandic data that such progressive decrease in sizes was due to an increase of the total mortality rate as a consequence of over-exploitation. This must be true, especially in the years that followed the peak catches of the fifties.

However, the total catch of sperm whales in the North Atlantic has slowly decreased since then, the present levels being much lower (IWC, 1981a). This has been mainly due to the reduction of the whaling activities in Madeira and Azores, the major areas where females are caught (Clarke, 1981).

This reduction in fishing pressure should mean that the population either would recover slowly or at least slow down the rate of decrease. In the first case, it is feasible to hope for a progressive increase in birth rates, which would result in a similar increase in the recruitment rates ten or twelve years later. The possibility that a progressive increase in recruits and thus in the availability of younger animals, has also contributed to the observed fall in sizes since about 1975, cannot therefore be discarded.

Thus this decreasing trend in the average lengths could be explained as a combination of the depletion of the older animals due to the over-exploitation of the fifties and a slight but progressive increase of the number of young whales. This would agree with the Spanish whalers' view, who confirm the decrease in size of sperm whales sighted, but not the availability in the whaling grounds compared with former years.

The yearly mean lengths of female sperm whales and their proportion in the total Spanish catch are given in Figs 3 and 5. Both parameters have remained fairly constant since 1957 and no conclusion can be drawn from them.

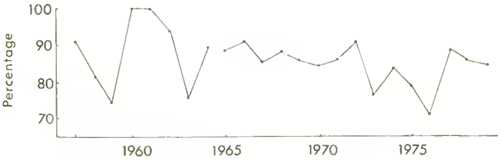

Fig. 5. Percentage of males in the Spanish sperm whale catch.

CPUE data

The yearly change in CPUE data is plotted in Fig. 2. In spite of the large variation there appears to be a slight increase from 1957 to 1975 (as is also seen for the fin whale) but it seems likely that this was due to improved knowledge of the whaling grounds by the whalers.

Since 1976, however the sperm whale CPUE has fallen abruptly, as a result of the greater commercial interest in the fin whale.

Conclusion

Finally, it is worthwhile pointing out that the similarity between the trends of the Icelandic and Spanish sperm whale lengths does not necessarily mean that the exploited stock is the same in both areas, but they have followed a similar process of exploitation.

Until this and other aspects of the biology of the North Atlantic sperm whale such as its vulnerability to pollution, and the implications of the intensive cephalopod fisheries of recent years are better understood, the management of the stock must be carried out with care.

FIN WHALE, *Balaenoptera physalus* Linnaeus 1758

The IWC population units for the North Atlantic fin whale were established after comparison of CPUE trends between areas which suggested that the populations in these areas behaved in an independent manner. Marking results indicated a similar pattern (Jonsgård, 1966; Brown, 1976).

Differences or similarities of such parameters as the average length, percent males and females or percent sexually mature in the catch are not a great help in stock identity, since there is always the possibility of a cline in the distribution of the population (Rørvik and Jonsgård, 1975; Mitchell, 1974), but are useful when studying the development of the catches within an area.

At present, and after having seen some similarities between the development of the Spanish fishery with that of the Scottish whaling factories in the twenties (Jonsgård, 1966), the stock is considered for management purposes to stretch from 20° to 60°N; nevertheless, little or nothing is known about the movements of the fin whales within this area, and whether segregation by length or sex exists.

The average length of the fin whales caught in Spain decreases as the season develops and, with it, the age and the percent sexually mature. The biological parameters can, for this reason, be considered affected by the opening and closing dates of the whaling season and only reflect the characteristics of the exploited component of the stock, and not that of the whole population. This aspect will be examined in greater detail in a future paper. Since 1957 the season has begun progressively later; in spite of this, no correction on the data has been made.

In Spanish and Portuguese waters, the fin whale suffered intensive exploitation in the twenties, in both the northern and southern areas. The combined action of land stations and pelagic factories which killed a few thousand baleen whales per year produced a decline in the stock levels which forced whaling activities in the area to be terminated (Aguilar and Lens, 1981).

When the fisheries were reopened in the fifties, the industry still had to face a population not yet fully recovered which may explain the lack of interest given by the whalers to that species in the early years.

At the last Scientific Committee Meeting an estimate of the fin whale population and its trends was made (Allen, 1981). The available data revealed that the stock had suffered a large decline at the beginning of the 1930s, as a consequence of over-exploitation and that, since then, it has been recovering at a constant rate. In the second half of the seventies the rise in the catches (see Table 1) will have resulted in a slight decrease in the population level.

These trends are shown in Fig. 6 together with the trend in male and female average lengths. These have progressively increased, especially in the case of the females, until the seventies, as was predicted by the model.

Length is not as clearly correlated with age in baleen whales as it is in sperm whales, but it may, at lower lengths at least give an approximate idea of the trend in catches of the different components of the population.

Figs 7 and 8 show the male and female length distributions by 5-year periods and in the early years there are a greater percentage of young animals.

Table 1

Catches at the land factories of Spain

Year	No. boats	Fin	Sei	Blue	Humpback	Sperm
1957	3	47	2	—	—	227
1958	3	33	1	2	—	153
1959	3	53	18	1	—	221
1960	3	124	11	—	—	190
1961	3	156	15	—	—	159
1962	3	50	10	—	—	264
1963	3	20	10	—	—	180
1964	3	59	13	2	—	303
1965	5	157	19	1	—	287
1966	5	107	12	—	—	280
1967	5	97	11	1	—	305
1968	5	106	12	—	—	365
1969	5	113	33	1	—	244
1970	5	181	11	1	—	338
1971	5	100	15	1	—	347
1972	5	98	13	—	—	236
1973	5	113	15	1	—	297
1974	5	120	5	—	1	375
1975	5	138	26	—	—	379
1976	5	236	10	1	1	270
1977	2	153	5	2	—	90
1978	5	462	15	3	—	118
1979	4	452	13	—	—	82
1980	3	219	2	—	—	13

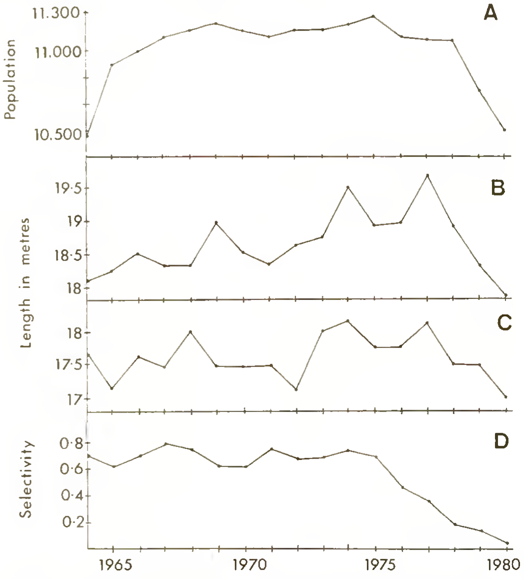

Fig. 6. (A) Population trend of fin whales. (B) Average length of fin whale females. (C) Average length of fin whale males. (D) Selectivity (see text).

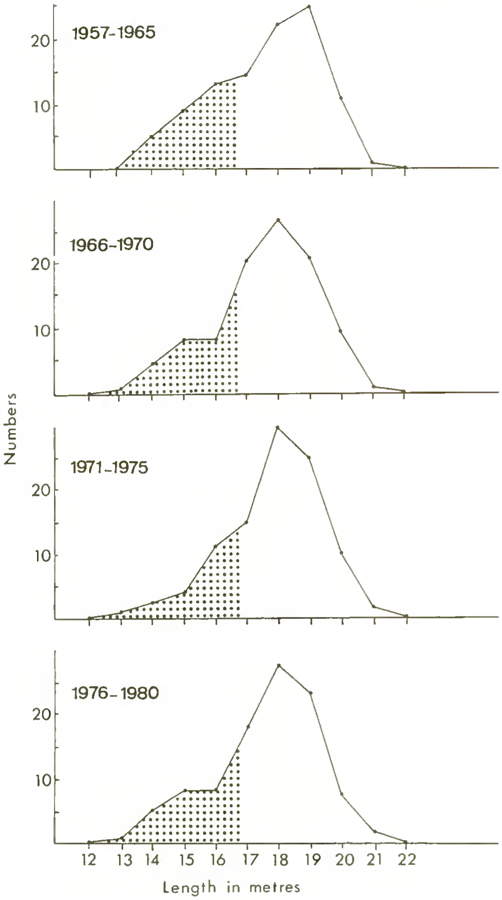

Fig. 7. Length distribution of male fin whales (shaded = immatured).

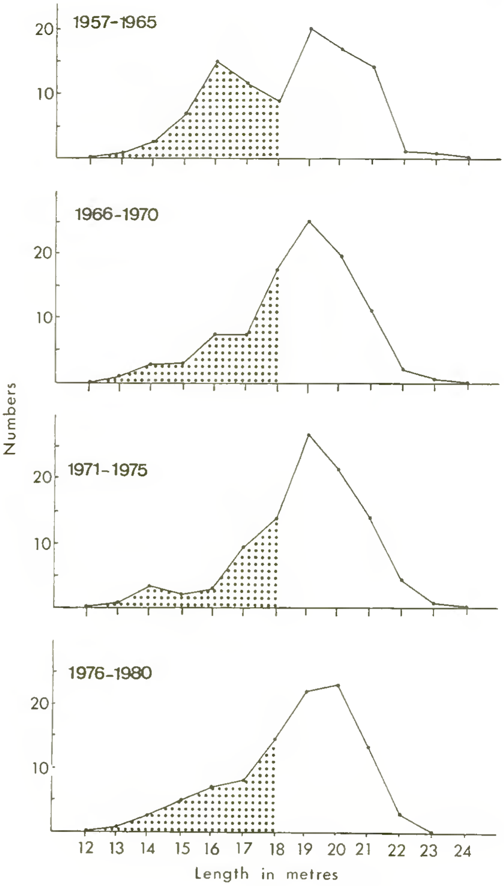

Fig. 8. Length distribution of female fin whales (shaded = immature).

If we assume that the lengths at sexual maturity are similar to those found by Lockyer and Brown (1979) for Icelandic fin whales, then the percentages of immature whales in the catch are as follows;

1957–65	29.6%	39.0%
1966–70	25.0%	29.4%
1971–75	21.5%	22.8%
1976–80	26.2%	29.7%

which concurs reasonably well with the model proposed by Allen.

However, the decrease in the length of the whales captured (and the increase in the percent immature) in the 1976–80 period seems excessive for the size of the catch, even supporting that it was greater than the replacement yield.

If an exploitation rate of 100 whales per year (the average from 1957 to 1977) allowed the population to slowly recover, to raise the catch to 400 whales per year could explain a depletion of the older animals and thus a fall in length a few years later. However it seems unreasonable for this fall to occur not only in the first year of the large catches, but even before the end of the season.

A more plausible explanation is that other factors have taken place, in particular a decrease in the selectivity of the gunners, with the aim of increasing catches without having to proportionally increase the effort. Fig. 2 shows that the CPUE has radically changed in the last four years.

In general, it seems that, at least until 1980 when for the first time a quota existed the boats would kill as many whales as they could. The distribution of the catches among the species will thus depend on two factors: the availability of species and its commercial value.

Until the middle of the seventies the major interest was in sperm whales and its share of the catch remained fairly constant and greater than that of the fin whale. However, since 1975 the percentage of baleen whales in relation to toothed whales has risen abruptly which cannot in any way be explained solely by an increase in the availability of baleen whales, and is in fact, the result of greater commercial interest.

If we suppose that the availability of baleen whales was not suddenly modified, then the selectivity of the catcher-boats must have decreased to increase the baleen whale catches while maintaining the traditional effort.

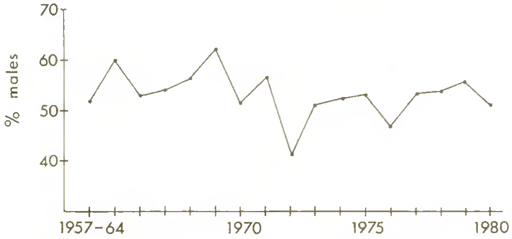

Fig. 9. Percentage of males in the Spanish fin whale catch.

A rough way of expressing that selectivity in order to compare between years, is to establish an index as follows:

$$S = 1 - \frac{\text{No. baleen whales}}{\text{Total catch}}$$

The results for each season are plotted in Fig. 6d. It shows a clear correlation between the fall in selectivity and the decrease in the average length of the fin whale catch in recent years.

Although in 1980 a quota existed which should have resulted in an increase in selectivity, the reduced number of working days and the abnormalities of the campaign have produced a relationship between catch and effort similar to that of former years and thus, a similar low selectivity (Anon., 1982).

For these reasons we believe that, although it is possible that the average lengths of the whales caught may have decreased in the last three or four years as a result of a slight population decrease, the trend has been strongly exaggerated by a fall in the selectivity of the whalers. For the 1981 season measures have been already taken to protect the undersized whales.

In Fig. 9 the percentage of males in the catch is plotted in relation to the total fin whale catch. Although the values found are very close to 50%, in nearly all years males are more abundant. This is difficult to explain, given that females are larger and commercially more valuable. One explanation may be that the gunners do not usually shoot lactating females and animals with calves (which is against IWC regulations). It may also, of course reflect a differential distribution of sexes in the whaling grounds, but there may be other biological or behavioural factors which influence the probability of each sex being captured.

SEI WHALE, *Balaenoptera borealis* Lesson 1828

The sei whale catches have always been very low; commercially less valuable than the larger baleen whales, this secondary catch has never risen above a few dozens per year.

Although a few sei whales are killed from the opening of the season, the proportion in the total catch increases reaching a maximum in the last fortnight of October (Fig. 1).

As in the case in fin whales, males seem to be more abundant: 56.8% of the total catch since 1957.

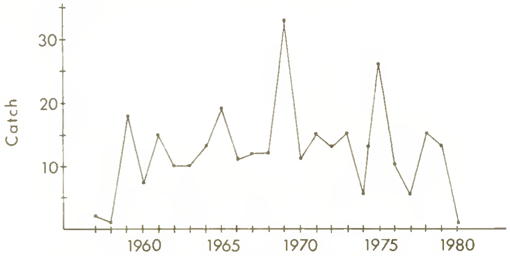

Fig. 10. Catch of sei whales from Spain, 1957–80.

Nothing is known about the identity of that population of sei whales, recently classified by the IWC as part of the Eastern Stock, or of its possible relationships with the sei whales of the Faroes, Iceland and Nova Scotia.

ACKNOWLEDGEMENT

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REFERENCES

Aguilar, A. and Lens, S. 1981. Preliminary report on the Spanish whaling activities. *Rep. int. Whal. Commn* 31: 639–43.

Allen, K. R. 1980. Size distribution of male sperm whales in the pelagic catches. *Rep. int. Whal. Commn* (special issue 2): 51–6.

Allen, K. R. 1981. British Isles, Spain and Portugal stock. *Rep. int. Whal. Commn* 31: 131.

Brown, S. G. 1976. Modern whaling in Britain and the North-East Atlantic Ocean. *Mammal. Rev.* 6(1): 25–36.

Clarke, R. 1956. Sperm whales of the Azores. *Discovery Rep.* 28: 237–98.

Clarke, R. 1981. Whales and dolphins of the Azores and their exploitation. *Rep. int. Whal. Commn* 31: 607–15.

Gulland, J. A. 1974. Distribution and abundance of whales in relation to basic productivity. pp. 27–52. *In:* W. E. Schevill (ed.) *The Whale Problem: a status report.* Harvard University Press. 419 pp.

Holt, S. 1980. North Atlantic whale stocks with particular reference to the situation in Icelandic waters regarding fin and sperm whales. Paper SC/32/O 7 presented to the IWC Scientific Committee, June 1980.

International Whaling Commission. 1981a. Report of the Sperm Whale Workshop (Annex K). *Rep. int. Whal. Commn* 31: 703–5.

International Whaling Commission. 1981b. Report of the Sub-Committee on Other Baleen Whales. *Rep. int. Whal. Commn* 31: 122–32.

Jonsgård, A. 1966. Biology of the North Atlantic fin whale, *Balaenoptera physalus* (L). Taxonomy, distribution, migration and food. *Hvalradets Skrifter* 49, 62 pp.

Lockyer, C. and Brown, S. G. 1979. A review of recent biological data for the fin whale population off Iceland. *Rep. int. Whal. Commn* 29: 185–9.

Martin, A. R. 1980. An examination of sperm whale age and length data from the 1949–78 Icelandic catch. *Rep. int. Whal. Commn* 30: 227–32.

Martin, A. R. 1981. Further analysis of the post-war Icelandic sperm whale catch. *Rep. int. Whal. Commn* 31: 765–8.

Mitchell, E. 1974. Present status of Northwest Atlantic fin and other whale stocks. pp. 108–69. *In:* W. E. Schevill (ed.) *The Whale Problem: a status report.* Harvard University Press. 419 pp.

Rørvik, C. J. and Jonsgård, A. 1975. Review of balaenopterids in the North Atlantic Ocean. Paper ACMRR/MM/EC 13 presented to the FAO Marine Mammal Symposium, Dec. 1975.

SC/33/O 3

Some Statistical Aspects of the Beddington and Cooke Estimation Technique

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ABSTRACT

The Beddington and Cooke estimation technique allows estimation of the population size and related biological parameters using as primary data source the length frequency distributions of the catches. The parameters are estimated by minimising the sum of squared differences between observed catches at length and expected catches at length calculated using a population model. The statistical model underlying the estimation process is examined. It is shown that in order to obtain asymptotically efficient estimators and asymptotic confidence regions, the technique of maximum likelihood estimation is to be preferred. Possible use of robust estimation techniques is also discussed.

1. INTRODUCTION

The Beddington and Cooke (1981) technique for estimating population size and related biological parameters using the length frequency distributions of the known catches represents an important advance. Although it had not been subjected to exhaustive testing, it appeared that for sperm whales the technique performed at least as well as alternative techniques based on relative abundance data in those situations in which it was applied. Additionally, it avoided some of the difficult problems associated with relative abundance data, particularly catches per unit effort, although of course it introduced its own set of assumptions.

For the purposes of this paper, the technique may be described in simple terms as follows. The population dynamics are described by a fully age structured model, in which the initial population size and possibly some of the biological parameters are to be estimated. The population is assumed initially to have an unexploited equilibrium age structure. Using a smoothed age-length key or growth curve, the age structure is updated annually by adding in births and subtracting deaths due to natural mortality, as well as the known catches by length class. In this way, given values of the unknown parameters, the full annual population age or length structure can be predicted. If the catches were truly representative of the population from which they were taken, the observed catch age or length structure could be directly compared with the underlying population structure. However it is known that this is not the case, and additional assumptions regarding catch selectivities need to be made. Discussions here will be restricted for convenience to the length-specific technique (Beddington and Cooke, 1981), which assumes that for a given operation and span of years the length-specific selectivities remain constant. With these assumptions, Beddington and Cooke describe estimation of the unknown parameters by minimising the sums of squared differences between observed and expected catches by length class. They also describe a method for calculation of confidence regions for these estimates.

In section 2, the statistical model underlying the estimation process is described, and the performance of several estimators is compared. Also the possible use of robust estimation methods is considered briefly. In the final section, possible modifications to the Beddington and Cooke techniques are discussed.

2. PARAMETER ESTIMATION

2.1 Equal selectivities, data only for one year

The simplest possible case is that in which estimation is based on catches by length for only one year, and the selectivities are all equal. The latter assumption implies that the catches are assumed to be representative of the population. Suppose the observed catch consists of n_i animals of length class i, $i = 1, \dots m$, with $\Sigma n_i = N$. Further suppose that, given the unknown parameter β (taken as a scalar purely for convenience, exactly the same arguments hold if β is a vector), the underlying population before the observed catch is taken comprises p_i animals of length class i, $i = 1, 2, \dots m$, with $\Sigma p_i = P$. Define

$$\pi(\beta) = \frac{p_i}{P} \text{ for } i = 1, 2, \dots m$$

where the dependence on unknown β is specifically indicated.

Provided $p_i >> n_i$, to a close approximation the observed catches $\{n_i\}$ are a sample of size N from a multinomial distribution with cell probabilities $\{\pi_i(\beta)\}$ for given β. In this case, up to an additive constant the log-likelihood function of the sample is

$$\log L(\beta) = \sum_{i=1}^{m} n_i \log (\pi_i(\beta))$$

and the maximum likelihood estimator of β is found by maximising log L.

An alternative class of estimators T_n is defined by the estimating equation

$$g(T_n ; \frac{n_1}{N}, \frac{n_2}{N}, \dots \frac{n_m}{N}) = 0.$$

Rao (1965) shows that if g(.) is continuous, and $g(\theta; \pi_i(\theta)) = 0$, then T_n is a strongly consistent estimator of θ.

Three familiar estimators satisfying this properly are the minimum chi-squared and minimum modified chi-squared estimators found by minimising respectively

$$\sum_{i=1}^{m} \frac{(n_i - N\pi_i(\theta))^2}{N\pi_i(\theta)} \quad \text{and} \quad \sum_{i=1}^{m} \frac{(n_i - N\pi_i(\theta))^2}{n_i}$$

and the least squares estimator proposed by Beddington and Cooke, found by minimising

$$\sum_{i=1}^{m} (n_i - N\pi_i(\theta))^2 .$$

However, following Cox and Hinkley (1974), it can be shown that while the minimum chi-squared and minimum modified chi-squared estimators are asymptotically efficient, the same is not true for the least squares estimator. Thus, leaving aside second order efficiency properties (Rao, 1961), the maximum likelihood and both minimum chi-squared estimators are equally suitable for efficient estimation of β.

In the usual way, an asymptotic level α confidence interval based on the likelihood ratio statistic is available as that β-interval surrounding the maximum likelihood estimator β_o within which

$$2 \log \frac{L(\beta_o)}{L(\beta)} \leq \chi^2_{m-2,\, 1-\alpha} .$$

Cox and Hinkley (1974) also show that a test of the adequacy of the model is also available through a test of the composite null hypothesis $H_o{:}\pi_i = \pi_i(\beta)$ against the general alternative that π is an arbitrary multinomial distribution. In this null hypothesis, β takes the role of an unspecified nuisance parameter. Using the sufficient cell frequencies

$\frac{n_1}{N}, \frac{n_2}{N} \ldots \frac{n_m}{N}$, the likelihood ratio test statistic

$$2 \sum_{i=1}^{m} n_i \log\left(\frac{n_i}{N\pi_i(\beta_o)}\right)$$

has an asymptotic χ^2_{m-2} distribution, where β_o is the maximum likelihood estimator of β. Cox and Hinkley (1974) also show that asymptotically equivalent tests are available based on

$$\sum_{i=1}^{m} \frac{(n_i - N\pi_i(\hat{\beta}))^2}{N\pi_i(\hat{\beta})} \quad \text{and} \quad \sum_{i=1}^{m} \frac{(n_i - N\pi_i(\hat{\beta}))^2}{n_i}$$

These are respectively the minimum values of the chi-squared and modified chi-squared criteria described earlier.

2.2 Multiple years, unequal selectivities

In its normal application, the Beddington and Cooke technique uses data from a series of years, and selectivities are expected to vary across lengths, though not across years. Suppose the observed catch data comprise catches by length class for t years, n_{ij}, $i = 1, 2, \ldots t$; $j = 1, 2, \ldots m$, where $\Sigma_j n_{ij} = N_i$. For each year, suppose the selectivity of length class j is S_j, $j = 1, 2, \ldots m$. Then the expected catch length proportion for class j in year i is

$$\pi_{ij}(\beta, \underset{\sim}{S}) = S_j f_{ij}(\beta),$$

where $f_{ij}(\beta)$ is the expected proportion of animals in the population in length class j and year i, calculated using the population model, the observed catches up to year i–1, and for given β.

It is quite clear that there is a complicated dependence structure between catch length frequencies in successive years. However, since the likelihood of a sample $x_i, \ldots x_n$ may be written as

$$f(x_1, x_2, \ldots x_n) = f(x_1)\, f(x_2|x_1)\, f(x_3|x_1, x_2) \ldots f(x_n|x_1, x_2, \ldots, x_{n-1}),$$

the log likelihood in the current problem is

$$\log L = \sum_{i=1}^{t} \sum_{j=1}^{m} n_{ij} \log(\pi_{ij}(\beta, \underset{\sim}{S}))$$

in view of the above definition of the π_{ij}.

Proceeding formally, β and $\underset{\sim}{S}$ may be estimated by maximum likelihood or minimum chi-squared techniques. Confidence intervals for β may be calculated using the statistic

$$2 \log\left(\frac{L(\beta_o, \underset{\sim}{S}_o)}{\sup_{\underset{\sim}{S}} L(\beta, \underset{\sim}{S})}\right)$$

where β_o and $\underset{\sim}{S}_o$ are the maximum likelihood estimates of β and $\underset{\sim}{S}$, and an overall test of the model adequacy may be carried out, as before, using the statistic

$$2 \sum_{i=1}^{t} \sum_{j=1}^{m} n_{ij} \log\left(\frac{n_{ij}}{N_i \pi_{ij}(\beta, \underset{\sim}{S})}\right)$$

Similar confidence intervals and tests are available using the asymptotically equivalent chi-squared statistics.

Unfortunately the asymptotic properties of the estimators and test statistics (and hence confidence interval estimates) no longer hold under general assumptions regarding the dependence structure. It is known that these properties hold under Markov dependence (Billingsley, 1961), however if the dependence is stronger, the asymptotics may not be valid.

2.3 Robust estimation

Apart from the dependence on the correctness of the underlying population model and its associated parameters, which this estimation technique has in common with all other techniques, the Beddington and Cooke technique depends critically on the assumption of equal selectivities across years. In their applications of the technique, Beddington and Cooke (1981) went to great lengths to attempt to ensure that this assumption was warranted. In particular, they split the data by country of operation, and by geographical location, as well as using data from only a selected subset of years, even though this resulted in an enormous escalation in the computing burden.

It is still of value, however, to examine the possible effects of departures from this assumption, and possible means to minimise the effects of such departures. It seems clear that a year trend in selectivities will have an appreciable effect on the estimates of β, but there is no possibility of testing for such a trend using the available data. Most likely, progress may be made only if departures from the assumption of constant selectivities occur only in a few of the years. In this case, there are two possibilities.

If the data from successive years were independent, it would be possible to split up the likelihood ratio statistic (1) for testing model adequacy by years (or more easily the equivalent chi-squared statistics), and examine each year separately for large deviations. Unfortunately these data are not independent, but extremely large deviations in a few years would still suggest omission of data from these years. In this manner, a type of trimmed estimate could be obtained.

This type of situation also suggests possible use of a jack-knifed estimate, in which successively data from a single year are omitted from the estimation, and the resulting $t-1$ estimates combined. However, as such a procedure will increase greatly the computing burden, it may be impractical.

4. DISCUSSION

Beddington and Cooke (1981) use the method of least squares to estimate the unknown parameters of their model. Although this estimator is strongly consistent, it is not asymptotically efficient, and on these grounds the maximum likelihood estimator or minimum chi-squared estimators are to be preferred. More importantly, the method they suggest for calculation of confidence regions assumes that the differences between observed and expected catches by length are independent and identically normally distributed with constant variance. This is clearly not true, and confidence regions should be obtained as described in section 2.2. To reduce the computational load, the minimum chi-squared or modified chi-squared techniques appear preferable to maximum likelihood, in view of the need to calculate logarithms in the latter.

It must be emphasised that the good properties of each of the estimators discussed depend on all of the assumptions and parameter values of the population model being correct. We have seen that there may be some useful methods for detecting departures from the constant selectivity assumption, if they occur only in a small number of years. In any case, the overall adequacy of the model should be examined using the statistic described in 2.2. If the test of model adequacy fails, then at the very least, the confidence regions calculated will be inappropriate, and the estimates themselves could be seriously biased.

In one sense, the confidence regions for the parameters may be useful only in a negative sense. As Beddington and Cooke (1981) note, the 'true' confidence regions, i.e. those making full allowance for uncertainty in the model etc., must be larger than those obtained assuming the model is correct. Thus the estimates might only be considered useful if the calculated confidence regions are relatively tight.

REFERENCES

Beddington, J. R. and Cooke, J. G. 1981. Development of an assessment technique for male sperm whales based on the use of length data from the catches, with special reference to the North-West Pacific Stock. *Rep. int. Whal. Commn* 31: 747–60.

Billingsley, P. 1961. Statistical methods in Markov chains. *Ann. Math. Statist.* 32: 12–40.

Cox, D. R. and Hinkley, D. V. 1974. *Theoretical Statistics*. Chapman and Hall, London, 511 pp.

Rao, C. R. 1961. Asymptotic efficiency and limiting information. Proc. 4th Berkeley Symposium on Mathematical Statistics and Probability 1: 531–45.

Rao, C. R. 1965. *Linear Statistical Inference and its Applications*. John Wiley & Sons, New York. 522 pp.

SC/33/O 4

Aerial Line-transect Estimates of Abundance of Humpback, Fin, and Long-finned Pilot Whales in the Newfoundland-Labrador Area[1]

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ABSTRACT

A fixed-wing aerial sampling survey of whales in the coastal and offshore (*ca.* 100 nautical miles offshore) waters of eastern Newfoundland and southeastern Labrador during August 1980 produced the following minimum abundance estimates based on line-transect analysis: 738 (±250, std. error) humpback whales, 478 (±221) fin whales and 13,167 (±3,155) pilot whales. The large variances of these estimates are due almost entirely to the variance of total number of whale pods detected in each sampling area.

INTRODUCTION

The ban on commercial whaling in eastern Canada in 1972 has necessitated the development of alternate, more direct techniques of assessing East Coast whale stocks. Until that time, assessments could be based on catch-effort analyses and life history data derived from the commercial harvest (Mitchell, 1974). Use of stranded or incidentally net-caught animals to provide life history data is sporadic and may introduce bias.

Recently, attention has focused on direct survey methods of assessing whale stocks (IWC, 1980), particularly in view of drastically-reduced quotas for many stocks of large whales. The workshop on whale sighting methodology held in Seattle in September 1980, emphasized the need to develop survey methodology and analytical procedures which can be applied to whales. Line-transect and strip-census survey methods have been applied to terrestrial animals successfully for many years (see Burnham, Anderson and Laake, 1980), but their application to marine mammals is relatively recent and requires extensive modification owing to the unique survey problems posed by marine mammals, particularly whales.

Scott and Winn (1980) have outlined the historical development of whale survey methodology (particularly surveys conducted from shipboard) and the more recent development of aerial survey methodology for whales. The Cetacean and Turtle Assessment Program (CETAP) of the University of Rhode Island (sponsored by the US Bureau of Land Management) has developed aerial survey methodology and analytical procedures which are being used to assess the numbers and seasonal distributions of whales and turtles over the continental shelf of the eastern US from Cape Hatteras to Nova Scotia (Scott and Gilbert, 1980). This methodology is now being applied and utilized in aerial surveys of cetaceans in the Newfoundland – Labrador region, reported herein.

In response to the management need to assess stocks of whales in the Newfoundland – Labrador region, a shipboard survey of the Grand Banks was conducted from 12 June to 7 July 1980, and an aerial survey over eastern Newfoundland and S.E. Labrador waters was conducted from 1–22 August 1980. The purpose of these surveys was to estimate the abundance of whales summering in the Newfoundland – Labrador region, with emphasis on the large baleen whales of potential commercial importance (the humpback whale, *Megaptera novaeangliae* and the fin whale, *Balaenoptera physalus*) and the long-finned or Atlantic pilot whale, *Globicephala melaena*. The need for these assessments also stems from the whale-fishery conflict (Lien, 1980) and the intensifying exploratory drilling and potential commercial development of hydrocarbon resources on the continental shelf off Newfoundland and Labrador. This report documents results of the 1980 aerial survey.

MATERIALS AND METHODS

Aerial survey methodology

The area to be surveyed was originally intended to comprise the eastern Newfoundland and S.E. Labrador marine areas, from 47°48′N (Cape St Francis) to 55°00′N and seaward to the 2,000 m depth contour. The total survey area was partitioned into the south and east coast bays of insular Newfoundland and 10 large offshore blocks. However, due to time constraints, the five outermost blocks were not surveyed. Fig. 1 shows the inshore sampling zones (bays) and the transects flown while Fig. 2 shows the offshore sampling blocks and the transects flown. A total of 3,554 nautical track miles were flown during the period 1–22 August, 1980. The total area surveyed is approximately 51,030 square nautical miles. The sampling intensities (percent sampled) shown in Table 1 are based on the assumption that the sampled strip is one nautical mile wide (G. Scott, pers. comm.).

The bays and inshore areas were sampled at a higher intensity (up to 24%) than the offshore blocks (approximately 5% coverage), since it was expected that whales would be more numerous in the bays (J. Lien, unpublished data). Once the sampling zones were circumscribed, the potential total number of transects in each zone was determined as the number of non-overlapping one-nautical mile wide strips in that zone (it was assumed that 0.5 nautical mile to each side of the aircraft's track would be effectively sampled). The transects to be flown were drawn at random without replacement from the pool of available

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[1] Prepared for 1981 meeting of the Scientific Committee of the International Whaling Commission, Cambridge, England.

Table 1

Survey zones, fixed-wing aerial sampling survey.

Survey zone	Area	Date	Area (n. mi.^{2})	Total line length (n. mi.)	Percent sampled	No. lines flown	Potential no. lines
A	Conception Bay	800802	375	82.1	21.9	4	18
B	Trinity Bay	800802	820	196.1	23.9	10	43
J	Fortune Bay	800806	822	83.8	10.2	6	59
H	St Mary's Bay	800806	261	47.6	18.2	6	28
I	Placentia Bay	800806	1,682	184.2	11.0	7	84
C	Bonavista Bay	800807	549	110.1	20.1	5	23
D	Notre Dame Bay	800807	866	186.4	21.5	5	22
E	White Bay	800807	419	90.2	21.5	7	44
F	Southern Shore	800809	1,381	130.6	9.5	8	70
5	Offshore Block	800812	8,870	491.9	5.5	4	76
7	Offshore Block	800815	9,526	489.5	5.1	4	74
1	Offshore Block	800816	7,588	360.8	4.8	4	89
3	Offshore Block	800819	8,292	440.5	5.3	5	94
Funk	Near Funk Isl.	800820	2,065	201.1	9.7	6	30
9	Offshore Block	800822	9,579	459.5	4.8	5	99

These rules help to ensure that sightings are independent, an important assumption of line-transect theory (Burnham *et al.*, 1980). There was only one exception to these rules: since pilot whales and dolphins commonly associate, the initial sightings of both were taken as primary sightings. Large pods of pilot whales or white-beaked dolphins (*Lagenorhynchus albirostris*) were circled and counted repetitively until a final estimated count was accepted, with a specified level of precision (up to ±10 for pods of 50 or more). If there was any doubt that a particular group of animals might not be re-located (to continue circling and allow identification and counting), a paper bag containing powdered aluminum and a small rock was dropped from the aircraft in the immediate vicinity of the sighting. This produced a persistent discrete 'dye' mark on the sea surface which was useful in re-locating pods of dolphins, especially in higher sea states.

After the observers were satisfied that the sighting was adequately documented, the navigator guided the aircraft back to the break-off point where the survey was resumed.

The blister observers were also responsible for transmitting environmental data at the beginning and end of each transect and as conditions changed. These data included Beaufort wind force (from the sea surface appearance), cloud cover, visibility and weather, amount and position of glare, and the presence of human activities (e.g., vessels, fishing gear).

The navigator is responsible for ensuring that the pilot flies the aircraft along the pre-defined track lines. He records local time, aircraft position, sea surface temperature (from a *Barnes* PRT-5 radiometer), altitude and speed at the beginning and end of each transect, every 5 minutes and also at the following events: break-off from the track-line to investigate a sighting; directly over a sighting; back on the track-line; and, whenever requested by the observers (e.g., at changes in Beaufort sea state or visibility which may impair the survey).

Survey sampling was conducted at an altitude of 750 feet and air speed of 120 knots. The barometric altimeter was occasionally checked and calibrated (at 500 feet A.S.L.) with a radar altimeter. Sampling was conducted only in Beaufort wind forces of 4 or less and with clear visibility of at least two nautical miles. Segments of transects flown outside these bounds were excluded from the analysis. Scott and Gilbert (1980) conducted sampling at Beaufort 3 or less; however, as large baleen whales were the target of the present surveys, it was felt that survey sampling could be successfully conducted at Beaufort force 4. All Cetacea and marine turtles were the targets of the studies of Scott and Gilbert (1980).

Estimation of abundance

Line-transect sampling theory was used to estimate densities and abundances of whales in each aerial survey zone. Pooled primary sightings data for each species (or group of related species) were used to estimate the essential parameter, f(o), which is the sighting probability density function evaluated at a perpendicular distance of zero. The estimation of f(o) and other essential parameters for each species is outlined in more detail in the Results and Discussion section.

For each species in each survey zone, i, the density of groups ($\hat{D}_{gi}$) was calculated as:

$$\hat{D}_{gi} = \frac{n_i \hat{f}(o)}{2l_i} \qquad (1)$$

where n_i is the number of primary groups observed within one nautical mile of the plan's track in zone i, $\hat{f}(o)$ is the species-specific sighting probability density at a perpendicular distance of zero, and l_i is total transect length. The variance of group density was calculated as $\widehat{\mathrm{var}}$ ($\hat{D}_{gi}$):

$$\widehat{\mathrm{Var}}\,(\hat{D}_{gi}) = (\hat{D}_{gi})^2 \left[\frac{\widehat{\mathrm{Var}}(\hat{f}(o))}{(\hat{f}(o))^2} + \frac{\widehat{\mathrm{Var}}(n_i)}{(n_i)^2}\right] \qquad (2)$$

The density of individuals ($\hat{D}_{ii}$) is calculated as:

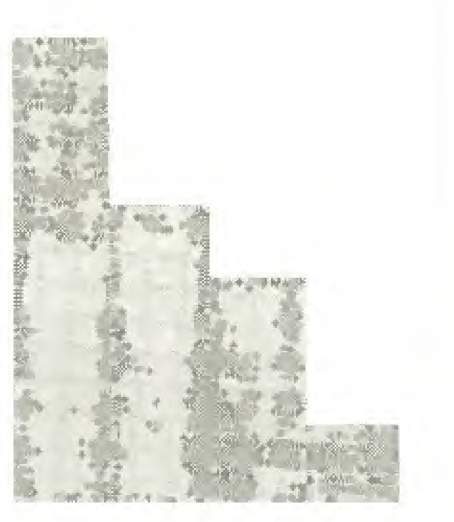
$$\hat{D}_{ii} = \hat{D}_{gi}\bar{g} \qquad (3)$$

where $\bar{g}$ is the mean group size for the particular species, calculated using all primary sightings for that species.

The number of animals in each survey zone was estimated as:

$$\hat{N}_i = \hat{D}_{ii}A_i \qquad (4)$$

where A_i is the area of zone i.



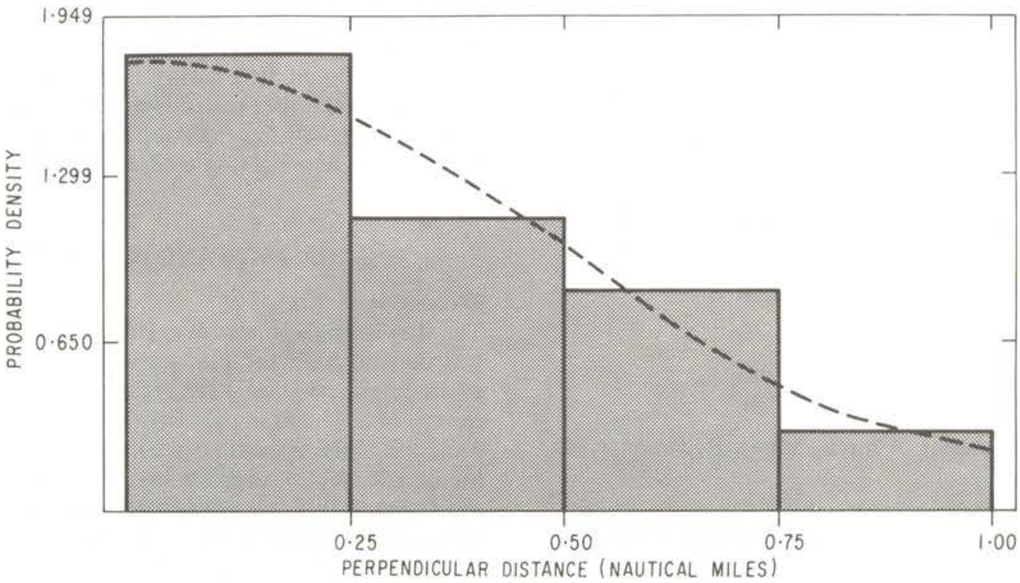


Fig. 4. The Fourier series estimator of the probability density function of perpendicular distances (dashed line) fit to the histogram of the data for all primary large whale sightings.

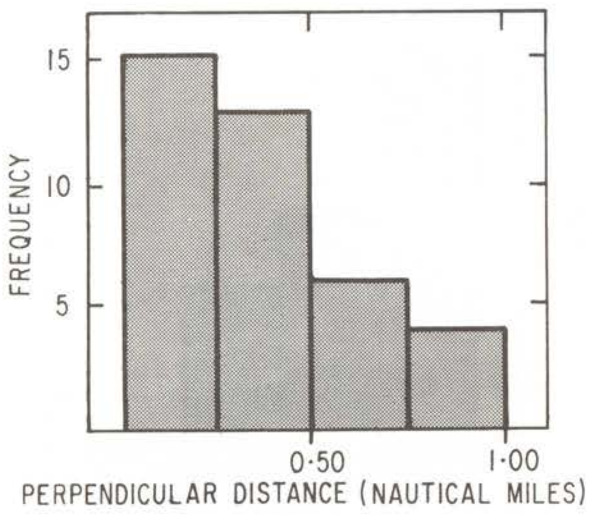


Fig. 5. Frequency distribution of right-angle distances, primary pilot whale sightings.

Group size

The mean pod sizes (considering primary sightings only) with their standard errors for each species are presented in Table 2. Although it is intuitively obvious that sighting probability should be a function of pod size, differential sightability of different pod sizes does not present problems for the estimation of pod density. Quinn (1979) has demonstrated, by computer simulation, that several

Table 2

Primary group sizes recorded during the 1980 aerial survey.

Species	No of observations	Mean group size	Range	Standard error
Humpback	31	2.8710	1–8	0.4089
Fin	18	2.6111	1–7	0.4724
Minke	9	1.1111	1–2	0.1111
Pilot	41	26.0488	7–56	2.2064
White-beaked dolphin	20	23.5500	1–100	6.0374
White-sided dolphin	6	5.5000	1–19	2.9069

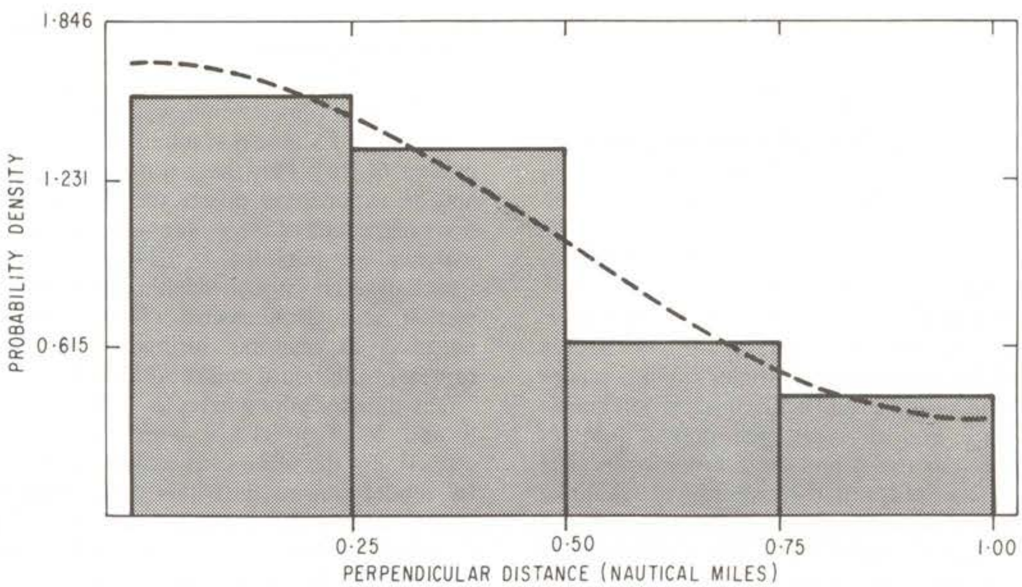


Fig. 6. The Fourier series estimator of the probability density function of perpendicular distances (dashed line) fit to the histogram of the data for primary pilot whale sightings.

line-transect estimators (including the Fourier series) are quite robust to marked differences in the sighting detection function for different pod sizes, and that analysis of pooled data using these estimators returns an essentially unbiased estimate of pod density. However, the calculated mean pod size may be a biased estimate of the true pod size due to differential detectability of different pod sizes (Quinn, 1979).

Estimation of abundance

Tables 3–5 present the density of individuals, its standard error, the estimated number and its 95% confidence limits for humpback whales, fin whales, and pilot whales in each aerial survey zone. As the aerial survey was not synoptic in its coverage, the estimates presented are valid only for each survey zone on a particular date. It is possible that migrations of whales between survey blocks occurred, invalidating the total (summed) estimate and its variance. Hay and McKinnon (unpublished MS) provided evidence that there were significant shifts in the distribution of baleen whales during August 1980 in the Newfoundland area. Also, Scott and Gilbert (1980) suggest that estimates need to be corrected for varying survey conditions which affect the sighting frequency (e.g. sea state, glare, observer fatigue, and inter-observer variability) and for diving behaviour of the whales. It must be emphasized that many whales may go undetected due to their diving behaviour. Corrections for aerial survey estimates based on dive time data have not been derived, and correction factors may be strongly influenced by behaviour, group size, season, time of day, and many other environmental and biological factors. Pending availability of dive time-based correction factors, it is conservatively assumed that 50% of whales go undetected (H. Whitehead, pers. comm.). Furthermore, humpback, fin, and pilot whales were present south of the study area (in the Grand Banks region) during August 1980 (Parsons, unpub. MS). In addition, the innermost small bays and inlets of eastern Newfoundland were not surveyed in order to facilitate an efficient survey design (see Fig. 1). This, however, is not considered to be a significant source of bias since humpback whales are present close to shore during June and July when capelin are spawning on the beaches, and the great majority should have moved further offshore by August (see Lien, 1980). Finally, the exclusion of secondary sightings from the analysis may render most estimates conservative. Therefore, the total estimates presented here must be considered to be preliminary and likely are minimum estimates.

The most critical assumption of the line transect sampling method is that animals directly on the track-line will be detected with probability 1.0 (Burnham *et al.*, 1980). Because of diving behaviour of whales, this assumption (in its strictest sense) is clearly violated. To apply line transect theory to whale sighting data, it is necessary to assume that the probability of detecting a whale which is available to be seen (i.e. at the surface) and which is on the track-line is unity. The technique should therefore produce minimum estimates of numbers which can be used as indices of population size. These indices should be comparable on a year-to-year basis, given that survey designs, timing of surveys, and the overall study area do not change, that whale behaviour is, on average, constant from year to year (i.e. the proportion of undetected whales is constant), and that there are no significant changes in seasonal whale distributions between years (i.e. no immigration to or emigration from the study area).

Table 3

Individual density (no./sq. nautical mile) and its standard error, total number and 95% confidence limits for humpback whales in each aerial survey zone, plus total estimate of numbers and its 95% confidence limits (Fourier series estimator, f(o) = 1.772 with s.e. = 0.1645). Only primary sightings were used.

Survey zone	Density	Standard error of density	Number	95% confidence interval on number[a]
A	0.0310	0.0326	12	8–51
B	0.0908	0.0461	75	42–160
J	0.0304	0.0217	25	3–71
H	0		0	
I	0.0138	0.0157	23	3–88
C	0.0231	0.0792	13	5–134
D	0		0	
E	0		0	
F	0.0195	0.0169	27	5–82
5	0		0	
7	0		0	
1	0.0282	0.0138	214	16–548
3	0.0231	0.0115	192	13–456
Funk	0.0379	0.0198	78	13–184
9	0.0166	0.0166	159	21–600
Total (excluding Funk)			738	235–1242

[a] When the lower 95% confidence limit is less than zero, then the lower limit given is the total number of groups seen in each survey zone multiplied by the mean overall group size for that species.

Humpbacks were most numerous in blocks 1, 3, and 9 (Table 3) with most groups being sighted close to the coast. However, densities of humpbacks were higher elsewhere, for example, in Trinity Bay (*ca* 0.09 humpbacks per square nautical mile). Their near-shore abundance off the south-east Labrador coast, producing a great deal of damage to salmon gillnets during June and July (Lien, 1980), was considered to be exceptional and due to an unusually early inshore movement of capelin (*Mallotus villosus*) during June (Lawrence Smith, pers. comm.). The total estimate for humpbacks is 738 ± 250 (std error).

Table 4

Individual density (no./sq. nautical mile) and its standard error, total number and 95% confidence limits for fin whales in each aerial survey zone, plus total estimate of numbers and its 95% confidence limits (Fourier series estimator, f(o) = 1.772 with s.e. = 0.1645). Only primary sightings were used.

Survey zone	Density	Standard error of density	Number	95% confidence interval on number[a]
A	0.0845	0.0333	32	8–71
B	0.0118	0.0122	10	26–32
J	0		0	
H	0		0	
I	0.0251	0.0227	42	8–136
C	0.0210	0.0282	12	3–55
D	0		0	
E	0		0	
F	0		0	
5	0		0	
7	0.0047	0.0041	45	5–170
1	0		0	
3	0		0	
Funk	0		0	
9	0.0352	0.0210	338	23–898
Total (excluding Funk)			478	79–926

[a] As note in Table 3.

Fin whales had a high density in Conception Bay (0.08 whales/sq. n. mi.). Their density was estimated to be 0.035 whales/sq. n. mi. in block 9, producing an estimate of total numbers of 338 (±202) in this block (Table 4). The scarcity of fin whales in offshore Notre Dame Bay (blocks 5 and 7) is surprising considering that these areas traditionally supplied most fin whales in the former Newfoundland whale fishery. The low sighting rate for fin whales in these areas may be a consequence of low sampling intensity (Fig. 2), although the aerial survey data indicate a generally southerly distribution for fin whales (most south of 50°00′N), while humpback whales were most numerous south of 49°00′N and north of 52°00′N. Blocks 5 and 7 had very low sighting rates for large baleen whales. The total estimate for fin whales (478 ± 221) is probably seriously biased downward, given the very large catches of this species in the earlier fishery.

The total estimate of numbers for minke whales is 174 (±102), 105 of which were in block 7. This figure is likely negatively biased since minkes are generally solitary and quite inconspicuous and spend little time at the surface. Only nine primary groups were detected on 3,554 track miles, and most (six of nine) sightings were within 0.25 n. mi. of the track-line. Minke whales could be the most abundant mysticete in the Newfoundland area, so it is believed that aerial surveys seriously underestimate their numbers. The sighting cue provided by the minke whale is most commonly the appearance of the animal itself near the track line; occasionally it was detected by a splash.

Pilot whales were the most numerous cetacean recorded during the aerial survey, with a total estimate of 13,167 ± 3,155 (Table 5). High densities were recorded for this species off the east coast of the Avalon Peninsula (Zone F—1.7 individuals/sq. n. mi.) and in block 9 (0.8 animals/sq. n. mi.). The total estimate for block 9 is 7,750 ± 2,371 pilot whales, most of which were observed to be moving shoreward. The sighting cue for pilot whales was usually the simultaneous surfacing of many animals, often accompanied by splashes and visible blows.

Table 5

Individual density (no./sq. nautical mile) and its standard error, total number and 95% confidence limits for pilot whales in each aerial survey zone, plus total estimate of numbers and its 95% confidence limits (Fourier series estimator, f(o) = 1.679 with s.e. = 0.1911). Only primary sightings were used.

Survey zone	Density	Standard error of density	Number	95% confidence interval on number[a]
A	0		0	
B	0.1115	0.0915	91	98–261
J	0		0	
H	0		0	
I	0		0	
C	0		0	
D	0		0	
E	0		0	
F	1.6744	0.5180	2,312	624–4,001
5	0		0	
7	0.2680	0.1230	2,553	147–6,280
1	0.0606	0.0839	460	25–2,483
3	0		0	
Funk	0.3262	0.2001	674	74–1,736
9	0.8090	0.2475	7,750	1,160–14,340
Total (excluding Funk)			13,167	6,731–19,603

[a] As note in Table 3.

White-beaked dolphins had high densities in Fortune and Placentia bays (0.81 and 0.99 individuals/sq. n. mi., respectively). The total estimate for white-beaked dolphins in the study area is 5,539 (±1,954). However, there are no baseline data or previous population estimates for dolphins in the Newfoundland-Labrador area.

Variability of the estimates

Table 6 presents an analysis of the components of variance of the estimates for humpbacks, fin whales, minke whales, pilot whales, and white-beaked dolphins. These components are expressed as squared coefficients of variation of group size ($\bar{g}$), f(o) and sample size n (number of primary groups detected), the form in which these variables enter into the variance equations. The probability density function at distance 0 (f(o)) contributes very little to the variance estimates, except for the minke whale (for which the total sample size was small, n = 9). The squared coefficient of variation for sample size is extremely variable, being entirely dependent on the spatial distribution of pods (relative to the transect lines) and the total sample size, n. Thus, in several cases it is clear that $(cv(n))^2$ is quite high owing either to aggregation of pods (i.e. $\hat{var}$ (n) is high) or to a very small sample size (i.e. n is too small, often n = 1). In most cases, therefore, sample size variation constitutes a very high proportion of the total variance of the estimates. The contribution of group size variability to the total variance of the estimates is usually only slightly greater than that contributed by f(o). It is concluded that the variance of total number of pods detected is the most important component of the variances. Variance estimates might be further reduced using well-designed stratified aerial sampling surveys, although the small number of pods usually detected might preclude such an approach.

Estes and Gilbert (1978), on the other hand, showed that group size variability is an important component of the variance of Chukchi Sea walrus population estimates. They further demonstrated that errors of about 10–20% in estimating pod size contributed only a small proportion of the total variance in pod size, suggesting that the high variances of their population estimates were largely due to the distributional properties and behavioural characteristics of walruses. This is assuming that estimates of mean pod size were unbiased (i.e. that errors in estimating mean pod size were random).

Humpback densities recorded in other studies

Scott and Winn (1980) report densities of humpback whales to be 1.75 whales/sq. n. mi. on Silver Bank and 2.20 whales/sq. n. mi. on Navidad Bank in the West Indies, utilizing shipboard census data. These densities are approximately 7 to 10 times greater than densities of humpback whales on the Southeast Shoal of the Grand Banks (Hay, unpub. MS). Densities of humpback whales on Silver and Navidad Banks, utilizing high-altitude aerial line-transect data, were 1.37 and 1.55 whales per square nautical mile, respectively (Scott and Winn, 1980).

Densities of whales recorded during the first year of the CETAP studies are similar to densities recorded off Newfoundland – Labrador. Examples from Scott and Gilbert (1980) include: fin whales, block A, survey A5, 0.0950 whales/sq. n. mi.; humpback, block A, survey A4, 0.0669 whales/sq. n. mi.; and minkes, block C, survey A4, 0.0141 whales/sq. n. mi. These are maximum densities

Table 6

Squared coefficients of variation for pod size ($\bar{g}$), f(o) and sample size (n) for humpbacks, fin whales, minke whales, pilot whales, and white-beaked dolphins for each aerial survey zone. Only primary sightings are considered.[a]

Component of variance	Humpback	Fin	Minke	Pilot	White-beaked dolphin
$(cv(\bar{g}))^2$	0.0203	0.0327	0.0100	0.0072	0.0657
$(cv(f(o)))^2$	0.0086	0.0086	0.1702	0.0130	0.0100
$(cv(n))^2$ for zones:					
A	1.0773	0.1134	1.0082	—	—
B	0.2289	1.0297	0.9518	0.6534	0.6534
J	0.4841	—	—	—	0.0549
H	—	—	—	—	—
I	1.2679	0.7753	—	—	0.1071
C	11.7174	1.7591	—	—	—
D	—	—	—	—	—
E	—	—	0.9227	—	—
F	0.7209	—	—	0.0756	—
5	—	—	—	—	—
7	—	0.7248	0.2798	0.1905	0.1905
1	0.2120	—	—	1.8938	0.2813
3	0.2178	—	—	—	0.4653
Funk	0.2437	—	0.7906	0.3562	—
9	0.9656	0.3152	1.0765	0.0734	—

[a] The squared coefficients of variation for $\bar{g}$ and f(o) are derived from pooled data, thus there is only one value of each for each species. The $(cv(n))^2$ are calculated separately for each species in each survey zone.

tabulated by Scott and Gilbert (1980) and refer to aerial surveys in the Gulf of Maine during spring and early summer of 1979, which might present an ecological situation similar to that off Newfoundland – Labrador in summer.

Scott and Gilbert (1980) calculated f(o) to be 1.2120 for whales and 1.4736 for dolphins. These values are somewhat lower than those calculated in the present study. They used only two right-angle distance intervals (0 to 0.5 n. mi. and 0.5 to 1.0 n. mi.) compared to four intervals in the present studies.

Previous population estimates for northwest Atlantic whales

Knowledge of stock identities, distributions and boundaries is essential to the accurate estimation of population or stock size and the estimation of other parameters (Prescott, Kraus, and Gilbert, 1981). Mitchell (1973) emphasized that knowledge of stock distinctions of humpback whales in the northwest Atlantic was incomplete, and Mitchell and Reeves (1981) cautioned investigators to consider stock boundaries and total summer or winter distributions of humpback whales in their survey designs.

The method of individual identification of humpback whales by means of fluke photographs has great potential for delimiting stocks of this species in the northwest Atlantic and other oceans. Katona *et al.* (1980) have catalogued approximately 1,010 individual northwest Atlantic humpback fluke photographs, and they have suggested tentative substock distinctions based on re-sightings of humpbacks to date. Their analysis indicates that Gulf of Maine – Nova Scotia and Newfoundland – Labrador humpbacks comprise separate non-overlapping summering substocks, which may, however, mingle on wintering grounds in the West Indies. There are photographic connections between these wintering areas (Silver, Navidad and Mouchoir Banks and the Banks off Puerto Rico) and the Gulf of Maine and Newfoundland – Labrador, but no connections between the latter two potential substocks have been demonstrated to date. The affinities of humpbacks which summer in waters around Greenland and Iceland are at present unknown, although studies are now underway on humpbacks along the west coast of Greenland (Hal Whitehead, George Nichols, and others).

Aerial surveys carried out in eastern Newfoundland and southeastern Labrador waters during August 1980 did not sample the entire summering northwest Atlantic population(s) or stock(s) of humpback whales. Humpbacks also summer in the Gulf of St Lawrence (possibly a small distinct subpopulation according to fluke photograph data, see Katona *et al.*, 1980), the Gulf of Maine and waters off Nova Scotia, and off the coasts of Greenland and Iceland. Humpbacks are present on the Grand Bank of Newfoundland during August (Parsons, unpub. MS), although their abundance here is much lower at this time than during the period of capelin spawning in late June and early July (Hay, unpub. MS). In addition, the outermost blocks to the 2,000 m depth contour were not surveyed as originally planned (Fig. 2). It is clear, then, that these aerial surveys sampled only a portion of all northwest Atlantic humpbacks and only a portion of the possible Newfoundland-Labrador 'substock'.

However, this survey probably sampled a fairly high proportion of the total summer population of northwest Atlantic humpbacks, judging by population estimates for Newfoundland – Labrador waters compared with those for the entire northwest Atlantic or the West Indies wintering grounds (see Table 7, especially Whitehead, 1981), and a very high proportion of the Newfoundland – Labrador 'substock', judging by the distribution of past catches (Sergeant, 1966), recent sightings (Parsons, unpub. MS; Lien, 1980), and net-entrapments of humpbacks (Lien, 1980) during late summer (August). At this season humpbacks tend to concentrate in the nearshore waters of northeastern Newfoundland and southeastern Labrador.

Table 7

Previous population estimates for northwest Atlantic humpback whales.

Geographical area	Year	Method	Population size	Authority
Bay de Verde area, Newfoundland	1979–80	mark-recapture[a]	905–1,400	Whitehead, 1981
E. Nfld.[b]	1978–80	mark-recapture[a]	1,375–2,075	Whitehead, 1981
Labrador	1966–69	vessel-strip census	480	Mitchell, 1973
E. Nfld.,[b] Labrador	1978–79	mark-recapture[a]	1,535–2,720	Whitehead, 1981
	1980	aerial line-transect	235–1,242	this study
Nfld.-Labrador[c]	1898	cumulative catch	1,500	Sergeant, 1966
Silver and Navidad Banks, West Indies	1973	vessel-strip census	864[d]	Winn *et al.*, 1975
	1977	vessel-strip census	905	Balcomb and Nichols, 1978
	1978	vessel-strip census	1,375–1,747	Scott and Winn, 1980
Silver, Navidad, and Mouchoir Banks	1978, 80	vessel-line transect	2,000–3,500	Whitehead, 1981
	1980	vessel-strip census	1,923[d]	Balcomb and Nichols, 1981
West Indies	1972–73	vessel-strip census	1,018[d]	Winn *et al.*, 1975
Northwest Atlantic	1865 (initial popn)	cumulative catch	4,200–4,400[e]	Mitchell and Reeves, 1981
	1966–69	vessel-strip census	1,259[f]	Mitchell, 1973
	1980	mark-recapture[a]	2,000–6,000	Whitehead, 1981
	1980	no. of individual fluke photos catalogued (minimum popn. estimate)	1,010	Katona *et al.*, 1980

[a] Using uniquely-identifiable fluke photographs.
[b] Includes Bay de Verde area.
[c] All coasts of Newfoundland.
[d] Considered to be conservative.
[e] Considered to be conservative and probably substantially below the 'virgin' population size.
[f] Considered to be an overestimate.

The aerial-survey estimate of 738 (95% confidence interval of 235–1,242) humpbacks in eastern Newfoundland and southeastern Labrador waters during August 1980 (Table 3), when corrected for animals missed due to submergence as the aircraft passed (possibly about a 50% submergence rate), compares favourably with Whitehead's (1981) mark-recapture estimate of 1,535 to 2,720 humpbacks in the same area during 1978–79.

Table 7 presents several population estimates for northwest Atlantic humpback whales, censused in various portions of their total summer and winter ranges and by investigators utilizing various platforms of observation and field and analytical methodologies. Mitchell and Reeves (1981) have estimated the initial population size of humpbacks in the northwest Atlantic Ocean to be at least 4,200 to 4,400 in 1865. This is much greater than Sergeant's (1966) estimate of about 1,500 based on calculations of cumulative catches at Newfoundland and Labrador whaling stations in the early 20th century. Martin's (1981) records of early catches of humpback whales in the West Indies also suggest that Sergeant's (1966) estimate of initial population size is negatively-biased. The most recent estimates of abundance of humpback whales in the northwest Atlantic Ocean range from about 1,500 to 3,000 (Table 7). The increase in the estimated population from 1966–69 (during which years Mitchell (1973) conducted shipboard censuses in the north Atlantic) through the 1970s to the present time could be partially due to biological growth of the population, but I believe that much of the variation in recent estimates is due to differences in field sampling methodologies and analytical techniques (see Whitehead, 1981; Prescott *et al.*, 1981) and to differences in definition of population ranges and the surface areas to which calculated densities were extrapolated. Therefore, it can be concluded that these various estimates may not be strictly comparable. The workshop on humpback whales of the northwest Atlantic concluded that this population probably exceeds 2,000 animals, with a possibility that it is considerably higher (Prescott *et al.*, 1981).

Winn, Edel, and Taruski (1975) estimated that 85% of humpbacks wintering in the West Indies occurred on Silver and Navidad banks, and this figure has been utilized by subsequent investigators in calculating the total West Indies population based on winter surveys of these two banks. However, this figure was derived from sightings recorded during two consecutive seasons (1972 and 1973) and the 85% figure could, therefore, be incorrect if humpbacks do not demonstrate tenacious breeding site fidelity in successive winters.

Stock identities and relationships of fin whales in the northwest Atlantic are not well-known. Tag returns and other evidence from fin whale fisheries in northern Newfoundland and in Nova Scotian waters suggest that these two stock components are largely separate but that there may be some interchange between them of the order of 10% (Mitchell, 1974). The survey area (Figs 1 and 2) includes the grounds which supplied fin whales to fisheries in northeastern Newfoundland and southeastern Labrador during the summer and early autumn months, from 1945–72 (Sergeant, 1966; Mitchell, 1974). On the basis of extensive shipboard surveys, Mitchell (1972, 1974) concluded that the summer range of fin whales in the northwest Atlantic extended from 41°20′N to 57°00′N and from the shore to the 1,000 fathom depth contour. Therefore, the aerial survey of 1980 probably sampled a very high proportion of the total summering stock of fin whales in Newfoundland – Labrador waters but a much lower proportion of the total northwest Atlantic population.

Population estimates for fin whales in the northwest Atlantic, based upon catch-effort methods, tag-recapture

Table 8

Previous population estimates for northwest Atlantic fin whales.

Geographical area	Year	Method	Population size	Authority
Nova Scotia	1966	catch-effort	1,180–1,248	Allen, 1971, 1973
	1966–69	vessel-strip census	2,800	Mitchell, 1972, 1974
	1972	catch-effort	320	Allen, 1973
Gulf of St Lawrence	1966–69	vessel-strip census	340	Mitchell, 1972, 1974
Nova Scotia-Gulf of St Lawrence	1966–70	mark-recapture	3,600	Mitchell, 1972
E. Nfld.-Labrador	1967	catch-effort	3,530	Allen, 1973
	1968	catch-effort	5,000	Allen, 1971
	1972	catch-effort	2,050	Allen, 1973
	1980	aerial line-transect	79–926	this study
E. Canada	1966	mark-recapture	6,789	Mitchell, 1972, 1974
	1966–67	mark-recapture	12,075[a]	Mitchell, 1972, 1974
	1966–68	mark-recapture	11,610[a]	Mitchell, 1972
Northwest Atlantic	1966	vessel-strip census	7,205	Mitchell, 1972, 1974
	1967	vessel-strip census	3,162	Mitchell, 1972, 1974

[a] Considered to be overestimates.

experiments, and vessel strip and aerial line-transect surveys, are presented in Table 8. In spite of high variability among these estimates, it can be concluded that the fin whale stocks at Nova Scotia and Newfoundland – Labrador have responded differently to exploitation (Allen, 1971, 1973; Mitchell, 1974). The Nova Scotian stock declined drastically in numbers from 1966 to 1972 while that at Newfoundland apparently did not suffer such a dramatic decline (Table 8). This is further evidence for the existence of separate stocks in Nova Scotian and Newfoundland – Labrador waters.

The population estimate for fin whales in this study (79–926) is much lower than the comparable estimates shown in Table 8. It is also discordant with the fact that large catches of fin whales were obtained from the survey area in earlier years. It is therefore suggested that this estimate (478 ± 221) is negatively biased, perhaps a consequence of low aerial sampling effort in the offshore waters of northeastern Newfoundland and southeastern Labrador.

Stock divisions and relationships of long-finned pilot whales in the northwest Atlantic are not well-documented. The population fished in eastern Newfoundland waters is estimated to have numbered 50,000 to 60,000 at the onset of exploitation in 1947 (Mitchell, 1974; Mercer, 1975). The estimate from the 1980 survey (6,731 to 19,603 pilot whales) suggests that this population may have recovered to a significant extent from the depleted levels of the early 1960s (Mitchell, 1974), although no estimates of post-exploitation population size are presently available.

Blue whales (*Balaenoptera musculus*) were not detected in this study. They are reportedly rare along the northeastern Newfoundland and southeastern Labrador coasts, and earlier fisheries captured blue whales mainly in the Gulf of St Lawrence and the Straits of Belle Isle (Sergeant, 1966). Mitchell (1974) estimated that blue whales now probably number in the very low hundreds in the northwest Atlantic. Sei whales (*B. borealis*) were not seen during this survey, although there is a population of this species in the Labrador Sea whose relationship to the sei whale population off Nova Scotia is unclear (Mitchell and Chapman, 1977). Whaling stations in northern Newfoundland and southern Labrador usually captured only small and variable numbers of sei whales during late summer and autumn, with fin whales always predominating in the catches (Sergeant, 1966; Mitchell, 1974).

No previous population estimates for minke whales in the Newfoundland – Labrador region are apparently available. This species is difficult to census, particularly from fast-moving aircraft, owing to its inconspicuous behaviour and the fact that it spends relatively little time at the surface. The estimate of 174 (± 102) minkes in the study area is certainly negatively biased.

Table 9

Previous population estimates for other northwest Atlantic cetaceans.

Species	Geographical area	Year	Method	Population size	Authority
Sei whale	Nova Scotia	1966–69	vessel-strip census	870	Mitchell and Chapman, 1977
	Nova Scotia	1966–72	mark-recapture	1,393–2,248	Mitchell and Chapman, 1977
	Labrador Sea	1966–69	vessel-strip census	828–965	Mitchell and Chapman, 1977
	N.W. Atlantic	1966–69	vessel-strip census	2,078	Mitchell and Chapman, 1977
Blue whale	Nfld.-Labrador (all coasts)	1898	cumulative catch	1,500	Sergeant, 1966
Long-finned pilot whale	E. Nfld.	1947[a]	modified Leslie-Delury models	60,000	Mercer, 1975
	E. Nfld.	1947[a]	cumulative catch	50,000	Mitchell, 1974
	E. Nfld.-Labrador	1980	aerial line-transect	6,731–19,603	this study

[a] Initial population size.

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REFERENCES

Allen, K. R. 1971. A preliminary assessment of fin whale stocks off the Canadian Atlantic coast. *Rep. int. Whal. Commn* 21: 64–6.

Allen, K. R. 1973. Catch per effort estimates of northwest Atlantic fin whale stocks. *Rep. int. Whal. Commn* 23: 97–8.

Balcomb, K. C. III, and Nichols, G. 1978. Western north Atlantic humpback whales. *Rep. int. Whal. Commn* 28: 159–64.

Balcomb, K. C. III, and Nichols, G. Jr. 1981. Western North Atlantic humpback whale censuses in the West Indies. Paper SC/33/PS17 (published in this volume).

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* No. 72, 202p.

Butterworth, D. S. 1980. An investigation of possible bias introduced into sightings estimates of the minke whale population by the method used for right-angle distance calculation. Progress Report. SS/6 presented to the IWC Workshop on the Design of Sighting Surveys, Seattle, Sept. 11–16, 1980.

Estes, J. A. and Gilbert, J. R. 1978. Evaluation of an aerial survey of Pacific walruses (*Odobenus rosmarus divergens*). *J. Fish. Res. Board Can.* 35: 1,130–40.

International Whaling Commission. 1982. Report of the workshop on the design of sightings surveys, Seattle, Washington, Sept. 11–16, 1980 (published in this volume).

Katona, S. K., Harcourt, P. M., Perkins, J. S. and Kraus, S. D. 1980. Humpback whales: a catalogue of individuals identified in the western North Atlantic Ocean by means of fluke photographs. (Second edition.) College of the Atlantic, Bar Harbor, Maine 04609.

Laake, J. L., Burnham, K. P. and Anderson, D. R. 1979. User's manual for program TRANSECT. Utah State Univ. Press, Logan, Utah. 26pp.

Lien, J. 1980. Whale entrapment in inshore fishing gear in Newfoundland. Final Report to Department of Fisheries and Oceans, December 31, 1980.

Martin, K. R. 1981. Humpback whales and whaling: a look at historical habitats and abundance levels of the humpback whale in the western North Atlantic, pp. 88–95. *In:* J. H. Prescott, S. D. Kraus, and J. R. Gilbert (eds) Proceedings of a workshop on humpback whales of the western North Atlantic. New England Aquarium, Boston, Mass. Nov. 17–21, 1980.

Mercer, M. C. 1975. Modified Leslie-Delury population models of the long-finned pilot whale (*Globicephala melaena*) and annual production of the short-finned squid (*Illex illecebrosus*) based upon their interaction at Newfoundland. *J. Fish. Res. Bd Can.* 32: 1,145–54.

Mitchell, E. D. 1972. Assessments of northwest Atlantic fin whale stocks. *Rep. int. Whal. Commn* 22: 111–18.

Mitchell, E. D. 1973. Draft report on humpback whales taken under special scientific permit by eastern Canadian land stations, 1969–1971. *Rep. int. Whal., Commn* 23: 138–54.

Mitchell, E. D. 1974. Present status of northwest Atlantic fin and other whale stocks, pp. 108–169. *In:* W. E. Schevill (ed) *The Whale Problem: A Status Report.* Harvard Univ. Press, Harvard.

Mitchell, E. D. and Chapman, D. G. 1977. Preliminary assessment of stocks of northwest Atlantic sei whales (*Balaenoptera borealis*). *Rep. int. Whal. Commn* (special issue 1): 117–20.

Mitchell, E. D. and Reeves, R. R. 1982. Catch history, abundance, and present status of northwest Atlantic humpback whales. *Rep. int. Whal. Commn* (special issue 5).

Prescott, J. H., Kraus, S. D. and Gilbert, J. R. 1981. Proceedings of a workshop on humpback whales of the western North Atlantic. New England Aquarium, Boston, Mass., Nov. 17–21, 1980.

Quinn, T. J. II. 1979. The effects of school structure on line transect estimators of abundance, pp. 473–91. *In:* G. P. Patil and M. L. Rosenzweig (eds) *Contemporary Quantitative Ecology and related Ecometrics.* International Cooperative Publishing House, Fairland, Maryland.

Scott, G. P. and Gilbert, J. R. 1980. Problems and progress in the US BLM-sponsored CETAP surveys. Cetacean and Turtle Assessment Program Report, prepared for IWC Workshop on the Design of Sighting Surveys, Seattle, Washington, Sept. 11–16, 1980.

Scott, G. P. and Winn, H. E. 1980. Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales (*Megaptera novaeangliae*). Final report to US Marine Mammal Commission, Contract MM7 ACO29. 96pp.

Sergeant, D. E. 1966. Populations of large whale species in the western North Atlantic with special reference to the fin whale. Circular No. 9, Arctic Biological Station, Ste. Anne de Bellevue, Quebec.

Whitehead, H. 1981. Populations of humpback whale in the Northwest Atlantic. Paper SC/33/PS2 (published in this volume).

Winn, H. E., Edel, R. K. and Taruski, A. G. 1975. Population estimate of the humpback whale (*Megaptera novaeangliae*) in the West Indies by visual and acoustic techniques. *J. Fish. Res. Bd Can.* 32: 499–506.

SC/33/O 6

Catch Statistics for Minke Whales (*Balaenoptera acutorostrata*) and Killer Whales (*Orcinus orca*) Caught by Norway in 1980

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The information given in the tables is based upon data obtained from forms filled out by the whalers. The forms were introduced in 1938, when minke whaling was made dependent upon licences and revised five years ago.

The minke whaling in the North Atlantic is internationally regulated by a six month whaling season and quotas set by the International Whaling Commission. In addition, the Norwegian government has put into force restrictions including three kinds of effort limitation: regulation by licences; regulation by time and area; and limitation of meat production per season per vessel.

The Norwegian Government regulation in the 1980 season was as follows:

1. Ninety-two licences were issued, 89 of which were used.
2. In the waters north of 70°N between 5°W and 33°E and also south of 70°N between 25°E and 33°E whaling was permitted from 16 May to 15 July. In the waters east of 33°E whaling was permitted from 28 May to 15 July.
3. In the waters off the coast of Norway whaling was permitted south of 70°N and west of 25°E from 15 April to 31 August. No whaling operations were allowed from 1 July to 21 July.
4. In the waters off East Greenland, Iceland and Jan Mayen whaling was permitted from 25 July to 31 August.
5. In the waters off West Greenland whaling was permitted from 16 May to 31 August. No whaling was allowed north of 71°N.
6. A limitation for minke whale meat production was set at 70 tons per vessel per season.

In the 1980 season further action was taken to reduce the taking of female minke whales by postponing the opening date in the eastern Barents Sea from 15 May to 28 May.

Table 1

Participating vessels grouped according to length of vessels in feet and engine power in HP

Length of vessels in feet	Number of vessels	Engine power in HP	Number of vessels
30–39.9	3	Below 100	2
40–49.9	14	100–199	10
50–59.9	13	200–299	26
60–69.9	26	300–399	28
70–79.9	13	Above 400	23
80–89.9	9		
90–99.9	1		
Total	89		89

Table 2

Number of vessels grouped according to minke and killer whales caught

Number of vessels	Number of whales per vessel
21	Below 10
21	10–19
16	20–29
15	30–39
15	40–49
1	50 and above
89	

Table 3

Number of small whales caught in each of the seasons 1961–80

Species	1961	1962	1963	1964	1965	1966	1967	1968	1969
Minke	3,219	3,286	3,233	2,732	2,467	2,153	2,175	2,733	2,391
Bottlenose	87	321	267	307	682	340	264	384	485
Killer	111	124	90	77	104	161	36	86	231
Pilot	295	43	71	54	32	339	117	31	27
	3,712	3,774	3,661	3,170	3,295	2,993	2,592	3,234	3,134

Species	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Minke	2,307	2,330	2,659	2,055	1,820	1,778	2,146	1,772	1,592	1,980	2,002
Bottlenose	535	213	17	3	0	0	0	0	0	0	0
Killer	246	57	28	1	6	2	0	7	63	221	52
Pilot	43	0	0	0	1	0	0	0	0	0	0
	3,131	2,600	2,695	2,059	1,827	1,790	2,146	1,779	1,655	2,201	2,054

Table 4a

Number of minke whales caught by area and month.
Areas by number are shown in Fig. 1.

	April	May	June	July	Aug.	Sum
00 Vestfjorden	13	9	15	25	6	68
01 Kaninbanken			1			1
02 Murmanskkysten		160	248			408
03 Øst-Finnmark		96	45	42		183
04 Vest-Finnmark		9	23	1		33
05 Røstbanken til Malangsgr.			4	36	1	41
06 Helgeland			4	1	1	6
07 Møre			3			3
08 Egersundbanken	4	9	6	1		20
10 Skolpenbanken		15	330	82		427
11 Gåsebanken			4			4
12 Nordkappbanken		55	51	12		118
13 Thor Iversensbanken		3				3
20 Bjørnøya		48	79	44		171
21 Vest-Spitsbergen			27	6		33
22 Sør-Spitsbergen			4	1		5
23 Hopen		1				1
24 Storbanken			2			2
25 Nordvest-Spitsbergen			179	43		222
27 Sørvest-Spitsbergen			1			1
28 Vikingbanken		9	7	22	3	41
37 Norskehavet		1	8			9
39 Nordlige Norskehav			1			1
41 Sentrale Nordsjø		2	4			6
60 Skjoldungen				4	10	14
61 Danmarkstredet				15	78	93
62 Gammeloch				6	7	13
65 Disko					5	5
66 Hellefisk			10	48	11	69
68 Fyllas Bank					1	1
Total	17	417	1,056	389	123	2.002

Table 4b

Number of killer whales taken by area (Fig. 1) and month.

	Jan.	Feb.	Sum
00 Vestfjorden	36	3	39
05 Røstbanken til Malangsgr.	12	1	13
Total	48	4	52

Table 6

Minke and killer whale catches (2,054) according to visibility.

Visibility	Whales caught
1. Fog	32
2. Poor	113
3. Moderate	332
4. Good	862
5. Very good	550
6. Variable	55
No information	110

Table 7

Minke and killer whale catches (2.054) according to wind speed.

Wind speed	Whales caught
0—Calm	382
1—Light air	299
2—Light breeze	440
3—Gentle breeze	485
4—Moderate breeze	222
5—Fresh breeze	106
6—Strong breeze	41
7—Moderate gale	20
8—Above moderate gale	15
No information	44

Table 5

Number of days in which minke whales and killer whales have been caught in different areas and months. Areas by number are shown in Fig. 1

	Jan.	Feb.	March	April	May	June	July	Aug.	Sum
00 Vestfjorden	14	1	—	8	8	12	6	4	53
01 Kaninbanken	—	—	—	—	—	1	—	—	1
02 Murmanskkysten	—	—	—	—	4	20	—	—	24
03 Øst-Finnmark	—	—	—	—	9	17	5	—	31
04 Vest-Finnmark	—	—	—	—	4	15	1	—	20
05 Røstbanken til Malangsgr.	9	1	—	—	—	1	5	1	17
06 Helgeland	—	—	—	—	—	3	1	1	5
07 Møre	—	—	—	—	—	3	—	—	3
08 Egersundbanken	—	—	—	3	5	5	1	—	14
10 Skolpenbanken	—	—	—	—	2	26	5	—	33
11 Gåsebanken	—	—	—	—	—	4	—	—	4
12 Nordkappbanken	—	—	—	—	6	13	2	—	21
13 Thor Iversensbanken	—	—	—	—	2	—	—	—	2
20 Bjørnøya	—	—	—	—	9	12	11	—	32
21 Vest-Spitsbergen	—	—	—	—	—	12	5	—	17
22 Sør-Spitsbergen	—	—	—	—	—	2	1	—	3
23 Hopen	—	—	—	—	1	—	—	—	1
24 Storbanken	—	—	—	—	—	2	—	—	2
25 Nordvest-Spitsbergen	—	—	—	—	—	15	6	—	21
27 Sørvest-Spitsbergen	—	—	—	—	—	1	—	—	1
28 Vikingbanken	—	—	—	—	7	2	7	2	18
37 Norskehavet	—	—	—	—	1	5	—	—	6
39 Nordlige Norskehav	—	—	—	—	—	1	—	—	1
41 Sentrale Nordsjø	—	—	—	—	1	2	—	—	3
60 Skjoldungen	—	—	—	—	—	—	1	4	5
61 Danmarkstredet	—	—	—		—	—	6	24	30
62 Gammeloch	—	—	—		—	—	2	5	7
65 Disko	—	—	—		—	—	—	2	2
66 Hellefisk	—	—	—		—	5	15	4	24
68 Fyllas Bank	—	—	—		—	—	—	1	1

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Whale Census in the Gulf of Alaska June to August 1980

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ABSTRACT

The authors conducted a line-transect vessel census over the continental shelf, continental slope, and immediate offshore waters of the Gulf of Alaska between Cape Fairweather (138°W) and Chirikof Island (156°W), from 17 June to 28 August 1980. Populations of all species of great whales have been severely depleted. Estimated total populations in the 221,915 km^2 census area were: fin whale, *Balaenoptera physalus*—159; humpback whale, *Megaptera novaeangliae*—364; sperm whale, *Physeter macrocephalus*—few (36 sighted). No blue whales *B. musculus*, sei whales *B. borealis*, right whales *Balaena glacialis*, or gray whales *Eschrichtius robustus*, were sighted. Ten other species of marine mammals were recorded.

INTRODUCTION

The Gulf of Alaska is inhabited by 7 of the world's 10 species of baleen whales (Fiscus *et al.*, 1978). Six of these species—the minke *Balaenoptera acutorostrata*, sei *B. borealis*, fin *B. physalus*, blue *B. musculus*, humpback *Megaptera novaeangliae*, and right *Balaena glacialis* whales—utilize the gulf as one of their major feeding grounds from spring to autumn. Although all six species are virtually cosmopolitan in distribution, all except the small minke whale are classified as endangered species throughout their ranges (US Dept. Comm., 1979). The seventh species—the gray whale *Eschrichtius robustus*—is endemic to the North Pacific, and virtually the entire world population migrates along the shore of the Gulf twice each year, in spring and fall; the gray whale is also classified by the US Department of Commerce as an endangered species.

The Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973 stipulate that studies be made to determine whether proposed habitat alterations will have any adverse effects on populations of endangered species of marine mammals, and to determine what measures might be used to alleviate any such effects. In the summer of 1980 we conducted a preliminary survey to determine whether petroleum exploration and development lease sites on the outer continental shelf around Kodiak Island (Sale No. 48) and in the northeastern Gulf of Alaska (Sale No. 55) are important habitats for the endangered whale populations that inhabit this gulf, especially fin, humpback and gray whales.

Most species of baleen whales spend the winter in lower latitudes where they mate and, a year later, bear their calves (Mackintosh, 1965). They largely fast during this period. They migrate long distances to their summer feeding grounds in productive high-latitude waters. During the summer they must accumulate sufficient fat reserves to sustain them through their winter fast. Pregnant females must support a rapidly-growing fetus, and lactating females must nurture an even more rapidly-growing calf to independence before the fall migration and winter fast. Being filter feeders, baleen whales require dense concentrations of their prey species to ingest adequate nourishment. For this reason, they tend to be nomadic during the summer, aggregating in local areas with temporarily high food densities. Patterns of distribution and movement may vary considerably from month to month and year to year.

In the Gulf of Alaska, aboriginal whaling was practised only from Kodiak Island westward (Heizer, 1973; Mitchell, 1979). It ceased many decades ago. However, the gray whales that migrate through the Gulf and into the Bering Sea (Rugh and Braham, 1979) are the object of an important subsistence fishery around Chukotka, USSR, and a few of these whales are sometimes taken by Eskimos in Arctic Alaska.

Populations of all species of great whales that inhabit the Gulf of Alaska have been greatly reduced by commercial whaling (Table 1). During the 19th century, right whales were heavily exploited on the 'Northwest Coast Grounds' by the American high-seas whale fishery (Townsend, 1935). During the same period, gray whales were also heavily exploited while migrating past California and while in their Mexican calving lagoons (Rice and Wolman, 1971). Between 1910 and 1940, rorquals—(blue, fin, sei, and humpback whales)—were exploited by shore whaling stations in Alaska, British Columbia, Washington and California, and by floating factory ships off Mexico. From 1946 to 1976, large numbers of rorquals were killed throughout the North Pacific by Japanese and Soviet pelagic whaling fleets.

Two species of whales that inhabit the Gulf of Alaska–the humpback and the gray whale—now support a lucrative tourist industry on their respective winter grounds in Hawaii and in southern California and Baja California, Mexico.

There are many data on the past distribution and numbers of whales in the Gulf of Alaska. These data derive mainly from commercial whale catches (Nishiwaki, 1966; Townsend, 1935), and from sightings by scouting vessels attached to whaling expeditions (Berzin and Rovnin, 1966; Wada, 1979). Since the cessation of commercial whaling, little information has become available on the distribution and numbers of the surviving populations of these species. The NMML has censused humpback populations in southeastern Alaska and Prince William Sound, and annually monitors the gray whale population as it migrates along the California coast. A considerable amount of sighting data has been collected in the last five years under NMFS's continuing Platforms of Opportunity Program

Table 2

Water area (square nautical miles) of quadrats (each 1° latitude by 2° longitude) in study area

Northern latitude	Western longitude									
	156°	154°	152°	150°	148°	146°	144°	142°	140°	138°
61°						638	798			
60°				1,020	3,125	3,398	3,654	3,654	3,290	950
59°				3,750	3,762	3,762	3,762	3,762	3,762	3,739
58°			1,740	3,869	3,869					
57°		3,790	3,893	3,974						
56°		4,078	4,078							
55°										

coastal waters from Chirikof Island west to Dutch Harbor in the Aleutian Islands.

METHODS

The cruise was conducted with the chartered fishing vessel *US Dominator*. This vessel, designed for the Bering Sea king crab fishery, is 37.8 m long and its gross tonnage is 199. Its cruising speed is 10 knots (18.5 km/hr). The bridge affords excellent visibility in all directions. The observer's eye level is 7.7 m above the waterline.

Research methods included (1) line-transect censuses of marine mammals; (2) photography of humpback whales for individual identification; (3) radio-monitoring for previously radio-tagged gray whales; and (4) acoustic recording.

Line-transect census

A series of north-south transects were established at regular intervals across the study area. During the first half of the cruise (17 June to 20 July), 15 transects were run (Fig. 2 and Table 3); these were spaced at intervals of 1° longitude through the sectors that include lease sites, and at intervals of 2° longitude through the remaining sectors. These transects totalled 1,927 nautical miles.

During the second half of the cruise (24 July to 28 August), 9 transects were run (Fig. 3 and Table 4); all were spaced at intervals of 2° of longitude. These transects totalled 1,179 miles.

In addition, 3 shorter transects, spaced at intervals of 30 minutes of longitude, were run in the vicinity of Middleton Island (Fig. 3 and Table 5); these totalled 222 miles. Four short transects, spaced at intervals of 30 minutes of longitude, were also run in the vicinity of the Barren Islands (Fig. 3 and Table 5); these totalled 75 miles.

The systematic census tracks for the entire cruise totalled 3,403 nautical miles.

While running the transect lines the vessel maintained a steady speed. When whales were sighted more than 0.5 km from the trackline, the vessel immediately altered course and closed with the animals. After confirmation of the identity and number of whales (and photography in the case of humpbacks), the vessel headed due east or west until it was back on the trackline, and then continued along the pre-established course.

Three observers (in addition to the helmsman) were continuously on watch on the bridge. We attempted to keep the entire 360° arc under surveillance.

Each time that marine mammals were sighted, we recorded the sighting angle relative to the vessel's heading, and the distance of the animals from the vessel at the time of sighting. Distances were estimated by three methods:

(1) Visual estimates were made at the time of sighting.
(2) Dead-reckoning estimates were made by noting the time it took at known speed to close with the animals.
(3) Loran-C positions were recorded at the moment of sighting, and again when we closed with the animals. These positions are accurate to within 0.01 second of latitude and longitude (9 to 18 meters).

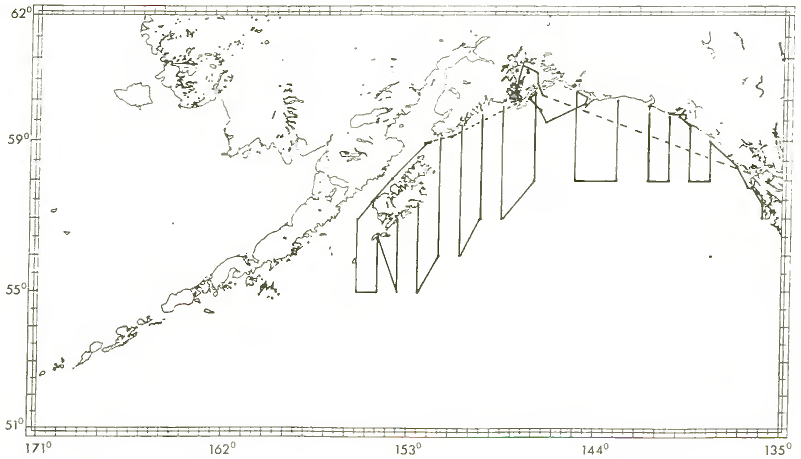

Fig. 2. Chart of cruise track, 17 June to 20 July.

Table 3

Main census transects and whale sightings during first half of cruise

Date	Longitude	Latitude		Miles	Whale sightings[1]		
		Northern End	Southern End		Humpback	Fin	Sperm
22 June	138°30′W	59°02′N	58°00′N	62			
23 June	139°30′W	59°22′N	58°00′N	82	2 (4)		
25 June	140°30′W	59°40′N	58°00′N	100		1 (2)	1 (2)
26 June	141°30′W	59°51′N	58°00′N	111			
27–28 June	143°00′W	60°03′N	58°00′N	123	2 (3)		
29 June	145°00′W	60°07′N	58°00′N	127	1 (2)		
1 July	147°00′W	60°12′N	58°00′N	132		5 (10)	
2–3 July	148°30′W	59°55′N	57°00′N	175	1 (1)		1 (2)
4–5 July	149°30′W	59°39′N	57°00′N	159			
6–7 July	150°30′W	59°24′N	56°00′N	204	1 (2)		
8–9 July	151°30′W	59°05′N	56°00′N	185			
10 July	152°30′W	57°20′N	55°00′N	140			
13 July	153°30′W	57°00′N	55°00′N	120			
14 July	154°30′W	56°27′N	55°00′N	87	1 (2)	1 (1)	
15 July	155°30′W	57°00′N	55°00′N	120	1 (2)		
Total				1,927	9 (16)	7 (13)	2 (4)

[1] Number of sightings, with number of individuals in parentheses.

Photo-identification

Photographs were taken of the flukes of as many humpback whales as possible. The color pattern of the underside of the flukes provides a reliable means of identifying individual animals. The photographs were entered into the National Marine Mammal Laboratory's computerized Photographic Identification Storage and Retrieval (PISAR) system for comparison with the extensive file of photographs already in the system.

Radio-tracking

During the second half of the cruise (24 July to 28 August) a radio-receiver was mounted on the bridge. It was monitored continuously while the vessel was underway, to detect any radio-tagged gray whales that might be within range. These whales had been tagged the previous winter in Laguna San Ignacio, Baja California Sur, Mexico, by Bruce R. Mate of Oregon State University.

Acoustic recording

During the second half of the cruise (24 July to 28 August), underwater phonations of cetaceans were recorded on an opportunistic basis.

Data management

Data acquisition and archival, and quality control, followed the procedures outlined by Mercer, Krogman, and Sonntag (1978) for the Platforms of Opportunity Project and Outer Continental Shelf Environmental Assessment Program.

RESULTS

A total of 1,231 sightings, totalling 6,968 individuals, of 13 species of marine mammals were recorded during the cruise (Table 6).

Humpback whale

Humpbacks were sighted on 90 occasions, totalling 190 individuals. They were thinly scattered over the entire area, and small aggregations were found during both halves of the cruise in four areas: (1) Yakutat Bay; (2) Cape Saint Elias to Middleton Island; (3) the Barren Islands and (4) Prince William Sound.

Only 14 of the sightings, totalling 25 individuals, were made during the main systematic census transects (Tables 3–4). A sample size of at least 40 sightings is necessary to

Table 4

Main census transects and whale sightings during second half of cruise

Date	Longitude	Latitude		Miles	Whale sightings[1]		
		Northern end	Southern end		Humpback	Fin	Sperm
25 July	139°00′W	59°13′N	58°00′N	73			
27 July	141°00′W	59°42′N	58°00′N	102	1 (1)		3 (32)
28 July	143°00′W	60°03′N	58°00′N	123	1 (3)		
29 July	145°00′W	60°10′N	58°00′N	91	1 (1)		
30 July	147°00′W	60°13′N	58°00′N	133	1 (2)		
8–9 Aug	149°00′W	59°55′N	57°00′N	175			
10–11 Aug	151°00′W	59°10′N	55°00′N	190			1 (1)
19 Aug	153°00′W	57°03′N	55°00′N	123			
20–21 Aug	155°00′W	57°49′N	55°00′N	169	1 (2)		
Total				1,179	5 (9)		4 (33)

[1] Number of sightings, with number of individuals in parentheses.

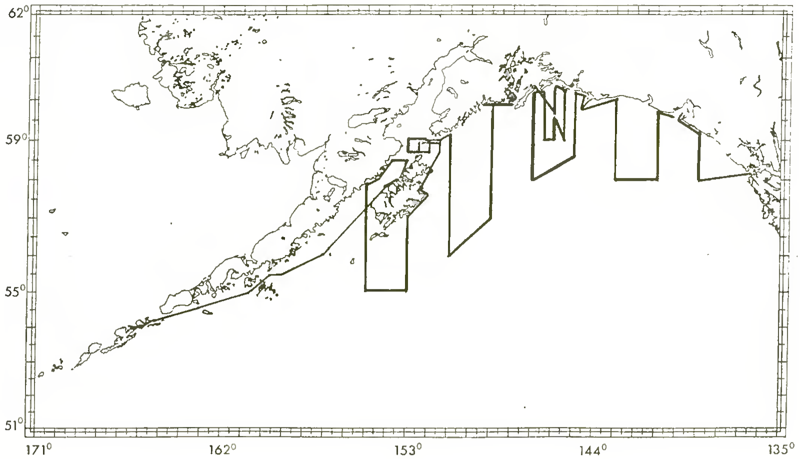

Fig. 3. Chart of cruise track, 24 July to 28 August.

Table 5

Supplementary census transects and whale sightings during second half of cruise

Date	Longitude	Latitude		Miles	Whale sightings[1]		
		Northern end	Southern end		Humpback	Fin	Sperm
Middleton Island:							
1 August	145°30′W	60°12′N	59°00′N	72			
31 July–1 August	146°00′W	60°16′N	59°00′N	76	2 (8)	1 (1)	
31 July	146°30′W	60°14′N	59°00′N	74			
Total				222	2 (8)	1 (1)	
Barren Islands:							
13 August	151°30′W	59°05′N	58°45′N	20	1 (2)		
13 August	152°00′W	59°05′N	58°45′N	20	2 (4)		
12 August	152°30′W	59°05′N	58°45′N	20	1 (10)		
12 August	153°00′W	59°00′N	58°45′N	15			
Total				75	4 (16)		

[1] Number of sightings, with number of individuals in parentheses.

Table 6

Summary of marine mammals sighted during Gulf of Alaska cruise

Species	First half		Second half		Total	
	Number of sightings	Number of individuals	Number of sightings	Number of individuals	Number of sightings	Number of individuals
Eumetopias jubatus	59	303	45	2,558	104	2,861
Callorhinus ursinus	105	144	31	32	136	176
Enhydra lutris	16	41	53	110	69	151
Phoca vitulina	16	167	29	48	45	215
Balaenoptera acutorostrata	21	21	16	16	37	37
B. physalus	13	19	4	14	17	33
Megaptera novaeangliae	43	82	46	109	89	191
Lagenorhynchus obliquidens	11	874	2	32	13	906
Orcinus orca	6	41	13	92	19	133
Phocoena phocoena	15	25	37	43	52	68
Phocoenoides dalli	372	1,301	269	852	641	2,153
Physeter macrocephalus	3	4	4	33	7	37
Ziphius cavirostris	2	7	0	0	2	7
Total	682	3,029	549	3,939	1,231	6,968

enable valid statistical inferences to be drawn (Burnham, Anderson and Laake, 1980). An approximation of population size may be made, however, by assuming that the 'effective transect width' was 1.0 mile (1.85 km) on either side of the vessel's track, as we found during four seasons' censusing of humpbacks around the Hawaiian Islands. On this basis, the 25 whales sighted along 3,106 miles of main census transect may be extrapolated over the entire 76,117 square mile study area to provide an estimate of 306 humpback whales.

Our maximum counts of humpback whales in each of the four aggregation areas (Table 7), which were not counted during the systematic offshore line transects, were as follows: Yakutat Bay—13; Cape Saint Elias to Middleton Island—13; Prince William Sound—12; Barren Islands—20. These counts are minimum estimates of the number of humpback whales using these areas.

Table 7

Counts of humpback whales in aggregation areas

	First count		Second count	
Area	Date	No.	Date	No.
Yakutat Bay	24 June	13	26 July	4
Middleton Island	30 June	13	31 July–1 August	8
Prince William Sound	17–18 July	5	2–6 August	12
Barren Islands	16 July	15	12–14 August	20

Movements of humpback whales were revealed by photographic documentation of individually recognizable whales. During the cruise we obtained photographs of 36 such whales (19% of the total seen). Repeat observations of four of these animals at intervals of 2 to 27 days were all very close to the positions where they were first found (Table 8); two of them had been observed in the same area in 1977 (and one in 1978) by Hall (1979). Humpback whales that inhabit inshore waters during the summer thus appear to have strong site-fidelity, with little if any dispersal between aggregation areas.

Table 8

Repeat sightings of individually-recognizable photo-documented humpback whales

PISAR Whale Number	Date	Location
000331	24 June 1980	Yakutat Bay
	26 July 1980	Yakutat Bay
000337	June 1977[1]	Prince William Sound
	June 1978[1]	Prince William Sound
	August 1978[1]	Prince William Sound
	4 August 1980	Prince William Sound: Icy Bay
	5 August 1980	Prince William Sound: Icy Bay
	31 August 1980[2]	Prince William Sound: Whale Ba
000342	June 1977[1]	Prince William Sound
	4 August 1980	Prince William Sound: Icy Bay
	5 August 1980	Prince William Sound: Whale Bay
	30 August 1980[2]	Prince William Sound: Chenega Island
000365	5 August 1980	Prince William Sound: Whale Bay
	27 August 1980[2]	Prince William Sound: Bainbridge Passage

[1] Photographed by Hall (1979).

[2] Photographed by Craig Matkin.

Fin whale

Finbacks were sighted on only 13 occasions, totalling 19 individuals. The only minor aggregation that we encountered was 10 animals west of Middleton Island on 1 July. The remaining sightings were thinly scattered over the entire area.

Only 7 of the sightings, totalling 13 individuals, were made during the main systematic census transects (Tables 3 and 4). A crude approximation of total numbers may be made by assuming an 'effective transect width' of 1.0 mile, as for the humpback whale, and extrapolating over the entire 76,117 square mile study area. This gives an estimate of 159 fin whales.

Gray whale

No gray whales were seen during the cruise, even though most of their preferred close-inshore habitat was searched. No radio signals were received from tagged gray whales.

Other endangered species

Sperm whales were sighted over deep water beyond the continental shelf on six occasions, totalling at least 36 individuals.

No blue whales, sei or right whales were sighted. At least until the early 1960s, the immediate offshore waters were a major summer ground for blue whales (Berzin and Rovnin, 1966; Nemoto and Kasuya, 1965). Sei whales tend to range farther offshore (Nemoto and Kasuya, 1965) so our census may have missed most of the Gulf of Alaska population. Right whales are on the verge of extinction in the North Pacific (Rice, 1974); most of the recent sightings have been made in the area immediately south of Kodiak Island (Omura *et al.*, 1969).

SUMMARY AND CONCLUSIONS

Our preliminary survey indicated that the populations of all species of great whales in the Gulf of Alaska have been severely depleted.

Humpback whales were sparsely distributed throughout the area from 138° to 156°W longitude, where the total population is calculated to be 306; we made too few sightings to calculate confidence limits. In addition, minor aggregations of humpbacks were found in Yakutat Bay (≥ 13), around Middleton Island (≥ 13), in Prince William Sound (≥ 12), and around the Barren Islands (≥ 20). Humpback whales in inshore waters show strong site-fidelity and rarely move between aggregation areas.

Fin whales are sparsely distributed throughout the area, where a rough estimate of the total population is only 159 animals.

No gray whales, blue whales, sei whales or right whales were sighted. Sperm whales were seen far offshore on six occasions, totalling 36 individuals.

Baleen whales in offshore waters tend to be nomadic during the summer, when they aggregate temporarily in areas of denser food supplies. Therefore one season's observations are inadequate to reveal distribution patterns and numbers in a limited area.

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REFERENCES

Berzin, A. A. and Rovnin, A. A. 1966. [Distribution and migrations of whales in the north-eastern section of the Pacific Ocean and in the Bering and the Chukotka Seas] *Izv. Tikhookean. Nauchno-issled. Inst. Norsk. Rybn. Khoz. Okeanogr.* 58: 179–207.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72: 1–202.

Fiscus, C. H., Braham, H. W., Mercer, R. W., Everitt, R. D., Krogman, B. D., McGuire, P. D., Peterson, C. E., Sonntag, R. M. and Withrow, D. E. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. Northwest and Alaska Fisheries Center Processed Report 238 pp.

Gambell, R. 1976. World whale stocks. *Mammal Review* 6(1): 41–53.

Hall, J. D. 1979. A survey of cetaceans of Prince William Sound and adjacent vicinity—their numbers and seasonal movements. Final report NOAA/OCSEAP Contract 01-6-022-1560. 83 pp.

Heizer, R. F. 1943. Aconite poison whaling in Asia and America: an Aleutian transfer to the New World. *Bull. Bureau Amer. Ethnology* 133: 415–68.

Mackintosh, N. A. 1965. *The Stocks of Whales*. Fishing News (Books) Ltd., London, 232 p.

Mercer, R. W., Krogman, B. D. and Sonntag, R. M. 1978. Marine mammal data documentation for the Platforms of Opportunity Project and Outer Continental Shelf Environmental Assessment Program. Northwest and Alaska Fisheries Center Proc. Rep. 92 pp.

Mitchell, E. 1979. Comments on magnitude of early catch of east Pacific gray whale (*Eschrichtius robustus*). *Rep. int. Whal. Commn* 29: 307–14.

Nemoto, T., and Kasuya, T. 1965. Foods of baleen whales in the Gulf of Alaska in the North Pacific. *Sci. Rep. Whales Res. Inst.* 19: 45–51.

Nishiwaki, M. 1966. Distribution and migration of the larger cetaceans in the North Pacific as shown by Japanese whaling results. pp. 171–91. *In:* K. S. Norris, (ed.) *Whales, Dolphins and Porpoises.* Univ. Calif. Press. 789 pp.

Omura, H., Ohsumi, S., Nemoto, T., Nasu, K. and Kasuya, T. 1969. Black right whales in the North Pacific. *Sci. Rep. Whales Res. Inst.* 21: 1–78.

Reilly, S. B., Rice, D. W. and Wolman, A. A. 1980. Preliminary population estimate for the California gray whale based upon Monterey shore censuses, 1967/68 to 1978/79. *Rep. int. Whal. Commn* 30: 359–68.

Rice, D. W. 1974. Whales and whale research in the eastern North Pacific. pp. 170–95. *In:* W. E. Schevill (ed.), *The Whale Problem: a Status Report.* Harvard Univ. Press., Cambridge. 491 pp.

Rice, D. W. 1978. The humpback whale in the North Pacific: distribution, exploitation, and numbers. pp. 29–44. *In:* Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. *Mar. Mamm. Commn. Rep.* No. MMC-77/03.

Rice, D. W. and Wolman, A. A. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Amer. Soc. Mamm. Spec. Pub. 3, 142 pp.

Rugh, D. J. and Braham, H. W. 1979. California gray whale fall migration through Unimak Pass, Alaska, 1977: a preliminary report. *Rep. int. Whal. Commn* 29: 315–20.

Tillman, M. F. 1977. Estimates of population size for the North Pacific sei whale. *Rep. int. Whal. Commn* (special issue 1): 98–106.

Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American whale ships. *Zoologica.* 19(1): 1–50.

U. S. Department of Commerce. 1979. Annual report on the Marine Mammal Protection Act of 1972: April 1 1978 to March 31 1979. Govt. Printing Office, Wash., D.C. 78 pp.

Wada, S. 1979. Indices of abundance of large-sized whales in the North Pacific in the 1977 whaling season. *Rep. int. Whal. Commn* 29: 253–64.

SC/33/O 8

Occurrence of Baleen and Killer Whales Off Chukotka

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INTRODUCTION

Since gray whales were first taken by a modern catcher boat (the *Zvezdny*) on behalf of the native peoples of Chukotka, in 1969, records of all species of whales seen have been kept. In recent years this has become progressively better organised (Votrogov and Ivashin, 1980; Ivashin and Votrogov, 1981 a and b). This was particularly true for the 1980 season when the weather and ice conditions were exceptionally favourable. The results are discussed below.

GRAY WHALES

Although most of the observations were made during the whaling season (29 June–28 October 1980), six sightings were made on the way to the grounds on the 27 June between 61°46′N, 174°33′E: three single animals; one pair; eight singles within a small area; and at the end of the day an aggregation of 30 animals (62°14′N, 179°05′E) comprising five groups each of 2 and 3 animals (of different lengths) and five single animals. In 1979 a similar aggregation had been sighted to the west of this (61°42′N, 173°36′E) comprising single animals and small groups. Ichihara (1958) reported three sightings of gray whales in early August to the west of St Lawrence Island; the first was a pair of animals (37 feet and 41 feet), the second a group of 20 animals (36—40 feet) and the third about 150 animals (35—40 feet). These latter aggregations were also composed of single animals and small groups. By July the number of whales sighted had increased and over 500 whales were seen each month until the end of the season (Table 1). The numbers of whales seen in each whaling area (Fig. 1) varied according to the length of time spent there by both the whales and the vessel.

Braham *et al.*, (1979) reported that 1,044 gray whales were sighted from the vessel, *Western Viking* from 14 June to 15 July 1978 including 664 between St Lawrence Island and Diomede Island and 364 in the Chukchi Sea.

Table 1

Occurrence of gray whales off Chukotka (for Divisions see Fig. 1).

Division	June	July	August	September	October	Total
1	10					10
2	31					31
2a	2					2
3		43	12			55
4		118	46	14	3	181
5		6				6
6				9		9
7		39	119	205	63	426
8		5	3			8
8a		32		1		33
9		39	101	65	13	218
10		83	114	14		211
11		52	20	36	133	241
12		4		28	32	64
13		24	6	6	4	40
14	21	51	17	95		184
15						
16						
17	36	17		5		58
18		9	34	4		47
19	4	3				7
20						
21						
10—11		20	12	1		33
10—13			55	24	30	109
11—12					234	234
13—14			3	17		20
Total	104	545	542	524	512	2,227
Miles covered	450	5,643	4,719	3,480	3,230	17,522
Whales/100 miles	23.1	9.7	11.5	15.1	15.9	12.7

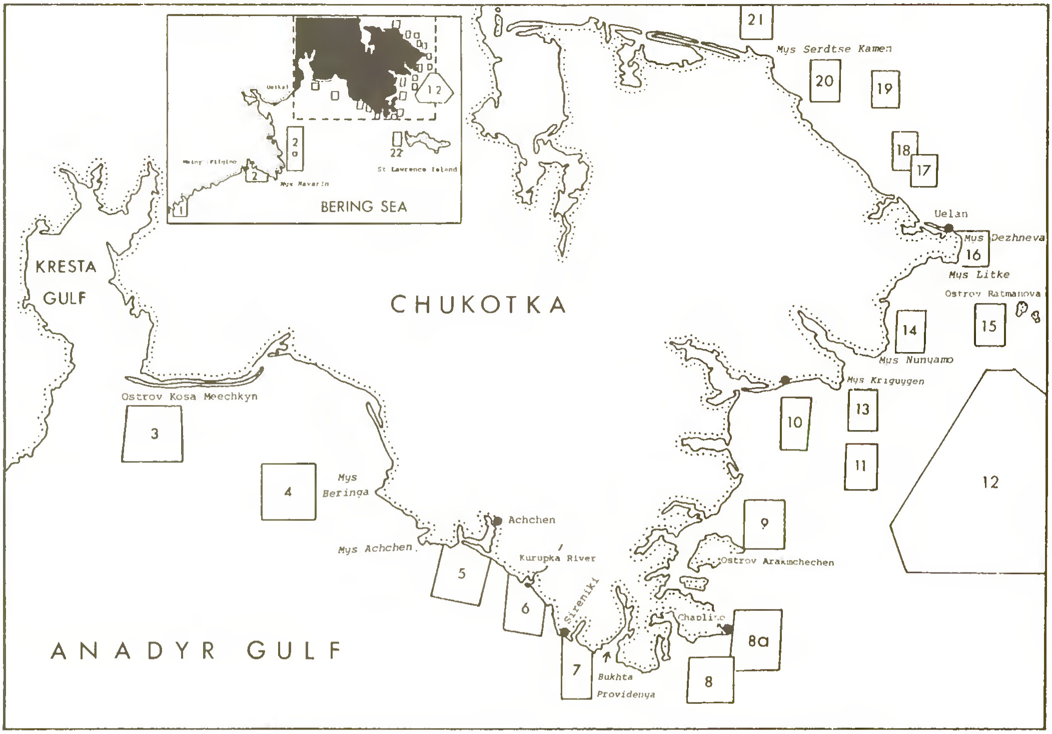

Fig. 1. Map showing divisions referred to in Table 1 (from Votrogov and Bogoslovskaya, 1980).

FIN WHALES

Very few fin whales have been seen on the gray whaling grounds: two single animals were seen in 1977 and five singles in 1979; no fin whales were seen in 1978 or 1980.

Braham *et al.*, (1980) reported that in 1968 64 fin whales 'and /or' minke whales were seen near St Lawrence Island, mainly between July and October.

HUMPBACK WHALES

Occurrence of humpback whales in the gray whaling area has been sporadic (Votrogov and Ivashin, 1980). Four humpbacks were sighted in 1980: one on 16 August (65°32′N, 179°13′W) in an area where humpback whales had not been previously sighted; a pair on 16 October (64°16′N, 173°45′W) which were swimming slowly to the southeast; and one sighted by A. Ankalin of Sireniki on 10 October near Mys Stoletiya.

MINKE WHALES

Earlier sightings of minke whales in these waters have been reported by Ivashin and Votrogov (1981a). In 1980, 17 minke whales were observed between 24 June and 28 October; 10 single animals, one group of three and two groups of two. The behaviour of the whales was interesting. The pair of animals seen on 4 June and the animals seen on 3 August did not react to the vessel; neither did the group of three whales seen on 1 July which remained with a group of gray whales. By contrast the animal seen on 27 June left the area at speed and on three occasions (27 July, 4 August and 12 August) animals breached 1–2 times and hurriedly left the area. Whales observed by a Soviet fishing vessel on 27 and 28 September were associated with shoals of fish (herring?) and paid no attention to passing vessels.

Braham *et al.* (1979) reported that two minke whales between Dutch Harbor and St Lawrence Island and five

Table 2

Occurrence of killer whales off Chukotka (for Divisions see Fig. 1).

Division	3[1]	4[1]	7	8	11	12	20	Total
July	2	14	2[2]	—	3	3	5	29
August	25	—	—	—	—	—	—	25
September	8	—	4	—	—	—	—	12
October	—	—	—	2	—	2	—	4
Grand total	35	14	6	2	3	5	5	70

[1] And adjacent waters

[2] Excluding groups where whales not counted

between St Lawrence and Diomede Islands were seen during the *Western Viking* cruise.

KILLER WHALES

Ivashin and Votrogov (1981b) reported on earlier sightings of killer whales in this area. On 24–25 June 1980 single large killer whales were seen near the Kuril Islands. On 26 June a group of five animals, swimming peacefully and blowing in synchrony, were seen as *Zvezdny* entered the Bering Sea where a total of 65 animals was seen (24 in July; 25 in August; 12 in September; 4 in October). Five animals were seen in the Chukchi Sea. The distribution of killer whales seen (by gray whaling area) is given in Table 2.

Most of the whales seen in July were large single males although occasionally groups of 2–3 animals (once a group of 2 large and 1 small animal) and once a group of six animals were sighted. Five sightings of killer whales were made in August: a single male; a pair of males; a group of four males; a group of eight (including two large males; and a group of ten (including four large males). Two groups were seen in September: one comprising two large and six small whales and the other one large and three small whales. Four whales, a pair and two singles were seen in October.

The behaviour and swimming direction of the groups varied: some moved quickly while others moved slowly. In July a group of five whales were seen swimming quickly near a group of gray whales although no aggressive behaviour was observed. Some of the groups were seen near walrus rookeries (e.g. Ostrov Kosa Meechkyn). A. Lemberg and L. Bogoslovskaya (pers. comm.) reported an attack by three males on a gray whale on 18 July but did not observe the outcome.

Braham *et al.* (1979) reported that five killer whales were seen between Dutch Harbor and St Lawrence Island and 13 in the Chukchi Sea on the *Western Viking* cruise. Two groups of eight animals (28 June and 23 July) and one 'group' (10 October) were seen near St Lawrence Island (Braham *et al.* 1980).

REFERENCES

Braham, H., Krogman, B., Marquette, W., Rugh, D., Johnson, J., Nerini, M., Leatherwood, S., Dahlheim, M., Sonntag, R., Carrol, G., Bray, T., Savage, S. and Cubbage, J. 1979. Bowhead whale (*Balaena mysticetus*) preliminary research results, June–December 1978. Paper SC/31/Doc 51 presented to the IWC Scientific Committee, June 1979 (unpublished).

Braham, H., Krogman, B., Nerini, M., Rugh, D., Marquette, W. and Johnson, J. 1980. Research on bowhead whales, June–December 1978. *Rep. int. Whal. Commn* 30: 391–404. (*This is a revised version of Braham* et al., *1979 which excluded detailed information on the* Western Viking *cruise*).

Ichihara, T. 1958. Gray whale observed in the Bering Sea. *Sci. Rep. Whales Res. Tokyo* 13: 201–6.

Ivashin, M. V. and Votrogov, L. M. 1981a. Minke whales, *Balaenoptera acutorostrata davidsoni*, inhabiting inshore waters of the Chukotka coast. *Rep. int. Whal. Commn* 31: 231.

Ivashin, M. V. and Votrogov, L. M. 1981b. Killer whales, *Orcinus orca*, inhabiting inshore waters of the Chukotka coast. *Rep. int. Whal. Commn* 31: 521.

Votrogov, L. M. and Bogoslovskaya, L. S. 1980. Gray whales off the Chukotka peninsula. *Rep. int. Whal. Commn* 30: 435–8.

Votrogov, L. M. and Ivashin, M. V. 1980. Sightings of fin and humpback whales in the Bering and Chukchi Seas. *Rep. int. Whal. Commn* 30: 247–8.

SC/33/O 9

Indian Ocean Cetacean Survey, Seychelle Islands, April through June 1980

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ABSTRACT

Aerial surveys for cetaceans were conducted along randomly selected transects radiating from Mahe, in the northeastern islands of the Republics of the Seychelles, from April through June 1980. Identified cetaceans were observed in the following relative frequencies (number of observations/number of individuals): sperm whales (18/36), bottlenose dolphins (12/555), Risso's dolphins (5/210), pilot whales (1/4) and a fin whale (1/1). Six groups of unidentified porpoises included two which were probably rough-toothed dolphins (2/81) and one of probable spotted dolphins (1/60); five sightings of unidentified small whales included two groups of what were probably beaked whales (2/6). Boat surveys resulted in sightings of bottlenose dolphins, and unidentified dolphins, and probably spotted dolphins. Evidence was also obtained for the occurrence of goosebeaked whales and killer whales in the Seychelles.

INTRODUCTION

At the 1979 meeting of the International Whaling Commission a proposal by the Republic of the Seychelles was adopted creating the huge Indian Ocean Cetacean Sanctuary (IWC, 1980). This sanctuary, in which commercial whaling is forbidden, consists of those waters of the Northern Hemisphere from the coast of Africa to 100°E—including the Red and Arabian Seas and the Gulf of Oman—and those waters of the Southern Hemisphere between 20°E and 130°E from the equator to latitude (see Fig. 1, inset). Included are the approximately 100 islands comprising the Seychelles.

Forty-three species of cetaceans are known to exist in the Indian Ocean Sanctuary (IWC, 1980), and whaling for some of those species has been conducted by local subsistence fisheries (Mitchell, 1975; IWC, 1980), yankee whalers (Townsend, 1935), and modern whalers (e.g. Bannister, 1963; Mackintosh, 1965; Rørvik, 1979). Even so, most species are known from only fragmentary records and distribution and movements within particular portions of the sanctuary are poorly documented. In 1980 aerial and vessel surveys were conducted to inventory cetaceans occurring within the Economic Maritime Zone of the Seychelles (Fig. 1). This paper summarizes results of those surveys and such other information as is available on the cetaceans occurring in and near the waters of the Seychelles.

Description of the Area

The archipelago of the Seychelles extends across some 150,000 nm^2 (278,000 km^2). The islands of the archipelago, which comprise a total land mass of less than 81 nm^2 (280 km^2), occur as four clusters: one on the broad plateau around Mahe, the capital and center of human activity (this plateau is known as the Seychelles Bank); the nearby Amirante Isles: the Farquhar Group; and the Aldabra/Cosmolido Group. (Salm, 1978) (Fig. 1).

The Seychelles Bank, which covers some 12,000 nm^2 (41,160 km^2), is covered by only 40 fathoms (73 m) of water. At the edges of the bank, and around the other island groups as well, the sea floor drops away precipitously, so that depths of over 1,000 fathoms (1,829 m) separate the island groups from one another. The exception is the extensive, Seychelles Mountain Ridge which extends generally southward from the Seychelles Bank to Mauritius, some 2,000 nm (3,700 km) away.

Oceanographically, the Seychelles are principally influenced by the equatorial counter-current and the equatorial current, the relative strengths of which vary seasonally. The counter-current is most northerly in November and most southerly in February (Salm, 1978). Between these two currents is an area of mixing that seasonally produces a dome of rich, colder water southeast of the Seychelles Bank. The region is principally tropical and subtropical.

The Seychelles are outside the cyclone belt, but weather patterns vary significantly within and among years. In general, between November and April northwest monsoon winds dominate the weather with frequent overcast skies and rains. December and January are usually the wettest months (High, 1973; Salm, 1978). Between May and October, steadily blowing southeast tradewinds often bring overcast skies and heavy rains. It is during the period between these dominant winds, a period which varies in its duration but usually occurs between late March and early June, when monsoon winds have subsided and the tradewinds have not yet begun to blow steadily, that optimal survey conditions can be expected, with a cloudless sky and glassy sea surface.

MATERIALS AND METHODS

The area within 200 nm (370 km) of Mahe Island was divided by 36 radial transects at 10 degree intervals beginning at magnetic north (Fig. 2). The transects were

numbered and divided into four quadrants: I = 1–9, II = 10–18, III = 19–27, and IV = 28–36. Except on days when government business dictated the area where effort was to be concentrated, we daily selected a survey quadrant at random.

Transect numbers for the quadrant were placed in a hat and two were drawn. By a coin toss it was determined which transect would be flown out, which back. Once a number was drawn it was eliminated as a choice until each of the 36 transects had been flown at least once (that had occurred by 26 May 1980). The process was then repeated.

Actual surveys were flown in a twin-engine *Cessna* 340A, equipped with a 200 gal (758 l) auxiliary fuel tank and *Omega* Directional Navigational System. Surveys were conducted from an altitude of 1,000 ft (308 m) at a speed of 140 knots (260 km/hr). Personnel were placed as follows: pilot–left front; principal observer–right front; and photographer–left rear, where the door could be removed. The one or two guest observers who commonly accompanied us occupied right rear or mid-aircraft seats.

The aircraft maintained transect heading while all observers searched. When cetaceans were sighted the aircraft was diverted from transect and the animals circled for identification, estimates of numbers, descriptions of behavior (including swimming direction), position (read from the *Omega* display), and notation of environmental conditions of interest. Photographs were taken of selected groups. Once all data were collected the aircraft returned to the transect and observers resumed searching. Surveys were not initiated at all or were terminated prematurely when weather conditions exceeded Beaufort 3 (winds less than 10 knots [18.6 km/hr] and no more than occasional white foam crests). A total of 71 transects covering 15,666 nm (29,220 km) was completed in 34 days of flying between 16 April and 28 June 1980 (Table 1; Fig. 3).

Table 1

Aerial survey effort, expressed as number of linear miles on transect

Period	No. of flights	No. of nautical miles	$\bar{x}$	S
April	8	3,505.6	438.2	
May	14	6,508.2	464.9	
June	12	5,652.2	471.0	
Total	34	15,666.0	460.8	73.60

Two indices of abundance were calculated from sightings data: I_1 = number of encounters (herds) per 100 nm; I_2 = number of individuals per 100 nm.

Two reconnaissance cruises were conducted among the islands: one 24 May through 4 June from Mahe to the islands of Aldabra to the Grand Comores and back to Mahe, another 21 to 30 June from Mahe to Platte Island to Desroche Island and back to Mahe (Fig. 4). Weather permitting, observers maintained casual marine mammal watches during daylight hours. When cetaceans were observed, observers determined location of the sighting, species, and estimated number of individuals. Boat surveys covered an estimated 1,200 nm (2,220 km), though concentrated survey effort for cetaceans occupied only a small portion of the tracks.

The Seychelle archives in Mahe were perused for information on occurrence and exploitation of cetaceans. Knowledgeable local inhabitants were queried for anecdotal accounts of cetaceans around the islands.

RESULTS AND DISCUSSION

Seven species of cetaceans have been reported as occurring in the waters of the Seychelle Islands (see Table 2 and discussion under species accounts below)[1]. In addition, Best (1971) considered that five of the six rorqual whale species are distributed 'throughout the Indian Ocean'. From the studies reported herein we are able to reconfirm the occurrence of four and tentatively reconfirm the occurrence of 2 of those 11 species and document the occurrence of five species not previously reported. Two or three additional species are provisionally listed based on our tentative identification. Seven species previously reported from the area were not encountered during this study.

Aerial surveys

The aerial surveys resulted in 48 sightings of whales or whale groups (estimated total of 1,288 individuals) (Fig. 5). Indices of abundance are shown in Table 3. Except for May, when we saw more groups of large whales than of other classes of cetaceans, we consistently saw more groups and more individuals of the medium-sized to small whale and dolphin categories. The I_1 values declined steadily through the survey season. The I_2 values dropped substantially after the first month to roughly consistent low values for the next two. It is not known to what extent these apparent trends reflect actual changes in cetacean distribution and numbers or simply the unquantified but certain deterioration of weather which we observed after April. Assessments are discussed by species and include reviews of other pertinent information.

Sperm Whale, *Physeter macrocephalus*

Sperm whales were encountered on 19 occasions (Fig. 5), usually as single individuals but also in groups containing from 2 to 5 animals ($\bar{x}$ = 1.85). Of the 35 individuals observed, 8 (23%) were judged to be large adult males and at least 4 (11%) were calves of the season. Behavior which we interpreted as mating was observed on 25 May. Two large individuals were seen to 'pitchpole' repeatedly, surfacing head first in a ventral to ventral position and raising their bodies out of the water to near the flippers.

Water depth at all but one of the sighting locations was between 1,440 and 5,080 m ($\bar{x}$ = 4, 105). One individual was observed on 15 May southeast of Frigate Island in only 55 m of water. Eleven sightings were made off the African Banks, west and north of the Amirante Island group. The rest were widely distributed over deep water.

Observed density of sperm whales declined steadily from April through June (Table 3). Sightings in April and May were widely distributed in the study area, but the only two groups seen in June were south of Mahe and heading southward. Only two sperm whales (1 in April, 1 in May) were seen north of Denis and Bird Islands in an area in which whaling for sperm whales has taken place in two historical episodes.

In the 19th century, yankee whalers took sperm whales year-round on the 'Zanzibar Grounds', far west of Seychelles, and on what they referred to as Seychelle Banks—virtually all the ocean area now included in the Republic of the Seychelles (Townsend, 1935, charts A and

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[1] Scientific and common names used are those adopted by the IWC (IWC, 1977).

Table 2

Cetacean species now verified (×) or tentatively reported (†) from waters of the Seychelle Islands, with remarks on their occurrence in nearby tropical areas. * = Reported as occurring 'throughout the Indian Ocean' and therefore by inference in Seychelles, though records specifically from Seychelles not available; 0 = not observed present study. Information sources are shown in parentheses and identified in footnote 1

Species	Occurrence in Seychelles	Remarks
Right whale, *Eubalaena glacialis*	× (A)	Taken in 19th century on Delagoa Grounds, S.E. Mozambique (F).
Blue whale, *Balaenoptera musculus*	* (C): 0	Observed in October in Gulf of Aden (E); in November through January below 26°, between longs. 36°E and 48°30′W (D).
Fin whale, *B. physalus*	× (B), * (C)	Observed in December and January below lat. 31°10′S, between longs. 33°21′E and 45°23′E (D).
Sei whale, *B. borealis*	† (A); *(C); 0	
Bryde's whale, *B. edeni*	0	Reported in October in Gulf of Aden (E); Abundant in Indian Ocean (R, S).
Minke whale, *B. acutorostrata*	*(C); 0	Reported November–January below lat. 70°50′S between longs. 37°45′E and 63°06′E (D).
Humpback whale, *Megaptera novaeangliae*	*(C); 0	Taken in 19th century off eastern Mozambique and both coasts of Madagascar (F) and 1911–1915, 1923 off Mozambique (H, I, J, K, L); observed in Gulf of Aden, October (E).
Sperm whale, *Physeter macrocephalus*	× (A, B, C, F)	Taken widely in Indian Ocean during 19th century (F).
Beaked whales:		
Dense beaked whale, *Mesoplodon densirostris*	× (G, N, P); 0	See footnote 2.
Unidentified, *M. sp.*	× (B)	See footnote 2.
Longman's beaked whale, *M. pacificus* (= *Indopacetus pacificus*)	? (B)	Single stranding at Danane, Somalia Republic (M).
Gray's beaked whale, *M. grayi*	? (B)	4 sightings in January below lat. 31°08′S, between longs. 47°28′E and 65°24′E (D).
Goosebeaked whale, *Ziphius cavirostris*	× (B)	5 sightings in November and December below lat. 26°46′S, between longs. 30°29′E and 43°10′E (D).
Killer whale, *Orcinus orca*	× (B, C)	Observed in October in Gulf of Aden and Arabian Sea (E).
Pygmy killer whale, *Feresa attenuata*	× (G); 0	—
Melon-headed whale, *Peponocephala electra*	× (G); 0	—
Pilot whale, *Globicephala sp.*	× (B)	—
Risso's dolphin, *Grampus griseus*	× (B)	Observed in December at lat. 20°43′S, long. 50°48′E (D). Reported from Red Sea (C).
Bottlenose dolphin, *Tursiops truncatus*	× (B, C, G)	Widely distributed in warm temperate and tropical waters worldwide (Q).
Spotted dolphin, *Stenella sp.*	† (B, C, G)	Seen off Western Madagascar (D).
Rough toothed dolphin, *Steno bredanensis*	† (B)	Reported from Zambesi Coast and Aden District (C).

[1] Information sources: Seychelles Archives (A); Present study (B); Best, 1971 (C); Gambell *et al.*, 1975 (D); Yukov, 1969 (E); Townsend, 1935 (F); Racey and Nicoll, in press (G); Rørvik, 1979 (H); Anonymous, 1961 (I); Tønnessen, 1967 (J); Risting, 1922 (K); Mackintosh, 1965 (L); Azzarolli, 1968 (M); Gray, 1846 (N); Hershkovitz, 1966 (P); Leatherwood and Reeves, in press (Q); Ohsumi, 1980 (R); Ohsumi, 1981 (S).

[2] Beaked whales are in general poorly known and difficult to identify, particularly at sea. For further data on beaked whales in the Indian Ocean, consult Best (1971) and Gambell *et al.* (1975).

Bottlenose Dolphin, *Tursiops truncatus*

Bottlenose dolphins were positively identified on 13 occasions (627 individuals, x̄ = 48.23). Three of these sightings were over the continental shelf (60–80 m of water), the rest in offshore waters from 2,030–4,760 m deep. Seven of the groups contained calves of the season (46 individuals, 7.3% of all animals observed).

Bottlenose dolphins are distributed worldwide in warm temperate and tropical waters, including mainland coastal, pelagic, and oceanic island shelf regions (Leatherwood and Reeves, in press). Their not surprising occurrence around Seychelles has been reported previously (Best, 1971).

Racey and Nicoll (in press) report that bottlenose dolphins, locally called 'marsouin blanc', are common in the central Seychelles and are often harpooned for food. Norman Van Swelm (May 1981, pers. comm.) reports that the former manager of Providence Island estimated that prior to 1979, when a prohibition went into effect, as many as 100 dolphins per year, mostly this species, were killed in the Seychelles.

Risso's Dolphin, *Grampus griseus*

Risso's dolphins were observed on 5 occasions (210 animals) in groups of 3 to 58 individuals, all in waters deeper than 3,200 m. Of these, 20 (9.5%) were calves or juveniles. They were distinguished by their darker slate color and small size from the larger, almost white adults.

These five observations appear to constitute the first records of Risso's dolphins in the Seychelles. Because of the conspicuous coloration and other distinctive features, Risso's dolphins are unlikely to have been previously overlooked or not identified. The absence of records may be attributed to the generally offshore distribution of the species. (See Leatherwood, Perrin, Kirby, Hubbs, and Dahlheim, 1980.)

Short-finned Pilot Whale, *Globicephala macrorhynchus*

On 16 April 1980, four pilot whales were observed in the company of 90 bottlenose dolphins, in 4,330 m of water at 2°51′S, 55°12′E. The whales appeared all black with no traces of gray post-dorsal saddle or of light gray blazes on the side of the head. Further, from examination of near-vertical photographs of an animal rafting at the surface the pectoral fins were estimated to have been no more than one-sixth the body length, a feature commonly taken reliably to separate short-finned pilot whales, *G. macrorhynchus,* from the larger, usually colder water form *G. melaena* (Leatherwood, Caldwell and Winn, 1976). In noting the occurrence of pilot whales from South Africa, Best (1971) wrote '*G.m. edwardii* from the southern

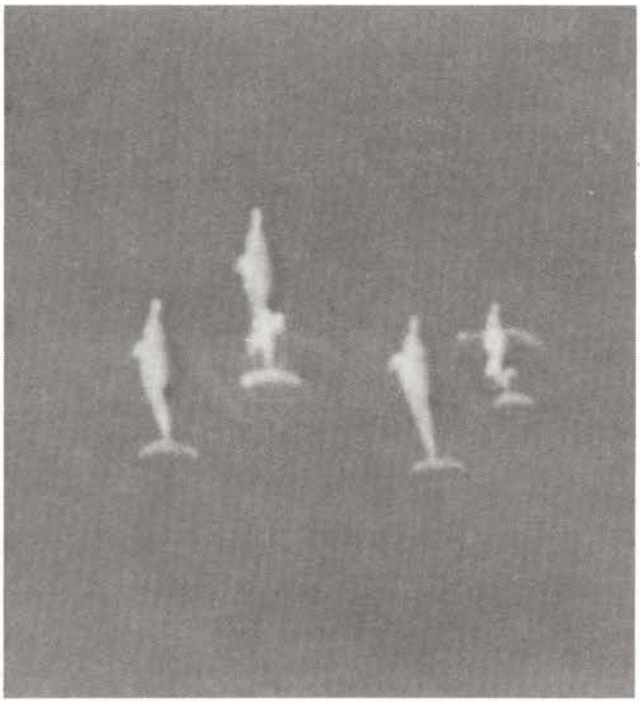

Fig. 6. Four unidentified medium-sized whales, believed to be beaked whales, *Mesoplodon sp.*, including a calf, observed 27 April 1980 at lat. 04°03.1′S, long. 56°70′E. They were tentatively identified as *M. grayi* or *M. pacificus* (= *Indopacetus pacificus*).

Other information

Best (1971) reported that killer whales occur in the Seychelles. On 16 August 1980 David Plows and Francois Jackson (October 1980 pers. comm.) observed three whales at 06°06′S, 57°36′E. From their detailed descriptions the whales were unquestionably killer whales.

Seven species of cetaceans previously reported to occur in the Seychelles were not observed during the present survey (Table 2). A whale, identified as a right whale, *Balaena glacialis* (cited as *Baleine franche* or *Baloena australi*), was included in the take of the fishery for sperm whales near Bird and Denis Islands discussed above[2]. At least twelve pygmy killer whales, *Feresa attenuata,* were reportedly observed in May of 1977, west of Seychelles Bank; and nine small whales stranded on Aldabra in spring of 1975 were later identified from skulls as melon-headed whales, *Peponocephala electra* (Racey and Nicoll, in press).

Sei whales are regarded as 'probably [occurring] throughout Indian . . . Ocean' (Best, 1971) and were thought by Seychelles authorities in 1915 to migrate seasonally into the area and therefore likely to be harpooned in the fishery. Blue and minke whales have been seen in the Gulf of Aden (Yukhov, 1969) and in temperate waters well south of Madagascar (Gambell *et al.*, 1975). Minke whales were observed as far north as about 21°S off both coasts of Madagascar and eastwards towards Mauritius (Gambell *et al.*, 1975). Humpback whales were killed off Mozambique and Madagascar by yankee whalers in the 19th century (Townsend, 1935) and off Mozambique by modern whaling from 1911–1915 and in 1923 (Rørvik, 1979).

[2] No substantive evidence supporting the identification of this specimen as a right whale was presented. Because of the much reduced stocks of right whales and oceanic nature of the islands the identification must be regarded with caution (G. J. B. Ross, 1981, pers. comm.).

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Fig. 7. Lateral view of the skull of a goosebeaked whale (*Ziphius cavirostris*) stranded on Bird Island, March 1977.

REFERENCES

Anon. 1961. *International Whaling Statistics*, II.

Azzaroli, M. L. 1968. Second specimen of *Mesoplodon pacificus*, the rarest living beaked whale. *Monitore Zool. ital.* (N.S.) 2 (Suppl.): 67–79.

Bannister, J. L. 1963. Australian whaling, 1963, catch results and research. Australia—Commonwealth Scientific and Industrial Organization. Division of Fisheries and Oceanography. Report 38, 13 pp.

Best, P. B. 1971. Order *Cetacea*. Part 7. pp. 7–1 through 7–11. *In:* J. Meester and H. W. Setzer (eds) *The Mammals of Africa. An Identification Manual*. Washington, D.C. Smithsonian Institution. ISBN-0-87474-116-5.

Best, P. B. 1979. Social organization in sperm whales, *Physeter macrocephalus*. pp. 227–89. *In:* H. E. Winn and B. L. Olla (eds), *Behavior of Marine Animals; Current Perspectives in Research*. Vol. 3. Cetaceans. Plenum Press, New York and London.

Bree, P. J. H. van, Best, P. B. and Ross, G. J. B. 1979. Occurrence of the two species of pilot whale (genus *Globicephala*) on the coast of South Africa. *Mammalia* 42(3): 323–8.

Davies, J. L. 1960. The southern form of the pilot whale. *J. Mammal.* 41(1): 29–34.

Gambell, R., Best, P. B. and Rice, D. W. 1975. Report on the International Indian Ocean Whale Marking Cruise. *Rep. int. Whal. Commn* 26: 240–52.

Gray, J. E. 1846. On the cetaceous animals. Part III, pp. 13–53. *In:* J. Richardson and J. E. Gray (eds), *The Zoology of the Voyage of the H.M.S.* Erebus *and* Terror, *under the command of Captain Sir James Clark Ross, R.N., F.R.S., during the years 1839–1843*. Vol. 1; Mammalia, Birds. London, E. W. Janson, 28 Museum Street, W.C., M.DCCC.XLIV–M.DCC.LXXXV.

Hershkovitz, P. 1966. *Catalog of Living Whales*. Washington, D.C., U.S. National Museum Bulletin 246. 259 pp.

High, J. (undated, published after 1973). *The Natural History of the Seychelles*. G. T. Phillips and Co. (London) Ltd. 64 pp.

International Whaling Commission. 1977. Appendix 1. List of smaller cetaceans recognised. *Rep. int. Whal. Commn* 27: 30–1.

International Whaling Commission. 1980. Chairman's Report of the Thirty-First Annual Meeting, Item 9 *Rep. int. Whal. Commn* 30: 27

Leatherwood, S. and Reeves, R. R., 1981 in press. Bottlenose dolphins, *Tursiops* c.f. *T. truncatus*, and other toothed cetaceans. Chapter 18 *In:* G. Feldhamer and R. Chapman (eds). *Game, pest and commercial mammals*. Baltimore, John Hopkins Press.

Leatherwood, S., Caldwell, D. K. and Winn, H. E. 1976. *The Whales, Dolphins and Porpoises of the Western North Atlantic; a Guide to their Identification*. NOAA Technical Report, NMFS Circular 396. 176 pp.

Leatherwood, S. Perrin, W. F., Kirby, V. L., Hubbs, C. L. and Dahlheim, M. F. 1980. Distribution and movements of Risso's dolphin, *Grampus griseus*, in the eastern North Pacific. *Fish. Bull.* (US) 77(4): 951–63.

Mackintosh, N. A. 1965. *The Stocks of Whales*. Fishing News (Books) Ltd., London, 232 pp.

Michel, C. and van Bree, P. J. N. 1976. On two strandings of the beaked whale, *Mesoplodon densirostris* (de Blainville, 1877) on Mauritius. *Z. Sangerierk* 41: 194–6.

Mitchell, E. D. 1975. *Porpoise, Dolphin and Small Whale Fisheries of the World*. Morges, Switzerland. International Union for the Conservation of Nature. IUCN Monograph N:3:129 pp.

Moore, J. C. 1972. More skull characteristics of the beaked whale *Indopacetus pacificus* and comparative measurements of austral relatives. *Fieldiana, Zoology*, 62(1): 1–19.

Ohsumi, S. 1980. Population study of the Bryde's whale in the Southern Hemisphere under scientific permit in the three seasons, 1976/77–1978–79, *Rep. int. Whal. Commn* 30: 319–31.

Ohsumi, S. 1981. Further estimation of population sizes of Bryde's whales in the South Pacific and Indian Ocean using sightings data. *Rep. int. Whal. Commn* 31: 407–15.

Racey, P. A. and M. E. Nicoll, in press. Mammals, Chapter 22. *In:* D. R. Stoddart (ed.) *Ecology and Biogeography of the Seychelles Islands*. Leiden.

Risting, S. 1922. *Av Hvalfangsterns Historie*. J. Petlitz Boktrykkeri, Kristiana. 625 pp.

Robineau, D. 1975. Echourage d'un *Ziphius cavirostri* Cuiver 1823 (Cetacea, Hyperoodontidae) dans d'Archipel des Comores (Ocean Indien). *Mammalia* 32(2): 222–4.

Rørvik, C. J. 1979. Whales and whaling off Mozambique. *Rep. int. Whal. Commn* 31: 233–5.

Ross, G. J. B. 1979. The smaller cetaceans of the southeast coast of southern Africa. Ph.D. dissertation. Dept of Zoology, Univ. of Port Elizabeth, South Africa, 415pp.

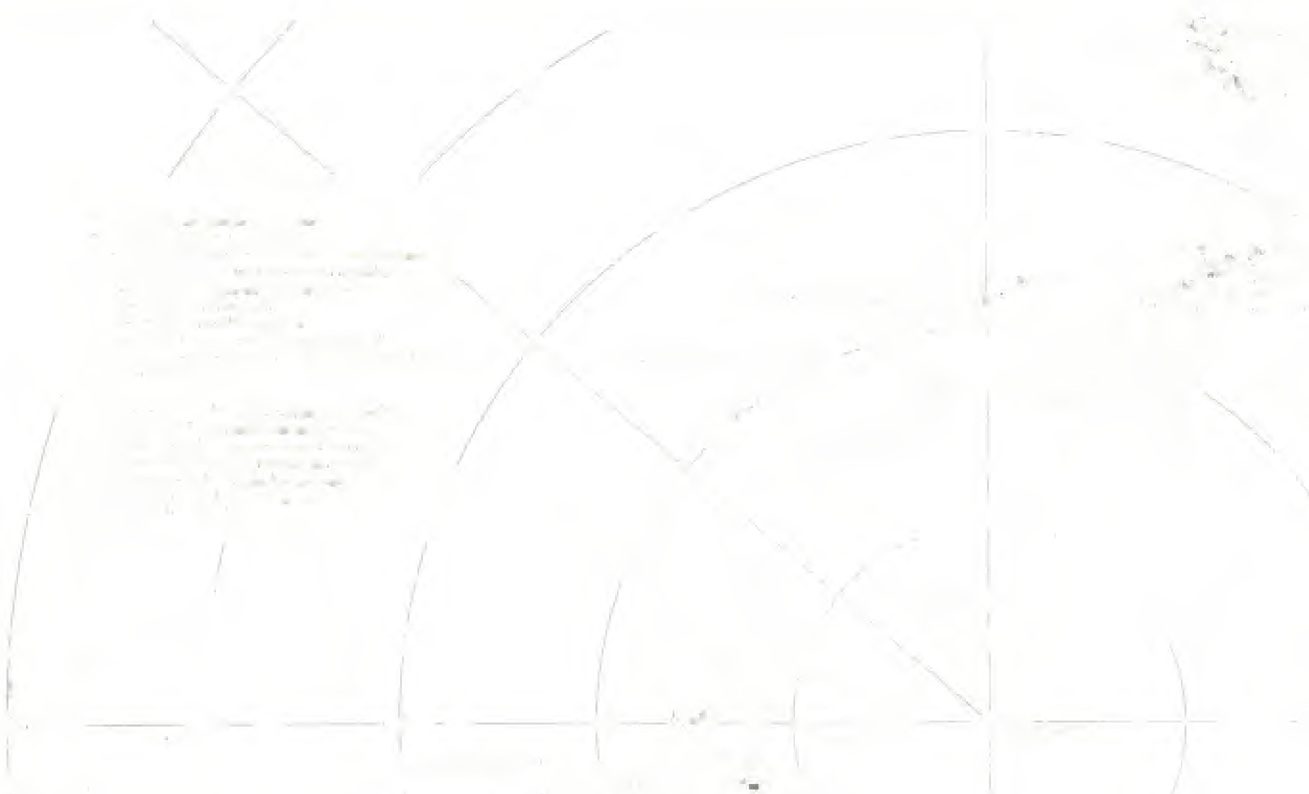
Salm, R. V. 1978. Conservation of Marine Resources in Seychelles. Report on current status and Future Management. Morges, Switzerland. International Union for the Conservation of Nature (IUCN) report. 41 pp.

Tønnessen, J. N. 1967. *Den Moderne Hvalfangsts Historie II.* Kommandor Chr. Christensens Hvalfanstmuseum, Sandefjord, 619 pp.—1969.

Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Sci. Contr. New York Zool. Soc., Zoologica* 19(1): 1–50.

True, F. W. 1894. Notes on Mammals of Balistan and the vale of Kashmir, Presented to the National Museum by Dr W. L. Abbott. Proe. U.S. Nat. Mus., Vol. XVII, pp. 1–16 [No. 976] Smithsonian Inst., USN Mus., Wash: U.S. Govt. Print Office.

Yukhov, V. L. 1969. Observations of cetaceans in the Gulf of Aden and the northwestern part of the Arabic Sea. *In: Morskie Mlekopitayushchie, 3rd All Union conference. Mar. Mamm.*, F.R.B.C. Translation Service. No. 1510.



MATERIALS AND METHODS

Marine mammal and marine bird watches were maintained, weather and other duties permitting, during all daylight hours. Principal observers usually occupied positions as follows, in order of descending frequency for each vessel: *World Discoverer*—the stern deck, elevation 10 m (total watch time about 5 hrs per day); *Glacier*—the bridge, elevation 16 m, flying bridge, elevation 19 m, and crow's nest, elevation 32 m (total watch time between 8 and 12 hrs per day); and *Polar Star*—the bridge, elevation 18 m, flying bridge, elevation 21 m (total watch time between 12 and 14 hrs per day). Vantage points were excellent for all three platforms though slightly better for the icebreakers. Even when observers were not standing watch, we were generally notified by the ship's crew when marine mammals were sighted.

Whenever we encountered cetaceans we noted date, local time, position (read from ship's navigation instrumentation or later interpolated from ship's log), estimated radial bearing and distance of the whales from the ship, and recorded species, number of individuals and details of their behavior. Examination of photographs later permitted verification of some doubtful species identifications. In only a few instances were we able to divert from our cruise track for a closer look, so some whales could not be positively identified.

Sea surface temperature (in degrees Fahrenheit) at the sighting location was read directly from shipboard instruments or later estimated from temperatures recorded in the ship's log. Water depth (in fathoms) at the sighting location was determined directly from the fathometer or precision depth recorder or later interpolated from bathymetric charts.

In all, the three vessels covered an estimated 18,580 nm (34,430 km). For approximately 90 percent of that distance the surface water temperature was below 40°F (4.5°C); for approximately 85 percent it was below 35°F (1.7°C). Because of significant differences in the three platforms, unquantified and irregular effort, and our lack of confidence in subjective estimates from shipboard of distance to whales we decided not to use any of the available transect estimators (see Laake, Burnham and Anderson, 1979; Burnham, Anderson and Laake, 1980; IWC, 1981) to calculate estimates of abundance. Instead, we calculated simple indices of abundance as follows: I_1 = number of sightings (herds) per 100 nm (185 km); I_2 = number of individuals per 100 nm (185 km).

RESULTS AND DISCUSSION

The locations of observations are plotted, by species, in Fig. 1. Indices of abundance have been calculated for cetaceans grouped into three categories: the great whales (all baleen whales and the sperm whale); medium-sized whales (about 4 to 10 m in length); and dolphins/porpoises (Table 1). The majority of groups seen were great whales (63.7%), but there were more dolphin individuals (48.2%) than individuals of either of the other groups.

Great Whales

Reviews of data on great whales and whaling in Southern Seas are contained in Mackintosh (1965), Mackintosh and Brown (1974), and in various reports of the International Whaling Commission and Discovery Expeditions.

We encountered an estimated 0.463 herds and 0.834 individuals of great whales per 100 nm (185 km). Five species were positively identified (Table 2). Of those, minke whales, *Balaenoptera* c.f. *B. acutorostrata*, occurring as individuals and in groups of from 2–7 animals ($\bar{x}$ = 1.9, s = 1.23), were by far the most common, comprising 50 sightings (58.1% of all groups) and 94 individuals (61.0% of all individuals). They also were found over the broadest range, from Cape Horn, throughout the Antarctic waters examined and to nearly 60°S on the crossings to New Zealand. For the 38 instances in which it was noted, water temperatures where minke whales were seen ranged between 30.0° and 42.5°F (−1.0 and 5.9°C) ($\bar{x}$ = 33.7, s = 3.49). The 26 locations where water depth was determined ranged from 250 to 2,250 fathoms (457 to 4,115 m) ($\bar{x}$ = 1,409 (2,577 m), s = 753.7).

Minke whale distribution appeared to be more strongly influenced by still another factor. The majority of minke whales (74%) were seen along the ice edge and not in open water. When the vessels were moving parallel to the ice edge nearly 90% of the minke whales sighted were on the ice side of the ship. In such locations, the whales were observed most frequently cruising along the ice edge, exhibiting highly regular patterns of respiration, or emerging from beneath the ice, swimming slowly in a wide turn while they blew from a few to as many as 15 times, and then resubmerging beneath the ice (Fig. 2). Dives of up to 14 minutes were observed under such instances. When they could be closely approached or observed breaching or 'spyhopping', the whales' appearance could be easily described. All individuals seen were black to dark gray

Table 1

Indices of abundance of cetaceans incidentally observed in southern seas, January–February, 1981. (To convert I_1 and I_2 to km² multiply by 0.29.)

Whale group	No. of cruise miles	No. of sightings	I_1= No. of sightings per 100 nm	No. of individuals	I_2= No. of individuals per 100 nm
Great whales	18,580	86 (63.7%)	0.46	154 (27.0%)	0.83
Medium-sized whales	18,580	24 (17.8%)	0.13	142 (24.9%)	0.71
Dolphins/porpoises	18,580	25 (18.5%)	0.13	275 (48.2%)	1.48
Total	18,580	135	0.72	571	3.02

Table 2

Number of observations, group size, and indices of abundance of great whales incidentally observed in southern seas, January–February, 1981. (to convert I_1 and I_2 to 100 km² multiply by 0.29)

Species	Number of sightings	Number of individuals	Group size		I_1= No. of sightings/ 100 nm	I_2= No. of individuals/ 100 nm
			$\bar{x}$	S_x		
Minke whale *Balaenoptera acutorostrata*	50 (58.1%)	94 (61.0%)	1.90	1.23	0.27	0.51
Humpback whale *Megaptera novaeangliae*	7 (8.1%)	15 (9.7%)	2.14	1.86	0.03	0.08
Fin whale *B. physalus*	1 (0.9%)	1 (0.6%)	—	—	0.01	0.01
Sei whale *B. borealis*	1 (0.9%)	1 (0.6%)	—	—	0.01	0.01
All Rorquals	59 (68.8%)	111 (72.1%)	1.85	1.23	0.32	0.41
Sperm whale *Physeter macrocephalus*	3 (3.5%)	12 (7.8%)	—	—	0.02	0.07
Unidentified	24 (27.9%)	31 (20.1%)	1.29	0.75	0.13	0.17
Total	86	154	1.79	1.36	0.47	0.85

dorsally, lighter ventrally. They were marked by two broad extensions of the lighter ventral color onto the side. The forwardmost light area thinned and continued dorsoanteriorly to form a 'V', with the vertex just behind the blowholes. The chin and the ventrum were also white. On many individuals the light areas were more yellowish than gray or white, presumably due to algal concentrations adhering to the skin. Of special note was the fact that none of the animals clearly seen had a white band or any trace of light on the dorsal surface of the flippers. Variability in flipper coloration or other aspects of color might be useful in distinguishing stocks of minke whales (Tomilin, 1957; Evans and Yablokov, 1978).

Humpback whales, *Megaptera novaeangliae*, were the second most frequently seen great whale, comprising seven groups, fifteen individuals. Humpbacks were encountered seven times, off Cape Adaire, in the Bellinghausen Sea, and along the west side of the Antarctic Peninsula. They were located in water from 31.0° to 34.6°F (−0.6° to 1.5°C) and mostly less than 300 fathoms (550 m) in depth. The one exception, a single animal located in 1,800 fathoms, was nonetheless along the edge of (3,290 m) the steep shelf, just west of Sandefjord Bay, Peter I Island. Several of the groups of humpbacks approached the vessel as if curious, remaining with the ship as long as 1.5 hrs. Similar behavior was observed in the same area in 1979 from the R/V *Hero* (J. Holbrook, pers. comm.).

The three groups of sperm whales, *Physeter macrocephalus*, were all found in pelagic water 46°–50°F (7.8° to 10°C) in temperature, and greater than 1,500 fathoms (2,740 m) deep.

A single sei whale, *B. borealis*, was seen off Balleny Islands, in 700 fathoms; a single fin whale, *B. physalus*, was seen off Cape Horn.

Twenty-four groups (28%) of the great whales encountered could not be positively identified to species. Twenty of those groups were most certainly balaenopterid whales, and ten of those were tentatively identified as minke whales.

Other Cetaceans

The most useful summary of records of medium sized whales and dolphins/porpoises in Antarctic and adjacent subantarctic waters was provided by Brownell (1974). That summary is expanded in Table 3 to indicate occurrence by species in Antarctic Areas I–VI and in subantarctic waters contiguous with those Areas.

Medium Sized Whales

We encountered an estimated 0.129 herds and 0.710 individuals of medium-sized whales per 100 nm (185 km). Four species were positively identified (Table 4).

Killer whales, *Orcinus orca*, were the most frequent. The nine groups seen, totalling 93 individuals, occurred as singles or in groups of 2 to 30 ($\bar{x}$ = 10.33, s = 11.79). Except for two groups seen in open water off Cape Adaire all sightings were along the ice edge in water less than 400 fathoms (730 m) in depth and 32°F (0°C) in temperature.

Pilot whales, *Globicephala* sp., were seen on six occasions, as individuals or groups of up to 15 ($\bar{x}$ = 5.33, s = 5.61). Water temperatures ranged from 33.8° to 53°F (1° to 12°C). All sightings were in water between 1,400 and 2,500 fathoms (2,560 and 4,570 m) deep.

Southern bottlenose whales, *Hyperoodon ampullatus*, were encountered on three occasions in the following depths and water temperatures: a group of two, 35.7°F (2°C), 1,820 fathoms (3,330 m); a group of three, 35.8°F (2°C), 1,740 fathoms (3,180 m); and a single individual, 32.4°F (0.3°C), 1,845 fathoms (3,375 m). In two of the three encounters the whales were extremely animated, creating considerable disturbance as they approached the vessel obliquely from the stern, closed to within 100 m, and then retreated abeam. They must have reached speeds in excess of 15 kts (28 km/m) to overtake the vessel, which

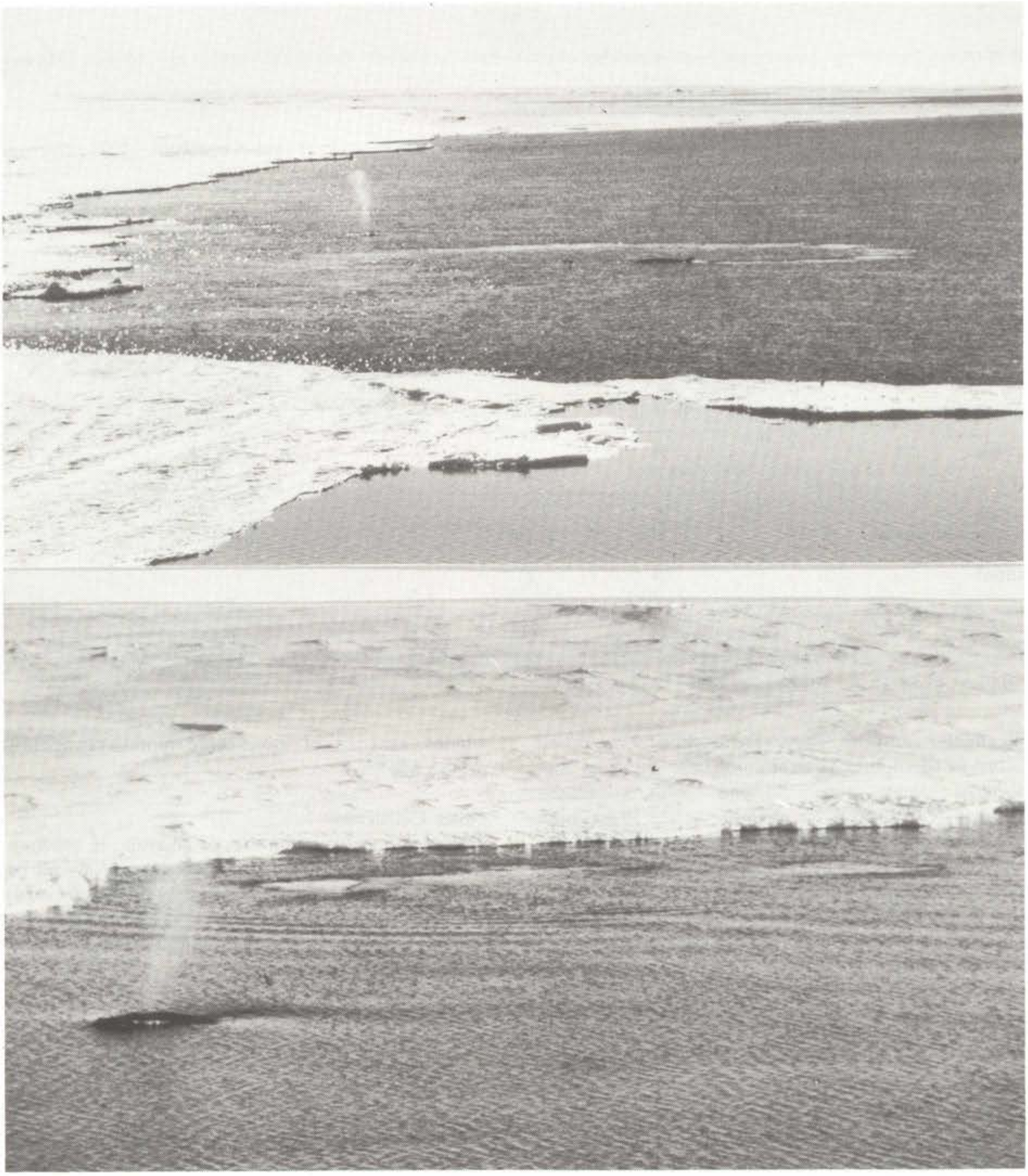


Fig. 2. Minke whales near the fast-ice edge in the southwestern Ross Sea. Note the arrangement of the slicks, parallel to the ice edge (bottom) and semicircular (top). This second pattern was a typical record of whales emerging from under the ice into open water and briefly hyperventilating before resubmerging under the ice.

was travelling at 11–12 kts (20.3–22.2 km/m). When reaching burst speeds, the whales half-breached, clearly presenting features at the cape, head, beak and body proportions sufficient for identification.

Arnoux's beaked whales, *Berardius arnuxii*, were encountered on two occasions, a pair in water 32°F (0°C) and 1,988 fathoms (3,636 m) and an individual in water 39°F (3.9°C) and 1,959 fathoms (3,583). Identification was facilitated by the animals' propensity for surfacing at angles steep to water surface, exposing much of the beak, head and upper body nearly to the flippers, and by the small, sub-triangular dorsal fin. This species has not been previously reported from Area VI (Brownell, 1974).

Of the four instances in which medium sized whales encountered could not be positively identified, two groups were most likely pilot whales and one individual was tentatively identified as a beaked whale.

Dolphins/Porpoises

We encountered an estimated 0.135 herds and 1.480 individuals of dolphins, and, possibly, porpoises per 100 nm (185 km) (Table 5). Five species were positively identified. Of the 25 herds and 275 individuals encountered, 13 herds and 140 individuals were members of the genus *Lagenorhynchus*.

Table 3

Known distribution of medium-sized whales, dolphins and porpoises of Antarctic and subantarctic waters by Antarctic whaling Areas (I–VI) and subantarctic waters contiguous with those areas (Ia–VIa).

	Killer whale	Pilot whale	Southern bottlenose whale	Arnoux's beaked whale	Hourglass dolphin	Peale's dolphin	Dusky dolphin	Southern right whale dolphin	Commerson's dolphin
Brownell (1974)	I, Ia II, IIa III IV V, Va VI	Ia IIa III, IIIa V, Va VI, VIa	I, Ia II, IIa III IV V, Va VI	Ia V	I, Ia II, IIa III, IIIa IV, IVa VI, VIa	Ia	Ia IIa IIIa IVa Va	I, Ia IIa IIIa Va VIa	Ia IIa IIIa
Present Paper	I II V VI	VI, VIa	I VI	VI	Ia VI	Ia	VIa		

Table 4

Number of observations, group size, and indices of abundance of medium-sized whales incidentally observed in southern seas, January–February 1981. (To convert I_1 and I_2 to 100 km² multiply by 0.29.)

Species	Number of sightings	Number of individuals	Group size			I_1= No. of sightings/ 100 nm	I_2= No. of individuals/ 100 nm
			Range	$\bar{x}$	S_x		
Killer whale *Orcinus orca*	9	93	1–30	10.33	11.79	0.05	0.51
Pilot whale *Globicephala* sp.	6	32	1–15	5.33	5.61	0.03	0.17
Southern bottlenose whale *Hyperoodon planifrons*	3	6	1–3	—	—	0.02	0.03
Arnoux's beaked whale *Berardius arnuxii*	2	3	1–2	—	—	0.01	0.02
Unidentified	4	8	1–4	—	—	0.02	0.04
Total	24	142	1–30	5.92	8.35	0.13	0.77

Table 5

Number of observations, group size, and indices of abundance of dolphins/porpoises observed in southern seas, January–February 1981. (To convert I_1 and I_2 to 100 km² multiply by 0.29.)

Species	Number of sightings	Number of individuals	Group size			I_1= No. of sightings/ 100 nm	I_2= No. of individuals/ 100 nm
			Range	$\bar{x}$	S_x		
Hourglass dolphins *Lagenorhynchus cruciger*	5	33	1–20	6.6	8.44	0.03	0.18
Dusky dolphin *L. obscurus*	5	53	4–20	10.6	8.59	0.03	0.29
Unidentified *Lagenorhynchus* sp.	2	40	—	—	—	0.01	0.22
Peale's dolphin *L. australis*	1	6	—	—	—	0.01	0.03
All *Lagenorhynchus*	13	140	1–40	10.77	11.37	0.07	0.75
Common dolphin *Delphinus delphis*	3	106	1–70	—	—	0.02	0.57
Bottlenose dolphin *Tursiops* sp.	1	5	—	—	—	0.01	0.03
Unidentified	8	24	1–6	3.0	2.0	0.04	0.13
Total	25	275	1–70	11.0	16.18	0.22	2.20

Hourglass dolphins, *L. cruciger*, occurring as individuals or in groups of 10 to 20, ($\bar{x} = 6.6$, $s = 8.44$), were encountered in open, pelagic water, 1,800–1,900 fathoms (3,290–3,475 m) deep (x = 1,857 fathoms (3,396.5 m), $s = 67.7$), between Cape Horn and Palmer Station and again between Cape Adaire and Campbell Island. Dusky dolphins, *L. obscurus*, were seen off South America and between both Campbell and Auckland Islands and South Island, New Zealand. Water temperature and depth at the one location were 52.3°F (11.4°C) and 900 fathoms (1,645 m) respectively. Six Peale's dolphins, *L. australis*, approached the vessel off Falkland Islands; and two additional groups of unidentified *Lagenorhynchus* were observed briefly at a distance just south of Cape Horn.

Herds of common dolphins, *Delphinus delphis*, were seen at three locations, all off eastern New Zealand, in water from 48–55°F (9–12.9°C) and 800 to 2,000 fathoms (1,465–3,660 m) deep.

A single group of five bottlenose dolphins, *Tursiops* cf. *T. truncatus*, skirted the vessel as it hove-to in water 56.2°f (13.6°C) and 660 fathoms (1,210 m) deep, outside Wellington Harbor.

REFERENCES

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monograph* No. 72. 202 pp. (Supplement to *J. Wildl. Manage.* 44(2).)

Brownell, R. L. 1974. Small odontocetes of the Antarctic. pp. 13–19. *In:* V. C. Bushnell (ed), *Antarctic Map Folio Series*—Folio 18. Washington, D.C. Office of Polar Programs, National Science Foundation. Published by American Geographical Society, New York.

Evans, W. E. and Yablokov, A. V. 1978. Intraspecific variation of the color pattern in the killer whale (*Orcinus orca*). N. K. Kot'tzoff Inst. Developmental Biol., Acad. of Sci., Moscow, USSR; available from HSWRI, 20 pp.

International Whaling Commission. 1982. Report of the Workshop on the design of sighting surveys. (Published in this volume.)

Laake, J. L., Burnham, K. P., and Anderson, D. R. 1979. *User's Manual for Program Transect.* Utah State Univ. Press. Logan, Utah. 26 pp.

Mackintosh, N. A. 1965. *The Stocks of Whales.* British Museum (Natural History), Fishing News (Books) Ltd. 232 pp.

Mackintosh, N. A., and Brown, S. G. 1974. Whales and whaling. pp. 2–4. *In:* V. C. Bushnell (ed), *Antarctic Map Folio Series*—Folio 18. Washington, D.C. Office of Polar Programs, National Science Foundation. Published by American Geographical Society, New York.

Tomilin, A. G. 1957. *Mammals of the U.S.S.R. and Adjacent Countries.* Moskva; Dztatel'stvo Akademi Nauk, SSSR.

SC/33/O 12

Whale Sightings from a Norwegian Small-type Whaling Vessel off West Greenland, June–August 1980

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ABSTRACT

Observations of whales from the Norwegian small-type whaling vessel operating off West Greenland were recorded in 1980 together with data on weather conditions, as in 1979. Data on distance sailed during observation were also recorded. These data are discussed in an attempt to analyse any relationship between the number of whales seen, and the time, or weather condition. It is concluded that although the data contribute to the general knowledge on the distribution of whales off West Greenland, they do not allow any refined estimation of numbers, or stock size.

INTRODUCTION

Information on occasional observations on the occurrence of whales in the Davis Strait is available in a number of previous publications (e.g. Christensen, 1974; 1977; 1980; Hjort and Ruud, 1929; Kapel, 1979), but these data give little information on relative abundance.

Observations of whales from the Norwegian vessel *Kato* during minke whaling off West Greenland in 1979, were presented in a previous paper (Larsen, 1980). In 1980 Danish scientists participated in a similar cruise on the same vessel in the periods 27 June to 4 August (FL) and 13 August to 24 August (FK). Following the whaling season the vessel was chartered for a marking experiment which, unfortunately, had to be discontinued on 30 August due to leakage. (Marking results are given in Anon., 1982). An analysis of the catch of minke whales is given in Kapel and Larsen (1982). The present paper deals with sightings of all whale species during the cruise.

MATERIAL AND METHODS

Most observations were recorded by the scientists in cooperation with the crew. During catching and searching operations one crew member was posted on the top of the wheelhouse and another in the crow's nest. When the scientist was otherwise occupied, e.g. taking samples from the catch, sightings were recorded by these crew members and the captain.

Data on time, position, species, numbers, wind force and visibility were recorded for each observation. Occasional observations were recorded by the crew between the arrival into Greenland waters on 3 June and 27 June when a Danish observer joined the cruise. These data are available from the authors and from the International Whaling Commission Secretariat.

In order to reduce the number of possible repeated sightings, it was attempted to keep track of the movements of individual whales within visual range. Whenever a certain whale was considered recorded once, repeated sightings were not noted.

The time and position of the sightings were obtained from the satellite navigation equipment of the vessel. When this equipment was out of action for a short period, an ordinary wrist watch and the *Decca* position system was used.

The distance sailed was calculated from the data obtained from the satellite navigator, and occasionally checked against the automatic log recorder. The latter was also used in a few cases to estimate the distance from the ship to a sighted whale.

The wind force was estimated according to the Beaufort scale, and no value exceeding force 4 was recorded during the observation periods (up to wind force 8 was occasionally recorded during resting or drifting periods).

A scale from one to five was used for visibility: 1 = fog, 2 = poor visibility, 3 = moderate visibility, 4 = good visibility, and 5 = excellent visibility. Fog was rather common during the 1980 season, either as dense persistent fog or as fog banks. Systematic sightings were, of course, not carried out in dense fog, but occasionally a whale suddenly appeared among the fog banks, and was recorded as an observation.

In those instances, particularly during reduced visibility, when the exact number of whales could not be determined, an estimate was given. During the marking experiment a distinction was made between whales which were approached closely in order to attempt marking, and more distant sightings which were often recorded only as approximate numbers.

SIGHTINGS

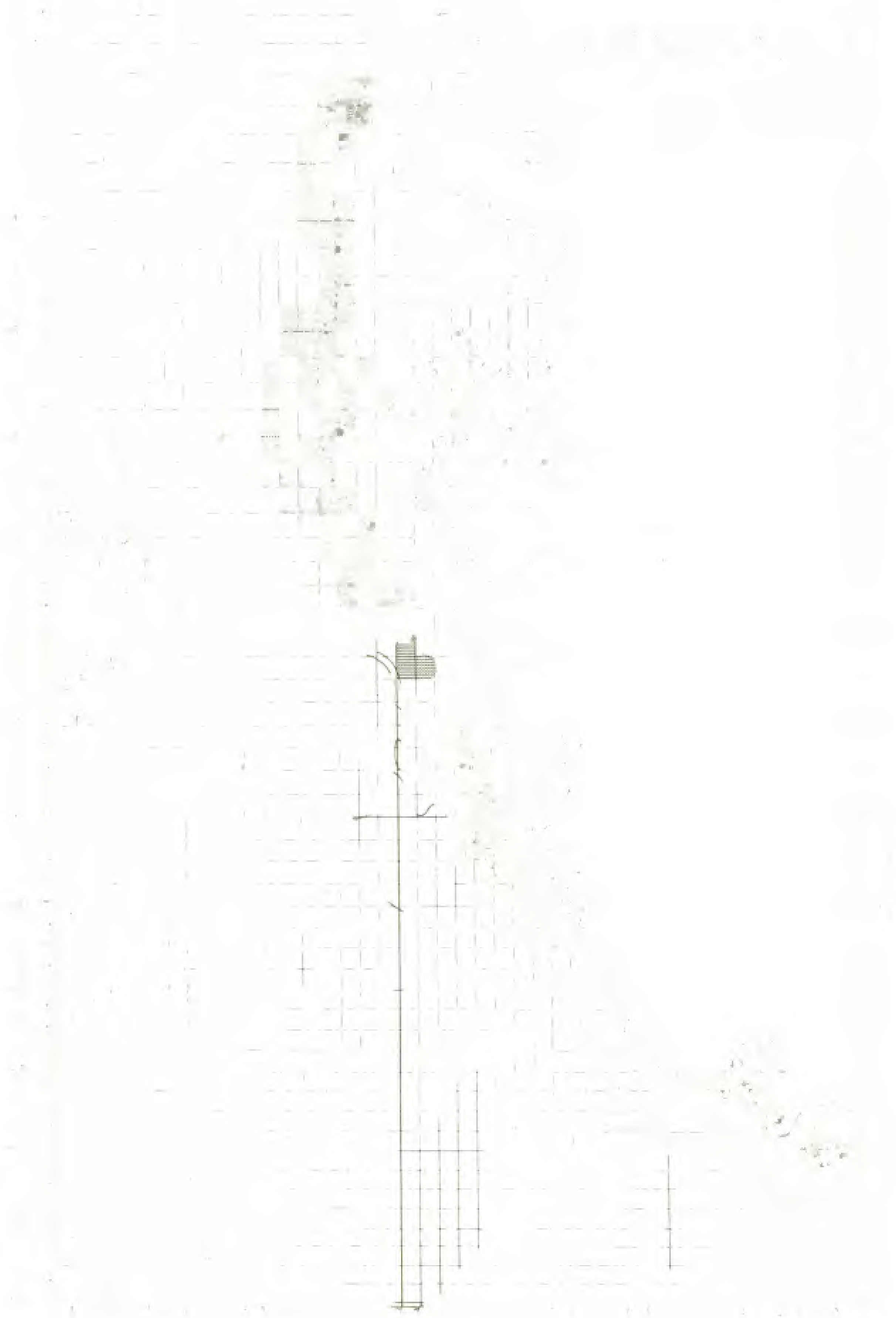
A total of 270 minke whales (*Balaenoptera acutorostrata*), 249 fin whales (*B. physalus*), 3 blue whales (*B. musculus*), 47 humpback whales (*Megaptera novaeangliae*), 29 sperm whales (*Physeter macrocephalus*), and 37 killer whales (*Orcinus orca*) were recorded. Sightings of porpoises and dolphins were not recorded systematically, but harbour porpoises (*Phocoena phocoena*) were seen rather frequently. The distribution of sightings is shown in Figs 1–3.

Sighting rates in relation to area and season

The time spent and the distance sailed within each subarea and 10-days period are summarized in Tables 1–3, and the number of minke, fin, blue, humpback and sperm whales seen are given in Table 4.

The subarea divisions used here are based partly on oceanographic characteristics and bottom topography, and partly on distribution of catches and observations of whales.

[*Text continues on p. 525*]



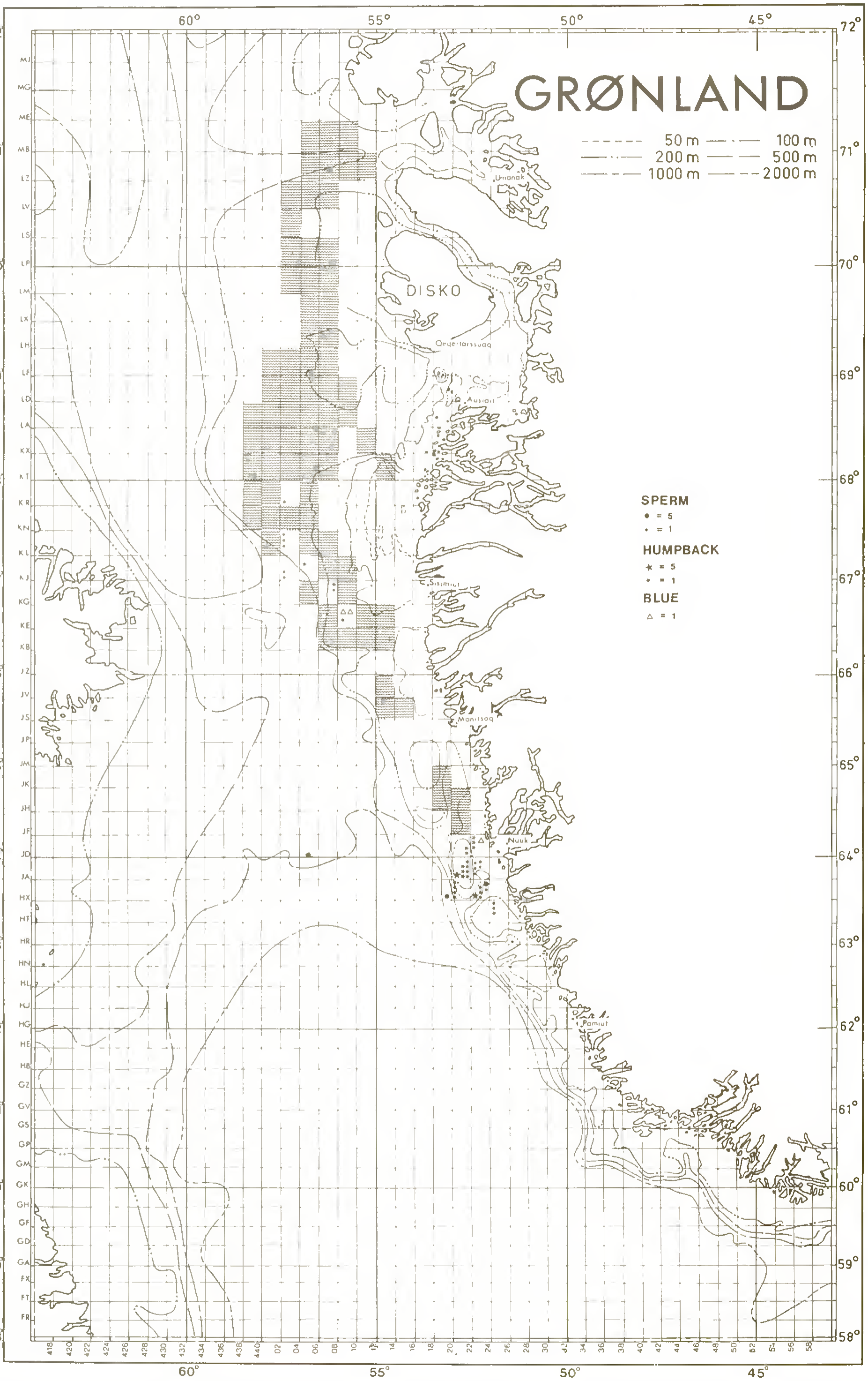


Fig. 3. Geographical distribution of sightings of humpback, sperm, and blue whales from m/s *Kato*, 1980. Shaded rectangles indicate surveyed areas without sightings.

Table 1

Approximate number of hours spent per subarea (4–0) and period.

	10-day period starting									
Subarea	3/6	13/6	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
4 N of 70°00′N	0	0	0	0	0	41	0	0	47	88
3 70°00′–68°30′N	0	0	0	0	17	54	0	5	35	110
2 68°30′–66°15′N	50	104	240	240	223	145	177	235	55	1,468
1 66°15′–64°15′N	24	57	0	0	0	0	46	0	19	145
0 S of 64°15′N	156	80	0	0	0	0	18	0	83	337
All subareas	230	240	240	240	240	240	240	240	238	2,148

Table 2

Estimated total distance sailed within each subarea and period (nautical miles).

4	0	0	0	0	0	165	0	0	211	386
3	0	0	0	0	99	359	0	40	219	717
2	190	159	601	420	869	524	376	877	219	4,237
1	127	250	0	0	0	0	286	0	135	797
0	536	234	0	0	0	0	140	0	510	1,420
All Subareas	853	643	601	420	968	1,049	803	917	1,304	7,557

Table 3

Calculated distance sailed during searching, chasing and sighting periods (nautical miles).

4	—	—	—	—	—	10	—	—	192	202
3	—	—	—	—	99	259	—	0	151	508
2	0	0	346	343	665	195	44	347	45	1,985
1	0	—	—	—	—	—	59	—	47	107
0	0	—	—	—	—	—	91	—	91	182
All subareas	0	0	346	343	764	464	195	347	527	2,984

For the period before 27 June, for 5–12 August, and for 30 August, the time and distance are minimum estimates based on rather few positions. Table 3, however, is based only on calculated distances within the observation periods for which a number of positions and detailed information are available.

From the data in Tables 3 and 4 it is possible to calculate a tentative 'index of abundance' expressed as the number of whales observed in relation to distance sailed (Tables 5.1–5.4). It is obvious that some of these values are of little use, because they are based on too limited data (single whales, few nautical miles). Even when these extremes are disregarded there remains, however, an impression of great variation in densities of whales with time, and from one area to the other. Minke whales were quite abundant in subarea 2 (Store Hellefiske Banke) all through the season whereas densities were low in 1980 at Disko and south of Store Hellefiske Banke (Table 5.1).

Although generally found in the same area as minke whales, fin whales showed great seasonal variation in abundance in subarea 2, and were common on Fylla Banke (subarea O) in late August (Table 5.2). They were often seen in small groups (2–4 animals) whereas minke whales were most often observed as single animals with no apparent attachment between individuals.

Humpback whales (Table 5.3) were only seen twice north of Fylla Banke (SW of Nuuk), whereas sperm whales (Table 5.4, Fig. 3) were observed at several occasions in this area as well as along the western slope of Store Hellefiske Banke. It was striking that not a single minke whale was seen during marking in the area SW of Nuuk in late August, whereas a fair number of fin, humpback, and sperm whales—and a single blue whale was observed.

Sighting rates in relation to weather conditions

In order to investigate whether the available data were sufficient to demonstrate any relationship between weather conditions and sighting rates, the number of whales observed per 100 nautical miles of sighting were calculated separately for excellent, moderate and poor sighting conditions (Tables 6–8).

The same reservation as expressed above with respect to extreme values is even more valid in relation to Tables 7 and 8, particularly concerning the sightings during adverse weather conditions (wind force 3–4, visibility 3–2).

For minke whales the sighting rates appear to show a general decline from optimal conditions with increasing wind, as also suggested by data collected in 1979 (Larsen, 1981). A similar tendency cannot be demonstrated for fin whales.

Table 4

Number of whales observed per period and subarea (4–0). KATO 1980.

	10-day period starting									
	3/6	13/6	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
4.1 Minke										
4 N of 70°00′N	—	—	—	—	—	0	—	—	13	13
3 70°00′–68°30′N	—	—	—	—	6	5	—	0	1	12
2 68°30′–66°15′N	(0)	(2)	53(55)	71(82)	40	19	3	35(36)	2	223(239)
1 66°15′–64°15′N	(0)	(0)	—	—	—	—	1	—	3	4
0 S of 64°15′N	(0)	(0)	—	—	—	—	1	—	0(1)	1(2)
All subareas	(0)	(2)	53(55)	71(82)	46	24	5	35 (36)	19(20)	253(270)
4.2 Fin										
4	—	—	—	—	—	0	—	—	3	3
3	—	—	—	—	7	8	—	0	6	21
2	(0)	(7)	12	100	28(30)	16	0	6	7	169(178)
1	(2)	(0)	—	—	—	—		—	0	0(4)
0	(0)	(13)	—	—	—	—	0	—	14–29(30)	14–29(42)
All subareas	(2)	(20)	12	100	35(37)	24	0(2)	6	30–45(46)	207–222 (249)
4.3 Humpback										
2	(0)	(1)	0	1	0	0	0	0(2)	0	1(4)
1	(0)	(0)	—	—	—	—	0	—	0	0
0	(4)	(0)	—	—	—	—	14	—	13–22(25)	27–36(43)
All subareas	(4)	(1)	0	1	0	0	14	0(2)	13–22(25)	28–37(47)
4.4 Sperm										
2	(0)	(0)	3	4	0	1	0	1	0	9
1	(0)	(0)	—	—	—	—	0	—	0	0
0	(5)	(4)	—	—	—	—	0	—	10(11)	10(20)
All subareas	(5)	(4)	3	4	0	1	0	1	10(11)	19(29)
4.5 Blue										
2	(0)	(0)	(2)	0	0	0	0	0	0	0
1	(0)	(0)	—	—	—	—	0	—	0	0
0	(0)	(0)	—	—	—	—	0	—	1	1
All subareas	(0)	(0)	(2)	0	0	0	0	0	1	1(3)

Note: numbers in parentheses include whales seen occasionally during steaming, drifting and resting.

RELATIVE ABUNDANCE OF DIFFERENT SPECIES

The measure used above to express densities of whales (number per sailed distance) cannot be used directly to calculate the number of animals present. In order to do this it is necessary to know the effective sightings width, and the total distribution area for each species. Neither of these conditions are fulfilled in relation to the present study.

The sighting distance was only measured in a few cases (approximately 2–3 times as large for fin whales as for minke whales). The total area of occurrence for the different species off West Greenland is still unknown, and it appears from the data presented here that densities are extremely variable which will make extrapolation from a chosen value a doubtful procedure.

In conclusion, the data collected in 1980 on distribution and abundance of whales off West Greenland are too limited to allow an estimation of the number of whales present in that area or of stock sizes. They do, however, add considerably to the knowledge of relative abundance and variation in respect to time, area and species. Finally, they may prove useful for comparison with similar data to be collected in future.

ACKNOWLEDGEMENTS

We wish to express our gratitude to the owners and crew of the Norwegian vessel *Kato* for kind assistance during the cruise in 1980.

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REFERENCES

Anon. 1982. Denmark (Greenland). Progress report on cetacean research. Paper SC/33ProgRep Denmark (published in this volume).

Christensen, I. 1977. Observations of whales in the North Atlantic. *Rep. int. Whal. Commn* 27: 388–97.

Table 5

Number of whales observed per 100 nautical miles of sighting per period and subarea (0–4).

	10-day period starting							
	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
5.1 Minke								
4 N of 70°00′N	—	—	—	0	—	—	6.76	6.42
3 70°00′–68°30′N	—	—	6.09	1.93	—	—	0.66	2.36
2 68°30′–66°15′N	15.34	20.73	6.01	9.74	6.80	10.07	4.41	11.23
1 66°15′–64°15′N	—	—	—	—	1.69	—	6.34	3.76
0 S of 64°15′N	—	—	—	—	1.10	—	0	0.55
All subareas	15.34	20.73	6.02	5.17	2.57	10.07	3.61	8.48
5.2 Fin								
4	—	—	—	0	—	—	1.55	1.48
3	—	—	7.11	3.09	—	—	3.97	4.13
2	3.47	29.20	4.21	8.20	0	1.73	15.42	8.51
1	—	—	—	—	0	—	0	0
0	—	—	—	—	0	—	15.42–31.94	7.69–15.93
All subareas	3.47	29.20	4.58	5.17	0	1.73	5.69–8.54	6.94–7.44
5.3 Humpback								
2	0	0.29	0	0	0	0	0	0.05
1	—	—	—	—	0	—	0	0
0	—	—	—	—	15.35	—	14.32–24.23	14.84–19.78
All subareas	0	0.29	0	0	7.20	0	2.47–4.18	0.94–1.24
5.4 Sperm								
2	0.87	1.17	0	0.51	0	0.29	0	0.45
1	—	—	—	—	0	—	0	0
0	—	—	—	—	0	—	11.01	5.49
All subareas	0.87	1.17	0	0.22	0	0.29	1.90	0.64

Christensen, I. 1974. Minke whale investigations in the Barents Sea and off East and West Greenland in 1973. *Fiskets Gang* 60: 278–86.

Christensen, I. 1980. Observations of large whales (minke not included) in the North Atlantic 1976–78 and markings of fin, sperm and humpback whales in 1978. *Rep. int. Whal. Commn* 30: 205–8.

Hjort, J. and Ruud, J. T. 1929. Whaling and fishing in the North Atlantic. *Rapp. Cons. Explor. Mer* 56(1): 1–123.

Kapel, F. O. 1979. Exploitation of large whales in West Greenland in the Twentieth Century. *Rep. int. Whal. Commn* 29: 197–214.

Kapel, F. O. and Larsen, F. 1982. Norwegian minke whaling of West Greenland, 1976–1980, and biological studies of West Greenland minke whales. Paper SC/33/Mi5 (published in this volume).

Larsen, F. 1981. Observations of large whales off West Greenland, 1979. *Rep. int. Whal. Commn* 31: 617–23.

[*Tables 6–8 are on the following 3 pages*]

Table 6

Distance sailed during sighting under different weather conditions per period and subarea (nautical miles).

Windforce 0–2	10-day period starting							
Visibility 5–4	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
4 N of 70°00′N	—	—	—	0	—	—	192.3	192.3
3 70°00′–68°30′N	—	—	15.9	258.6	—	0	151.1	425.7
2 68°30′–66°15′N	253.4	243.6	456.4	182.5	0	143.6	32.5	1312.0
1 66°15′–64°15′N	—	—	—	—	0	—	47.3	47.3
0 S of 64°15′N	—	—	—	—	0	—	90.8	90.8
Sum	253.4	243.6	472.3	441.1	0	143.6	514.0	2068.1
Windforce 3–4 Visibility 5–4								
4	—	—	—	10.1	—	—	0	10.1
3	—	—	0	0	—	0	0	0
2	92.1	21.4	79.0	11.6	43.1	9.1	12.9	269.2
1	—	—	—	—	0	—	0	0
0	—	—	—	—	0	—	0	0
Sum	92.1	21.4	79.0	21.7	43.1	9.1	12.9	179.3
Windforce 0–2 Visibility 3–2								
4	—	—	—	0	—	—	0	0
3	—	—	13.5	1.1	—	0	0	14.6
2	0	4.7	98.8	1.0	1.0	194.7	0	300.2
1	—	—	—	—	59.2	—	0	59.2
0	—	—	—	—	91.2	—	0	91.2
Sum	0	4.7	112.3	2.1	151.4	194.7	0	465.2
Windforce 3–4 Visibility 3–2								
4	—	—	—	0	—	—	0	0
3	—	—	69.1	0	—	0	0	69.1
2	0	72.8	31.1	0	0	0	0	103.9
1	—	—	—	—	0	—	0	0
0	—	—	—	—	0	—	0	0
Sum	0	72.8	100.2	0	0	0	0	173.0

Table 7

Number of minke whales observed per 100 nautical miles of sighting under different weather conditions, per 10-days period and subarea.

Windforce 0–2	10-day period starting							
Visibility 5–4	23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
4 N of 70°00′N	—	—	—	—	—	—	6.76	6.76
3 70°00′–68°30′N	—	—	18.87	1.93	—	—	0.66	2.11
2 68°30′–66°15′N	20.53	20.53	8.76	10.41	—	7.66	0	13.11
1 66°15′–64°15′N	—	—	—	—	—	—	6.34	6.34
0 S of 64°15′N	—	—	—	—	—	—	0	0
Sum	20.53	20.53	9.10	5.44	—	7.66	3.31	9.53
Windforce 3–4								
Visibility 5–4								
4	—	—	—	0	—	—	—	0
3	—	—	—	—	—	—	—	—
2	1.09	14.02	0	0	2.32	10.99	15.50	2.97
1	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—
Sum	1.09	14.02	0	0	2.32	10.99	15.50	2.97
Windforce 0–2								
Visibility 3–2								
4	—	—	—	—	—	—	—	—
3	—	—	14.81	0	—	—	—	13.70
2	—	0	0	0	200.00	11.81	—	9.29
1	—	—	—	—	1.64	—	—	1.69
0	—	—	—	—	1.10	—	—	1.10
Sum	—	0	1.78	0	2.64	11.81	—	6.23
Windforce 3–4								
Visibility 3–2								
4	—	—	—	—	—	—	—	—
3	—	—	1.45	—	—	—	—	1.45
2	—	24.73	0	—	—	—	—	17.32
1	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—
Sum	—	24.73	1.00	—	—	—	—	10.98

Table 8

Number of fin whales observed per 100 nautical miles of sighting under different weather conditions, per 10-days period and subarea (0–4).

Windforce 0–2 Visibility 5–4	10-day period starting 23/6	3/7	13/7	23/7	2/8	12/8	22/8	Total
4 N of 70°00′N	—	—	—	—	—	—	1.56	1.56
3 70°00′–68°30′N	—	—	12.58	3.09	—	—	3.97	4.23
2 68°30′–66°15′N	3.55	21.76	5.92	0.55	—	2.09	3.08	7.16
1 66°15′–64°15′N	—	—	—	—	—	—	0	0
0 S of 45°15′N	—	—	—	—	—	—	15.54–32.19	15.54–32.19
All subareas	3.55	21.76	6.14	2.04	—	2.09	4.67–7.59	6.24–6.96
Windforce 3–4 Visibility 5–4								
4	—	—	—	0	—	—	—	0
3	—	—	—	—	—	—	—	—
2	3.26	144.86	0	129.31	0	0	46.51	20.43
1	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—
All subareas	3.26	144.86	0	69.12	0	0	46.51	19.69
Windforce 0–2 Visibility 3–2								
4	—	—	—	—	—	—	—	—
3	—	—	37.04	0	—	—	—	34.25
2	—	21.28	1.01	0	0	1.54	—	1.67
1	—	—	—	—	0	—	—	0
0	—	—	—	—	0	—	—	0
All subareas	—	21.28	5.34	0	0	1.54	—	2.15
Windforce 3–4 Visibility 3–2								
4	—	—	—	—	—	—	—	—
3	—	—	0	—	—	—	—	0
2	—	20.60	0	—	—	—	—	14.44
1	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—
All subareas	—	20.60	0	—	—	—	—	8.67

SC/33/Rep 2

Report of the Workshop on the Design of Sightings Surveys

The workshop convened at 9.00 am on 11 September 1980 and following days, at the Northwest and Alaska Fisheries Center, Seattle, Washington. Participants are listed in Annex B.

1. GREETING BY CENTER DIRECTOR

Dr W. Aron, Director, Northwest and Alaska Fisheries Center, graciously welcomed the participants to Seattle.

2. ARRANGEMENTS

Participants were informed of arrangements to bring them to and from their lodgings. Computer access was arranged through a tie-in with the University of Washington Academic Computer Center.

3. APPOINTMENT OF CHAIRMAN

Dr D. G. Chapman was appointed Chairman.

4. APPOINTMENT OF RAPPORTEURS

Mizroch and Breiwick were appointed rapporteurs.

5. REVIEW OF AGENDA

The agenda (see Annex A) was reviewed and adopted.

6. REVIEW OF WHALE BIOLOGY AND BEHAVIOUR

SS/1 (see Annex C) discussed the biology of whales in relation to the applicability of sighting theory for population estimation. Mitchell showed a series of slide photographs which pointed out some of the problems in identifying whales located at varying distances from the platform of observation (aerial or shipboard) and also showed some of the difficulties posed by different environmental conditions, such as differing sea states, and presence or absence of glare.

It was suggested in SS/8 that 'sightability' should be standardised by creating an index of sighting conditions, which could be used as a means of compensating for whales missed due to poor sighting conditions. Some participants (Horwood, Krogman, Reilly, Bouchet) briefly described their own sightability indexing systems.

Chapman suggested that we need to distinguish between two different problems: (1) how to account for those whales that are located directly along the trackline but are not seen because they are diving or for other reasons, and (2) how to quantify the sighting or behavioural factors that affect the ability to view those whales that are located some distance from the trackline.

7. REVIEW OF ONGOING SURVEYS: PROGRESS AND PROBLEMS

7.1 Tuna/Porpoise Survey

Smith described the studies which the Southwest Fisheries Center has conducted to estimate abundance of porpoises. Porpoises are sighted using three types of platforms: (1) aircraft, (2) research vessels, and (3) commercial tuna boats. Data collected include the perpendicular distance from the trackline to the school of porpoises when the observations were made from an aircraft, and radial distance and the angle of observation for vessel surveys.

Factors which appear to cause problems with the survey data are: (1) the estimation of perpendicular and radial distances and angles may not be accurate, (2) the search for porpoise schools by commercial tuna boats may not be random, and (3) the school sizes may not be comparable among platforms/methods because the tuna fleet may select schools of certain sizes or species. Holt described the problems associated with the large size of the area of study (five million square miles) and the merits and problems of different platforms of observation. Chapman mentioned some of the problems that have been identified in porpoise abundance estimation:

(1) uncertainties in identification of the species composition of the different schools of porpoise sighted (generally more serious in aerial than in shipboard surveys owing to shorter observation times possible);
(2) errors in estimating the exact number of porpoises within a school;
(3) the appropriate use of sightings data when animals are seen off the trackline subsequent to the initial sighting (i.e. secondary sightings);
(4) failure to sight all animals that are present directly on the trackline.

7.2 Walrus survey

SS/11 described walrus populations which had been studied using aerial survey techniques. The extreme clustering and large daily variability (between and within days) of walrus distribution on ice and in water, as well as the significant daily shifts in ice position, were serious problems in analysing these data.

7.3 IDCR Southern minke whale survey

Best summarised the International Decade of Cetacean Research (IDCR) minke whale survey reports (SS/2, SS/13).

7.4 Japanese whale sightings surveys

SS/17 described the Japanese sighting system and the various sightings studies conducted by Japan. It particularly noted that survey coverage has been decreasing as whale catches have been reduced.

7.5 U.S. Bureau of Land Management sponsored CETAP surveys

SS/18 presented an overview of the problems and progress in surveys conducted by the Cetacean and Turtle Assessment Program (CETAP) at the University of Rhode Island. Several of the perceived problems in the CETAP study were also seen in the tuna/porpoise study including species identification and errors in estimating group sizes, especially for the porpoise species encountered. Additional problems, however, are unique to CETAP. These include the fact that the study is a multispecies one and, for this reason, the sampling design cannot be considered optimal for any single species. Secondly the study area is large (277,000 km^2) and cannot be sampled in a synoptic fashion. Therefore estimates of abundance must only be considered valid for the specific date and area of the sample taken. A final problem is that the study was designed with geographically specific rather than species specific goals. Estimates of abundance may not represent stock levels in the western North Atlantic except in the few special cases where the entire stock range is within the study area.

In spite of the problems identified, CETAP has made a great deal of progress. The CETAP aerial sampling programme is the only large scale sampling effort designed and implemented to estimate the spatio-temporal distributions and abundances of the cetacean and marine turtle species occurring in waters over the eastern US outer continental shelf. The sampling design and data collection methods are consistent with the most current models for estimating species abundance, and the data management system is flexible and responsive enough to allow revisions of sampling design when revisions are inferred (e.g. the stratified design was based on the results of the first year's effort). Environmental data are collected in such a manner to allow correlative analyses between species distributions and physical factors such as depth and surface water temperature. Continuation of the sampling effort will enable the development of a sufficient time-series data base for analysis of trends in seasonal abundance and distribution.

8. REVIEW OF METHODS OF ANALYSIS AND ASSUMPTIONS

8.1 and 8.2 Traditional sightings models, and non-parametric or distribution-free models

Line and strip transect theory were discussed by Burnham. An extensive review of this theory is presented in SS/4. It was stressed that it is important to have both a well-designed survey programme and careful analysis of the data. A survey should be designed to cover areas that are representative of the population, either by using randomly placed tracklines, or by using systematic placement of the lines, based on some prior knowledge of the population being examined. When analysing data, it is important to choose a detection function that represents the distribution of the sightings data. Points to consider when choosing a detection function are the robustness of the model and the effect of the pooling of sightings information on the final estimate (pooling robustness). Various parametric and non-parametric models were discussed, and Burnham felt that the non-parametric Fourier series estimator was a good model to choose for cetacean populations, because of its generality and the shapes of its family of curves. With a Fourier series model, the probability of sighting an animal declines slowly near the trackline and then decreases more rapidly with increasing distance from the trackline. Some problems with line transect theory that are to be addressed later include:

1. Since sighting theory assumes that animals are stationary with respect to a moving observer, what is the effect of animal movement on the population or density estimate?
2. If detection of the animals is related to cluster size, how does this affect the population or density estimate? (Some information on this is found in SS/4, Appendix D, SS/14, and Quinn, 1979; 1980.)
3. If some animals that are directly on the trackline are not sighted, how is the estimate to be modified? (One approach to deal with this is in SS/4.)
4. What is the effect of simultaneous errors or bias in angle and distance measurement?
5. What is the effect of grouping both radial distance and bearing measures into intervals when estimating f(0) from right angle distances?

Koopman described some theories of searching that were developed during World War II for military use in locating submarines. The theories, which are described in more detail in Koopman (1980), are summarised briefly below.

The simplest theory is based on the assumption that everything within a strip of width W is seen and nothing outside that strip appears. More realistically, the probability of sighting an object from the transect line drops off gradually with distance from the origin, and the model in this case would be continuous. However, if the area under the continuous function equals the area under the step function, it is expected that the same number of animals would be seen (called equivalent search law), and hence an effective sweep width can be defined.

The probability of detecting an object in a short period of time $(t, t + dt)$ is γdt. Here γ is proportional to the visual contrast experienced by the observer (C), and to the solid angle from the object to the observer (Ω). The contrast can be expressed as a function of range R and meteorological visibility V by the equation

$$C = C_o \exp(-3.912\ R/V)$$

where C_o is the intrinsic contrast of target to background. The angle Ω is proportional to the actual size of the object, and this proportionality can be expressed as the angle Ω is proportional to (actual projection/R^k). The power k of R varies usually from one to three depending on the visual cues observed. R^3 would be appropriate for a three dimensional object (e.g. wake), R^2 for an object in which the surface area is primarily visible and R for an object that appears to be a straight line.

Let P(t) be the probability of at least one detection during the time period (t_o, t). Then $Q(t) = 1 - P(t)$ is the probability of no detection during t_o, t.

By probability theory, $Q(t + dt) = Q(t)Q(dt|\text{no detection during } t_o, t)$. By assumed independence $Q(dt|\text{no detection during } t_o, t) = Q(dt)$. Then $Q(dt) = 1 - P(dt) = 1 - \gamma(t)dt$. Hence

$$Q(t + dt) = Q(t)\,(1 - \gamma(t)dt)$$

or

$$\frac{dQ(t)}{dt} = -\gamma(t)Q(t).$$

Given the reasonable initial condition $Q(t_o) = 1$, the solution is

$$Q(t) = \exp\{-\int_{t_o}^{t} \gamma(u)du\}.$$

Hence

$$P(t) = 1 - \exp\{-\int_{t_o}^{t} \gamma(u)du\}$$

Now P(t) will in general depend on a set of parameters due to external conditions which can be denoted by α. Thus the overall probability of sighting is

$$P(t) = \int P(t,\alpha)d\alpha = \int (1 - \exp\{-\int_{t_o}^{t} (u,\alpha)du\})d\alpha.$$

Transforming polar coordinates to Cartesian coordinates, the effective sweep width (W) can be defined as

$$W = \int P(y)dy$$

where y is the perpendicular distance from the vessel course.

The density (D) of objects in an area can be calculated using N, the number of objects sighted along a trackline of length L in the area A in which they are uniformly distributed:

$$\text{Number observed} = AD\{1 - \exp(-WL/A)\}$$

Note that this theory has not taken into account the possible directed movement of the target relative to the observer.

Doi described his studies of whale sighting theory, which is presented in detail in papers SS/9, SS/10, and supplement SS/10a. Doi considers many biological and behavioural aspects of both the whale (diving time, blowing time) and the observer (angular velocity of eye scanning, physiological discrimination), as well as characteristics of the viewing platform (speed, mast height, sighting range).

Doi's angle of observation covered by the observer is theoretically ±90°, but Doi determined empirically that the actual angle was closer to ±50° and that sightings dropped off at greater angles. Observers actually use high power binoculars with limited angle vision (5–7°) and sweep the total angle of observation noted above.

Doi's expression for the proportion of whales missed by observers $(1 - K_\omega)$ was discussed, as were correction factors, taking the behaviour of the whale into account. For example, it was determined in SS/2 that a minke is expected to surface about five times during a vessel's transit through the area within which an animal is within visual range. Butterworth and others suggested that Doi's expression

$$K_\omega = 1 - (1 - \frac{\theta p + \tfrac{1}{2}\omega\tau}{2\theta})^s$$

where s = number of observers, ω = angular velocity of eye-scanning, 2θ = theoretical visual angle of observers, θ_p = actual visual angle of observers, and τ = the whale's breathing time at the surface, should be adjusted by multiplying s by the number of instances an animal is expected to surface while in visual range. However, Doi believes that his function does not need a correction, and that K_ω is equivalent to g(0) of line transect theory (i.e. the probability of sighting an animal along the trackline). Others, however, stated that it does not appear to be equivalent to g(0).

SS/7 examined some of the components of sighting theory. The probability of sighting per unit time (γ) is a function of both distance from the observer to the object (r) and the angle or direction of the searching effort (θ). γ is set equal to $f(r)\,h(\theta)$, though whether it should be a more complicated function of r and θ is uncertain. There is some discussion in document SS/7 about the shapes of both functions, and it was decided that these warranted further study later in the workshop.

Some other points to be considered are the effects of movement of the target in relation to the platform. If movement is evasive or seeking, what are the effects on the model? It was also noted that even random movement of the object may cause the apparent density to increase, and it was suggested that correction factors, such as duration of sighting, could be applied. However, it was also agreed that the effect of relative velocities of whales and searching vessel on the sighting models is second order.

SS/12 suggested some methods for avoiding the violation of some of the basic assumptions of line transect theory, but it was mentioned that some of the suggestions might be impractical under field conditions. This is discussed in more detail in Annex D.

9. IDENTIFICATION OF COMMON PROBLEMS IN ESTIMATING DENSITY

9.1 'Sightability'

9.1.1 Sighting cues

These vary by species of animal (and its individual size, group size, and behaviour) and by weather. For example, flocks of birds sometimes congregate near porpoise schools, and can indicate the presence of a porpoise school well beyond the range a school could normally be sighted. The great whales cue their presence by their blow, their large body size, their splash when rising, diving or spy-hopping, and the slick or ring that persists on the surface of the water after diving. Different cues will predominate under differing weather conditions, e.g. blows are sometimes obvious in calm, relatively clear weather, and body form plus blows become the principal cues in more disturbed weather conditions.

9.1.2 Distance and angle measurements

These are subject to human error. It is difficult to train observers to estimate distances and angles accurately, so it was suggested that existing advanced technology be used where appropriate (for example, theodolites, used currently in bowhead estimations) and new technologies be developed if possible (for example, a computer-linked binocular system which would automatically record the angle of each sighting as it occurred). Methods to study the effects of bias in the measurements also need to be considered. It was noted that errors in measurements, if unbiased, result in negligible bias of the density estimates (Gates, 1969) but do increase the variance. However, the problem of likely bias in the recording of small angles was also noted (see SS/5, SS/6. See also Quinn and Galluci, 1980).

9.1.3 Observer fatigue

This must be considered when designing a sightings study. The effective observation period will vary with the survey platform, sighting conditions, and possibly the frequency of animal sightings per unit time. The duration of sightings watches must be duly adjusted.

9.2 Whale behaviour

9.2.1 Dive times

These are tabulated for some whale species in SS/9 and SS/10. It was suggested that dive time data for all species be catalogued and tabulated for use in sightings models (see Annex E).

9.2.2 Target reaction to platform

This probably varies by species and could well vary by platform and geographical area. Anecdotal information was presented that some groups of whales were observed to avoid whaling vessels but to seek out or ignore fishing or pleasure boats. It was also mentioned that minke whales that had been hunted recently appeared to avoid the research boats. There is also the possibility that response might vary with weather (e.g. Leatherwood reported that as sea state deteriorates, gray whales are more difficult to approach and more likely to startle). It was also noted that ship-seeking behaviour could be dependent on boat velocity, and that this could be studied experimentally.

9.3 Schooling and aggregation

9.3.1 School size

This varies with species and possibly with the density of a given species in an area. If the probability of sighting an animal or cluster of animals proves to be a function of school size for a target species this function must be modelled. School size variation is not a problem in estimating the number of schools but it may complicate the estimate of the number of animals (see Quinn, 1979, 1980).

9.3.2 Distribution of clusters

This will not present modelling problems, as statistical estimation techniques can be used for clusters of animals as well as individuals.

9.4 Proportion observed along the trackline

This was considered partly under agenda items 6 and 8.

A subgroup was organised (1) to study in more detail the underlying models of sightings theory and how they apply to whales, (2) to find methods of determining the probability of sighting an animal along the trackline, and (3) to account for the effects of animal movements on the sightings models. Chapman volunteered to chair this subgroup; its report appears as Annex D.

Bouchet convened a small working group that used the computer program TRANSECT to analyse various data sets (see SS/4 for a detailed description of the program and Annex D, Addendum 3 for results).

9.5 Correlations between factors

Reciprocal relations between factors e.g. school size, sightability, and sighting distance, must be determined. This was considered briefly under agenda item 9.3.

9.6 Other factors

Many relevant factors were discussed elsewhere under other agenda items.

Eberhardt suggested that with respect to protected species, it might be a good idea to calculate an index of abundance rather than to estimate overall abundance. This index could be monitored from year-to-year. Smith mentioned that a year-to-year index of the porpoise stocks would be difficult to calculate since current and previous surveys have been designed and redesigned to estimate overall abundance, and methods are continually refined from year-to-year. Regarding the baleen whale stocks, Ohsumi stated that an unbiased index would be difficult to calculate since some areas of fishing emphasis shift sufficiently that continuous, same area, same time period information is difficult to obtain. Some participants urged caution in using commercial sightings data as an index of abundance, since the commercial search would be looking specifically for aggregations, instead of monitoring randomly a fixed area.

9.7 Comparison of aerial and shipboard surveys

This was discussed in some detail. Most participants felt that some calibration should be attempted where possible, to compare results of sightings from aerial and shipboard platforms. Some animals are apparently more accessible by air, in that airborne observers might see more animals in a given location and time period, than would shipboard observers. Leatherwood reported that for his *Tursiops* studies, aircraft sightings tended to be more consistent, pointing out that the protected coastal habitat is something of a 'goldfish-bowl' and that results of surveys on *Tursiops* must be used with caution as basis for other species occurring in pelagic habitats. Gilbert indicated that aerial counts of harbour porpoise in a small channel off New Brunswick-Maine seemed to be less complete than an intensive shore-based counting scheme. It was suggested that a subgroup be formed to study the problems of interplatform comparisons and calibration, and to catalogue as best as possible the previous calibration studies. Best agreed to chair the subgroup; its report appears as Annex E.

There was a brief discussion of ways in which acoustic devices have been used to estimate densities of groups of animals. Scott described some passive acoustic systems which have monitored humpback whale sounds on the breeding grounds, but stressed that this information could not be used for counts, since some animals do not produce sounds in breeding areas. Braham mentioned that acoustic data from passive devices had been somewhat helpful to observers for detecting the presence of bowhead whales, but again could not be used for counts because some whales did not vocalise. Fleischer has undertaken preliminary studies with an active acoustic system, monitoring gray whales on their breeding grounds in Baja California, but the system is still in developmental stages. Smith briefly described Roger Payne's hydrophone station data for eastern tropical Pacific dolphin populations, and mentioned that identification of animal sounds by species still needs work. Some work in this area has been done by Steiner (1980). Leatherwood mentioned low success in tracking large whales using even the most sophisticated active sonar systems. Even sperm whales, far better targets that baleen whales, and which could be tracked once located by other means could not be reliably censused without independent identification of their presence.

10. METHODS AND PROBLEMS IN ESTIMATING ABUNDANCE

10.1 and 10.2 Problems of defining stock areas, and extrapolating density estimates

Quinn queried whether both the density and range of a population and stock could be defined in one experiment, or if it were necessary to determine range first, and then density. If the range boundaries of a population are not clear, a survey which goes beyond the boundaries is safe but inefficient. With some species, however, range boundaries are indistinct. Ohsumi stated that distributional boundaries vary by species, and survey designs must take this fact into account. Smith warned that if stock distributions become diffuse towards their edges, one must be careful in extrapolating population estimates over large areas, if the experimental design does not take this into account.

The group concluded that it is inefficient to use the same survey to estimate both distribution and density, and suggested that opportunistic sightings data (e.g. Platforms of Opportunity, commercial data, incidental observations) be used for a first estimation of a population's range. Since most populations are not homogeneous over space and time, it may be useful to stratify or contour the sighting data during analysis, in order to get a reasonable estimate of a population over a large area of study.

To stratify sightings data, the data are separated into geographic blocks and the population density between blocks is assumed different. When contouring data, usually the analysis defines the contours, and then the density is calculated from the contouring. Reference was made to a technique devised by Burdick (1979) that calculates contours and densities simultaneously, and it was thought that this warranted further study.

Butterworth referred to a geostatistical technique known as 'Kriging' (Rendu, 1978), which is used to estimate density of mineral deposits. A series of random samples is collected, and density gradients are then ascertained. The overall density and its variance are then calculated taking the contouring into account. It is not known how well this method handles discontinuities in the distribution of the object of the study. In mineral surveys, one expects a high degree of auto-correlation, with samples taken near one another expected to be similar, and samples taken far apart to be rather dissimilar.

Chapman suggested exploring the demographic statistical literature, where contouring techniques have also been used, to determine if this has any possible applications to contouring techniques for biological sighting data.

11. METHODS AND PROBLEMS IN DESIGNING SURVEYS

11.1 and 11.2 Deployment of vessels, and stratification schemes

Stratification of the Southern Hemisphere minke whale population was discussed in great detail. Minke whales are densely concentrated near the pack ice, and their apparent density declines to the north, away from the ice edge. Survey designs used on previous IDCR cruises were discussed (SS/2, SS/13); in both the 1978/79 cruise and the 1979/80 cruise, two strata were selected and two vessels were used, each operating half the time in each stratum, at alternate time periods. Both vessels conducted sightings surveys and marking experiments, and switched positions midway through the season to minimise effects of possible differences between vessels. This year's IDCR minke whale programme will have an additional vessel for study, and suggestions were solicited for ways to best utilise the third boat.

Some experiments suggested for the third boat included:

(1) varying the speed methodically to determine if sightings are affected by boat speed,
(2) using one boat to follow the other and determine how many animals on the trackline might be missed, and
(3) using two boats running transects parallel to each other to look for whale response to ships. If the sightings distributions of each boat are not symmetrical, this might indicate ship seeking or avoidance behaviour.

The following deployment scheme was suggested:

(1) the northern boat should continue as in previous years (i.e. conducting both marking and sightings work), since apparent density in the northern stratum is much lower than that in the south,
(2) one southern boat should concentrate primarily on marking, and
(3) the other southern boat should do sightings only.

One of the two southern boats might devote time to some of the suggested ancillary experiments.

Horwood noted that the nature of the density gradient of minke whales as one moves away from the pack ice is still undefined and suggested an experiment in which a series of transects are undertaken (roughly perpendicular to the ice edge) to attempt to define the gradient.

It is unclear whether minke whales exhibit ship-seeking behaviour, and if so, how one would estimate a zone of attraction. Mitchell gave anecdotal information on the ship-seeking behaviour of North Atlantic minke whales, but Ohsumi noted that minke whales in the high southern latitudes do not appear to respond in the same manner. He suggested that any ship-seeking animals would be young ones which tend to be found farther north. Horwood mentioned that minke whale behaviour differed somewhat under different conditions. For example, they appeared to avoid the research vessel when it entered an area where there had been recent hunting by other expeditions.

Chapman noted that concrete ideas are needed on the design of some of the proposed experiments, e.g. how far apart should the vessels be in carrying out a parallel cruise track procedure, what speeds should be used for the experiment on sightings at varying speeds, and how many observations are needed at each speed?

11.3 Diversion from track and secondary sightings

The Southern Hemisphere minke whale IDCR cruises spend a considerable amount of time 'off-effort', tagging animals and examining school sizes and length frequencies of animals sighted from the track line ('on-effort').

The problems of analysing the sightings data of animals seen incidentally while investigating an initial sighting were discussed in some detail, but no conclusions were reached. In the absence of simulation studies that would examine the effects of ignoring or including secondary sightings data, it was felt that it would be best to include only primary sightings in abundance analyses. It was noted that if targets are aggregated, then going 'off-effort' is more probable in high density areas. This will lead to an underestimate of density.

12. METHODS OF DATA COLLECTION

12.1 Types of data needed

Data needed for sightings surveys include:

1. Continuous log of effort, including
   (a) meterological information such as wind direction and speed, glare factor;
   (b) water temperature;
   (c) sea state;

- (d) swell;
- (e) some measure of visibility.

2. Details of each sighting, including
   - (a) radial distance and angle of sighting, or perpendicular distance;
   - (b) distance searched;
   - (c) sighting cue;
   - (d) position of the platform of observation.

12.2 Procedures to collect data on board ship

Sightings, effort, weather and sea state condition data are collected for line transect studies. It was recommended that weather information be recorded hourly or each time there has been a change. Effort information is recorded manually by the officer on watch, who keeps track of vessel speed and each change in course.

It was suggested that since the data are eventually entered into computers, the forms on which these data are recorded be directly 'key-punchable', to reduce errors in transcription (see SS/14 for sample).

12.3 Ancillary experiments needed

Observer behaviour needs further study, and there was a suggestion to monitor observation habits with a video camera. Yamamura offered to check into the technical details of this proposal, and if possible, initiate it during one of the IDCR minke cruises. Other experiments suggested are found in the reports of the subgroups.

13. CONSIDERATION OF OPPORTUNISTIC SIGHTINGS PROGRAMS

It was felt that opportunistic sightings are only as reliable as the observers doing the sightings. It was recommended, therefore, that those responsible for FIBEX be aware that unless they take the effort to obtain experienced observers or provide them with extensive training and some relevant field experience, the resulting data may be of little use for any purpose. Frost and Best (1976) have devised a sighting form to be used by inexperienced observers, and in response to a specific request from the FIBEX research programme on how to collect such sighting data, it was suggested that FIBEX use this form, in addition to a form developed by the Platforms of Opportunity Sighting Program, US National Marine Mammal Laboratory, the field guides developed by Leatherwood (Leatherwood *et al.*, 1972; Leatherwood *et al.*, 1976; Leatherwood *et al.*, in press), and the Antarctic Map folio series (Brown *et al.*, 1974).

14. RECOMMENDATIONS OF THE WORKSHOP ON THE DESIGN OF SIGHTINGS SURVEYS

These recommendations fall into several categories. Some refer specifically to whale surveys such as those to be carried out under IDCR but others are concerned generally with sightings theory. It is hoped that workshop participants, other members of the Scientific Committee of the IWC and members of the scientific community will respond to the theoretical challenges posed. In addition a specific task was assigned and agreed.

Recommendations for whale surveys:

1. Sightings studies should include the following data collection:
   - (i) radial distance and angle of sighting, or perpendicular distance, if it can be measured;
   - (ii) sighting cue;
   - (iii) position of the observation platform;
   - (iv) meteorological information—wind direction, speed, glare factor;
   - (v) water temperature (shipboard surveys);
   - (vi) sea state;
   - (vii) swell;
   - (viii) visibility;
   - (ix) observer noting the sighting (if two or more observers are on duty).

These data should be entered onto forms which are directly 'key-punchable'.

2. The best existing technology should be used to measure distances and angles. Where visual estimates are used, there should be careful calibration and appropriate training of observers. A variety of methods to carry out such calibration and/or check on estimated values are listed in Annex E.

3. At the present time, density estimations should utilise only primary sightings. Studies need to be carried out to determine the effects of ignoring or including secondary sightings.

4. Surveys should include systematic collection of data on the submergence and respiratory patterns of different whale species. Such information should be made for both undisturbed animals and pursued animals. Items that should be recorded are listed in Annex E.

5. Detailed information should be provided of the observation process: instructions to observers, their behaviour under varying conditions with fatigue. Where possible, individual sighting curves should be determined for each observer.

6. Where there are different platforms in a survey, calibration experiments should be carried out. A series of such experiments are listed in Annex E. Multiple platforms may be used to carry out experiments to test the assumptions of the sighting model. Some general suggestions are listed in Annex D and Annex E, and specific suggestions for the 1980/81 IDCR survey in the main report.

7. While some experiments may be carried out using multiple platforms to assess the effect of target reaction to observations platform, the best way of assessing this is with the aid of helicopters.

8. It will generally be inefficient to attempt to measure both population range and density in the same survey. Opportunistic data will usually provide a reasonable first approximation to the range as well as a basis of stratification for design and analysis of the survey.

9. Those responsible for FIBEX should obtain experienced observers for whale sightings effort or provide their observers with training utilising forms developed by Best or by the US National Marine Mammal Laboratory plus the field guides of Leatherwood.

Recommendations for theoretical considerations:

1. Further experimental and theoretical work is necessary to estimate the probability that a target on the trackline is actually seen.

2. Additional theoretical or simulation studies are needed to confirm the conjectures concerning the effects of random movements of the targets on density estimates.

3. Determination of the 'best methods' of curve fitting in the presence of probable bias in the angle and/or distance measurements needs further study. While in general Fourier series estimates of the sighting curve have good properties for sighting surveys, other non-parametric

series estimators (c.f. Annex D) and effects of grouping data both need investigation.

4. While stratification is generally recommended in survey design and analysis, several additional statistical techniques using contours warrant study. These include a technique due to Burdick (1979), the technique known as 'Kriging' (Rendu, 1978) from geostatistics, and possible techniques used in demography.

5. Further exploration should be made of the model developed in SS/12 and particularly to determine how the variance of the estimates calculated for this procedure using a subsampling scheme would compare to those of the standard line transect model. A simulation study is one method of such exploration.

Specific task:

Leatherwood undertook to circulate a list of questions relative to whale diving behavior to scientists known to have information on this and to compile published information and to forward this to the IWC meeting beginning in late June 1981.

REFERENCES

Andrews, R. C. 1916. *Whale Hunting with Gun and Camera.* D. Appleton and Company, New York. 333 pp.

Bowers, C. A. and Henderson, R. S. 1972. Project deep OPS: deep object recovery with pilot and killer whales. Naval Undersea Center Technical Publication No. 306. 91 pp. (Naval Undersea Research and Development Center, San Diego, CA).

Braham, H., Krogman, B., Leatherwood, S., Marquette, W., Rugh, D., Tillman, M., Johnson, J. and Carroll, G. 1979. Preliminary report of the 1978 spring bowhead research program results. *Rep. int. Whal. Commn* 29: 291–306.

Braham, H., Krogman, B., Johnson, J., Marquette, W., Rugh, D., Nerini, M., Sonntag, R., Bray, T., Brueggeman, J., Dahlheim, M., Savage, S. and Goebel, C. 1980a. Population studies of the bowhead whale (*Balaena mysticetus*) Results of the 1979 spring research season. *Rep. int. Whal. Commn* 30: 391–404.

Braham, H., Krogman, B., Nerini, M., Rugh, D., Marquette, W. and Johnson, J. 1980b. Research on bowhead whales, June–December 1978. *Rep. int. Whal. Commn* 30: 405–13.

Brown, S. G., Brownell, R. L., Jr., Erickson, A. W., Hofman, R. J., Llano, G. A. and Mackintosh, N. A. 1974. *Antarctic Mammals.* Antarctic Map Folio Series, Folio 18.

Burdick, D. 1979. On estimating the number of porpoise schools. United States Tuna Foundation, Publication 79–2, Tech. Bull. No. 1.

Caughley, G. 1974. Bias in aerial survey. *J. Wildl. Manage.* 38(4): 921–33.

Erickson, A. W. 1978. Population studies of killer whales (*Orcinus orca*) in the Pacific Northwest: A radio-marking and tracking study of killer whales. US Marine Mammal Commn Rep. No. MMC-75/10. Available from: NTIS, Springfield, VA; Order number PB-285 615.

Evans, W. E. 1974. Telemetering of temperature and depth information from a free-ranging yearling California gray whale, *Eschrichtius robustus. Mar. Fish. Rev.* 36(4): 52–8.

Frost, P. G. H. and Best, P. B. 1976. Design and application of a coded format for recording observations of cetaceans at sea. *S. Afr. J. Antarct. Res.* 6: 9–14.

Gates, C. E. 1969. Simulation study of estimators for the transect method. *Biometrics* 25: 317–28.

Gunther, E. R. 1949. The habits of fin whales. *Discovery Rep.* 25: 113–42.

Koopman, B. O. 1980. *Search and Screening.* Pergamon Press. 369 pp.

Leatherwood, S., Evans, W. E. and Rice, D. W. 1972. The whales, dolphins and porpoises of the eastern North Pacific. A guide to their identification in the water. Naval Undersea Center Technical Publication No. 282. 175 pp. (Naval Undersea Research and Development Center, San Diego, CA).

Leatherwood, S., Caldwell, D. K. and Winn, H. E. 1976. Whales, dolphins and porpoises of the western North Atlantic. A guide to their identification. US Dept. of Commerce NOAA Technical Report NMFS Circular 396. 176 pp.

Leatherwood, S., Reeves, R. R., Perrin, W. and Evans, W. E. (In press) Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters. A guide to their identification. US Dept. of Commerce NOAA Technical Report NMFS Circular.

Lockyer, C. 1977. Observations on diving behaviour of the sperm whale. *In:* M. Angel (ed.). *A Voyage of Discovery: George Deacon 70th Anniversary Volume.* Pergamon Press, Ltd., Oxford.

Norris, K., Evans, W. and Ray, G. C. 1974. New tagging and tracking methods for the study of marine mammal biology and migration. *In:* W. E. Schevill (ed.). *The Whale Problem: A Status Report.* Harvard University Press, Cambridge, MA.

Norris, K. S., Goodman, R. M., Villa-Ramirez, B. and Hobbs, L. 1977. Behavior of California gray whale, *Eschrichtius robustus* in southern Baja California, Mexico. *Fish. Bull.* 75(1): 159–72.

Quinn, T. J., II. 1979. The effect of school structure on line transect estimators of abundance. *In:* G. P. Patil and M. L. Rosenzweig (eds). *Contemporary Quantitative Ecology and Related Econometrics.* International Cooperative Publishing House, Fairland, Maryland.

Quinn, T. J., II. 1980. Sampling for the abundance of school populations with line-transect, mark-recapture and catch-effort methods. Ph.D. thesis, University of Washington.

Quinn, T. J. and Galluci, V. F. 1980. Parametric models for line transect estimators of abundance. *Ecology* 61(2): 293–302.

Ray, G. C., Mitchell, E. D., Wartzok, D., Kozicki, V. M. and Maiefski, R. 1978. Radio tracking of a fin whale (*Balaenoptera physalus*). *Science* 202(3): 521–4.

Reilly, S. B., Rice, D. W. and Wolman, A. A. 1980. Preliminary population estimate for the California gray whale based upon Monterey shore censuses, 1967/68 to 1978/79. *Rep. int. Whal. Commn* 31: 359–68.

Rendu, J.-M. 1978. An introduction to geostatical methods of mineral evaluation. S. Africa Institute of Mining and Metallurgy, Monograph Series, Geostatics 2. (Kelvin House, 2 Holland Street, Johannesburg, South Africa, 2001).

Rice, D. W., Wolman, A. A., Withrow, D. E. and Fleischer, L. 1981. Gray whales on the winter grounds in Baja California. *Rep. int. Whal. Commn* 31: 477–93.

Smith, T. (ed). 1979. Report of the status of Porpoise Stocks Workshop, August 27–31, 1979. Southwest Fish. Ctr. Admin. Rep. LJ-79-41, Nat. Mar. Fish. Serv., La Jolla, CA.

Steiner, W. W. 1980. A comparative study of interspecific characteristics in odontocete whistle vocalizations. Ph.D. thesis, University of Rhode Island.

Watkins, W. A., Johnson, J. H. and Wartzok, D. 1978. Radiotagging report of finback and humpback whales. Technical Report Ref. No. WHOI-78-51 Woods Hole Oceanographic Institution, Woods Hole, MA. 13 pp.

Watkins, W. A., di Sciara, G. N. and Moore, K. E. 1979. Observations and radio tagging of *Balaenoptera edeni* near Puerto La Cruz, Venezuela. Technical Report Ref. No. WHOI-79-89 Woods Hole Oceanographic Institution, Woods Hole, MA. 8 pp.

Watkins, W. A. 1981. Radio tagging of finback whales—Iceland, June–July 1980. Technical Report Ref. No. WHOI 81–2 Woods Hole Oceanographic Institution, Woods Hole, MA. 46 pp.

Annex A
Agenda

1. Greeting by Center Director

2. Arrangements

3. Appointment of Chairman

4. Appointment of rapporteurs

5. Review of agenda

6. Review of whale biology and behavior

7. Review of ongoing surveys; progress and problems
    - 7.1 Tuna/Porpoise survey
    - 7.2 Walrus survey
    - 7.3 IDCR Southern Hemisphere minke whale survey
    - 7.4 Japanese whale sighting surveys
    - 7.5 US Bureau of Land Management CETAP surveys

8. Review of methods of analysis and assumptions
    - 8.1 Traditional sighting models
    - 8.2 Non-parametric or distribution free models

9. Identification of common problems in estimating density
    - 9.1 Sightability—sighting cues, distance and angle estimates, observer fatigue versus number of observers, weather and visibility (glare)
    - 9.2 Whale behaviour—dive times, target reaction to platform (seeking or avoidance)
    - 9.3 Schooling and aggregation—school size, distribution of clusters
    - 9.4 Proportion observed along the trackline
    - 9.5 Correlations between factors—e.g. school size, sightability and sighting distance
    - 9.6 Other factors
    - 9.7 Comparison of aerial and shipboard abundance

10. Methods and problems in estimating abundance
    - 10.1 Problems of defining stock areas
    - 10.2 Extrapolating density estimates

11. Methods and problems in designing surveys
    - 11.1 Deployment of vessels
    - 11.2 Stratification schemes
    - 11.3 Diversion from track and secondary sightings

12. Methods of data collection
    - 12.1 Types of data needed
    - 12.2 Procedures to collect data on board ship
    - 12.3 Ancillary experiments needed

13. Consideration of Opportunistic Sightings Programme

14. Recommendations

Annex B
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Annex C
List of Documents

SS/1 *Best, P. B. Whales as target animals for sightings surveys.

SS/2 Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

SS/3 Broadhead, G. C. 1980. Analysis of methods employed to estimate 1979 stock levels of porpoise and proposed adjustments in the level for the offshore spotted stock. [Extract: pp. i + 2–28 *from:* Publ. SO-1, Tech. Bull. No. 2, US Tuna Foundation].

SS/4 Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72: 1–202.

SS/5 Butterworth, D. S. 1980. An investigation of possible bias introduced into sightings estimates of the minke whale population by the method used for right-angle distance calculation. A brief preliminary report. Paper SC/32/Mi12, submitted to the IWC Scientific Committee, Cambridge, July 1980.

SS/6 Butterworth, D. S. 1980. An investigation of possible bias introduced into sightings estimates of the minke whale population by the method used for right-angle distance calculation. Progress report.

SS/7 *Butterworth, D. S. 1980. A possible basis for choosing a functional form for the distribution of sightings with right-angle distance.

SS/8 *Clarke, R. 1980. An index of sighting conditions for surveys of whales and dolphins.

SS/9 Doi, T. 1974. Further development of whale sighting theory. *In:* W. E. Schevill (ed.). *The Whale Problem: a Status Report.* Harvard Univ. Press, Cambridge, Mass.

SS/10 Doi, T. 1971. Further development of sighting theory on whale. *Bull. Tokai Reg. Fish. Res. Lab.* 68: 1–22.

SS/10a Doi, T. 1980 [Schematic diagram of:] Doi's sighting theory. 1 p., unpubl.

SS/11 Estes, J. A. and Gilbert, J. R. 1978. Evaluation of an aerial survey of Pacific walruses (*Odobenus rosmarus divergens*). *J. Fish. Res. Bd Can.* 35(8): 1,130–40.

SS/12 *Hiby, L. 1980. Using average number of whales in view to estimate population density.

SS/13 Horwood, J. W. 1980. Results from the IWC/IDCR minke whale marking and sighting cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

SS/14 *Leatherwood, S. and Show, I. T. Jr. 1980. Development of procedures for estimating sizes of population(s) of bottlenose dolphins, *Tursiops truncatus.* Final Contract Report for NMFS, SEFC, Miami, Florida.

SS/15 Leatherwood, S., Show, I. T. Jr. and Reeves, R. R. 1980. Effects of varying altitude on results of aerial surveys of bottlenose dolphins. Submitted to J. Wildl. Manage.

SS/16 Ohsumi, S. Estimation of population size of the fin whale in the Antarctic Area IV by whale sightings. *Rep. int. Whal. Commn* 31: 403–6.

SS/17 *Ohsumi, S. and Yamamura, K. 1980. A review on whale sightings systems in Japan.

SS/18 *Scott, G. P. and Gilbert, J. R. 1980. Problems and progress in the US BLM-sponsored CETAP surveys. Cetacean and Turtle Assessment Program report.

SS/19 Scott, G. P. and Winn, H. E. 1980. Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales (*Megaptera novaeangliae*). Final report to US Marine Mammal Commission, Contract MM7ACO29.

SS/19a Scott, G. P. and Winn, H. E. 1980. Errata for SS/19.

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* Papers published in this volume.

Annex D

Report of the Subgroup on Modelling

Members included:

Bouchet, Breiwick, Burnham, Butterworth, Chapman (Convenor), Doi, Free, Gilbert, Hammond, Hiby, Holt, Horwood, Kirkwood, Koopman, Laake, Pollock, Quinn.

This subgroup was assigned the task of resolving the question of alternative models and then considering what could be done about estimating the population of whales seen on the trackline and also the effect of movement (random, attractive or avoidance) on the estimation process.

Therefore the following agenda was set up:

(1) Alternative models;
(2) Estimation of the proportion on the transect line;
(3) Effects of movement (random, attractive or avoidance);
(4) 'Best methods' of curve fitting.

1. ALTERNATIVE MODELS

A number of different models were considered and discussed in some depth (their various forms, advantages and disadvantages). In one class are those based on *line transects*. In another class are those based on exploiting the usually random relations (in position and motion) between the observer's platform and the targets; they lead to the exponential formula of *random search*, much used in search theory, giving the probability of sighting at least one whale in an area A as

$$1 - \exp(-wT\phi/A)$$

where T is the length of time in A (or line length if transit velocity varies), ϕ the proportion of time that the whale is above water and/or blowing, and w its coefficient of visibility in the latter case. In a very special case $w = WV$ (V = constant speed and W = sweep width). In sampling with replacement, this formula and the formulae of the transect models give essentially similar results. The problem of finding the values of the parameters contained in all classes of models—e.g. by curve fitting or by *a priori* physical calculations—remains an essential one. Most participants believe that there is not available sufficient information to model the processes involved, and that it will take considerable time to acquire the information and to develop these models. In the interim, curve fitting is the only possibility and a curve fitting procedure should be chosen that is biologically and physically reasonable and relatively insensitive to the problems that are involved in line transect experiments. The limitations of this process, however, were emphasised by some participants (see Appendices 1 and 2).

The subgroup carried out a further review of the model proposed in SS/12 and noted that while successive estimates could be dependent, variances of the estimates could be obtained by a subsampling procedure. Furthermore the sightings could be taken on some sector of the whole 360° surrounding the observer and thus reduce some of the practical difficulties. A simulation study could be carried out to determine how the variances of the estimates compare to those of the standard line transect model. The advantage of this proposed new model is that it requires only that the probability of sighting at zero distance be known, not the probability of a sighting on the whole transect line, and this should be easily determined from information on dive times.

2. ESTIMATION OF g(0), THE PROBABILITY OF SIGHTING A TARGET ON THE TRANSECT LINE

It was queried whether the discussion should begin with stationary targets or if only moving targets should be considered. It was agreed that it was necessary to consider the simpler situation of stationary targets first. It was pointed out that there are three approaches: (a) development of a theoretical model, (b) use of experimental methods, (c) use of computer simulation. For both (a) and (c), a fairly complete understanding of the sighting process in general and along the transect line in particular are necessary as starting points. This would involve knowledge of the behaviour of both the observer and the whale as well as of such physical aspects as sea state, meteorological visibility, etc.

There was considerable discussion of the sighting procedures of the observers on the IDCR minke whale cruise. A different procedure is followed in some aircraft sightings when a bow observer is assigned to concentrate on the trackline. The probability that this observer sees the target at a distance x to $(x + dx)$ for the first time is related to $\phi h(x)dx$ where $h(x)$ = probability (per unit distance) the bow observer detects a target visible on the trackline at distance x in front of the platform and ϕ, the proportion of time that the whale is above the water or blowing. If ϕ is known and if there are sufficient observations it may be possible to estimate $h(x)$ empirically, i.e. carry out curve fitting and then determine $g(0)$. Alternatively it may be possible to relate $h(x)$ to $g(0)$ if enough information is available on the total sighting process.

Butterworth presented a document detailing a mathematical model relating $g(0)$ to $h(x)$ based on the approach of document SS/7. This is to be investigated further.

Butterworth suggested an experimental approach to estimating $g(0)$ for IDCR minke whale cruises (or other vessel transects). This method (expanding on an idea of Caughley, 1974) assumes that $g(0)$ is a function of vessel velocity (on the basis that at a slower vessel velocity, a given whale would surface more frequently within visible 'range', so diminishing the probability that observers miss seeing it if it is on the trackline). If we indicate this dependence by $g_v(0)$, and make the broad assumption that $g_o(0) = 1$, then the following experimental procedure was suggested:

In a small area, limited such that the population density may be assumed uniform, and over a period of unchanging visibility conditions, carry out transects at three values of v (say v = 4, 8, and 12 knots). Neglecting the g(0) factor, each of these transect sets at different velocity will yield density estimates D_v which are related to the true density D (= D_o by assumption) in that area by the relation:

$$\frac{D_v}{g_v(0)} = \frac{D_o}{g_o(0)} = D$$

It may be possible by using extrapolation procedures, or by developing a model for $g_v(0)$, to estimate D and hence obtain a value for $g_v(0)$ for, say, v = 12 knots (the standard sighting vessel velocity for the IDCR minke whale cruises), which can be used to correct density estimates (D_v) obtained from observations at this velocity. Clearly it would be necessary to plan the experiment to obtain sufficient observations at each velocity v to estimate the D_v's such that the extrapolated value D and hence $g_v(0)$ do not have unreasonably large variances.

Some members seriously doubted the reasonableness of estimating D by extrapolating back from observed D_v values with only tentative and untested models of the velocity dependence available.

Doi commented that in terms of his sighting model, the number of observers in the crow's nest (1, 2, or 3) could also be used to assess g(0). It was noted that in some aerial sightings experiments, observations by more than one observer have been found not to be independent as assumed by this model.

In summary it would seem that:

(i) there needs to be further theoretical work on estimating g(0), including studies of the procedures noted above;

(ii) there is need for more detailed information on the observation process, i.e. what are the instructions to the observers; how do the observers behave; what are the sighting curves and how do they vary between observers, or with sun and weather conditions, or with fatigue; and how do these affect the probability of detection, particularly on the transect line;

(iii) consideration should be given to modifying the sighting process so as to (a) either reasonably assure that all visible targets on the transect line are observed—this reduces the problem to estimating the proportion of time the target is visible or (b) design experiments necessary for the development of a model which can be used to estimate g(0) and then take the observations.

3. MOVEMENT OF THE TARGETS

The effect of random movement was considered in SS/2 for a simplified sighting model. It appears to have minor effect though it does bias sightings upwards. For a more realistic situation with a continuous sighting probability model the effect may be even less. It is desirable that this be confirmed by theoretical or simulation studies.

Evasive or attractive movements can also bias population estimates. The group had some information from Bouchet on the work of his group with helicopters to attempt to assess the movement of Dall's porpoise which are attracted by the vessel. It was generally agreed that helicopter observations are the best approach at the present time to build up the data base either to construct models of attraction and avoidance or to 'correct' standard shipboard sightings to yield meaningful density estimates.

4. 'BEST METHODS' OF CURVE FITTING

An examination of the computer output from TRANSECT for IDCR minke whale cruises (see Appendix 3) as a basis for consideration of this topic led to an extensive discussion of the problems of measuring small angles and the need to improve the process. Burnham noted that it should be possible to work directly with the sighting distances and angles as grouped data, and develop models that are minimally affected by errors, but those models need further work.

In regard to the question of fitting curves to sighting distance, Butterworth suggested that (1) orthogonal functions should be tried that give more weight near zero, e.g. Laguerre or Hermite polynomials and (2) the sighting function g(x) should be transformed prior to fitting if it exhibits unsatisfactory behaviour near the origin. These ideas merit exploration but need further study before any recommendation can be made.

Appendix 1

COMMENTS ON THE APPROPRIATENESS OF THE 'DESCRIPTIVE STATISTICS' APPROACH

Bernard O. Koopman

At various stages of the meeting, I emphasised a number of points as necessary conditions for a logical passage from any particular set of whale observations under given conditions to inferences regarding the real densities of the various types of whales in the locality of the observations. These remarks can be summed up in the following points:

1. The scientific study of any such problem must be based on some conception of the physical structure of the situation. This naturally includes the facts that the members of the meeting have all set forth at length: the emergence and appearance of the target (the whale: blowing, splashing in disturbing the water, jumping out, and all similar factors); the background (state of wind and waves, etc.); the medium through which the search takes place, characterised by the meteorological visibility; the nature of the illumination, sky and clouds, etc. Finally the platform and actions of the human operators are a necessary part of the whole picture. The point made here is

that in addition to these constantly mentioned items, one must use the already considerable body of knowledge contained in search theory—including of course the broader scientific facts of the geometry, kinematics, and probability that such operations inevitably bring into play.

2. Evidently no single formulation ('model') dealing with all possible situations is possible. Statistical curve-fitting may give a condensed representation of bodies of past observations, but they are too often made under heterogeneous varieties of conditions, usually too complicated to be stated in sufficient detail to serve as a basis for logical conclusions. They cannot therefore serve as reliable guides in planning future operations or in interpreting their results.

3. Long experience in applying science to practical problems has shown the necessity of isolating special cases for intensive study. Descriptive statistics can show that there is a problem somewhere, and even suggest where to look for an attack, but it cannot in principle provide a reliable solution. Once such a special case has been isolated (as in the whale counting), the physical structure must be recognised and formulated—and, as in all cases in which a structure is precisely formulated, the terms of the formulation are mathematical. In the formulation, there will be parameters whose values reflect the physical situation under examination. Inasmuch as the latter is physical, these parameters must have a physical meaning and in principle be measurable *a priori*: before the search operation is made. There are only two cases in which the parameters are appropriately found by curve-fitting. The first is to test the mathematical formulation as hypothesized: this is a valid process only when the formula is capable in principle of being wrong (Newton's inverse n'th power law of gravitation would have been demonstrably wrong for any power other than the value n = 2). Clearly no 'robust' formula, such as the Fourier and other formulas containing infinitely many parameters could comply with this requirement; as the Columbia chemist Hans Clark remarked 'with 6 parameters I could fit an elephant', such manipulations prove nothing. The second case is the one in which the fitted parameters do not change sensibly in value passing from one series of observations to a second independent set, made under similar conditions. This invariant property has been called by Morse and Kimball 'operational constant'. Then the same values are a good basis for future operational planning.

4. To give some examples: in visual search, the parameters that describe some important special cases are (i) the solid angle at the eye subtended by the target (whether horizontal or a bulk); (ii) the intrinsic contrast of the target, depending on the emitted light relative to the immediate background, including possible white-caps as well as the stiller water in its immediate vicinity; (iii) the meteorological visibility, which depends on atmospheric conditions and illumination, and which may strongly affect the apparent contrast as seen by the observer. To these three parameters of detectability are naturally to be added the height of the point of observation and the speed and mode of travel of the platform: whether in a constant course during the whole part of the search being analysed, or proceeding in a more varied path. Evidently there may be other items to be specified such as the geographic locality, time of year or day, and many others, but it may be better to separate these and not include them in the same model: similarly, when different species of whales are being observed.

5. A slight modification (to take into account the fact that we are dealing with a disappearing target, etc.) of a classical and well-known formula of search theory can be made to handle the transect case, leading to the lateral range law, and sweep width appropriate to the whale counting problem can be given. In cases of less precisely fixed course of the platform, an adaptation of the law of random search (i.e. the exponential formula representing such a situation) can be given. I am subjecting the precise mathematical details for these cases to continuing study and shall report any results I obtain to the International Whaling Commission.

Appendix 2

A SHORT COMPARISON OF RANDOM SEARCH THEORY AND LINE TRANSECT THEORY

K. P. Burnham

I believe that the theory of random search, as presented by B. O. Koopman, does not conflict at all with line transect theory. Let the area samples be A, D = density and N = AD = the true population size. For sampling with replacement, let n = the observed sample size after a random search of line length L. For sampling without replacement, let n* = the observed count. Then n is a Poisson random variable with mean WL/A. In Koopman's notation,

$W = 2 \int_0^\infty g(y)dy$. Hence

$$\Pr[n] = \frac{\{\exp(-WL/A)\}(WL/A)^n}{n!}$$

For estimation purposes, the maximum likelihood estimator (MLE) of D satisfies $\hat{D} = n/LW$, or using $N = AN$, $\hat{N} = n/(WL/A) = \frac{nA}{LW}$ (note that $W = 2/f(0)$).

In sampling replacement one assumes the targets are uniquely identifiable and will be recognised if seen again; hence they are counted only once. Then n* is binomial (N,p), $p = 1 - \exp(-WL/A)$ and

$$\Pr[n^*] = \binom{N}{n^*} p^{n^*}(1-p)^{N-n^*}$$

Now the MLE derives from $E(n^*) = Np$, or $n^* = N(1 - \exp(-WL/A))$. The variables n* and n are not the same, although for most line transect sampling, we would have $n^* = n$.

If WL/A is small, and it generally will be, then

$$1 - \exp(-WL/A) \doteq WL/A$$

and we get the approximation $n^* = NWL/A$, or

$$N = \frac{n^*A}{LW}.$$

This is, however, not the basis for reconciling line transect sampling and random search as they seem to be formulated in slightly different ways.

To back-up my belief that random search counts an object only once (or not at all if it is never seen) note that in

$$\text{Number observed} = AD\ (1 - \exp(-WL/A))$$

and bearing in mind that $AD = N$ (objects in area A), the number observed can never exceed N, even if search effort (L) becomes infinite. If objects are counted every time they are seen, then $L \rightarrow \infty$ implies the number observed becomes infinite.

Appendix 3

ADDENDUM WITH RESPECT TO COMPUTER RUNS

Subsets of the data from the 1978/79 IDCR minke whale cruise were analysed using the computer program TRANSECT (SS/4). The results, with associated coefficients of variation, are shown in Table 1 overleaf. For convenience of comparison the resultant density estimates are shown relative to the density estimate for an untruncated negative exponential fit to g(y), where g(y) is the probability of sighting a whale at a perpendicular distance, y, from the trackline.

A feature of previous estimates using the negative exponential fit for g(y) (SS/2; SS/5; SS/6) was a continuing increase in the density estimates as the right-angle distance data truncation point was moved nearer to $y = 0$. This effect was also very clear in fits of other functional forms (Fourier series; exponential polynomial; and half-normal) to the data by TRANSECT. The Fourier series fit to g(y) was unrealistic in many cases, in that it showed pronounced oscillations. It should be noted that the Fourier series model, though a general line transect model, will not be suitable for all data.

When the data were grouped, the effect of density increase with lowering of the data truncation point remained, though to a somewhat lesser extent. (Copies of the computer output are available for inspection at the IWC office in Cambridge, England).

One difficulty these models have fitting the data was due to the relatively large proportion of observations with y-values less than 0.1 nautical mile. This arises predominantly from observations for which the recorded angle of sighting from the ship's track, θ is given as 0°. Clearly the accuracy of estimation of small y values plays an important role.

SS/5 and SS/6 attempted to assess the bias introduced by inaccuracies in angle and time (distance = velocity × time) measurements, from which the y-values are calculated. By introducing a random factor into the recorded angle, time and speed to simulate the inaccuracies in recording these measurements, the contribution of the inaccuracies to the relative bias was estimated and the effect on density estimates was plotted. It was shown that the primary contribution to the bias arises from observations for which the recorded angle or time is zero. In all cases with simulated data the increase in density estimates was reduced as the truncation point was lowered, though for most cases some increase nevertheless remained.

Butterworth's evaluation assumed that angles were measured correct to the nearest 10° and that times were correct to the nearest minute. If errors in these measurements are in fact larger, the density estimates would stabilize as the truncation point was lowered. However after detailed discussion it was felt that measurement errors were unlikely to be greater than the values indicated above. Hence it appears that curve-fitting procedures for g(y) may yield satisfactory lower limits for the density (i.e. from untruncated data). However before the degree to which the true density is higher than these lower limits can be accurately assessed, further analyses and observations are necessary to determine whether the relatively large number of small y observations is a feature of:

(i) errors in distance and angle estimates in part due to the discrete nature of these observations;
(ii) the underlying true data genuinely being strongly small-y peaked as observed, due to a rapid decrease in sightings with distance, in a manner that presently used functional forms for g(y) have difficulty in representing;
(iii) other effects (e.g. ship-seeking);
(iv) some combination of the above.

Table 1

Comparison of minke whale density estimates for the 1978/79 IDCR minke whale cruise sectors, for various functional form fits to g(y) by the program TRANSECT. Density estimates are shown relative to that for the untruncated negative exponential. The figures marked with an asterisk (*) are those Fourier series fits for which the g(y) function fitted was unrealistic (e.g. marked oscillations or negative values). The density estimates for these fits should be regarded as unreliable.

(a) Ungrouped data.

Cruise 16TS	Truncation point (nautical miles)	∞	1	0.4	0.2
Fourier series		*0.709 (11%)	*1.502 (16%)	*2.936 (18%)	*5.693 (18%)
Exponential polynomial		0.953 (9%)	1.091 (14%)	1.675 (13%)	2.154 (16%)
Negative exponential		1.000 (13%)	1.091 (14%)	1.834 (17%)	2.523 (20%)
Half normal		0.464 (11%)	0.641 (13%)	1.113 (14%)	1.472 (17%)

Cruise 16TN	Truncation point (nautical miles)	∞	1	0.4	0.2
Fourier series		*0.937 (13%)	*1.791 (15%)	*4.036 (16%)	*7.759 (16%)
Exponential polynomial		0.928 (11%)	1.833 (16%)	2.337 (12%)	3.336 (16%)
Negative exponential		1.000 (15%)	1.833 (16%)	2.397 (18%)	3.818 (19%)
Half normal		0.388 (13%)	0.858 (14%)	1.190 (15%)	1.826 (17%)

Cruise 18TS	Truncation point (nautical miles)	∞	1	0.4	0.2
Fourier series		1.038 (12%)	*1.498 (17%)	*3.058 (18%)	*5.199 (20%)
Exponential polynomial		0.967 (8%)	1.293 (8%)	1.484 (13%)	2.074 (16%)
Negative exponential		1.000 (11%)	1.326 (13%)	1.640 (17%)	2.389 (20%)
Half normal		0.533 (9%)	0.861 (11%)	1.144 (14%)	1.424 (17%)

Cruise 18TN	Truncation point (nautical miles)	∞	1	0.4	0.2
Fourier series		*0.981 (15%)	*1.711 (20%)	*3.322 (24%)	*6.770 (22%)
Exponential polynomial		0.949 (16%)	1.511 (18%)	2.105 (17%)	2.589 (20%)
Negative exponential		1.000 (16%)	1.511 (18%)	2.275 (22%)	3.049 (25%)
Half normal		0.453 (14%)	0.872 (15%)	1.351 (18%)	1.742 (21%)

(b) Grouped data (intervals of 0.1 nautical miles)
Only cruise 18TS is considered; the grouped data refer to simulated allowance for angle and time measurement errors (Butterworth, SS/5). Density estimates are shown relative to untruncated, ungrouped, negative exponential.

Cruise 18TS	Truncation point (nautical miles)	∞	1	0.4	0.2
Fourier series:	actual	0.865 (11%)	0.768 (9%)	1.124 (13%)	1.483 (17%)
	grouped	0.778 (10%)	1.046 (13%)	1.080 (13%)	1.399 (18%)
Negative exponential:	actual	1.000 (11%)	1.229 (13%)	1.438 (18%)	1.826 (24%)
	grouped	1.001 (11%)	1.205 (13%)	1.342 (18%)	1.673 (24%)
Half normal:	actual	0.553 (9%)	0.824 (11%)	1.106 (14%)	1.462 (18%)
	grouped	0.557 (9%)	0.812 (11%)	1.053 (14%)	1.374 (18%)

Annex E

Report of the Subgroup on Calibration Procedures

Members included Alverson, Belov, Best (Convenor), Borodin, Braham, Clarke, Eberhardt, Fleischer, Hay, Leatherwood, Mitchell, Reilly, Rice, Scott, Smith, Tillman, Yamamura.

The subgroup established the following working agenda:

1. Interplatform comparison
    1.1 Summary of previous work
        1.1.1 Questions previously addressed
    1.2 Summary of ongoing and future work
        1.2.1 Questions being addressed
        1.2.2 Additional questions that need to be addressed
2. Methods and Precision of Measurement
    2.1 Distance
        2.1.1 Summary of previous work
        2.1.2 Future development and problems
    2.2 Angle
        2.2.1 Summary of previous work
        2.2.2 Future development and problems

1. INTERPLATFORM COMPARISON

Several previous experiments on calibration procedures were examined in some detail (Table 1). These had different objectives, were on a variety of species, and were conducted in several different situations. Results were also sometimes inconsistent, so that general conclusions were difficult to draw. Where comparable, density estimates from vessel data seemed similar to or higher than those from aircraft data. Precision of estimates was not consistent—in some cases, vessel estimates had lower variability and in some cases, higher variability. Problems identified with aircraft surveys were that density estimates could be affected by speed and/or altitude; problems identified for vessel surveys were difficulties in accuracy of measuring distances and angles from the trackline and the non-random behaviour of animals. Other experiments (yet to be published) for which no data were available at the meeting were identified as follows: gray whale (Storro-Patterson, Swartz and Jones); harbor porpoise (Prescott

Table 1

Comparison of survey techniques

Area	Species	Methods	Comments	Results	Source
Indian River, Florida	*Tursiops*	Complete coverage vessel counts vs aerial transects	High density 'closed' area	Total vessel counts lower than population estimates from aerial transects but within 95% confidence limits	Leatherwood and Show (SS/14)
W. Coast, Florida	*Tursiops*	Vessel vs aerial transects	Low density area	Vessel estimates approximately five times higher than aerial with much higher variability; aerial estimates considered more reasonable given previous experience with the species	Leatherwood and Show (SS/14)
Silver and Navidad Banks, W. Indies	*Megaptera*	Vessel vs aerial transects of three types	High density 'closed' area	Aerial density estimates always lower than vessel estimates (high altitude 0.77, low altitude 0.67, photo 0.46). Vessel estimates much lower variability	Scott and Winn (SS/19)
Bering Sea	*Balaena*	Aerial (circling) vs shore counts	Narrow shore lead in ice	Counts from both methods comparable	Braham *et al.*, 1979
Baja Calif.	*Eschrichtius*	Vessel vs aerial counts	High density 'closed' area	Aircraft counts lower and less consistent than boat counts	Rice *et al.* (in press); Fleischer, pers. comm.
Monterey Coast, Calif.	*Eschrichtius*	Aerial transects vs shore counts	Migrating stream	Aerial used to characterize offshore distribution for comparison with shore counts	Reilly *et al.*, 1980
Eastern Tropical Pacific	*Stenella* *Delphinus*	Aerial vs vessel transects	Large scale survey	Density estimates from faster aerial lower than slower aerial. Vessel data not used for density estimates by line transect methods because of errors in rounding sighting angles to zero. Vessel sightings/track mile calibrated with aerial data in same area.	Smith, 1979

and Gaskin); humpback (Herman, Shallenberger, Jurasz, Levenson, Anderson); Bryde's whale (di Sciara).

In reviewing suggestions for future work, it was recommended that any calibration experiment should take place in areas of high density, and that platform comparisons should be as closely related to the actual survey situation as possible. One promising region was considered to be the southward migration of California gray whales (very predictable, high density, and restricted to a narrow, near-shore corridor), where shore counts, aircraft and vessel transects could all be compared simultaneously in an area where the size of the population could be estimated from shore counts with reasonable accuracy and where short-term ground truth could be obtained from land for aerial and vessel surveys. Some members saw difficulties, however, in applying the results of such a comparison to other species and areas, due to differing behavioural and geographical characteristics and survey equipment. As regards the behavioural characteristics, it was felt that a comparison of surfacing and respiration patterns might enable some inter-species comparison.

Other situations that might provide useful calibration experiments were (a) the use of shore observers, vessels and aircraft transects on humpback and fin whales off Newfoundland (concentrating on areas where the whales were close to shore) and (b) the use of similar platforms for humpbacks off Hawaii.

The group recognised that besides calibration experiments between different platforms, experiments were needed to measure or compensate for the inefficiencies of different platforms themselves.

Both aircraft and vessel surveys suffered from an unknown proportion of animals missed on the trackline. To address this problem it was suggested that:

(a) Replicate surveys be flown or cruised at different altitudes or speeds in areas of high density and density estimates recorded and compared for each set of conditions. Different vessels or aircraft could be tested simultaneously.
(b) An observer be placed facing backwards to identify numbers of targets missed by primary observers.

In the case of aircraft, the effect of obscured visibility below the plane should be measured whenever possible (e.g. by comparing aircraft with and without special viewing ports).

A specific problem identified for vessel surveys was the possible non-random reaction of the animals to the observer. The following were suggested as experiments to measure this effect if present:

(a) Independent aircraft observations of cetacean behaviour before and after the vessel comes within sighting range.
(b) Two vessels steaming in parallel (opposite one another or even slightly staggered) to investigate the possible asymmetry of sightings on either side of each vessel.
(c) Hydrophone experiments to determine the acoustic properties ('envelope') of the survey vessel.
(d) Continuous monitoring of the animal's motion relative to the observer from initial sighting to closing or passing.

The feasibility of some of these suggestions (in the light of the sample size required for significant results) should be investigated.

A suggestion was made that 'ground truth' could be obtained for some pelagic surveys by placing numerous vessels close together in an area, counting all the animals present and then sending the survey vessel or aircraft through the region.

2. MEASUREMENTS OF DISTANCE AND ANGLE

2.1 Distance

At present, visually estimated distances are the most commonly used but their accuracy requires careful calibration. The following other methods currently in use or used in the past might help improve the accuracy of distance estimates:

(a) Elapsed time at known speed to close with target (course-recorder).
(b) Inclinometer from known height.
(c) Optical rangefinders (very limited use).
(d) Theodolite (land based only).
(e) Radar for direct measurement to target (only useful under ideal conditions).
(f) Radar to measure distance from target initial position (once boat has closed) to reflector jettisoned at the time of sighting.
(g) Two navigational fixes (e.g. via OMEGA, GNS, NN SS). With some systems (e.g. GNS) courses can be programmed and deviation from those courses readily determined.

The following methods were under consideration or in the process of development:

(a) Measurement of angle of target below horizon with high power binoculars bearing calibrated eyepieces.
(b) Active acoustic methods (over short ranges).
(c) Passive acoustic methods using triangulation.
(d) Change in angles (accurately measured) as observer moves relative to target or comparison of distance estimated to the same target from two observers, at known distance apart, to the same target with known angles to the sighting in each case.

2.2 Angle

The following methods are currently in use:

(a) Hand-held or mounted compasses or azimuth scales plus sighting device (alidade).
(b) Graduated brass ring and moving pointer on fixed, high power binoculars.

The following methods are under consideration:

(a) Wiring binoculars of observers and ship's compass into shipboard computer.
(b) Two navigational fixes from ship or aircraft which closes with target.

It was pointed out that with direct methods of measuring the perpendicular distances, the problem of accurate angle measurement would be much reduced. Some improvement in accuracy might also be achieved if angle measurement was delayed until the observer was closer to the position where the target was when initially sighted, thus maximizing the angle and the visibility of the target. In view of the fact that all methods suffer from inaccuracies, until an optimal one can be found, it would be useful to have independent checks by using several different methods for measuring both distance and angle for each sighting where possible.

3. DIVE PATTERNS

It was felt that systematic collection of data on the submergence and respiratory patterns of different whale species might assist in modelling at least the maximum proportion of animals that might be seen on the trackline. The following were identified as the types of information required. For individual animals, continuous temporal sequences of the pattern of surfacing, blowing and submergence, with an indication of the behavioural activity (e.g. feeding, courtship, migrating) at the time of the observations. For schooling animals, the time during which any cue was provided by the school would be recorded as a minimum (i.e. the time from the first cue provided on a cycle at the surface to the last one). If possible, the number and sequence of blows from the school would also be provided. Different records should be made under conditions approximating to undisturbed animals and approached animals, and at different times of day. Permanent (i.e. video tape, voice tape, or DATAMITE) recording of the situation might assist in subsequent analysis.

All such observations should be made during the time of the actual survey itself if possible.

Existing data on dive patterns consisted of two main types, that from radiotelemetry (where normally the patterns of surfacing and diving are known but the duration of visits to the surface and the number of visible blows provided are unknown), and direct observations:

1. Radiotelemetry

Fin	(Ray *et al.*, 1978, Watkins, 1981)
Bryde's	(Watkins, diSciara and Moore, 1979)
Humpback	(Watkins, Johnson and Wartzok, 1978; Norris *et al.*, 1974)
Killer	(Erickson, 1978; Bowers and Henderson, 1972)
Pilot	(Bowers and Henderson, 1972)
Gray	(Evans, 1974; Norris *et al.*, 1977; Mate).

2. Direct observations

Several spp—(Doi, SS/9, SS/10; Clarke, SS/8; Staff, Southwest Fisheries Center)
Humpback whale—(Beamish; Balcomb; Shallenberger; Herman; Jurasz)
Gray whale—(Reilly, 1980; Rice *et al.* (in press); Swartz and Jones; Sumich; Aguayo; Norris)
Sperm whale—(Lockyer, 1977; Best)
Right whale—(Payne; Best)
Minke whale—(Nemoto)
Bowhead whale—(Braham *et al.*, 1979, 1980a, 1980b)
Fin whale—(Gunther, 1949)
Humpback/Fin/Right whales—(CETAP)
Gray/Fin/Humpback whales—(Andrews, 1916)

It was realised that not all this information would be in the desired format and that some of the above references are unpublished. Leatherwood agreed to circulate a list of questions concerning those data to the above people and compile what published information was available. The following were suggested as relevant questions to be asked: for each species, what sequences of diving and surfacing times and respiration rates were available, for what duration, under what behavioral circumstances, at what times of the day and year, and in which locations? The group requested that whatever data were available be forwarded to Leatherwood, who would compile a listing for the IWC meeting in June 1981 (see Paper SC/33/O 11, published in this volume).

SS/1

Whales as Target Animals for Sighting Surveys

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ABSTRACT

Five characteristics of whales (their intermittent visibility, inconspicuousness, behaviour, mobility and gregariousness) pose special problems for surveys based on line transect techniques.

INTRODUCTION

Traditionally the International Whaling Commission (IWC) has based most of its assessments of whale populations on trends in catch per unit effort (CPUE) data from the commercial fishery, with lesser emphasis placed on methods such as mark-recapture experiments or cohort analysis. Sightings of whales have often been used as indices of relative abundance, but rarely have attempts been made to use these to obtain estimates of population size. More recently, however, a combination of more rigorous management regimes and more conservative quotas have caused the IWC's Scientific Committee to look more closely at methods independent of CPUE, of which sighting surveys may be one of the more promising (particularly for protected or previously unexploited stocks).

This paper presents a short discussion of the biology of whales in relation to the applicability of sighting theory for producing estimates of density and population size. 'Whales' in this sense include only those species large enough to produce a visible (in-air) blow, thus excluding most species below about 15 feet in length.

CHARACTERISTICS OF WHALES AS TARGET ANIMALS

1. Intermittent visibility

Being entirely aquatic, air-breathing animals, whales have to be surveyed at sea and are only visible from above water when on or near the surface. The chances of all the animals on a survey trackline being seen (one of the critical assumptions of line transect theory) are therefore dependent on the speed of the surveying vehicle and the frequency with which the whales surface to breathe.[1] Clearly the faster the vehicle moves, and the more infrequently the whale surfaces, the greater are the chances that not all animals on the trackline will be detected. On this criterion, therefore, shipboard surveys are likely to be more accurate than surveys from a fast-moving aircraft. A list of average submergence times between breaths is given by Doi (1974), and varies from 1.30 minutes for minke whales (*Balaenoptera acutorostrata*) to 9.70 minutes for pigmy blue whales (*Balaenoptera musculus brevicauda*): the accuracy of even shipboard surveys is therefore likely to vary with the species involved. The synchrony of respiration within a school may also affect the probability of missing that school on the trackline, the greater the synchrony the higher the probability of the school being missed.

2. Inconspicuousness

The transitory nature of the visits of whales to the surface to breathe has several further important consequences for sighting surveys. Firstly, identification of the species involved is difficult and must usually be determined from the blow characteristics and the small portion of the body exposed above the surface. Correct identification can often only be achieved by a close approach to the animals, and if this should involve deviation from the cruise track it would have obvious implications for the design of a sighting survey. Secondly, the brief nature of the cues offered makes it difficult to fix the sighting distance or angle accurately, and both parameters usually have to be estimated rather than measured. This produces rounding errors which can lead to biases in the estimation of density (Butterworth, 1982). Thirdly, the rapid appearance and disappearance of individuals at the surface makes determination of school size difficult, and a close approach is also frequently needed to establish this parameter accurately. Lastly, the ephemeral nature of some of the cues (particularly the blows) used for detection means that they are potentially greatly affected by weather and other environmental conditions at the time of the survey (particularly wind strength, sea state and light conditions).

3. Behaviour

The sightability of whales at the surface is greatly dependent on their behaviour. Cues for sightings can vary from jumps or splashes (due to most or part of the body being lifted clear of the water and then brought sharply down on the surface, usually during play) to blows, a sighting of the animal itself, or 'rings' (the slick) left on the surface when an animal accelerates rapidly away from the vessel and the upstrokes of the tail leave eddies at the surface (Figs 1a–d). Other less common cues are the body colour or 'loom' of the animal underwater and associated wildlife such as flocks of birds. These cues differ greatly in the distance at which they can be detected (blows of minke whales, for instance, being detected on average at 1.12–1.82 miles, but rings at only 0.09–0.41 miles), and there is some evidence that the whales' behaviour (and therefore the cues offered) can differ in different localities or at different times of the year (Best and Butterworth, 1980). Environmental conditions may also affect behaviour: in flat calm conditions for instance, Antarctic minke whales appear to cease making visible in-air blows and most sightings are of the body.

4. Mobility

Whales are potentially highly mobile animals. This has several important implications. Firstly, care must be taken to avoid or correct for possible duplicate sightings of an

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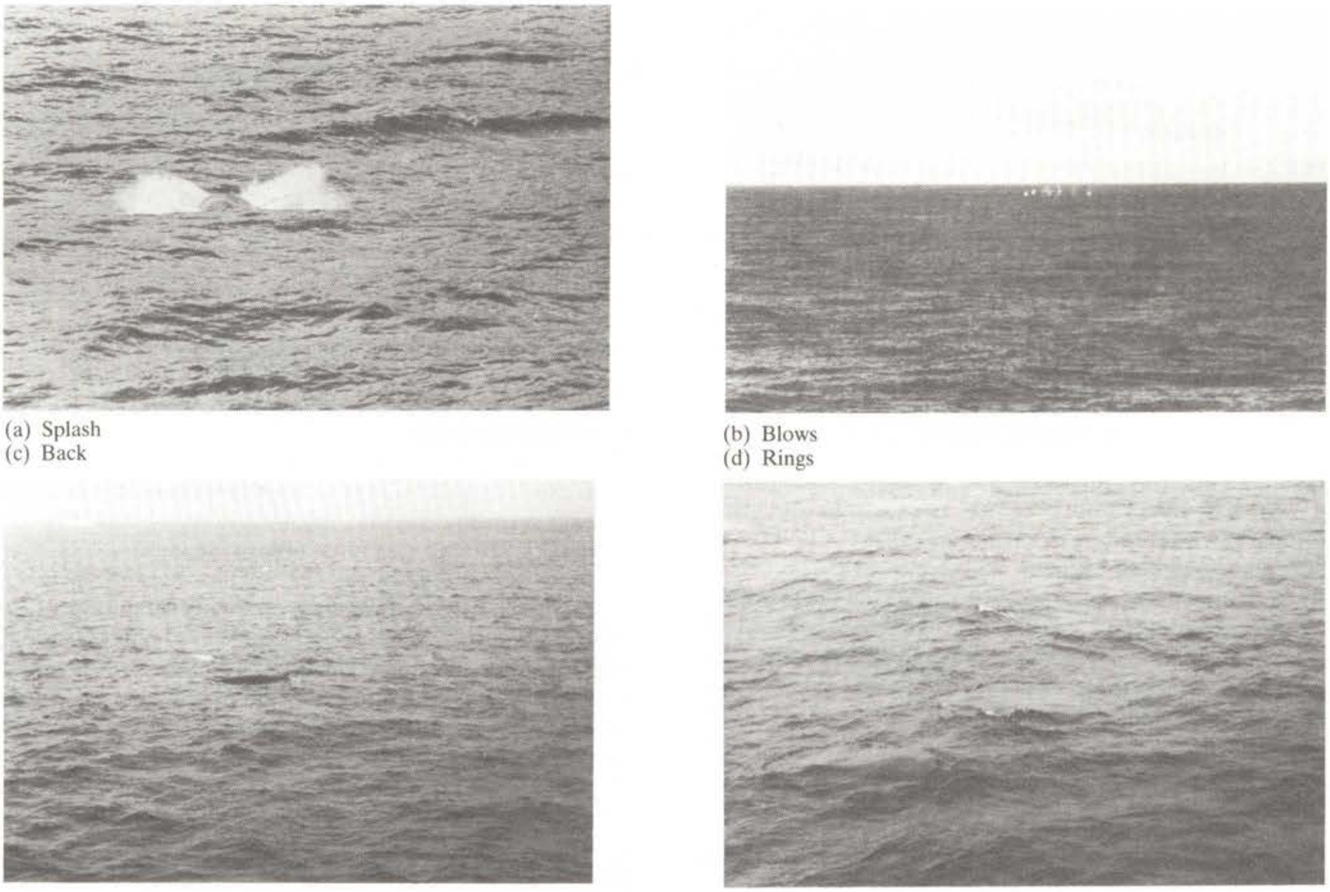
[1] The results of an experiment on the effect of survey vessel speed carried out as a result of the meeting to which this paper was presented are given in Butterworth, Best and Basson (1982).



(a) Splash
(b) Blows
(c) Back
(d) Rings

Fig. 1. Different sightings cues for minke whales.

animal or group. Secondly, it has been shown that a positive bias can be introduced into density estimates if the target is moving at a significant velocity relative to that of the surveying vehicle (Koopman, 1956). Thirdly, the potential mobility of the animals means that if they should react to the approach of the surveying vehicle a further bias might be introduced into density estimates. Such a reaction could be positive or negative, producing a respective over- or under-estimation of density. While it might be thought that a negative reaction would be more likely, positive 'ship-seeking' behaviour has been postulated for at least one species of *Balaenoptera* (Mitchell, 1978), although field data do not necessarily support this contention (Best and Butterworth, 1980; Horwood, 1981).[2] Ship-avoidance or ship-seeking behaviour could also have considerable bearing on the type of detection function to be used (Horwood, 1981). Lastly, the mobility of the animals confounds the difficulties of obtaining accurate sighting distance measurements if the time lapsed × speed method is used to calculate distance.

5. Gregariousness

Most whales are gregarious animals, so that the sighting of one animal is not necessarily independent of the sighting of another ('clustered objects'). Although this may not cause any problem in terms of estimation of the number of schools, if the probability of detection is related to the size of the school then the sample of school sizes obtained by line transect sampling will be biassed towards larger schools, thus creating a bias in estimation of total whale numbers. Because larger schools presumably produce more cues (blows, jumps, etc) per unit time than smaller schools, a greater probability of detecting larger schools of minke whales has been identified, and attempts have been made to account for this bias in estimating the total population size (Best and Butterworth, 1980; Chapman, 1980; Horwood, 1981).

CONCLUSIONS

Certain characteristics of the biology of whales do not make them ideal subjects for the use of line transect theory to estimate density or population size. Burnham *et al.* (1980) list four assumptions that they consider critical to the achievement of reliable estimates from line transect sampling, given in order of importance below.

1. Objects directly on the line will never be missed.
2. Objects are fixed at the initial sighting position; they do not move before being detected and none are counted twice.
3. Distances and angles are measured exactly; thus, neither measurement errors nor rounding errors occur.
4. Sightings are independent events.

Clearly there are problems in satisfying the first three assumptions in the case of surveys for whales. In view of the discussions to be held at this meeting, however, it would be premature to conclude that these difficulties preclude the use of line transect sampling as one method of population estimation for these species. The likely direction (if not the possible extent) of some of the biases in such estimates could be identified and subsequently taken into account in the setting of appropriate management regimes.

[2] Results of experiments concerned with ship-seeking behaviour, which were carried out as a result of the meeting to which this paper was presented are given in Leatherwood *et al.* (1982) and Butterworth, Best and Basson (1982).

REFERENCES

Best, P. B., and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monographs* 72: 1–202.

Butterworth, D. S. 1982. A possible basis for choosing a functional form for the distribution of sightings with right angle distance: some preliminary ideas. Paper SS/7 (published in this volume).

Butterworth, D. S., Best, P. B. and Basson, M. A. 1982. Results of analysis of sighting experiments carried out during the 1980/81 Southern Hemisphere minke whale assessment cruise. Combination of Papers SC/Jn81/MiS5+13+17 (published in this volume).

Chapman, D. G. 1980. Stratified estimate of Area IV Series B minke whale population from sightings data of assessment cruise 1978/79 and estimate of its variance. *Rep. int. Whal. Commn* 30: 100–1.

Doi, T. 1974. Further development of whale sighting theory. pp 359–368. *In:* W. E. Schevill (ed.). *The Whale Problem. A Status Report.* Harvard University Press, Cambridge, 419pp.

Horwood, J. 1981. Results from the IWC/IDCR minke whale marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Koopman, B. O. 1956. The theory of search I. Kinematic Bases. *Ops Res.* 4: 324–46.

Leatherwood, S., Awbrey, F. T. and Thomas, J. A. 1982. Minke whale response to a transiting survey vessel. Paper SC/Jn81/MiS9 (published in this volume).

Mitchell, E. 1978. Minority statement on southern minke stock assessment. *Rep. int. Whal. Commn* 28: 84–5.

SS/7

A Possible Basis for Choosing a Functional Form for the Distribution of Sightings with Right Angle Distance: Some Preliminary Ideas

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INTRODUCTION

Line transect methods of population estimation assume that the probability of (in this case) a whale being seen, given that it is a right-angle distance y from the vessel's track, is a simple function $g(y)$ of y.

A plausible functional form is then usually chosen for $g(y)$. The function must sensibly be monotonically decreasing with y, but otherwise the choice is largely empirical. The negative exponential form $g(y) = e^{-\mu y}$ has the convenience of a particularly simple formula for the maximum likelihood estimate of the parameter μ. However there are indications that this form is inadequate to fit the minke whale observations; the data suggest more observations at small y, and a slower fall-off of observations at large y, than the negative exponential can represent.

Accordingly the fundamentals that give rise to the particular form of $g(y)$ merit further consideration. The approach that follows is based on the integration of a sighting probability per unit time—an approach well-known in Search Theory originally developed by Koopman (1956).

THE FORMALISM

The symbols used in the following are defined by the diagram in Fig. 1. Rather than have the vessel moving with velocity $v\hat{x}$, we will consider the equivalent situation of the vessel being at rest and the whale moving with velocity $-v\hat{x}$.

We assume that the probability per unit time γ of sighting a whale position at (r,θ) is given by:

$$\gamma = f(r)\,h(\theta) \tag{1}$$

Here $h(\theta)$ describes the relative concentration of sighting effort at different directions from the vessel's track. In practice $h(\theta)$ would probably be larger near $\theta = 0$, i.e. more sighting effort concentrated in the forward direction.

Given a whale 'moving' at a right-angle distance y from the vessel, then the probability of that whale being seen between the points $(x + \delta x, y)$ and (x,y) is given by:

$$\gamma\delta t = f(r)\,h(\theta)\,\frac{1}{v}\,\delta x \equiv F(r,\theta)\delta x \tag{2}$$

Let $B(x,y)$ be the probability that the whale has not been seen by the time it reaches the point (x,y), then

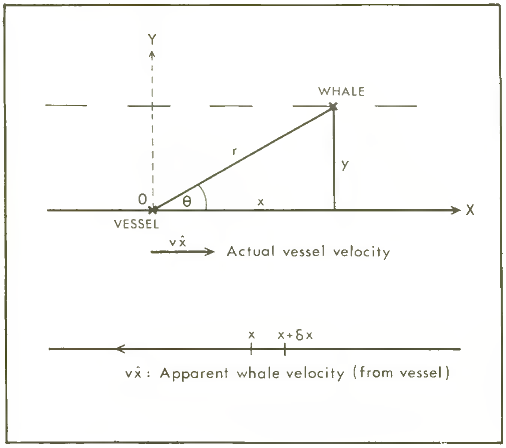

Fig. 1. Definition of variables used in formalism.

$B(x,y)$ = (Probability not seen when reached $x + \delta x$) × (Probability not seen between $x + \delta x$ and x)*

$$= B(x + \delta x, y)\,[1 - F\delta x] \tag{3}$$

From this we obtain:

$$\frac{\partial B}{\partial x} = FB \text{ where } B(+\infty, y) = 1$$

with solution

$$B(x,y) = e^{-\int_x^\infty F(x',y)dx'} \tag{4}$$

The probability that the whale is first spotted between $x + \delta x$ and x:

$P(x,y)\delta x$ = (Probability not seen when reached $x + \delta x$) × (Probability seen between $x + \delta x$ and x)

$$= \left(e^{-\int_{x+\delta x}^\infty F(x',y)dx'}\right)F(x,y)\delta x$$

$$P(x,y) = F(x,y)\,e^{-\int_x^\infty F(x',y)dx'} \tag{5}$$

Equation (5) can be used to obtain first sighting probability densities.

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* A whale is not potentially sightable at all times when 'within range', but only when at or near the surface. Thus the independence assumption of this equation is valid only if the whale's dives are Poisson distributed. For other dive time distributions a more complex formalism would be required.

Assume for simplicity that $h(\theta) = 0$ for $\theta > \pi/2$, i.e. that there is no sighting effort apportioned to the backward directions, then:

$$g(y) = 1 - (\text{Probability whale not seen when reached } x = 0)$$

$$= 1 - e^{-\int_0^\infty F(x,y)dx} \tag{6}$$

In particular note that for $y = 0$

$$\begin{aligned} g(0) &= 1 - e^{-\int_0^\infty F(x,0)\,dx} \\ &= 1 - e^{-\int_0^\infty f(x)h(0)\,\frac{1}{v}dx} \\ &\leqslant 1 \end{aligned} \tag{7}$$

Thus $g(0) = 1$ is obtained only in cases where $\int_0^\infty F(x,0)dx$ diverges.

SOME EXAMPLES

For simplicity we take

$$h(\theta) = \begin{cases} 1 & 0 \leqslant \theta \leqslant \pi/2 \\ 0 & \pi/2 < \theta \leqslant \pi \end{cases} \tag{8}$$

i.e. all forward directions are searched with the same intensity. (This is not a necessary assumption, but more realistic parametrizations would for most cases necessitate numerical evaluation of the integrals).

Two cases are considered:

$$\begin{aligned} &\text{(i)} \quad f(r) \sim e^{-\lambda r} \\ &\text{(ii)} \quad f(r) \sim {}^{1}/_{r}\, e^{-\lambda r} \\ &\phantom{\text{(ii)}} \quad f(r) \sim e^{-\lambda r} \end{aligned} \tag{9}$$

The $e^{-\lambda r}$ factor would be the behaviour expected of decreasing sightability with distance due to loss of contrast through scattering of the light by intermediate atmosphere. At larger distances a 1/r factor seems plausible to allow for decreasing apparent size of the object; though clearly this form could not hold down to the $r \rightarrow 0$ limit. A realistic evaluation might require a combination of the two cases.

Case (i):

$$\begin{aligned} \int_0^\infty F(x,y)dx &= \alpha \int_0^\infty e^{-\lambda r} dx \\ &= \alpha \int_y^\infty \frac{r\, e^{-\lambda r}}{\sqrt{r^2 - y^2}}\, dr \\ &= \alpha\, y\, K_1(\lambda y) \end{aligned}$$

$$\text{Thus } g(y) = 1 - e^{-\alpha y\, K_1(\lambda y)} \tag{10}$$

where K_1 is a first-order modified Bessel function.

Plots of $g(y)$ for various values of α/λ are shown in Fig. 2a.

Note that for:

$$\lambda y \ll 1 \qquad g(y) \approx 1 - e^{-\alpha/\lambda}$$

$$\lambda y \gg 1 \qquad g(y) \approx \alpha \sqrt{\frac{\pi y}{2\lambda}}\, e^{-\lambda y}$$

i.e. $g(0) < 1$

Case (ii): $f(r) \sim \frac{1}{r} e^{-\lambda r}$

$$\begin{aligned} \int_0^\infty F(x,y)dx &= \alpha \int_y^\infty \frac{e^{-\lambda r}}{\sqrt{r^2 - y^2}}\, dr \\ &= \alpha\, K_0(\lambda y) \end{aligned}$$

$$\text{Thus } g(y) = 1 - e^{-\alpha K_0(\lambda y)} \tag{11}$$

where K_0 is a zero-order modified Bessel function.

Plots of $g(y)$ for various values of α are shown in Fig. 2b.

Note that for:

$$\lambda y \ll 1 \qquad g(y) \approx 1 - (\lambda y)^{\alpha}$$

$$\lambda y \gg 1 \qquad g(y) \approx \alpha \sqrt{\frac{\pi}{2\lambda y}}\, e^{-\lambda y}$$

i.e. $g(0) = 1$ essentially because $f(r)$ becomes infinite as $r \rightarrow 0$.

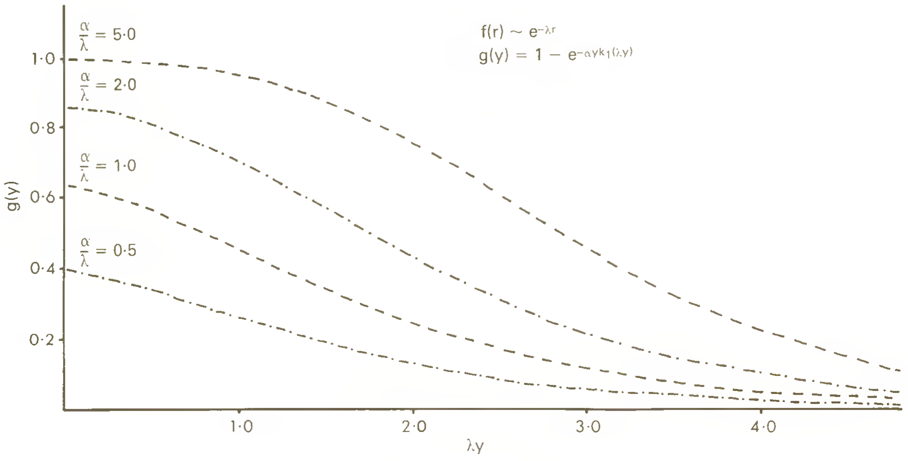

Fig. 2a. Plots of g(y) for case (i).

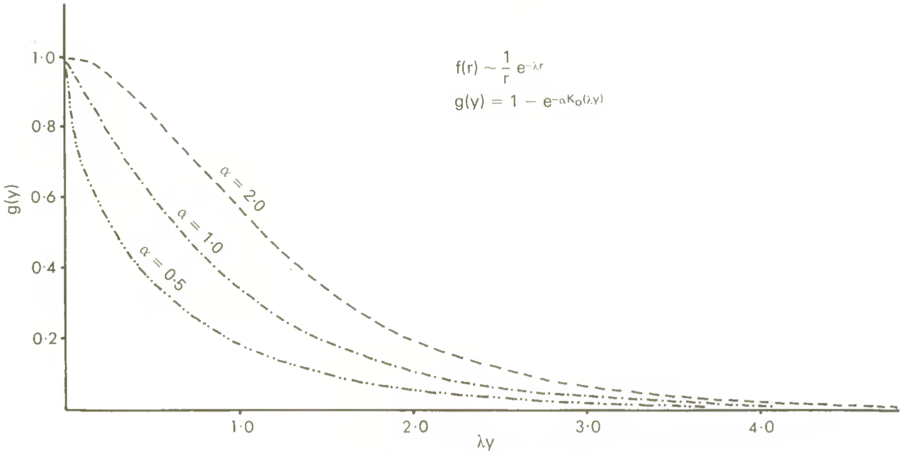

Fig. 2b. Plots of g(y) for case (ii).

Comparison with $g(y) = e^{-\mu y}$

The population estimate is proportioned to I_o^{-1}, where

$$I_o = \int_o^{\infty} g(y)dy \tag{12}$$

For a large number of observations, the mean sighting distance $\bar{y}$ is given by:

$$\bar{y} = I_o^{-1} \int_o^{\infty} y\, g(y)\, dy$$

For the case $g(y) = e^{-\mu y}$

$$\bar{y} = I_o = \frac{1}{\mu}$$

Table 1

Multiplicative correction factors for density estimates for which the mean sighting distance has been used to estimate the effective track-width (equation (13))

$f(r) \sim e^{-\lambda r}$ $g(y) = 1 - e^{-\alpha y K_1(\lambda y)}$		$f(r) \sim {}^1/r\, e^{-\lambda r}$ $g(y) = 1 - e^{-\alpha K_0(\lambda y)}$	
α/λ	C	α	C
0.1	8.45	0.1	4.05
0.2	4.40	0.2	2.47
0.4	2.38	0.4	1.55
0.6	1.71	0.6	1.22
0.8	1.38	0.8	1.06
1.0	1.19	1.0	0.96
1.2	1.06	1.2	0.89
1.4	0.97	1.4	0.84
1.6	0.90	1.6	0.81
1.8	0.85	1.8	0.78
2.0	0.81	2.0	0.76
2.5	0.74	2.5	0.72
3.0	0.70	3.0	0.69
4.0	0.65	4.0	0.66
5.0	0.62	5.0	0.63

Hence if $\bar{y}$ is used to estimate the effective track-width, the resultant population estimate should be corrected by a factor C

$$C = \frac{\bar{y}}{I_o} = \frac{\int_o^{\infty} y\, g(y)\, dy}{\left[\int_o^{\infty} g(y)\, dy\right]^2} \tag{13}$$

Calculations of this correction factor for cases (i) and (ii) were carried out numerically; the results are shown in Table 1 for various values of α. As would be expected from the shape of the $g(y)$ plots, the correction factor is greater than 1 for smaller α, and smaller than 1 for large α. (For case i), correction factors greater than 1 arise not because of greater concavity of the function compared to the negative exponential near $y = 0$, but to allow for $g(0) < 1$.)

DISCUSSION

Formula (11) with small α appears a promising candidate to fit the observed $g(y)$ as it yields a faster steepening increase rate near $y = 0$ than can the negative exponential.†

However preliminary attempts at a numerical fit run into difficulties. The problem, as with the negative exponential, is more observations at large y than the parametrization suggests. This could be a result of α being school-size dependent; the formalism could be extended to incorporate this, which could in turn provide a test for the model, depending on the degree of correlation in diving within a school.

Acceptance of the probability per unit time assumption would call into question the correction made for target velocity (Best and Butterworth, 1980). In terms of the

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† The fact that $g'(y)$ diverges as $y \to 0$ seems unrealistic; however this is a reflection of the unsatisfactory behaviour of the 1/r factor in f(r) as $r \to 0$. An adjustment of the 1/r factor for small r to preclude divergence as $r \to 0$ may avoid the problem.

model there stated, target velocity leads to an apparent population density increase essentially because more targets spend on average less total time within a fixed detection radius of the observer (within which detection is certain). However evaluating the detection chance on a probability per unit time basis, this increase could well cancel out (at least to first order), essentially because of fewer opportunities to see the relatively faster moving target while in 'range'.

Other problems that could be investigated using this formalism are relating the parameters α and λ to experimental results on visual perception; and choosing a function $h(\theta)$ and vessel speed, to optimise sighting probability, i.e. how should the lookouts allocate their effort in looking in various directions relative to the ship's heading.

ACKNOWLEDGEMENTS

Dr P. Furniss (University of Witwatersrand) collaborated in establishing the formalism, prior to the discovery that Koopman (1956) had developed essentially the same results. Mr D. Vogel carried out the numerical integrations.

REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Koopman, B. O. 1956. The theory of search II. Target detection. *Ops Res.* 4: 503–31.

SS/8

An Index of Sighting Conditions for Surveys of Whales and Dolphins

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ABSTRACT

Elaborated from the author's experience of observing whales and dolphins over 32 years, an index of sighting conditions is presented which attempts to quantify 'sightability' on a scale of 1–10, according to the different groups of genera or species of Cetacean which, in varying conditions of visibility, sea state and swell, may be expected to be sighted at given distances from the observer using either mounted binoculars, hand held binoculars or the unaided eye at a given height above sea level.

It is intended that the index be applied through an appropriate mathematical function as an effort modifier when estimating abundance from sightings surveys.

INTRODUCTION

All those who have taken part in voyages to mark whales and to observe whales and dolphins will be aware of the effect on the ability to sight these animals of weather conditions, as described by visibility, wind force, sea state and swell.

On the more recent of past voyages I have distinguished the periods of observations as being under good or poor conditions for sighting Cetacea, these conditions being a consensus of factors, prevailing at the time, which affect sighting and which are described below. Distances sailed and observations made under poor conditions were deducted from the totals when expressing relative abundance of different species as the numbers of sightings, and numbers of animals sighted, per 100 miles sailed (Clarke and Ruud, 1954; Clarke, 1962; Clarke, Aguayo and Basulto, 1978). However, I have long thought that it might be possible to develop an index of sighting conditions, a scale of 'sightability' under varying weather conditions of different species of Cetacea, or groups of species, so that this index could be judiciously applied as an effort modifier when making population assessments by direct sightings. Whilst a guest on board R.V. *David Starr Jordan* during a cruise to observe marine mammals off California and Baja California in September and October 1979, my ideas on this subject were crystallised and Table 1 was constructed.

The line transect method is now often applied in sightings surveys of whales and dolphins, and in theory at least, this method is independent of weather conditions. However, Horwood (1981), reporting on a recent assessment of minke whales employing line transect, has drawn attention to the major effect (which had not been considered) of weather on sighting distances. Moreover, not all scientists are agreed that the line transect approach is applicable to marine mammal surveys.

FACTORS AFFECTING THE SIGHTING OF CETACEA

The factors affecting the sighting of Cetacea are:

1. Weather conditions: visibility, wind force, sea state and swell.
2. Sun glint or glare on the water, a special aspect of visibility which may seriously impair observations over part of the arc of search.
3. Presence or absence of a visible blow in whales, and if present, the height, density and duration.
4. The sounding interval and its variability.
5. Size of the whales or dolphins, which is largely modified by
6. Their behaviour: how much of the beak or dorsal fin (if present) or back is shown at a rising; whether they show flukes or peak flukes when sounding; whether they breach, or skip over the water, to show bodies or tell-tale splashes; whether they are single individuals or in small or in large schools; whether they are attracted to ships (as *Delphinus* appears to be) or whether they avoid them, in which case a further factor is
7. The size of the survey vessel and its method of propulsion.
8. Height of the observation platform.
9. The aids to sighting: whether mounted high-power binoculars, or hand-held binoculars, or the naked eye.
10. The number of observers.

THE INDEX OF SIGHTING CONDITIONS

We can take into account these factors and make a list of genera, or genera and species, of Cetacea in order of their 'sightability', but this will not give an index which will quantify the conditions of observation during any one day at sea, or part of that day if conditions change.

Table 1 is an attempt to provide such an index by relating visibility, sea state (which is also an expression of wind force) and swell to the kinds of whales and dolphins which one may or may not expect to see in these conditions.

The table is a subjective composition derived from my experience of observing whales and dolphins over 32 years on expeditions to the Antarctic in Fl.F.

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Table 1

An index of sighting conditions for cetacea

Visibility excellent to good. Sighting conditions index for cetacea at 3 miles through ×25 mounted binoculars. 2 miles through hand-held binoculars, and 1 mile with the unaided eye. The observer's eye is 10 m above sea level.				Visibility Moderate	Visibility Poor
Sea state	Swell	Sighting conditions index	Cetacea NOT expected to be observed	Sighting conditions index	
0–1	Slight to moderate	1	NONE	2	4
	Heavy	2	*Kogia*	3	4
2–3	Slight to moderate	2	*Kogia*	3	5
	Heavy	3	*Kogia*, *Phocoena*, *Phocoenoides*, *Mesoplodon*	4	6
4	Slight	3	Above, and *Lissodelphis*	4	7
	Moderate to heavy	4	Above, and small schools of dolphins (*Delphinus*, *Tursiops*, *Lagenorhynchus*, *Stenella*, *Steno*, etc.)	4	8
5*	Slight to heavy	5	Above, and large schools of dolphins; also *Grampus*, *Orcinus*, *Globicephala*, *Ziphius*	6	9
5–6*	Slight to heavy	6	Above, and *Berardius*, *Hyperoodon*	7	10
6*	Slight to heavy	7	Above, and *Physeter macrocephalus*, *Eschrichtius robustus*, *Balaenoptera acutorostrata*	8	10
7*	Slight to moderate	8	Above, and *Megaptera novaeangliae*, *B. borealis* and *B. edeni*	9	10
	Heavy	9	Above, and *B. physalus*	10	10
8*	Slight	10	Above, and *B. musculus* (ALL)	10	10

* At and beyond sea state 5 it is not practicable to use mounted ×25 binoculars.

Southern Harvester 1947/48 and again in whale-catcher *Enern* 1953/54 (Clarke and Ruud, 1954); to the North and South Atlantic and the Indian Ocean in R.R.S. *William Scoresby* 1950; in the Southeast Pacific in whalecatcher *Indus X* 1958 and vessels of the Ecuadorian Navy 1959 (Clarke, 1962) and in the whalecatcher *Indus XIV* 1964 (Clarke, Aguayo and Basulto, 1978); and in the northeast Pacific 1979 (Clarke, Au and Dustan, *in press*); together with many excursions lasting a week or ten days each in whalecatchers from shore stations round the world. Only those genera and species are listed which I have observed at sea; thus right whales are not included because I have never been fortunate enough to see either the bowhead (*Balaena mysticetus*) or the pigmy right whale (*Caperea marginata*), and I have only seen black right whales (*Eubalaena australis*) from the shore (Clarke, 1965).

The table was constructed on board R.V. *David Starr Jordan*, so that these indices of sighting conditions refer to sightings where the observer's eye is 10 metres above the sea surface, as on the upper bridge of that ship. The indices would emerge differently, although in the same proportions, with different heights of the observation platform, and Bowditch's table (1975, vol. II, Table 8) of distances to the horizon at various heights above sea level might be used to arrive at revised indices. In Table 1 sea states are from the Beaufort scale; swell is given as slight, moderate or heavy; and visibility as excellent to good, moderate or poor, as defined by Turpin and MacEwen (1965, p. 7–22, Table 3).

The table shows first the genera and species which may *not* be expected to be observed in conditions of excellent to good visibility at three miles through mounted binoculars magnifying 25 times, at two miles through hand-held binoculars magnifying 7–10 times, and at one mile with the unaided eye. (The classification shows the kinds of animals *not* expected to be observed so as to avoid repetition of lists of genera and species in the table). It is of course possible, in conditions of calm and excellent visibility, to observe the larger whalebone whales, and perhaps the sperm whale, at much greater distances than three miles, say up to seven miles in the case of the blue whale, but this would require additional tables.

The index of sighting conditions goes from 1 to 10, as the conditions worsen. At the distances given, with sea state 0–1, and a slight to moderate swell, we should expect to observe all kinds of Cetacea, and the index is 1. In the same sea state of calm, but with a heavy swell, we should not expect to see the pigmy sperm whale *Kogia*, because it seems to have no visible blow and lies low, 'rafting' in the water, and so can be lost behind the rising swell. This condition receives the index 2, and so on. At sea state 4, and moderate to heavy swell, large schools of dolphins may still be expected to be seen (index 4) because, jostling each other with their numbers, they breach more and make more splash than small schools which can be expected to be seen as far at the same sea state but with a slight swell (index 3). At sea state 7 and a heavy swell (index 9) we should not expect to observe any whales except the blue whale (*Balaenoptera musculus*), whilst at sea state 8 the spout of this species will also have been blown by the wind and the rising obscured by sea and spindrift, whether the swell be slight or heavy. This is index 10 when we may expect to see no Cetacea at these distances in excellent to good visibility.

Although this is the sequence of Cetacea which we expect to observe (or rather, not observe) no categorical statements are intended of what may actually be observed in a given set of these conditions during a survey. Moreover, although according to the sighting conditions index such and such groups of Cetacea may be expected to be sighted, it is not suggested that they will necessarily be identified at these distances and in these conditions. After a sighting the ship would presumably attempt to approach the animals so that they may be identified.

The indices of sighting conditions when visibility is moderate or poor are shown on the right hand side of Table 1. Thus, in poor visibility with sea state 0–1 and slight to moderate swell, the index is put at 4 which means (consulting the table for index 4 in the columns for excellent to good visibility) that at the distances given we should not expect to see *Kogia*, *Phocoena*, *Phocoenoides*, *Mesoplodon* or *Lissodelphis*. Again, in poor visibility with sea state 5–6 and slight to heavy swell, the index is put at 10, that is to say, we should not expect to observe any species of Cetacea.

In constructing the table I have found no way to take into account sunglint on the water, which can so adversely affect sighting conditions over a part of the arc of search in conditions of visibility which are otherwise usually excellent to good.

With sufficient experience a similar table could be prepared for sighting pinnipeds at sea.

APPLICATION OF THE INDEX

During a voyage to observe Cetacea, conditions of visibility, sea state and swell are usually logged every hour by the officer of the watch, and sometimes independently by the scientific observers. Table 1 would then provide the appropriate index according to the conditions prevailing during each hour of observation. The index could then be applied separately for each hour, or a weighted mean obtained over the day's observations.

The results of past surveys could be revised by applying indices of sighting conditions obtained by consulting the metereological data in the logbooks of those surveys.

The index is intended as an effort modifier, to be applied to the distance sailed or the area searched. I have not the mathematics to propose how this might judiciously be done, although I have thought perhaps that an approach might be to apply the reciprocal of the square root of the index to the effort.

I wish this contribution to be regarded as a working paper, in the hope that, if the Workshop thinks the index can be usefully applied, members better qualified than I may suggest the mathematics of its application.

ACKNOWLEDGEMENTS

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REFERENCES

Bowditch, M. 1975. *American Practical Navigator. An Epitome of Navigation.* Defense Mapping Agency Hydrographic Centre, U.S.A. 2 vols.

Clarke, R., 1962. Whale observation and whale marking off the coast of Chile in 1958 and from Ecuador towards and beyond the Galápagos Islands in 1959. *Norsk Hvalfangsttid.* 51(7): 265–87.

Clarke, R., 1965. Southern right whales on the coast of Chile. *Norsk Hvalfangsttid.* 54(6): 121–8.

Clarke, R., Aguayo L., A. and Basulto del C., S. 1978. Whale observation and whale marking off the coast of Chile in 1964. *Sci. Rep. Whales Res. Inst., Tokyo*, 30, 117–77.

Clarke, R., Au, D. and Dustan, P. (In press). Observaciones sobre ballenas y delfines frente a las costas de California y Baja California en septiembre y octubre de 1979. *Ciencias Marinas.*

Clarke, R. and Ruud, J. T. 1954. International co-operation in whale marking: The voyage of the *Enern* to the Antarctic 1953. *Norsk Hvalfangsttid.* 43(3): 128–46.

Horwood, J. W. 1981. Results from the IWC/IDCR minke whale marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Turpin, E. A. and MacEwen, W. A. 1965. *Merchant Marine Officer's Handbook.* Cornell Maritime Press Inc., Cambridge, Maryland, 4th edn.

SS/12

Using Average Number of Whales in View to Estimate Population Density

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INTRODUCTION

Burnham, Anderson and Laake (1980) listed, in order of importance, a set of assumptions common to all the methods of estimating density from sightings data which they considered. The first two items in their list are:

(1) Objects directly on the line will never be missed
(2) Objects are fixed at their initial sighting position (they do not move before being sighted) and none are counted twice.

For certain combinations of whale species and sighting platform those assumptions seem hard to justify. A whale directly on the transect line may be missed if it dives under the sighting platform, particularly if that species dives for long periods, the platform is moving relatively fast and the sighting conditions are poor (using the notation of Doi (1974), if $VT > 1$ then $f(x) < 1$ for all x). On the other hand if the sighting platform is moving slowly the assumptions under (2) are likely to be violated.

Under certain circumstances, notably sightings from low flying aircraft or sailing boats, it may be possible to replace the assumptions under (1) and (2) by the following:

During those periods used for whale sighting, the location of each whale is independent of the location of the sighting platform at all times.

That assumption implies that whales do not move towards or away from the platform even after having been sighted and that, at least during the sighting periods, the platform does not change its speed or course in response to sighting a whale. The times chosen to start and finish the sighting periods must also be independent of the sightings themselves.

Under that, admittedly restrictive, assumption the p.d.f. of radial distance from a given whale to the platform at any time, is known. Then the model for perpendicular sighting distances in Burnham *et al.* (1980) can be modified for radial 'viewing' distances. 'Viewing' distances are the distances, at a given time, from the viewing platform to any whales in view at that time, as opposed to distances from the platform to the positions where whales are first sighted. That modification allows any independent estimate of the proportion of time spent at the surface by the whales to be used to allow for those whales missed during their diving period. It also eliminates any worry about whales moving at speeds of the same order as that of the platform, or of whales being counted more than once. The viewing platform may move at any speed along any track so long as that speed and track is independent of the perceived locations of the whales, e.g. viewing could be used from a stationary platform to assess local density.

THE MODEL

Let D represent the mean density in the area of interest. Suppose the assumption of independence of the location of the platform and each whale holds for the platform used and the species of whale observed. Then at any time the expected number of whales within a circle of radius ω of the platform is

$$\pi\omega^2 D$$

Let the proportion of time spent on the surface be S, on average. Then the expected number of whales on the surface within the circle is

$$\pi\omega^2 DS$$

Let the probability a whale is in view given it is on the surface in the circle be P_ω. Then the expected number of whales in view within the circle is

$$E(n) = \pi\omega^2 DSP_\omega \tag{1}$$

so

$$D = E(n)/\pi\omega^2 P_\omega S$$

Let $g(r)$ be the probability that a whale is in view given it is on the surface at distance r from the platform and assume that $g(r) = 1$ for $r \leqslant r_0$ where r_0 is some positive real number.

The probability a whale is on the surface at distance $< r$ from the platform given it is on the surface at distance $< \omega$ from the platform is

$$\pi r^2/\pi\omega^2$$

(neglecting the area of the platform itself) so the corresponding p.d.f. is

$$2r/\omega^2$$

Thus the probability it is in view at distance $< r$ from the platform given it is on the surface at distance $< w$ from the platform is

$$\int_0^r g(x)\,\frac{2x}{\omega^2}\,dx$$

and the probability it is at distance $< r$ from the platform given it is in view at distance $< w$ from the platform is

$$\int_0^r g(x)\,\frac{2x}{\omega^2}\,dx\Big/P_\omega$$

The corresponding p.d.f. of viewing distance is

$$f(r) = g(r)2r/\omega^2 P_\omega \tag{2a}$$

Thus

$$f'(r) = (g'(r)2r + g(r)2)/\omega^2 P_\omega \tag{2b}$$

and

$$f'(o) = 2/\omega^2 P_\omega$$

Thus

$$D = \frac{E(n)f'(o)}{2\pi S} \qquad (3)$$

Estimating E(n) *and* f′(0)

E(n) is the mean, for the population, of the number of whales in view from the platform at any time. One estimate of E(n) is

$$\Sigma i d_i / \Sigma d_i$$

where d_i is the duration of time for which i whales are visible, i = 0, 1, 2 . . . . This necessitates recording the start and finish time of each interval for which each whale is visible. It may be impractical to record the data in this way. Some species may be visible at the surface for only an instant. Even if the whales are visible for an extended period it may be difficult to decide at exactly what time they cease to be visible. A more practical alternative would be to record the number of whales seen in each of a large number of short intervals Δt and take the average of these numbers over all the intervals. Δt must be short enough for the probability of the same whale being counted more than once within that interval to be negligible. g(r) is then the probability that a whale is seen during the interval given it is on the surface at distance r at some time during the interval and S is the probability that a whale is on the surface at some time during that interval. S would have to be estimated from the stochastic process describing the whale's diving behaviour. For example, if dd and ds represent the mean dive duration and mean duration of time spent at the surface, an estimate of S is 1 − (dd − Δt)(dd + ds), i.e. 1 − prob {Δt falls entirely within dive duration}. It is the dependance of S on Δt which allows a certain leeway in the choice of the duration of Δt.

f(r) is the p.d.f. of viewing distance. The data for estimating f′(0) is the estimated distance from the platform to each whale seen in each interval (if the alternative of noting the durations of periods for which each whale is visible were used, this distance would be estimated at regular intervals). One method for estimating f′(0) from such data is to adapt the Fourier series estimate of f(n), given f′(0) = 0, described by Burnham *et al.*, to estimating f′(r), given f(0) = 0. Construct the odd extension Φ(r) of f(r) with period 2w:

$$\phi(r) = \begin{cases} f(r) & o \leqslant r \leqslant \omega \\ -f(-r) & -\omega \leqslant r \leqslant o \end{cases}$$

and expand Φ(r) in a Fourier series:

$$\phi(r + 2\omega) = \phi(r)$$

and expand $\phi(r)$ in a Fourier series:

$$\phi(r) = \sum_{j=1}^{\infty} b_j \sin\left(\frac{j\pi r}{\omega}\right)$$

where

$$b_j = \frac{2}{\omega} \int_o^\omega f(r) \sin\left(j\frac{\pi r}{\omega}\right) dr$$

Then over (o,w),

$$f(r) = \sum_{j=1}^{\infty} b_j \sin\left(j\frac{\pi r}{\omega}\right)$$

so that f(0) = 0 as required by equation (2a) and

$$f'(r) = \sum_{j=1}^{\infty} b_j\, j\frac{\pi}{\omega} \cos\left(j\frac{\pi r}{\omega}\right)$$

$$f'(o) = \sum_{j=1}^{\infty} b_j\, j\frac{\pi}{\omega}$$

$$\approx \sum_{j=1}^{m} b_j\, j\frac{\pi}{\omega}$$

for finite m.

An unbiased estimate for b_j is

$$\hat{b}_j = \frac{2}{\omega}\frac{1}{o}\sum_{i=1}^{o} \sin\left(j\frac{\pi r_i}{\omega}\right)$$

where 0 is the total number of radial distance estimates r_i, and m is chosen using the stopping rule described in Burnham *et al.*

SOME NOTES

1. The density estimator described above meets the model and pooling robustness criteria defined by Burham *et al.* For example, if $n_i \ldots n_k$ are the mean number of whales seen per Δt interval (or mean number of whales in view) for k stratifications of the population, and $0_i \ldots 0_k$ are the numbers of radial distance estimates for these strata then

$$\sum_{p=1}^{k} \frac{np}{2\pi S} \sum_{j=1}^{m} \left[\frac{2}{\omega}\frac{1}{op}\sum_{i=1}^{op} \sin\left(j\frac{\pi r_i}{\omega}\right)\right] j\frac{\pi}{\omega}$$

$$= \frac{n}{2\pi S} \sum_{j=1}^{m} \left[\frac{2}{\omega}\frac{1}{o}\sum_{i=1}^{o} \sin\left(j\frac{\pi r_i}{\omega}\right)\right] j\frac{\pi}{\omega}$$

as $0_l = cn_l$ for some constant c,

$$\text{i.e. } \sum_{l=1}^{k} n_l f'_l(o) = nf'(o)$$

Corresponding to the shape criterion f′(n) equals 0 at x = 0 which was based on the idea that g′(n) should equal 0 at u = 0, we now have that f″(r) should equal 0 at r = 0 for, from equation (2b),

$$f''(r) = \left(g'(r)2 + g''(r)2r + g'(r)2\right)/\omega^2 P_\omega$$

This third criterion is also satisfied by the F.S. estimator of f′(r).

2. The assumption that g(r) = 1 for $r \leqslant r_0$, for some positive real r_0 implies that a whale surfacing near the platform is certain to be seen, even if it surfaces for only an instant. If this were not the case given the number of observers, the sector of ocean viewed would have to be reduced to some angle, say θ, which could be kept in view continuously. 2π in equation (3) is then reduced to θ.

3. The assumption of independance of platform and whale location is crucial to the suggested method. It is presumably violated over short distances for any ocean going platform. The problem might be overcome as follows.

The assumption that g(r) = 1 for $r \leqslant r_0$ imples that if the independence assumption holds even for very short distances, f(r) would be straight line segment from (0,0) to $(r_0, f(r_0))$ (c.f. equation (2a)). Failure of the sample distribution of viewing distances to conform to this pattern thus indicates failure of the independence assumption, as does any obvious movement of whales away from or towards the platform. However that failure would not be a problem if it were certain that any distortion in the distribution of whales caused by the presence of the platform did not extend beyond r_0 from the platform, at least within the chosen viewing sector. In that case, viewing distances $r_i < r_0$ could be redistributed as a straight line segment from (0,0) to $(r_0, f(r_0))$ before estimation of $f'(0)$.

4. Values of n and r_i obtained from successive Δt intervals are positively correlated to a degree which must decrease with increasing speed of the platform but which is otherwise unknown. No general formulae for the variance of E(n) and $f'(0)$ estimates are therefore available, and the variance of the density estimate must be assessed by using replicate estimates.

5. Three possible answers to the problems of estimating viewing distances accurately and identifying species from the platform are:

(1) Limit radius w to a distance within which species identification and distance estimation can be reliably carried out from the platform. Ignore whales seen beyond w.
(2) Send a second platform to investigate more closely, well to the rear of the chosen viewing sector.
(3) Establish predetermined viewing and non-viewing periods, returning to a predetermined location by the start of the next viewing period.

REFERENCES

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72: 202 pp.

Doi, T. 1974. Further development of whale sighting theory. pp. 359–68 *In:* W. E. Schevill (ed.), *The Whale Problem: A Status Report* Harvard University Press, Cambridge, Mass.

SS/14A

Size of Bottlenose Dolphin Population(s) in Indian River, Florida

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Leatherwood (1979), Thompson (1981) and Leatherwood, Reeves and Show (1982) have published estimates of the size of the bottlenose dolphin population(s) in Indian and Banana Rivers, Florida from sightings made during low altitude aerial surveys. The former used a fixed-strip-width model with one-sided strip width of 0.463 km (0.25 nm), the middle a Fourier series fitted to rescaled data, and the latter the Anderson-Pospahala-Parr-Gates (APPG) estimator (Anderson and Pospahala, 1970; Gates, 1979) as modified by Leatherwood, Show, Reeves and Wright (1982) to account for the area of obstructed visibility along the transect center-line. Controversy continues over the efficacy of various line transect models for analysis of transect data on cetaceans. Further, there is far from agreement about which detailed procedures are appropriate for treating such transect data to calculate population estimates and measures of confidence (IWC, 1982), particularly when the transect-center-line and some associated strip along it cannot be observed (Thompson, 1981). Therefore, in order that the available estimates can be compared, I here present recalculations, from data presented in Leatherwood, Show and Reeves (1982), of the size of the Indian River bottlenose dolphin population(s) (Table 1).

Density calculations were made using sightings made in November 1979 and January 1980 within the 0.463 km strip while the aircraft was on transect and the fixed-strip-width model described by Leatherwood (1979). The estimated density of dolphins was calculated by:

$$\bar{d} = \bar{h}\bar{a} \qquad (1)$$

where $\bar{h}$ = mean herd size, calculated from all herds encountered, whether on transect or not; $\bar{a}$ = mean herd density, described as n/2Lw, where L = total length of transects, n = total sightings, and w = the one-sided strip width of 0.463 km.

The estimated variance of this product ($S^2(\bar{d})$) was calculated from Goodman (1960):

$$S^2(\bar{d}) = \bar{h}^2 S^2(\bar{a}) + \bar{a}^2 S^2(\bar{h}) - S^2(\bar{a}) S^2(\bar{h}) \qquad (2)$$

where $\bar{h}$ = mean herd size; $\bar{a}$ = mean herd density; $S^2(\bar{h})$ = estimated variance of mean herd size; and $S^2(\bar{a})$ = estimated variance of mean herd density.

The resultant estimates (Table 2) are consistently lower than those obtained using the APPG estimator. (Leatherwood, Show and Reeves, 1982; Thompson, 1981) although all available estimates for the area are in relatively close agreement. As noted above there are the troublesome difficulties preventing calculation of easily-agreed-upon estimates of population size using such survey data and line-transect models. Until such time as there is a satisfactory resolution of those difficulties by theoretical

Table 1

Values used to estimate herd density, dolphin density and total size of bottlenose dolphin population(s) in Indian and Banana Rivers, Florida. Total Area = 807.5 km²; w = 0.463 km/side.

Date	Length flown	No. of sightings	Herd density	Mean herd size	Dolphin density	Estimated dolphin totals
	(km)	(n)	($\bar{a}$)	($\bar{h}$)	($\bar{d}$)	
Nov 27 (1)	175.2	4	0.025	5.64	0.141	113.9
Nov 27 (2)	174.2	6	0.037	6.67	0.247	199.4
Nov 28	142.7	8	0.060	6.17	0.370	298.8
Nov 30	175.2	7	0.043	7.91	0.340	274.5
Mean	166.2	6.25	0.0412	6.598	0.274	221.6 (188.3, 254.9)*
Variance	258.9	2.92	0.00021	0.942	0.010	6520.6
Jan 25 (1)	130.9	4	0.033	7.9	0.261	210.8
Jan 25 (2)	130.9	4	0.033	5.5	0.182	147.0
Jan 30	130.9	8	0.066	5.3	0.350	282.6
Mean	130.9	5.33	0.044	6.233	0.264	213.5 (171.8, 255.2)*
Variance	0.0	5.33	0.00036	2.093	0.0094	6129.3

* Estimates include 95% confidence limits. Using the alternative method described by Leatherwood (1979, p. 50–3) the following pooled estimates were obtained: November: Density, $\bar{x}$ = 0.272, S^2 = 0.0070; Total population, $\bar{x}$ = 219.6, S^2 = 4,564.4; January: Density, $\bar{x}$ = 0.264, S^2 = 0.0052; Total population, $\bar{x}$ = 213.5, S^2 = 3,390.7.

Table 2

Available estimates of size of bottlenose dolphin population(s) in Indian and Banana Rivers, Florida

Source	Month	Year	Method	Estimate
Leatherwood (1979)	August	1977	Fixed-strip-width estimator, w = 0.463 km/side	438; 95% C.L. = 311, 749.
Leatherwood, Reeves and Show (1982)	November	1979	A–P–P–G	302.5, S^2 = 7,851
This paper	November	1979	Strip estimator, w = 0.463 km/side	221.6; 95% C.L. = 188.3, 254.9.
Leatherwood, Reeves and Show (1982)	January	1980		597.3, S^2 = 14,840.3
This paper	January	1980	Fixed-strip-width estimator, w = 0.463 km/side	213.5; 95% C.L. = 171.8, 255.2.
Thompson (1981)	May	1980	Fourier series	206.0; 95% C.L. = 32,380.
	August	1980	"	435.0; 95% C.L. = 263,607.
	November	1980	"	202; 95% C.L. = 96,308.

statisticians, fixed-strip-width estimators may be indicated. They minimize the assumptions required and freely admit negative bias of undetermined proportions. For figures used for management purposes such conservatism in population estimation is judicious.

REFERENCES

Anderson, D. R. and Pospahala, R. S. 1970. Correction of bias in belt transect studies of immotile objects. *J. Wildl. Manage.* 7: 322–7.

Gates, C. E. 1979. Line transects and related issues. pp. 71–154. *In:* R. M. Cormack, G. P. Patel, and D. S. Robson (eds), *Sampling Biological Populations.* Fairland, Maryland. International Cooperative Publishing House.

Goodman, L. A. 1960. On the exact variance of products. *J. Am. Stat. Assoc.* 55: 708–13.

International Whaling Commission. 1982. Report of the workshop on the design of sightings surveys. (Published in this volume.)

Leatherwood, S. 1979. Aerial survey of the bottlenose dolphin, *Tursiops truncatus*, and the West Indian manatee, *Trichechus manatus*, in the Indian and Banana Rivers, Florida. *Fish. Bull.* (U.S.) 77(1): 47–59.

Leatherwood, S., Reeves, R. R. and Show, I. T., Jr. 1982. Effects of varying altitude on aerial surveys of bottlenose dolphins. Published in this volume.

Leatherwood, S., Show, I. T., Jr., Reeves, R. R., and Wright, M. B. 1982. Proposed modification of transect models to estimate population size from aircraft with obstructed downward visibility. Published in this volume.

Thompson, N. B. 1981. Estimates of abundance in the Indian–Banana River complex, Florida in 1980. (abstract). Fourth Biennial conf. on biol and Conserv. of Marine Mammals. San Francisco, Calif. 14–19 Dec. 1981, p. 118.

SS/14B

Effects of Varying Altitude on Aerial Surveys of Bottlenose Dolphins[1,2]

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ABSTRACT

Replicate aerial surveys were flown at four test altitudes in January 1979 over Indian and Banana Rivers, eastern Florida, to determine effects of varying altitude on observed densities of bottlenose dolphins. In six sample periods, neither altitude nor flight had any significant linear effect on number of sightings or estimated population size ($\alpha = 0.05$). However, altitude did have a significant quadratic effect on the two response variables ($\alpha = 0.01$), resulting in the highest number of sightings and highest estimates of population size at 246 m, lower values approximately equal to one another at 164 m and 328 m, and significantly lower values at 410 m. The population estimate from the 164 m samples (597.3, $s^2 = 14{,}840.3$) was significantly higher ($\alpha = 0.01$) than that from comparable 164 m samples of the same area in November 1979 (302.5, $s^2 = 7{,}851$). In January large concentrations of dolphins were noted in close association with shoals of fish in adjacent offshore waters. High January counts in the inshore study area might indicate seasonal differences in population size due to immigration from offshore, or they may be an artifact of dolphin movement within the rivers.

INTRODUCTION

Low altitude aerial surveys recently have been used to estimate population size, and incidentally to describe other aspects of biology and behavior, of a variety of small odontocete cetaceans, including bottlenose dolphins, *Tursiops truncatus*. Leatherwood *et al.* (1978) compared the efficacy of several aerial survey techniques in obtaining population estimates of bottlenose dolphins and quantified effects on observed densities of varying time of day, day of survey, and observer. Surveys for that experiment were conducted at 164 m. Altitudes in other surveys of small cetaceans have ranged from 150–500 m (see Table 1). Choices of survey altitude apparently have been made on subjective grounds, such as safety, observer comfort, size and behavior of the target species, size of the area being surveyed, environmental conditions, etc.

Between 21 and 31 January 1980 we conducted 6 sets of flights (2 aircraft/flight each flying identical transects) in Banana River and the north end of Indian River, Florida, to determine effects of altitude and, secondarily, replicate flights on survey results.

MATERIALS AND METHODS

This experiment used a fully crossed factorial design analyzed by standard analysis of variance (ANOVA) techniques. We included only altitude and replicate survey flights as controlled independent variables. The other unavoidable major variables (aircraft/pilot combination, observer position assignment, and aircraft starting order) were randomized and became part of the overall experimental error.

Altitudes of 164, 246, 328 and 410 m were selected. Aircraft instrument altimeter readings are in feet. Surveys were actually flown at indicated altitudes of 500, 750, 1,000 and 1,250 ft. Six pairs of flights (experimental units) would have been required to balance observer pairings adequately, so 24 pairs of flights (6 pairs of flights × 4 altitudes) would have been necessary to execute a fully crossed factorial design. This approach would have mandated that 4 aircraft be aloft during each experimental unit, each flying the same set of transects at different altitudes. For logistical, safety, and financial reasons, we used only 2 aircraft at a time. We therefore used a balanced incomplete block of a full factorial design, performing a fraction (1/2) of the 24 possible experimental units by flying pairs of altitudes during each experimental unit. The pairs were chosen to give a balanced design, each altitude being flown 3 times with each possible pair occurring together only once (Table 2).

The aircraft were designated '1' and '2' to facilitate selections of altitude and starting order. It was neither safe nor desirable to fly both aircraft over each transect simultaneously. Doing so would have significantly increased the danger of a collision and the probability that one aircraft, in diverting from a transect to investigate a sighting, would alert the crew in the other aircraft to the presence of animals. Therefore, the aircraft began the first transect 1 hour apart, with the starting order reversed on each set of flights. The end of the study area on which transects began and the direction of flight along the first transect were similarly alternated.

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[1] Data and analyses included in this paper were originally presented to the U.S. National Marine Fisheries Service, Southeast Fisheries Center, 75 Virginia Beach Drive, Miami, Fla. 33149 USA as a final report on their contract NA79-GA-C-0038.

[2] This paper incorporates review comments by Drs. Clait E. Braun and W. S. Overton and an anonymous reviewer for the Journal of Wildlife Management.

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Table 1

Altitudes at which some aerial surveys of smaller toothed cetaceans have been conducted

Source of data	Principal study region	Target species	Reported altitude[1]	
Doan and Douglas (1953)	Churchill Region, western Hudson Bay, Canada	*Delphinapterus leucas*	1,000 & 2,000 ft	—
Kasuya (1971)	Pacific coast of Japan	All toothed whales	—	500 m
Zemsky and Yablokov (1974)	Black Sea	*T. truncatus, Delphinus delphis* and *Phocoena phocoena*	—	300 m
Evans (1975)	Southern California Bight	*D. delphis*	500–1,000 ft	(150–300 nm)
Smith (1975) and Barham *et al.* (1975)	Eastern tropical Pacific	*Stenella attenuata,* *S. longirostris,* *S. coeruleoalba* and *D. delphis*	1,000–1,500 ft	—
Anonymous (NMFS) (1977) and Barham and Powers (1977)	Eastern tropical Pacific	Odontocetes, primarily *Stenella* Spp. and *D. delphis*	900–1,200 ft	—
Leatherwood *et al.* (1978)	Alabama, Mississippi, Louisiana	*T. truncatus*	500 ft	(152 m)
Odell and Reynolds (1978)	Florida panhandle to Florida Bay	*T. truncatus*	1,000 ft	(304 m)
Leatherwood (1979)	Indian and Banana Rivers, Florida	*T. truncatus*	500 ft	(152 m)
Leatherwood and Walker (1979)	Southern California and NW Baja California	*Lissodelphis borealis*	500–1,000 ft	(150–300 m)
Barham *et al.* (1980)	Port Aransas to Matagorda, Texas	*T. truncatus*	500 ft	(152 m)
Jackson (1980) and Holt and Powers (1980)	Eastern tropical Pacific	Odontocetes, primarily *Stenella* Spp. and *D. delphis*	900 ft	—
Keller, Leatherwood and Holt (1981)	Seychelle Islands, Indian Ocean	All cetaceans primarily *Physeter macrocephalus* but including dolphins, as well.	1,000 ft	(308 m)
Hay (1981)	Eastern Newfoundland and southeastern Labrador	*Globicephala melaena* plus *Megaptera novaeangliae* and *Balaenoptera physalus.*	750 ft	—
Finley *et al.* (1981)	Northern Quebec	*Delphinapterus leucas*	—	150–70

[1] When reported, equivalents are included in parentheses.

The same 4 observers, each highly experienced in aerial surveys of cetaceans, were used throughout the experiment (of all variables previously examined, only observer experience and skill have been demonstrated to have a significant effect on survey results [Leatherwood *et al.*, 1978]). Observer assignments to aircraft were random and observer placement inside the aircraft (right front or left rear) was determined by coin toss.

The study area was divided into zones 4.63 km (2.5 nm) wide, north to south, spanning the entire river complex, following Leatherwood (1979). Each zone was numbered at 0.463 km (0.25 nm) increments along the west and east boundaries. For each experimental unit a single transect in each zone was selected randomly (Fig. 1). Transects were flown on magnetic headings of east (090°) or west (270°) to facilitate navigation.

Table 2

Schedules for assignment of altitudes; observer placement; and rotation of starting order, location, and direction in paired flights to examine effects of varying altitude on aerial counts of bottlenose dolphins

			Observer positions					
Day	Date	Aircraft	Left rear	Right front	Start order	Start point	Start direction	Altitude (m)
1	22 Jan	1	4	1	1	N	E	328
	22 Jan	2	2	3	2	N	E	410
2	24 Jan	1	3	2	2	S	W	246
	24 Jan	2	1	4	1	S	W	410
3	25 Jan	1	2	4	1	N	W	164
	25 Jan	2	1	3	2	N	W	246
4	25 Jan	1	4	3	2	S	E	164
	25 Jan	2	1	2	1	S	E	328
5	30 Jan	1	2	1	1	N	E	164
	30 Jan	2	4	3	2	N	E	410
6	31 Jan	1	1	3	2	S	W	246
	31 Jan	2	4	2	1	S	W	328

and

$$\hat{g}(o) = \frac{\hat{f}(o)}{1 - a\hat{f}(o)} \qquad (7)$$

Prior to the beginning of the experiment, we decided that no variable would be considered significant unless the appropriate F-ratio exceeded 0.95.

RESULTS

All 12 experiments units were completed between 22 and 31 January 1980 as planned, except that unsuitable weather conditions forced us to make 4 instead of 2 flights on 25 January. We do not consider this departure serious and have not given it special consideration in the analysis. We made 153 sightings (Table 3) at the locations indicated (Figs 2 and 3). The number of sightings, average herd size, and estimate of total population varied (Table 4).

Separate analyses were conducted for mean herd size, number of sightings, and estimated total population (Table 4). The method of analysis treated the experiment as a balanced incomplete block design. It was assumed that the time between passage of the aircraft as well as navigation error resulted in enough differential in location of dolphins to present spatially distinct target populations to the observer teams. Another method considered would have treated the day-transect (Table 2) as members of treatment pairs in a split-plot design. This design assumes that the treatment pairs each observe target populations that are not independent. We decided that the assumptions for the balanced incomplete block design were more reasonable. A careful study of Figs 2 and 3 support our contention intuitively; a transect by transect Chi-square comparison on number of sightings and herd size showed the day-transect pairings to be significantly different ($P < 0.001$).

Neither flight nor altitude has a significant ($P \leqslant 0.05$) linear effect on any of the response variables. But there were significant quadratic responses of number of sightings and estimated total population to altitude, with a strong maximum at 246 nm (Fig. 4); R^2 values were 0.4055 and 0.4664 with confidence levels of 0.992 and 0.995 respectively.

We analyzed herd size data in a one-way ANOVA to determine the effect of altitude on herd size estimation (Table 5) and found no differences ($P < 0.05$).

There were also no differences ($P < 0.05$) in percent calves and juveniles as altitude changed (Table 5). However, the number of sightings was affected ($P < 0.05$) by the observed sighting cues and was near significance ($P = 0.076$) by altitude (Table 5).

To allay the concern that observer differences and pairings significantly affected results we performed a t-test comparing right and left observers' sighting frequencies. We found no significant differences between right ($\bar{x} = 6.425$, $S^2 = 15.172$) and left ($\bar{x} = 6.325$, $S^2 = 9.670$) ($t_{calc} = 0.0695$, $P(t) = 0.527$).

DISCUSSION

The experiment indicated that higher numbers of sightings and estimated population totals were obtained at 246 m than at any other altitude. We assume that these two variables were estimated with a negative bias for two reasons. First, at 164 m and 90 knots, the observer has a maximum of only about 30 seconds in which to detect a

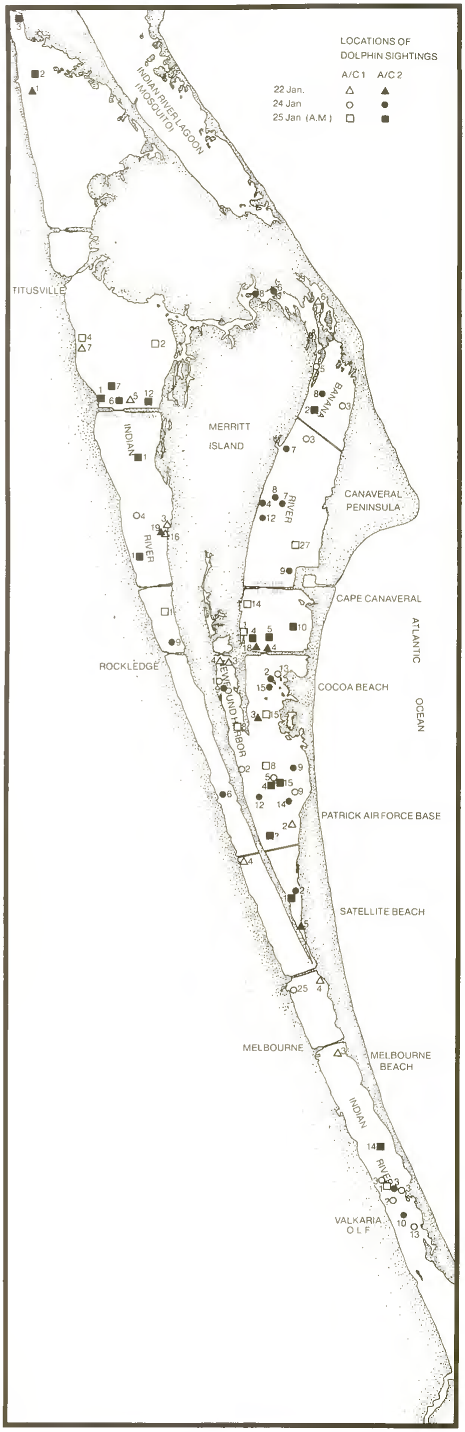

Fig. 2. Locations of sightings made during the first three pairs of flights. Numbers by the symbols indicate the number of individuals counted.

Table 3

Summary of bottlenose dolphin sightings by altitude

Attitude (m)	Date	No. of sightings	Total	No. of animals counted: Adults	Juveniles	Calves
	25 Jan	10	79	68	6	5
164	25 Jan	10	56	56	3	5
	30 Jan	14	74	74	5	4
	$\bar{X}$	11.3	69.7	60.3	4.7	4.7
	24 Jan	19	156	133	9	14
246	25 Jan	16	80	70	2	8
	31 Jan	17	117	98	9	10
	$\bar{X}$	17.3	117.7	100.3	6.7	10.7
	22 Jan	7	29	20	3	6
	25 Jan	18	176	149	8	19
	31 Jan	15	70	65	2	3
	$\bar{X}$	13.3	91.7	78.0	4.3	9.3
	22 Jan	4	28	21	0	7
410	24 Jan	14	89	75	5	9
	30 Jan	9	73	65	6	2
	$\bar{X}$	9.0	63.3	53.7	3.7	6.0

given herd of dolphins. As dolphins are not visible from the air at all times, the probability of missing a herd can be quite high. All herds present near the transect probably are not seen, and underestimates result. Second, the optimum viewing region along the center-line of the transect is invisible from the side-viewing aircraft, causing the observers to miss the otherwise most likely sightings. The altitude yielding the highest estimates would therefore be the most desirable as it would minimize the negative bias.

The extremely low significance of the dependence of herd size on altitude implies that for altitudes between 164 and 410 m, herd size estimation is almost totally unaffected by the altitude from which the estimate is obtained. The importance of this to aerial transect methodology is that although transects should be flown at or near 246 m, the orbital altitude at which the number of animals in a herd is counted can be varied as desired for crew comfort, safety and optimum viewing.

Identification and enumeration of juveniles and calves was also unaffected by altitude. At 164, 246, 328 and 410 m, the overall percentage of juveniles plus calves was 13, 15, 15 and 15% respectively. This is important as an inability to count juveniles and calves accurately at all altitudes would require orbiting at some optimum altitude despite the fact that overall herd size estimation is unaffected by altitude.

Analysis of sighting cues showed that there were significant differences in the number of sightings made as a result of various cues. Even though it cannot be shown statistically, different cues are favored to some extent at different altitudes. In particular, sightings at great distances from the transect track resulting from indirect cues (such as seeing birds and glitter off slight ripples) tend to occur more frequently at greater altitudes.

All analyses support the selection of 246 m as a standard survey altitude for censusing bottlenose dolphins. This altitude also is preferable to lower altitudes because of creature comfort; the comfortable wing-point orbital altitude for the commonly used *Cessna* 172 is around 260 m. Higher altitudes are not preferable for safety reasons. The altitude 328 m is popular for sightseeing and 328 and 410 m are important approach altitudes for small private airfields.

Because most aerial surveys of bottlenose dolphins have been conducted at 164 m and because various altitudes were shown by this study to produce significantly different

Table 4

Number of sightings (n), mean herd size ($\bar{H}$) and daily estimated population totals ($\hat{Y}$), by flight and altitude

		Altitude (m): 164			246			328			410		
Date	Flight	n	$\bar{H}$	$\hat{Y}$	n	$\bar{H}$	$\hat{Y}$	n	$\bar{H}$	$\hat{Y}$	n	$\bar{H}$	$\hat{Y}$
Jan 22	1							7	4.1	286			
Jan 22	2										4	7.0	275
Jan 24	1				19	8.4	1.587						
Jan 24	2										14	5.9	80
Jan 25	1	10	7.9	777									
Jan 25	2				16	5.7	898						
Jan 25	3	10	5.5	540									
Jan 25	4							18	10.4	1.023			
Jan 30	1	14	5.3	729									
Jan 30	2										9	8.1	719
Jan 31	1				17	7.2	1,208						
Jan 31	2							15	4.7	693			

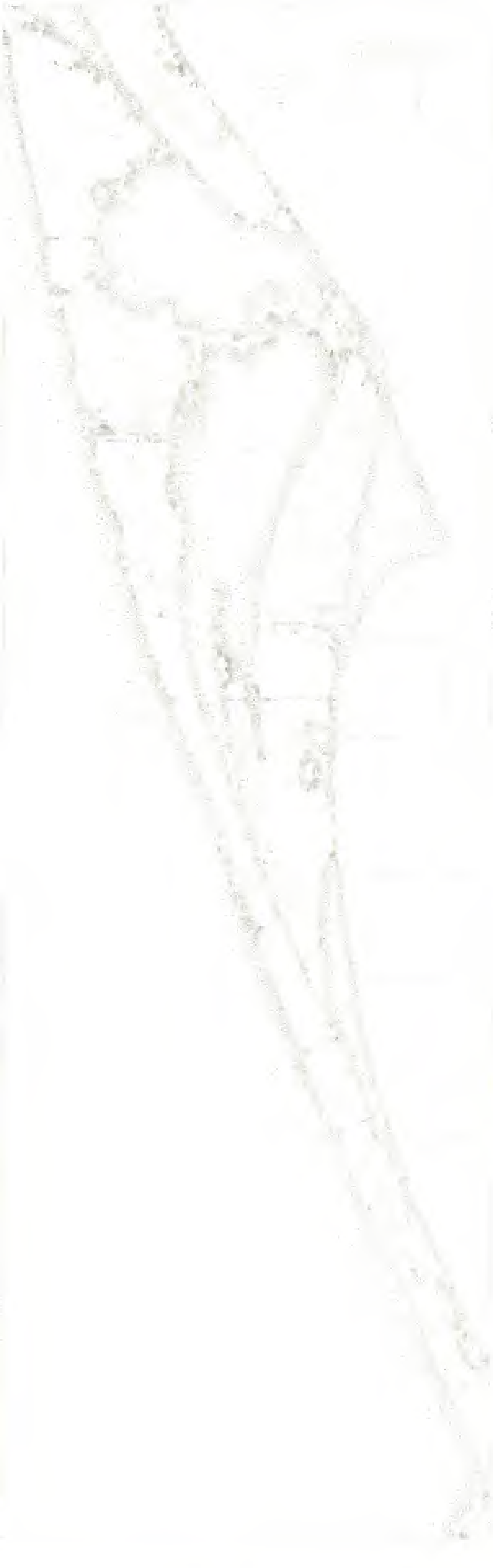

Table 5

Results of analysis of variance (ANOVA) to determine effects of altitude and/or flight on mean herd size (A), number of sightings (B), estimated population total (C), herd size (D), percentage of calves and juveniles observed (E) and sightings area (F). In the case of number of sightings and estimated total population the values at 246 m are higher than those at other altitudes

	Source of variation (SV)	Degrees of freedom (df)	Sums of squares (SS)	Mean squares (MS)	F-Ratio (F)	Probability (F ≤ f)
A	Total	11	32.736	—	—	—
	Altitude	2	0.977	0.4885	0.094	0.088
	Flight	3	0.616	0.2053	0.040	0.012
	Error	6	31.143	5.1905	—	—
B	Total	11	242.25	—	—	—
	Altitude	2	74.83	37.4	2.174	0.805
	Flight	3	64.30	21.4	1.244	0.626
	Error	6	103.12	17.2	—	—
C	Total	11	717,606.92	—	—	—
	Altitude	2	209,176.45	104,588.22	2.012	0.786
	Flight	3	196,571.77	65,523.92	1.261	0.631
	Error	6	311,858.70	51,976.45	—	—
D	Total	146	6,122.176	—	—	—
	Altitude	3	29.899	9.966	0.234	0.188
	Residual	143	6,092.28	42.60	—	—
E	Total	125	28,850.89	—	—	—
	Altitude	3	197.032	65.677	0.280	0.141
	Residual	122	28,653.86	234.868	—	—
F	Total	27	788.670	—	—	—
	Altitude	3	50.964	16.9880	2.711	0.924
	Sighting cue	6	624.929	104.1548	16.623	0.999
	Residual	18	112.786	6.2659	—	—

Anderson, D. R. and Pospahala, R. S. 1970. Correction of bias in belt transect studies of immotile objects. *J. Wildl. Manage.* 7: 322–27.

Barham, E. G. and Powers, J. 1977. Aerial survey of porpoise population in the eastern tropical Pacific; equipment, methods, procedures. Second Ann. Conf. Biology and Conserv. of Marine Mammals. San Diego, Calif. Abstract.

Barham, E. G., Evans, W. E. and Coe, J. M. 1975. Aerial survey of eastern Pacific porpoise populations: methods and impressions. First Ann. Conf. Biology and Conserv. of Marine Mammals. Univ. California, Santa Cruz. Abstract.

Barham, E. G., Sweeney, J. C., Leatherwood, S., Beggs, R. K. and Barham, C. L. 1980. Aerial census of the bottlenose dolphin, *Tursiops truncatus*, in a region of the Texas coast. *Fish. Bull.* 77(3): 585–95.

Doan, K. H. and Douglas, C. W. 1953. Beluga of the Churchill region of Hudson Bay. *Fish. Res. Bd Can., Bull.* 98. 27 pp.

Evans, W. E. 1975. Distribution, differentiation of populations and other aspects of the natural history of *Delphinus delphis* in the northeastern Pacific. Ph.D. Thesis, Univ. California, Los Angeles. 145 pp.

Finley, K. J., Miller, G. W., Allard, M., Davis, R. A. and Evans, C. R. 1981. The white whales (*Delphinapterus leucas*) of Northern Quebec: Distribution, abundance, stock identity and catch history. Paper SC/33/SM9 presented to the IWC Scientific Committee Cambridge, June 1981.

Gates, C. E. 1979. Line transects and related issues. pp. 71–154. *In:* R. M. Cormack, G. P. Patil and D. S. Robson (eds). *Sampling Biological Populations.* Fairland, Maryland. International Cooperative Publishing House.

Hay, K. 1982. Aerial line-transect estimates of abundance of humpback, fin and pilot whales in the Newfoundland area. Paper SC/33/O 4, (published in this volume).

Holt, R. S. and Powers, J. E. 1982 (in preparation). Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys.

Jackson, T. D. 1980. Trip report: porpoise population aerial survey of the eastern tropical Pacific Ocean. Jan 22–April 25, 1979. NOAA, NMFS. Southwest Fisheries Center. Administrative Report LJ-80-1, 74 pp.

Kasuya, T. 1971. Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based upon aerial sighting record. *Sci. Rep. Whales Res. Inst., Tokyo* 23: 37–60

Keller, R. W., Leatherwood, S. and Holt, S. J. 1981. Indian Ocean cetacean survey, Seychelle Islands, April through June, 1980. Paper SC/33/O 9 (published in this volume).

Kempthorne, O. 1973. *The Design and Analysis of Experiments.* Robert E. Krieger Publ. Co., Huntington, 631 pp.

Leatherwood, J. S. 1979. Aerial survey of populations of the bottlenosed dolphin, *Tursiops truncatus*, and the West Indian manatee, *Trichechus manatus*, in the Indian and Banana Rivers, Florida. *Fish. Bull.* (U.S.) 77(1): 47–59.

Leatherwood, S. and Show, I. T., Jr. 1980. Development of systematic procedures for estimating sizes of populations of bottlenose dolphins. Final contract report to National Marine Fisheries Service, SEFC, Miami, Florida. 98 pp.

Leatherwood, S. and Walker, W. A. 1979. The northern right whale dolphin, *Lissodelphis borealis* Peale, in the eastern north Pacific. pp. 85–114. *In:* H. E. Winn and B. L. Olla (eds) *Behavior of Marine Animals.* Vol. 3. Plenum Publ. Corp. New York, N.Y. 438 pp.

Leatherwood, S., Gilbert, J. R. and Chapman, D. G. 1978. An evaluation of some techniques for aerial censuses of bottlenose dolphins. *J. Wildl. Manage.* 42. 239–50.

Leatherwood, S., Show, I. T., Jr., Reeves, R. R. and Wright, M. B. 1982. Estimating population size of bottlenose dolphins from aircraft with obstructed downward visibility. Paper SS/14A (published in this volume).

Odell, D. K. and Reynolds, J. E., III. 1978. Distribution and abundance of the bottlenose dolphins, *Tursiops truncatus*, on the west coast of Florida. Final Report, Marine Mammal Commission Contract MMSAC026. 55 pp. Rosentiel School of Marine and Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida, 33149.

Smith, T. D. 1975. Estimates of sizes of two populations of porpoise (*Stenella*) in the eastern tropical Pacific Ocean. NOAA. National Marine Fisheries Service, Southwest Fisheries Center. Administrative Report No. LJ-75-67. July 1975. 55 pp.

Zemsky, V. and Yablokov, A. V. 1974. Catch statistics, short history of exploitation and present status of *Delphinus delphis*, *Tursiops truncatus*, and *Phocoena phocoena* in the Black Sea. ACMRR.MII/3F La Jolla, Calif. Dec. 1974.

SS/14C

Proposed Modification of Transect Models to Estimate Population Size from Aircraft with Obstructed Downward Visibility[1]

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ABSTRACT

A method is proposed for modifying transect estimators to account for the exclusion area along the transect centerline of aircraft with obstructed downward visibility. Six existing estimators are considered in detail. The method requires direct estimation of the area obscured and examination of sighting distance distributions to determine 'w', the calculated effective strip width. The modification is based on the assumption that nothing exceptional would happen to the curve representing distribution of sighting distances if the area beneath the aircraft were visible.

INTRODUCTION

Debate continues about which line-transect models are most appropriate for estimating size of a dolphin population from sightings made during low altitude aircraft surveys (IWC, 1982a). Moreover, even after a given model is selected as appropriate, there is far from consensus on the particular procedures which should be used to treat the data to produce an estimate and a measure of confidence (e.g. IWC, 1982b). The situation is complicated further in the case where surveys are conducted from aircraft with obstructed downward visibility. From such aircraft there results an 'exclusion area' along the transect centerline, an area of obstructed downward visibility in which sightings are not made. This causes violation of an assumption, fundamental to most available models, that all animals along the transect centerline be seen (Burnham, Anderson and Laake, 1980).

Between September, 1979 and February, 1980 we conducted aerial surveys to estimate sizes of 'populations' of bottlenose dolphins in three geographical regions of the United States and to refine field and analysis techniques for use in such censuses.[5] Because the high-wing *Cessna*-172's utilized in these surveys lack a bow-bubble or other means of 'guarding' the transect centerline, we modified the six basic estimators evaluated to account for the exclusion area.

ESTIMATORS, MODIFICATIONS AND DISCUSSION

Description of Estimators[6]

Estimates of density may be written in the form:

$$\hat{D} = \frac{n\,\hat{f}(0)}{2L} \qquad (1)$$

where $\hat{f}(0)$ is the estimated intercept, L is the total length of transects flown, and n the total number of herds sighted. The independent variable in $f(x)$ is the perpendicular sighting distance from the aircraft. Also,

$$w = \frac{1}{\hat{f}(0)} \qquad (2)$$

is the effective half-strip width (see Fig. 1). If the estimator is calculated using relative frequencies, the intercept is referred to as $\hat{f}'(0)$ and must be scaled by the width of the equal class interval 'i' to obtain

$$\hat{f}(0) = \frac{\hat{f}'(0)}{i}.$$

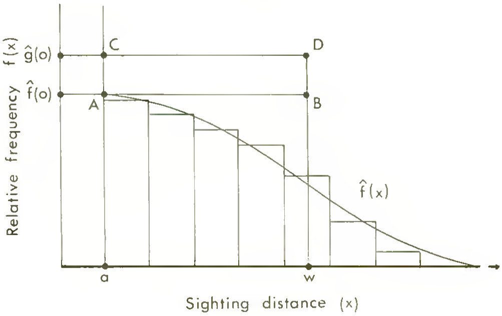

Fig. 1. Graphic representation of line transect estimator modification.

Six estimators available for analyzing strip and line-transect results to produce estimates of herd density, population density, and total population size were modified in response to special considerations prompting the present investigations.[6]

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[1] Originally submitted to the U.S. National Marine Fisheries Service (NMFS), Southeast Fisheries Center, 75 Virginia Beach Drive, Miami, Florida 33149 as final report on contract NA79-GA-C-0038. Copies of original data and the contract report can be obtained from NMFS.

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[5] Leatherwood, S. and Show, I. T., Jr. 1980. Development of systematic procedures for estimating sizes of 'population(s)' of bottlenose dolphins in three geographical areas; with incidental observations on densities of west Indian manatees and marine turtles. Final report from Hubbs/Sea World Research Institute, San Diego, Calif. to the U.S. National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, Florida 33149 on contract NA79-GA-C-0038. 98 pp.

[6] The estimators evaluated are described in detail in several publications. Particular format and presentation used here are taken largely from Gates (1979).

a. *Exponential* (Gates, Marshall and Olson, 1968):
This estimator was derived on the basis of the assumption that the underlying distribution of right angle distances fits the (negative) exponential function:

$$\hat{f}(0) = \frac{(n-1)}{n\bar{X}} \; . \tag{4}$$

The variance of D, under the additional assumption of independent sighting of animals, is

$$V(\hat{D}) = \frac{\hat{D}^2}{2}(Q + \frac{n}{n-2}) \tag{5}$$

where $Q = 1 - n/(A\hat{D})$ and A is the sample area. (This estimator should be considered the lower bounds on the true variance if the animals are not sighted entirely independently.)

b. *Burnham–Anderson–Gates (BAG) non-parametric* (Anderson and Pospahala, 1970; Burnham and Anderson, 1976):
This estimator requires no knowledge of underlying distributions of right angle distances. As used by Gates and Smith (1979) it may be described as follows:

Let P_m be a polynomial of degree m, say

$$P_m(X) = \sum_{i=0}^{m} \beta x^i,$$

let A_i be the observed area of the i-th rectangle and let $a_0 < a < \ldots < a_m$ ($a_0 = 0$, a_i = class boundaries). We want to solve for the β's so that the sum of squares of the difference between the area A_i and the area under P_m between a_{i-1} and a_i,

$$\sum_{i=1}^{m} [A_i - \int_{a_{i-1}}^{a_i} P_m dX]^2 \tag{6}$$

is minimized. (We note that ${}_{a_0}\!\int^{a_m} P_m dX$ will be unity for whatever spacing of the a_i is used.)

The actual method most often used is as described above except that (1) linear through quintic curves are fitted and the 'best' one selected that gives a minimum χ^2 fit, and (2) weighted least squares is used wherein the weights are inversely proportional to the distance from the origin, in this case $(a_i + a_{i-1})/2$.

An empirical variance formula for $\hat{D}$ is derived as follows: As has been noted,

$$\hat{D} = \frac{n\,\hat{f}(0)}{2L} \qquad \text{see equation (1)}$$

and the well-known approximation to the variance of the product is used:

$$V(\hat{D}) = c^2 \left\{n^2 V[\hat{f}(0)] + \hat{f}^2(0)V(n) - V[\hat{f}(0)]\,V(n)\right\} \tag{7}$$

where $c = 1/2L$. This expression assumes that n and $\hat{f}(0)$ are independent. This appears to us a reasonably safe biological assumption for dolphin populations. The mean square deviation from the fitted polynomial regression, $s_{y \cdot x}$ is calculated and then $V[\hat{f}(0)]$ is estimated as the usual variance of the intercept:

$$V[\hat{f}(0)] = S_{y \cdot x}\, C_{oo} \; , \tag{8}$$

where C_{00} is the appropriate element of the $(X',X)^{-1}$ matrix.

c. *Anderson–Pospahala–Parr–Gates* (Gates, 1979):
This estimator is a modification of the Anderson–Pospahala method of fitting a quadratic curve to frequency data, the first of the non-parametric estimators. The essence of the method is to fit a quadratic curve, obtain the intercept (b_0), and use b_0 to estimate the density. The Gates version differs from the Anderson–Pospahala estimator in that the area under the fitted curve is constrained to unity.
Let

$$E(y) = \hat{f}(x) = \beta_o + \beta_1 x + \beta_2 x \tag{9}$$

where $x \leq M$, M being the maximum distance at which reliable sightings are expected. Integrating this expression on the interval $0 \leq x \leq M$ and arbitrarily solving for one of the parameters, say β_2, we have

$$\beta_2 = \frac{3}{M^2}\left(\frac{1}{M} - \beta_o - \frac{\beta_1 M}{2}\right). \tag{10}$$

Thus we use

$$(y_i - c_{3i}) = {}_0c_{oi} + c_{1i} + \epsilon \tag{11}$$

where

$$c_{3i} = \frac{3x^2}{M^3} \;, \quad c_{oi} = 1 - 3\left(\frac{x}{M}\right)^2 \;, \quad c_{1i} = x - \frac{3x^2}{2M}$$

The estimator is non-parametric as no assumptions are required concerning the underlying distribution of distance measurements. An empirical variance formula for $\hat{D}$ is derived as in the BAG method previously discussed.

d. *Normal:*
Hemingway (1971) was the first to suggest using the half-normal distribution to fit right angle distances. A similar estimator based on the half-normal distribution is

$$\hat{f}(0) = 2/\sqrt{2\pi S^2} \tag{12}$$

S^2 is estimated from

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{X})^2. \tag{13}$$

e. *Weibull* (Pollock, 1978; Quinn, 1977):
There are numerous forms of the Weibull distribution. The one selected by Gates (1979) is:

$$\hat{f}(x) = \frac{\exp[-(x/\beta)^{\alpha}]}{\beta\Gamma(1/\alpha + 1)} \tag{14}$$

The advantage of this estimator is that it is a 'rich' distribution, fitting a variety of well-known distributions. For example, if α = 1, the (negative) exponential distribution obtains; for α = 2, β = 0, the normal distribution results.

The logarithm of the likelihood of the Weibull (L) is

$$\ln L = -n \ln\beta - n \ln[\Gamma(1/\alpha + 1)] - \sum_{i=1}^{n}(x_i/\beta)^{\alpha} \tag{15}$$

from whence we obtain the first partial derivative and the partial difference with respect to β and α, respectively:

$$\frac{\partial \ln L}{\partial \beta} = -(n/\beta) + (\alpha/\beta^{\alpha+1}) \sum_{i=1}^{n} x_i^{\alpha} = 0 \tag{16}$$

$$\triangle_{\alpha}\ln L = \frac{1}{h}\left[-n\left\{\ln[\Gamma\left(\frac{\alpha+h+1}{\alpha+h}\right)] - \ln[\left(\frac{\alpha+1}{\alpha}\right)]\right\} + \sum_{i=1}^{n}\left(\frac{x_i}{\beta}\right)^{\alpha} \left\{1 - \left(\frac{x}{\beta}\right)^{h}\right\}\right] = 0 \tag{17}$$

where h is a finite difference. From (17),

$$\beta = \left[\frac{\alpha}{n}\sum_{i=1}^{n} x_i^{\alpha}\right]^{1/\alpha} \tag{18}$$

Having solved for β in (16), we then solve numerically for α in (17).

The intercept $\hat{f}(0)$ is calculated by

$$\hat{f}(0) = [\beta\Gamma(1/\alpha + 1)]^{-1} \tag{19}$$

and, as previously, $\hat{D} = \frac{n\,\hat{f}(0)}{2L}$ (see Equation 1).

f. *Fixed strip-width estimator* (Leatherwood, 1979):
By this method, the individual herd density, '$\hat{D}_i$', is calculated as

$$\hat{D}_i = \hat{D}\bar{H} \tag{20}$$

where $\bar{H}$ is the mean herd size and $\hat{D}$ is defined by Equation (1) with f(0) expressed as 1/w, w being a one-sided strip-width of 0.463 km (0.25 nm). This value was considered a reasonable distance from the transect centerline within which 100% of the animals would be seen. (This method is known to produce negatively biased estimates.)

The estimated variance of this product is calculated from Goodman (1960):

$$S^2(\hat{D}_i) = \bar{H}^2S^2(\hat{D}) + \hat{D}^2S^2(\bar{H}) - S^2(\hat{D})S^2(\bar{H}). \tag{21}$$

$S^2(\bar{H})$ and $S^2(\hat{D})$ are the estimated variances of mean herd size and mean herd density, respectively.

Description of Modification

Use of the estimator in Equation (1) is predicted on the assumption that sightings occur from the transect centerline out to some effective strip-width (w). However, in situations where there is a strip of width '2a' straddling the transect centerline in which no sightings can be made, this estimator is inappropriate.

Referring to Fig. 1, let us assume that we have a relative frequency distribution represented by the histogram. Then let us further assume that we have successfully fit one of our theoretical sighting distance distributions to the histogram and have obtained the curve $\hat{f}(x)$ and its intercept $\hat{f}(0)$. No matter what estimator is employed to obtain $\hat{f}$, we now proceed to Equation (1) to obtain the density estimate $\hat{D}$; we are no longer concerned with what procedure was used to obtain $\hat{f}(0)$.

The process for estimating $\hat{D}$ is represented in Fig. 1. After obtaining $\hat{f}(0)$, the first step is to estimate an effective strip-width (w) such that the probability of sightings occurring in the interval $0 \leqslant x \leqslant w$ is uniform and equal to f(0). What results is a uniform probability distribution; this is important because of the requirement that

$$\int_o^w \hat{f}(0)dx = 1 \tag{22}$$

(i.e., the area under the curve of the distribution is equal to unity). The line $\hat{f}(0)$AB in Fig. 1 represents the curve of the uniform distribution with the rectangle $\hat{f}(0)$BSO, having its area equal to one. Therefore, it is required that

$$w = \frac{1}{\hat{f}(0)}\ . \tag{23}$$

If we now set $\hat{f}(0) = 1/w$ and substitute into Equation (1), we obtain

$$\hat{D} = \frac{n}{2Lw}\ . \tag{24}$$

Now, since all sightings are missing in the interval $0 \leqslant x \leqslant a$, the value of n is reduced and $\hat{D}$ is underestimated. To alleviate this problem, we create a new uniform probability distribution $\hat{g}(0)$ on the interval $a \leqslant x \leqslant w$ with the requirement again that

$$\int_a^w \hat{g}(0)dx = 1\ . \tag{25}$$

This procedure requires that we set

$$\hat{g}(0) = \frac{w}{w-a}\ \hat{f}(0) \tag{26}$$

which reduces (after substitution of f(0) = 1/w) to

$$\hat{g}(0) = \frac{1}{w-a} \tag{27}$$

Clearly the condition of Equation (25) is met; furthermore, there are no missing cells in the interval $a \leqslant x \leqslant w$.

The new estimate for $\hat{D}$ then may be written as

$$\hat{D} = \frac{n\,\hat{g}(0)}{2L} \tag{28}$$

or

$$\hat{D} = \frac{n\,\hat{f}(0)}{2L} \tag{29}$$

$$= \frac{n}{2L(w-a)}\ . \tag{30}$$

DISCUSSION

The effect of this modification is to adjust n and thus $\hat{D}$ upward by the ratio w/(w − a). In solving we have assumed that if we were somehow able to make observations in the interval $0 \leqslant x \leqslant a$, no radical change would occur in the existing histogram of Fig. 1. (This assumption could, of course, be tested by taking data obtained from an aircraft with unobstructed downward visibility and treating them with a previous estimator and with the modification proposed herein.) Accepting this assumption and treating cells in the interval $0 \leqslant x \leqslant a$ as missing values (rather than zero observed frequencies), $\hat{f}(0)$ represents our best intercept estimator for the situation where the cells were not missing. Thereby $\hat{D}$ is negatively biased only by the underestimation of n; the upward adjustment by w/(w − a) somewhat mitigates this problem. In addition, the upward adjustment appears logically supported as exemplified by the new estimator for $\hat{D}$ given by Equation (30).

Clearly, $\hat{D}$, estimated by Equation (1) is negatively biased because of the empty cells. There are at least two other possible approaches to this problem:

(a) Assuming that we see everything at distance 'a' from the transect, estimators may be used as they stand by replacing each sighting distance 'x' by 'x − a'.
(b) Each estimator could be revalued independently on the basis of observations with $x > a$.

The first suggestion, of course, results in the use of $\hat{f}(a)$ instead of $\hat{f}(0)$. While there is nothing intrinsically wrong with this suggestion, we preferred to attempt to estimate the situation in which no cells are missing. We recognize the major weakness in this approach; namely, that values are entirely missing from that portion of the distribution most critical to valid density estimation (i.e., nearest the origin). However, no method can alleviate that problem so long as data are collected from aircraft with restricted downward visibility.

The second method, though not considered herein, is worthy of further attention (see Thompson, 1981).

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Drs J. Powers, D. Butterworth and N. Thompson reviewed the method and proposed useful modifications. The dolphin project was supported by a U.S. National Marine Fisheries contract to Leatherwood.

REFERENCES

Anderson, D. R. and Pospahala, R. S. 1970. Correction of bias in belt transect studies of immotile objects. *J. Wildl. Manage.* 7: 322–27.

Burnham, K. P. and Anderson, D. R. 1976. Mathematical models for non-parametric inferences from line transect data. *Biometrics* 32: 325–36.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72: 1–202.

Gates, C. E. 1979. Line transects and related issues. pp. 71–154. *In:* R. M. Dormach, G. P. Patil, and D. S. Robson (eds.). *Sampling Biological Populations.* Fairland, Maryland. International Cooperative Publishing House.

Gates, C. E., Marshall, W. H. and Olson, D. P. 1968. Line transect method of estimating grouse population densities. *Biometrics* 24: 135–45.

Goodman, L. A. 1960. On the exact variance of products. *J. Am. Stat. Assoc.* 55: 708–13.

Hemingway, P. 1971. Field trials of the line transect method of sampling large populations of herbivores. pp. 405–11. *In:* E. Duffy and A. S. Watt, (eds.) *The Scientific Management of Animal and Plant Communities for Conservation.* Blackwell, Oxford.

International Whaling Commission, 1982a. Report of the workshop on the design of sightings surveys. (Published in this volume.)

International Whaling Commission, 1982b. Report of the Special Meeting on Southern Hemisphere Minke Whales, Appendix 16. (Published in this volume.)

Leatherwood, S. 1979. Aerial survey of the bottlenose dolphin, *Tursiops truncatus,* and the west Indian manatee, *Trichechus manatus,* in the Indian and Banana Rivers, Florida. *Fish. Bull.* (U.S.) 77(1): 47–59.

Pollock, K. H. 1978. A family of estimators for line transect sampling. *Biometrics* 34: 475–8.

Quinn, J. 1977. The effects of aggregation on line transect estimators of population abundance with application to marine mammal populations. M.S. Thesis, University of Washington.

Thompson, N. B. 1981. Population analysis of *Tursiops truncatus* in Florida (abstract). Fourth Biennial Conf. on Biol. and Conserv. of Marine Mammals. San Francisco, Calif., 14–19 Dec. 1981.

SS/17

A Review of the Japanese Whale Sightings System

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INTRODUCTION

Japanese traditional whaling, which lasted from the beginning of the 17th to the end of the 19th century, was directed towards those whales which approached the coast. Whale sightings were carried out systematically from lookout points on coastal hills during the whaling season. This was the first whale sightings system in Japan, but unfortunately the records have all been lost.

'Norwegian' whaling was introduced to Japan in 1897 and 'coastal' whaling in the waters around Japan has continued until now. In Japanese coastal whaling each catcher boat carries out its own sighting; no scouting boats or aeroplanes have been used. Therefore, the sighting by coastal whaling catcher boats is almost equivalent to the searching component of the catching operations.

Japanese pelagic whaling in the Antarctic began in the 1934/35 season, and some catcher boats were used to survey ice, weather and sea conditions, the distribution and abundance of whales and their food, etc. These data were transmitted to the manager of the fleet who used the information to plan the whaling operations. Not long after this some catcher boats began to work exclusively as scouting boats. Sometimes vessels other than catcher boats, e.g. trawlers were used for sighting (Anon., 1943). The advantage of trawlers is that they can operate at great distances from the fleet as they do not need to refuel at the factory ship as often as normal catchers. Helicopters were used by some Japanese whaling fleets for several years from 1953/54 (Takeda, 1960), but it is difficult for helicopters to fly in the bad weather which is common in the Antarctic, although they were good for determining the distribution of pack ice and icebergs.

In 1937 the trawler, *Yukki Maru*, carried out sightings independently in the Bering Sea in order to obtain information on the distribution and abundance of whales before the start of the pelagic whaling in 1940 and 1941 (Maeda and Teraoka, 1952). This was the first sightings cruise to be undertaken independently of a whaling fleet, even though the boat did belong to a whaling fleet and operated under instructions from a fleet manager. In 1949 the Japanese government began whale marking by chartered catcher boats in the North Pacific (Omura and Ohsumi, 1964). This was originally only for marking and not sightings. The marking system was established in Japan in 1949, and the scouting boats which belonged to whaling fleets in the North Pacific and the Antarctic began to co-operate in marking during sightings in 1955. At that time scientists did not fully realise that sightings should be carried out independently from whaling operations under systematically designed programmes.

The purpose of scouting boat operations carried out by vessels belonging to a whaling fleet was the collection of information for the forecast of the fleet's operations and companies naturally did not want their data to be obtained by their competitors; hence their reluctance to offer the data to scientists. The Whale Resources Research Section of the Far Seas Fisheries Research Laboratory was established in the Fisheries Agency, Ministry of Agriculture and Forestry, in 1966, and the Section developed a system whereby it was the duty of the fleets to submit sightings data from each scouting boat. At the same time sightings data from operating catcher boats in both the pelagic and coastal large-type whaling were reported by each whaling company.

The above data are related to whaling operations and so come from the whaling grounds during whaling seasons. The Fisheries Agency began to carry out sightings and marking by chartered catcher boats outside the whaling grounds and the whaling season in 1972 (Ohsumi and Masaki, 1975). In order to try and maintain sightings effort in spite of the decrease in pelagic whaling, the Japanese Government began to provide large amounts of money to charter catcher boats for whale sightings and whale marking in the North Pacific and the Southern Hemisphere in 1976. The offering of Japanese catcher boats for the IDCR/minke whale assessment cruise in the Antarctic since 1978/79 season (Best and Ohsumi, 1980) forms a link in the chain of this programme.

Whale sightings have been carried out by some ocean research vessels or fisheries research vessels (cf. Ozawa *et al.*, 1964), but as yet no system to collect such data has been established in Japan. In one exceptional case, sightings have been carried out by salmon research vessels in the northern part of the North Pacific for three years since 1978 (Ohsumi and Takagi, 1979, MS) as part of a co-operative research programme by Japan and the USA.

Sightings records by aeroplanes have been collected during flights for various kinds of fisheries research by one company, and Kasuya (1979) used these data for a study of the distribution of the finless porpoise in the Seto Inland Sea. However, there is no systematic reporting of cetacean sightings by aeroplanes yet in Japan.

I have briefly reviewed above the history of Japanese whale sightings. In the rest of this paper I concentrate on the reporting system for scouting boats established in 1966.

SCOUTING BOATS

Catcher boats are usually used for sightings in Japan, although trawlers or cargo boats are occasionally used. The catcher boat is built for whaling operations and is thus suitable for searching and chasing whales by virtue of its high 'crow's nest' on the main mast, its speed and its good manoeuverability. Most members of the crews have long experience in whale sightings, and are good at both finding and identifying whales. Efficiency in chasing is an important factor for scouting boats, as the schools must be approached in order to identify the species and to confirm the number of whales. Marking is often carried out from the scouting boat when a school is sighted. One disadvantage of using a catcher boat as a scouting boat is its high fuel consumption due to its large engine: the research area is thus limited unless refuelling can take place. This is not so important if the boat is with a whaling fleet, as the factory ship or tanker can move and supply oil and food to the vessel. However refuelling is one of the most important factors to be considered in the design of sightings cruises using catcher boats independent of the whaling fleet.

Japanese catcher boats are usually 400–900 gross tonnage and the crow's nest is between 10–11 m above sea level. There are usually 22 crew members on an operating catcher boat but this is reduced to 18 for scouting boats as the gunner, Asdic operator, one of the deck crew and one of the engine crew are not required. Asdic is not used on scouting boats, although it could be useful to measure the diving depth of whales (Lockyer, 1978).

The maximum speed of a catcher boat is 16–18 knots, but during sightings it sails at 11–12.5 knots. The maximum range in terms of days sailing obviously depends on the size and fuel consumption of the boat but is usually between 20–40 days.

SIGHTINGS AREA

We have seen that the purpose of scouting boats which belonged to whaling fleets was to collect information needed for the whaling operations of the fleet. Thus, the navigation plan was the responsibility of the manager of the fleet each day. It was almost impossible for scientists to set the research area of the scouting boats, although they could make suggestions to the manager, because the Government did not provide money for sightings by scouting boats. The research area was thus limited by the expected distribution of the target species of the fleet. Sightings effort was not even in each area: sightings were more thoroughly conducted in those areas which the manager considered to be potential whaling grounds than in other areas where there was no possibility of whaling in the future. Thus the systematic design of sightings was almost impossible for scouting boats attached to whaling fleets. However, the sightings data were gradually collected from a wider area with the change in target species. This change has also caused a serious problem in that sightings really need to be continued in the same area to monitor population trends in species.

The introduction of the catch quota system by species and by Area greatly changed the behaviour of scouting boats. They began to operate in larger areas within more limited periods resulting in rougher and rougher data. In addition scouting boats became less important to the operation of the fleet and have thus gradually decreased in number due to the rationalisation of the fleet. Since 1978/79, *Nissin Maru No. 3,* has not used a scouting boat in the Southern Hemisphere, as it is known that minke whales are very abundant in each Area near to the pack ice.

The other whale sightings system in Japan used catcher boats chartered by the Fisheries Agency. In this system, whale scientists can design the research area, course, grid and time period according to the objectives of the programme. Since 1972, a catcher boat has been chartered by the Far Seas Fisheries Research Laboratory every winter to carry out sightings and marking in the lower latitudinal waters of the Pacific Ocean, in particular to obtain ecological information on the Bryde's and sperm whales in the North Pacific. Since the 1976 and 1976/77 seasons the Japanese Government has provided money to charter two catcher boats in the North Pacific and three in the Southern Hemisphere to maintain sightings effort to monitor trends in the major whale populations.

Fixed sightings tracks have been designed for the North Pacific and two scouting boats follow a specific track every year. However, since the moratorium on pelagic whaling in the North Pacific in 1980, refuelling by the factory ship has not been possible and sighting has become less efficient as the scouting boats must return to Japanese ports in the middle of the research period.

Chartered scouting boats have made major contributions to the population study of the Bryde's whale, which has not yet been exploited in the Indian and South Pacific Oceans (Ohsumi, 1980a), the monitoring of fin whales in Area VI (Ohsumi, 1980b), and the international co-operative population study of minke whales in the Antarctic (Best and Ohsumi, 1980).

Although the itinerary and course of the chartered scouting boats are formulated by the scientists before departure, the researchers and captain on board decide on the research operation each day, taking into account the weather and sea condition along the proposed track.

MODE OF OPERATION OF SCOUTING BOATS

In principle a scouting boat engages in sightings from sunrise to sunset, but in practice the captain decides on the activity according to the weather and sea conditions. Total sightings time per day is usually limited to 15–16 hours even in high latitudinal waters where the day length is longer.

Sightings are carried out by two 'top men' in the crow's nest in two hour rotation, with five deck crew including the boatswain. On the upper-bridge a member of the crew who is steering and the captain or navigator usually help with sightings. The helmsman changes every hour. The accumulated work time per crewman per day should not exceed 14 hours and is usually 12 hours.

The scouting boat sails in a gentle zigzag manner, changing course every one or two hours along the track line. This is thought to be effective as it allows the top-men to refresh their eyes during the simple work of sighting and the scientists to obtain oceanographic data with some breadth.

The navigation speed varies according to the target species and environmental conditions, but usually is between 11–12.5 knots. When a whale is sighted the boat runs at full speed to the position where it was found to confirm the species and the school size for marking. If the whale is not refound by the time the boat reaches the position at which it was first sighted, the boat circles slowly or stops at that position to find the whale again.

The top-men usually use binoculars with 7 times magnification as does the captain or navigator on the upper-bridge.

Scouting boats have engaged in whale marking as well as sightings since 1955. Although the marking is not strictly compatible with a systematic sightings programme, the Far Seas Fisheries Research Laboratory allows the scouting boats to carry out as much marking as possible when a school of whales is found during sightings operations.

Communication between the scouting boat and the factory ship usually takes place at 08.00, 12.00, 16.00 and the end of sightings, although the scouting boat must in addition inform the manager and national inspector on board the ship on other matters.

At the end of the 'working' day the scouting boat drifts or sails during the night to the next position on the track.

DATA COLLECTION AND FORMAT

The Far Seas Fisheries Research Laboratory has developed a manual and several kinds of data record sheets for scouting boats and operating catcher boats (FSFRL, 1977):

A. *Report on sightings by scouting boats* (Fig. 2).
  1. Year
  2. Name of whaling fleet
  3. Name of scouting boat
  4. Name of captain
  5. Month and day
  6. Noon position
  7. Weather and sea conditions at noon
     (a) Visibility
     (b) Wind direction and force
     (c) Water temperature
     (d) Water colour
  8. Navigation distance for whale sightings
  9. Number/Schools of whales found
     (a) Blue whale
     (b) Fin whale
     (c) Humpback whale
     (d) Sei whale
     (e) Bryde's whale (separated from sei whales since 1971)
     (f) Right whale
     (g) Gray whale
     (h) Minke whale
     (i) Sperm whale
     (j) Beaked whales
     (k) Killer whale
  10. Smaller cetaceans: species and numbers
  11. Northern fur seal and other pinnipeds: number
  12. Cow and calf: species and number of schools
  13. Remarks

B. *Report on the finding (and catch) of whales by scouting boats and operating catcher boats in pelagic and coastal whaling*
  This kind of report has been collected since 1976/77 Southern Hemisphere pelagic whaling, since 1977 in the North Pacific pelagic whaling and since 1978 in the Japanese large-type coastal whaling.
  1. Year, month and day
  2. Name of whaling fleet or land station
  3. Name of scouting or operating catcher boat
  4. Serial number of school found
  5. Searching time:
     (a) start time of searching or sightings
     (b) time whale found
     (c) searching time (b or d minus a)
     (d) time at end of searching or sighting
  6. Whale species found
  7. Number of whales and number of schools
  8. Estimated body length
  9. Number of cow/calf pairs
  10. Position of finding of school
  11. Angle of school from the direction of movement of boat
  12. Distance of whale school from boat
  13. Swimming and escape direction of school
  14. Weather and sea conditions at finding of school
     (a) visibility
     (b) wind force
     (c) water temperature
  15. Remarks at finding of school
  16. Serial number of catch in the whaling fleet
  17. Whale species caught
  18. Serial number of whale caught by each boat in a day
  19. Name of boat which found the school and serial number of the school
  20. Estimated body length
  21. Chasing:
     (a) time at start of chasing
     (b) confirming time (21a minus 5b)
     (c) time at the first harpoon hit
     (d) chasing time (21b minus 21a)
  22. Death of whale:
     (a) time at the death of whale
     (b) death time (22a minus 21c)
  23. Handling:
     (a) time at end of handling
     (b) handling time (23a minus 21c)
  24. Towing:
     (a) time at start of towing
     (b) time at end of towing
     (c) towing time (24b minus 24a)
  25. Operation regulation:
     (a) time at start of 'stop operation' for regulation
     (b) time at end of 'stop operation' for regulation
     (c) regulation time (25b minus 25a)
  26. Time at end of operation
  27. Total time budget in a day
     (a) Total searching time
     (b) Total confirming time
     (c) Total chasing time
     (d) Total death time
     (e) Total handling time
     (f) Total towing time
     (g) Total regulation time
     (h) Total resting time (including refuelling and navigation times)
     (i) Total operation time (26 minus 5a minus 27f)
     (j) Total net operation time (27h minus 27e)
     (k) Total number and schools of whales found by species

C. *Report on whales found by operating catcher boats belonging to a whaling fleet*
  1. Year and month
  2. Name of whaling fleet
  3. Records by day
     (a) Noon position of mother ship
     (b) Number of operating catcher boats
     (c) Number of schools and total number of whales found by catcher boats by whale species
     (d) Remarks

水産庁　御中

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調査船による漁場調査報告

年　船団名　調査船名　船長名　No.

月	日	正午位置	海気象					探鯨浬数	鯨類（頭数）／（群数）											イルカ類		オットセイ	アザラシ	鯨の親子		備考
			視界	風向	風力	水温	水色		シロ	ナガス	ザトウ	イワシ	ニタリ	セミ	コク	ミンク	マッコウ	ツチ	シャチ	種類	数			種類	群数	

Fig. 2. Example of a sightings data sheet, 'Report on sightings by scouting boats'.

species in the Southern Hemisphere (cf. Masaki, 1980) and in the North Pacific (cf. Wada, 1980).

Attempts to directly estimate population sizes of whales using Japanese sightings records were first made by Nasu and Shimadzu (1970), and Doi (1971) developed a theory which used additional information collected with the co-operation of whalers over a short period. Recently Ohsumi has tried to estimate population sizes of several whale stocks using Doi's theory and accumulated sightings data including those obtained under Format B (cf. Ohsumi, 1980).

THE CURRENT POSITION OF THE SIGHTINGS SYSTEM

Sightings studies are recognised as important and fundamental to estimating the size of whale populations. The monitoring of currently projected whale species has been carried out by whale sightings in many places of the world (cf. Wolman and Rice, 1979) and an expanded system should be developed to cover all such stocks and determine their rate of recovery. Similarly there are still some whale stocks which have not yet been exploited. Whale sightings are one method of estimating the population size of such stocks in order to set sensible catch quotas.

Table 1

Sailing distance (n. miles) for Japanese scouting boats in the Southern Hemisphere and the North Pacific (including IDCR cruises).

	Southern Hemisphere	North Pacific	
Year	Summer	Summer	Winter
1965/66	126,180	52,922	
1966/67	106,870	66,934	
1967/68	180,931	37,912	
1968/69	231,212	68,317	
1969/70	182,330	108,712	
1970/71	215,353	118,964	
1971/72	236,182	105,660	4,086
1972/73	226,003	110,441	6,009
1973/74	195,873	73,844	—
1974/75	191,497	55,855	4,497
1975/76	147,402	37,251	6,090
1976/77	156,127	18,541	4,431
1977/78	73,758	22,143	7,341
1978/79	56,404	17,890	7,042
1979/80	42,856	11,417	—

Competent and experienced crews from catcher boats and suitable scouting boats are needed to obtain reliable sightings data. However, the number of both qualified personnel and vessels has been rapidly decreasing in recent years with the reduction of the whaling industry. Table 1 shows the yearly change in sighting distance by Japanese scouting boats in the Southern Hemisphere and the North Pacific since 1965/66. It is clear from this Table that the sightings effort has rapidly decreased in both oceans. The Japanese Government has provided large amounts of money to try to maintain sightings effort since 1976, but it is impossible to maintain the same level of effort that was extended at the beginning of the 1970s. Fig. 1 shows the sighting areas covered (accumulated data) from 1965 to 1979 (excluding sightings data by chartered scouting boats in winter). Japanese scouting boats have covered relatively large areas of the North Pacific and the Southern Hemisphere, but there are still large areas where sightings have not yet been carried out.

The cost of mounting a whale sightings survey is very high. For example, the Japanese Government contributed Y502,586,000 ($230,000) to charter two catcher boats in the North Pacific and three boats in the Southern Hemisphere in the 1978/79 season, and the total sighting distance (including other catcher boats) was 74,384 miles in the year (Anon., 1980): the cost of one nautical mile is thus about Y6,750 ($30.7). It will be impossible to maintain Japanese sighting effort at this level without an increase in catch quotas and thus an international sightings system should be organised with each member country providing money, equipment or manpower.

REFERENCES

Anon. 1943. *Handbook of Whaling. Vol. 2.* Japan Whaling Fishery Association. 92 pp (in Japanese).

Anon. 1980. Japan progress report on cetacean research, June 1978–May 1979. *Rep. int. Whal. Commn* 30: 155–60.

Best, P. B. and Ohsumi, S. 1980. IWC/IDCR Southern minke whale assessment cruise, 1978–79. *Polar Record* 20 (124): 52–7.

Doi, T. 1971. Further development of sighting theory in whales. *Bull. Tokai Reg. Fish. Res. Lab.*, 68: 1–22 (in Japanese).

Far Seas Fisheries Res. Lab. 1977. *Manual for Whale Resources Research* (revised in 1977). Far Seas Fish. Res. Lab., 86 pp. (in Japanese).

Kasuya, T. 1979. The population of finless porpoise in the Inland Sea of Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 31: 1–44.

Maeda, K. and Teraoka, Y. 1952. *Whaling.* Isana Book Pub. Co. Ltd., 450 pp. (in Japanese).

Masaki, Y. 1980. Additional comments on the result of whale sighting by scouting boats in the Antarctic season from 1965/66 to 1977/78 *Rep. int. Whal. Commn* 30: 339–58.

Nasu, K. and Shimadzu, Y. 1970. A method of estimating whale population by sighting observation. *Rep. int. Whal. Commn* 20: 114–29.

Ohsumi, S. 1980a. Population study of the Bryde's whale in the Southern Hemisphere under scientific permit in the three seasons, 1976/77–1978/79. *Rep. int. Whal. Commn* 30: 319–32.

Ohsumi, S. 1980b. Monitoring of the fin whale population in Area VI of the Southern Hemisphere. *Rep. int. Whal. Commn* 30: 333–6.

Ohsumi, S. and Masaki, Y. 1975. Japanese whale marking in the North Pacific, 1963–72. *Bull. Far Seas Fish. Res. Lab.* 12: 171–219.

Ohsumi, S. and Takagi, K. 1979, MS. Preliminary report on Dall porpoise sightings by Japanese salmon research vessels. *INPFC Doc.* 2150, 28 pp.

Omura, H. and Ohsumi, S. 1964. A review of Japanese whale marking in the North Pacific to the end of 1962, with some information on marking in the Antarctic. *Norsk Hvalfangsttid.* 53(4): 90–112.

Ozawa, K., Matsuike, K., Mimura, K., Egushi, H. and Nagano, K. 1964. Observations of whales of the Southern Oceans (1). *J. Tokyo Univ. Fish.* 7(2): 43–69 (in Japanese).

Takeda, S. 1960. *Worked in the Antarctic*. Isana Book Pub. Co. Ltd., 185 pp. (in Japanese).

Wolman, A. A. and Rice, D. W. 1979. Current status of the gray whale. *Rep. int. Whal. Commn* 29: 275–9.

SS/18

Problems and Progress in the US BLM-sponsored CETAP Surveys[a]

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BACKGROUND

The Outer Continental Shelf (OCS) Lands Act of 1953 established Federal jurisdiction over submerged lands of the US continental shelf seaward of state boundaries. The Bureau of Land Management (BLM) was designated the administrative agency responsible for leasing submerged Federal lands after passage of the OCS Lands Act.

The National Environmental Policy Act of 1969, the Marine Mammal Protection Act of 1972, and the Endangered Species Act of 1973 have, in combination, given responsibility to the BLM to insure that offshore submerged lands development be conducted in such a fashion so as not to jeopardize the continued existence of endangered and threatened species and to protect marine mammals 'to the greatest extent feasible commensurate with sound policies of resource management'.

In response to increased interests in offshore oil and gas development and the lack of general knowledge of marine mammals and endangered marine turtles in the Mid- and North Atlantic OCS regions, the BLM has sponsored a comprehensive study to inventory the cetaceans and marine turtles in waters over the OCS north of Cape Hatteras, North Carolina.

The Cetacean and Turtle Assessment Program (CETAP) was initiated at the University of Rhode Island in October 1978. The five general objectives of CETAP, as prescribed by the BLM, are as follows:

(1) To determine which species of cetaceans and marine turtles inhabit and/or migrate through the Mid- and North Atlantic regions;
(2) To identify, delineate and describe areas of importance for feeding, breeding, calving, etc. to cetaceans and marine turtles in these regions;
(3) To determine the temporal and spatial distribution of cetaceans and marine turtles in these regions;
(4) To determine behavioral characteristics of cetaceans and marine turtles in these regions;
(5) To estimate the size of and extent of cetacean and marine turtle populations in these regions; and
(6) To emphasize all the above objectives for those species classified as threatened or endangered by the US Departments of Interior and Commerce.

CETAP utilizes a variety of data sources to achieve these goals. Among these are a Platform of Opportunity Program (POP) and a dedicated aerial sampling program. The dedicated aerial sampling program is relied upon to provide the data base for estimating the abundances of the cetacean and marine turtle species in the study area. The sampling survey design and methods of analysis will be the topics for discussion in the remainder of this paper.

METHODS

The study area

The study area was defined to include that portion of the western North Atlantic from Cape Hatteras north to approximately Nova Scotia and from the coast to 9.26 km seaward of the 2,000 m contours. The total surface area is approximately 278,000 km^2.

Sampling design

Two sampling designs have been used to date for the main survey efforts. In the first year of field effort, sampling was conducted in a simple random fashion. The study area was divided into nine sampling areas (Fig. 1), eight (A–H)

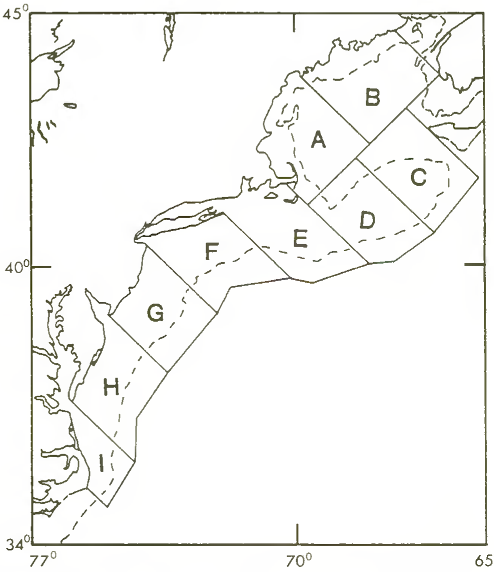

Fig. 1. The study area ranges from Cape Hatteras to Nova Scotia and from the coast to the 2,000 m depth contour. The study area was divided into 9 sampling areas as shown.

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[a] This CETAP study was supported by the Bureau of Land Management, Department of the Interior, under contract AA551-CT8-48.

with an average area of 33,300 km^2 and the last (I) with an area of approximately 11,600 km^2.

The sampling design allowed for a single sampling area to be completed per day. A minimum of four transects were drawn per area totalling at least 741 lineal km of flight track. The transects were defined to run northwest and southeast which, throughout most of the study area, is approximately normal to the depth contours and the expected density clines. The transects flown were drawn in a random fashion and without replacement from the pool of potential transects in each area. The number of potential transects was defined to be the number of parallel NE–SW oriented lines spaced at 3.7 km within a sampling area. The number of potential lines in an area ranged from 32 in I to 61 in H.

Sampling in the first year of effort was conducted within 45 day windows resulting in a total of eight sampling surveys throughout the year (23 January 1979–4 January 1980). The prevailing weather systems along the northeastern seaboard of the US require allotment of 3–4 days for each day of sampling.

Based on results of the first year's sampling effort, the second year's sampling design is a stratified random one. Each of the nine sampling areas were stratified on the basis of depth zones. Strata were defined as

(1) shallow, near shore (0–36.6 m [20 fathoms]);
(2) shelf (> 36.6–91.4 m [50 fathoms]); and
(3) slope (> 91.4–2,000 m).

The distribution of these depth zones in the nine sampling areas is depicted in Fig. 2.

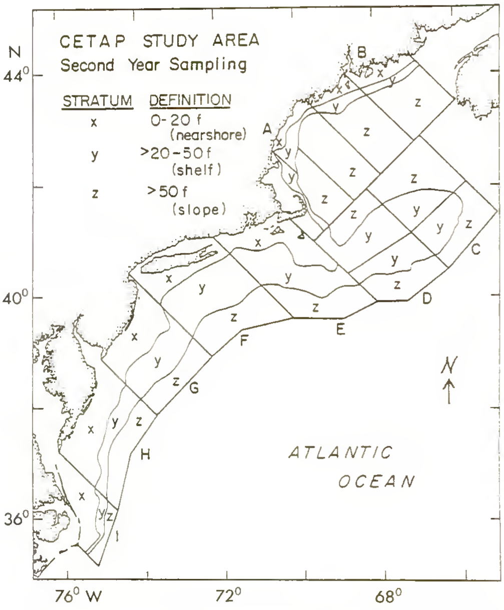

Fig. 2. The distribution of the depth strata defined in the study area.

The allocation of sampling effort in each stratum was based on the observed species densities and the size of each stratum. In this case, the observed species densities were based on the results of the first year's effort. Endangered species were weighted twice the value of non-endangered species. A total of 1,482 lineal km were allocated per sampling area per survey (twice the first year effort). Half of this value was assigned to each stratum proportional to stratum area. The remaining half was allocated based on species density in each stratum after Eberhardt *et al.* (1979):

$$l_i = L a_i D_i^{1/2} / \Sigma a_i D_i^{1/2} \qquad (1)$$

Here L is the total number of km to be allocated, a_i the area of stratum i, D_i an index of the density of animals in stratum i and l_i the allocated number of km to be sampled in area i. Sample allocation was constrained by the conventions that only 741 sampling km could be flown per day and that at least four transects per stratum must be drawn. If more than 741 km were allocated for a single day's sample, stratum allocations were rolled back on a proportional to area basis.

Although the total effort per sampling survey was doubled, the total number of sampling surveys was halved. Thus the number of flight hours per year has remained constant. The second year design calls for four approximately seasonal sampling surveys each within a 60 day window. Eighteen sampling days are required per survey.

Sampling platform

The platform employed for regular sampling surveys in the CETAP program is a *Beechcraft* AT-11, a military version of the *Beech* 18. The 7-place aircraft has a forward observation blister and is equipped with a full complement of navigation and communication components (see Table 1 and Fig. 3). The aircraft has a range of 2,220 km at

Table 1

Specifications and Equipment for the Aero-Marine Surveys, Inc. Twin *Beech* AT-11 (University of Rhode Island-CETAP-Configuration)[1]

Function	Equipment/Specification
Navigation	ONI TDL-711 (microprocessor-controlled LORAN-C) flight computer); SIMRAD 123 (autotracking LORAN-C)
Radiometer	BARNES PRT-5 Radiometer with chart recorder
Vertical Imagery	1 Hasselblad 500 El (data); 2 Hasselblad MK-70's (vertical)
Communications	1 Marine FM radio (all channel synthesizer); 2 VHF communication radios; 1 ADF (auto direction finder); 1 Sun Air S.S.B. transceiver (single side band); 1 Intercom system with 6 voice activated headsets
Miscellaneous	Fully equipped for IFR flying (instrument flight conditions capability); Radar altimeter; Fuel capacity 1,000 litre (300 gal.) with crew of six; 1,500 litre (450 gal.) maximum; Range 2,200 km (1,200 miles) – 10 hours (crew of six); Cruising speed 185–220 km/hr (100–120 knots); 2 Pratt & Whitney 450 horsepower radial engines; *Take off run full load 4.76 mT (10,500 lbs.) – 915–1,050 m (3,000–3,500 feet); **Take off run light load 450–610 m (1,500–2,000 feet); Deicing capabilities; Ejection tube for dye marker deployment; Overall length 10.7 m (35 ft); Wingspan 14 m (46 ft)
Survival equipment	4 Imperial cold water survival suits (no. 149); 1 Ten-man life raft; 1 Survival kit; 6 Inflatable life vests; 4 Nomex fire retardent flight suits (US Government Issue)
Carry on Equipment	2 Nikon F2-AS cameras with data backs—250 frame capacity; 1 Nikon 180 mm lens; 1 Nikon 300 mm lens; 1 Canon AE-1 camera with data back; 1 Canon 200 mm lens; 1 Pair Bushnell wide angle binoculars 7×35; 2 Pair Nikon binoculars 7×26; 1 Norelco cassette voice recorder.

[1] Adapted from Edel *et al.*, 1981.
* Full fuel, six people, equipment.
** Minimum fuel, crew of two.

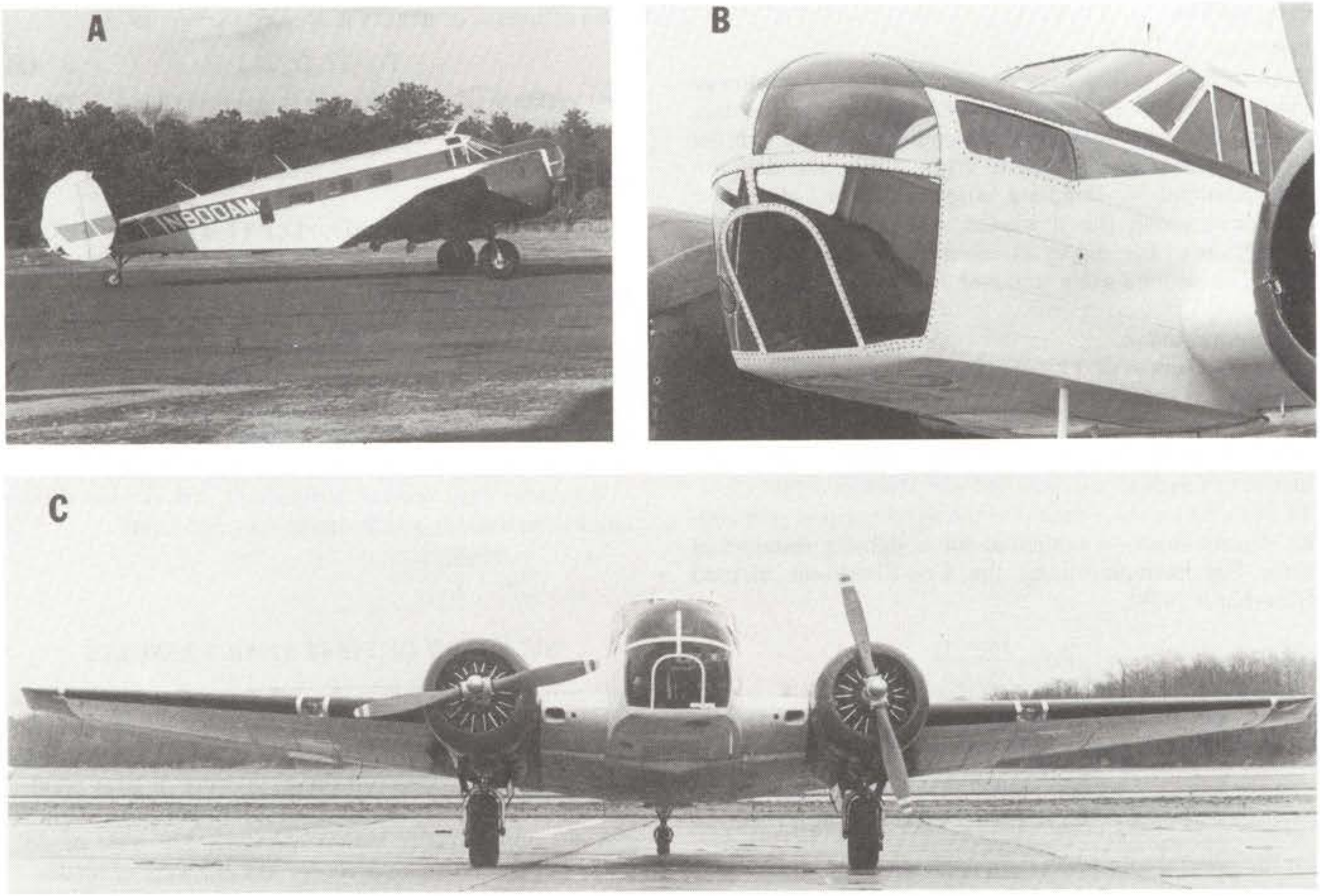

Fig. 3. The Beechcraft AT-11 survey plane. Plates A and C present the front and side aspects of the plane. Plate B is a close-up of the forward blister in which two observers are stationed.

cruising speeds of between 200 and 240 km/hr when in the CETAP configuration (six passengers).

Survey techniques

Survey teams consist of six persons including the pilot, a co-pilot/navigator and four observers. Observers are randomly paired and placed in the forward blister while on transect. Each observer scans the water surface from the bow to approximately 60° port or starboard. A full 90° scan is not possible due to the confined space in the observation blister. The blister observers are responsible for reporting sightings of cetaceans, turtles and other biological data (including human activities) in his(her) field of view over the intercom system to the data recorder. Additional data such as Beaufort sea state, amount and position of glare in the field of view, visibility and cloud cover are also reported and recorded at the beginning of each transect and as these conditions change. Observers are rotated from the blister at the end of each transect or after one hour on watch, whichever occurs first. The off-duty observers alternate off-watch periods at the data recorder station and the rest position. In addition to hand-written notes, voice notes are recorded on magnetic tape through the intercom system.

The navigator is responsible for recording the aircraft position at five minute intervals as well as marking the radiometer strip chart at the same time. Position and temperature information is also recorded upon each sighting and at other times when requested.

Sightings of cetaceans and turtles are classified by right angle distance intervals. The intervals used for classification are 0–0.118, >0.118–0.463, >0.463–0.926, >0.926–1.389, >1.389–1.852, and >1.852 km from the plane track. Sightings are classified into right angle distance intervals with the aid of reference marks placed on the blister. The reference marks represent degrees of declination below the visual horizon. The marks are calibrated for an altitude of 229 m.

Only sightings made by the blister observers are used in future analyses and eventual abundance estimation. The aircraft may break from the transect to approach sightings for positive identifications and counts. In the event additional animals are sighted while circling the original sighting, these are included in the total count for the sighting. If the aircraft then breaks to investigate the new sighting and additional sightings are made, the newest sightings are coded as off-transect sightings and are not included in future analysis for abundance estimation.

Survey parameter windows

Sampling was conducted at an altitude of 229 m and at a ground speed of 222 km/hr. Sampling was conducted only in sea states defined by a Beaufort value of 3 or less and with clear visibility of at least 3.7 km. Transects flown under conditions outside the bounds defined for 35% or more of the line were not considered for analysis. Lines flown with greater than 65% of the line within the bounds defined were considered. However, those line lengths outside of the 'sampling parameter windows' were not considered.

Data analysis

Effects on sightability.

The sampling survey data are analyzed using multiway contingency analysis (Fienberg, 1977) to examine the data for the effects of varying survey conditions on the sighting response curves (see Scott and Winn, 1980). The data are cross-classified by sampling strip, sea state, glare and taxonomic group (large whales, dolphins, and turtles). The effects of the survey variables on sighting frequency are also examined using standard ANOVA techniques.

Density estimation.

From Burnham *et al.* (1980) it has been shown that

$$\hat{D}_t = n_t\hat{f}(0)/2L_t \qquad (2)$$

where L_t is the length of transect sampled and n_t the number of individuals sampled per transect t (=1, 2, . . T). Here $\hat{f}(0)$ is the estimate of the sighting curve probability density function evaluated for a sighting distance of zero. For example, using the Cox-Eberhardt method (Eberhardt 1978):

$$\hat{f}(0) = \frac{3n_1 - n_2}{2n\triangle_i} \qquad (3)$$

for the specific case where right angle distance intervals ($\triangle_i$) are of equal length, and from Burnham *et al.* (1980):

$$\hat{f}(0) = \frac{C_1 + C_2}{C_1 \quad C_2} \cdot \left(\frac{n_1}{n}\right) - \frac{C_1}{C_2(C_2 + C_1)}\left(\frac{n_2}{n}\right) \qquad (4)$$

for the general case when right angle distance intervals C_1 and C_2 are of unequal length. Here n_1 is the number of individuals sighted in C_1 ($\triangle_1$), n_2, the number in C_2 ($\triangle_2$), and n, the total number of individuals sighted.

Since the transects sampled are of unequal lengths, a ratio estimator of density is applied (Seber, 1979):

$$\hat{D}_r = \Sigma L_t\hat{D}_t/\Sigma L_t \qquad (5)$$

The variance of this estimator is given as (Seber 1979):

$$V(\hat{D}_r) = \hat{\sigma}^2/\Sigma L_t \qquad (6)$$

where

$$\hat{\sigma}^2 = \Sigma L_t(\hat{D}_t - \hat{D}_r)^2/(T-1) \qquad (7)$$

An unadjusted estimate of the number of individuals in the sampling area is given as:

$$\hat{N} = \hat{D}_r A \qquad (8)$$

where A is the sampling area. Confidence intervals about N (or D_r) may be constructed in the usual manner using the product of the Student's t-value for T-1 degrees of freedom and the standard error of the estimate.

Estimates may require adjustments for varying survey conditions if those conditions prove 'significant'.

SUMMARY OF FIRST YEAR'S RESULTS

The transects sampled in the first year of field effort are presented in Fig. 4. The dates on which the samples were taken are presented in Table 2. A total of 634 sightings were used for analysis. Of these, 99 were of large whales (species in the family Balaenopteridae plus *Balaena glacialis* and *Physeter macrocephalus*), 320 were of dolphins (all remaining cetaceans), and 215 were of turtles.

Effects on sightability

The results of the tests of independence in the cross-classified data are presented in Table 3. The null

Table 2

Sampling transects per area and survey[1]

Sampling	Transects/date sampled per area								
Survey	A	B	C	D	E	F	G	H	I
I	4 4/2/79	0 —	0 —	3 12/2/79	4 24/1/79	4 23/1/79	4 19/1/79	2,3 16, 17/1/79	3 16/1/79
II	4 3/3/79	4 9/3/79	4 23/2/79	1,5 10,13/3/79	1,2,4 2,3,17/3/79	4 1/3/79	2,2 28/12/79 1/3/79	4 28/2/79	4 27/2/79
III	4 23/4/79	4 24/4/79	4 25/4/79	4 1/5/79	4 3/5/79	4 13/4/79	1,3 11,12/4/79	5 21/4/79	3,4 17,20/4/79
IV	2,4 1,6/6/79	5 7/6/79	4 8/6/79	4 9/6/79	4 14/6/79	4 31/5/79	4 30/5/79	5 16/6/79	4 3/6/79
V	5 9/7/79	5 10/7/79	4 11/7/79	3,4 19/7/79 7/8/79	4 30/7/79	4 18/7/79	4 6/8/79	5 5/8/79	4 4/8/79
VI	4 26/8/79	4 27/8/79	4 10/9/79	4 9/9/79	4 2/9/79	4 12/9/79	5 31/8/79	2 16/9/79	1 16/9/79
VII	0 —	4 28/10/79	0 —	4 6/11/79	4 1/11/79	4 19/10/79	5 18/10/79	5 16/10/79	4 17/10/79
VIII	5 15/12/79	5 21/12/79	0 —	0 —	4 4/1/80	0 —	5 12/1/80	5 19/1/80	4 18/12/79

[1] The numbers listed are as follows: a single number (n) placed above a date implies that n transects were sampled on that date. If several integers are listed above dates then those numbers of transects were sampled on the dates listed.

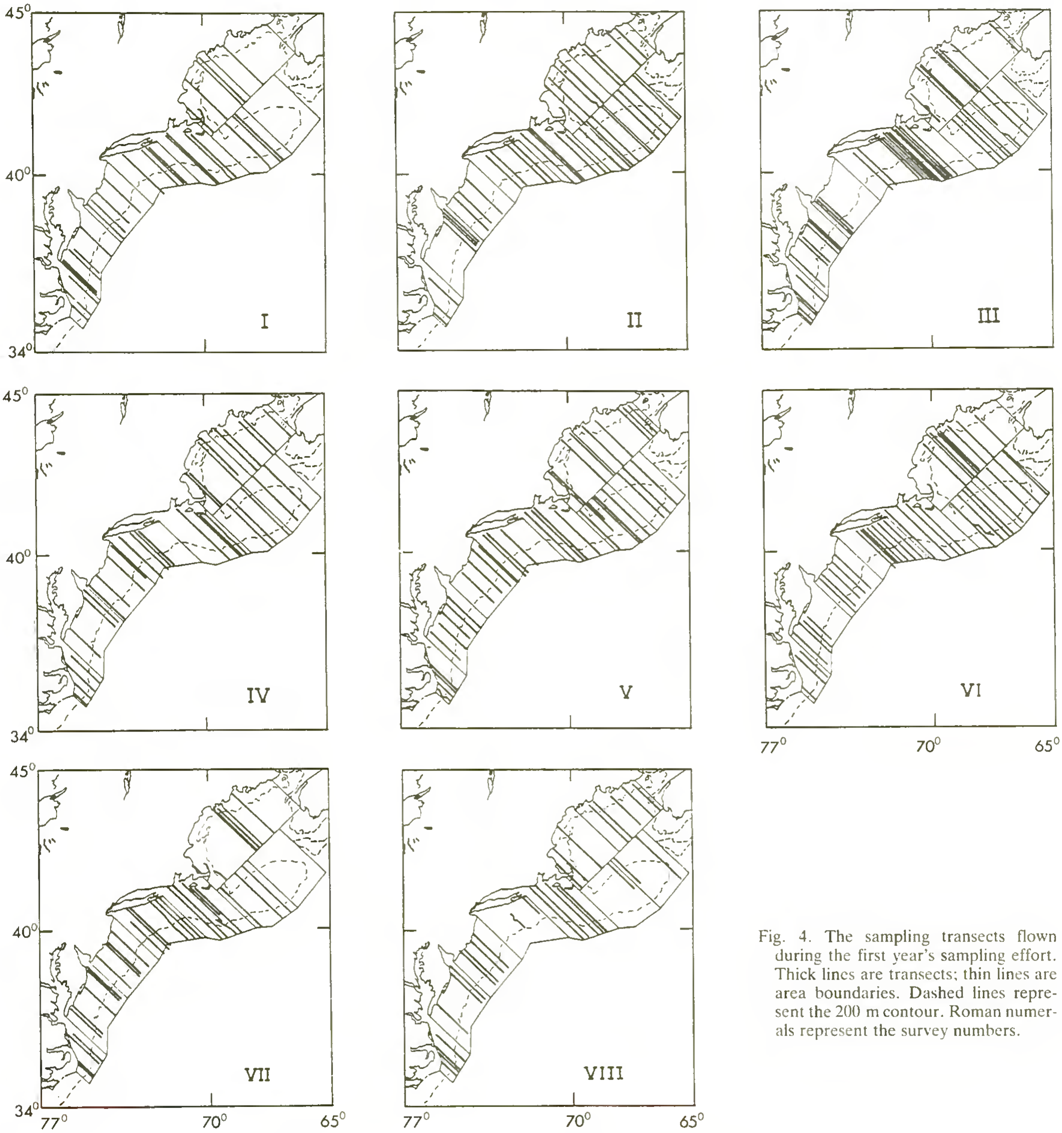

Fig. 4. The sampling transects flown during the first year's sampling effort. Thick lines are transects; thin lines are area boundaries. Dashed lines represent the 200 m contour. Roman numerals represent the survey numbers.

Table 3

Tests of Simultaneous Independence (** Significant at the 0.01 level).

K-factor[a]	DF	G^{2b}	Probability	X^{2b}	Probability
1	11	1,709.23**	<0.0001	5,163.48**	<0.0001
2	44	242.37**	<0.0001	325.66**	<0.0001
3	76	52.42	0.9822	56.40	0.9551
4	48	15.36	>0.9999	15.20	>0.9999

[a] The K-factor represents the level of interaction. The null hypothesis states that all K-factor interactions are simultaneously zero.

[b] Here G^2 represents the likelihood ratio chi-square and X^2 the Pearson chi-square statistic.

hypothesis tested is one of simultaneous independence for all interactions of K^th level. The results in Table 3 demonstrate that all third and higher order interaction terms are simultaneously zero (independent) and are not needed for log-linear model's fit to the data. First and second order terms, however, were found not to be simultaneously independent. This result implies that at least some of the first and second level terms are needed for an adequate log-linear fit.

Table 4 presents the result of the tests of partial and marginal association for the first and second level terms. As seen in Table 4, all of the first level terms and the interactions sampling strip×glare (SG), sampling strip× taxonomic group (ST), and Beaufort sea state×taxonomic group (BT) were found to be 'necessary' for an adequate log-linear fit to the data. The interaction of glare and taxonomic group (GT) was found a 'questionable' effect for the model.

Table 4

Tests of Partial and Marginal Association

Effect[a]	DF	Partial association G^2[b]	Partial association Probability	Marginal association G^2[b]	Marginal association Probability
S	4	595.17	<0.0001		
B	3	69.96	<0.0001		
G	2	584.10	<0.0001		
T	2	106.10	<0.0001		
SB	12	15.69	0.2061	14.68	0.2594
SG	8	82.06**	<0.0001	100.76**	<0.0001
ST	8	63.99**	<0.0001	80.87**	<0.0001
BG	6	3.53	0.7403	3.27	0.7746
BT	6	36.73**	<0.0001	34.64**	<0.0001
GT	4	6.58	0.1599	24.20**	0.0001

[a] The effects are: S, sampling strip; B, Beaufort sea state; G, amount of glare; and T, taxonomic group.
[b] Likelihood ratio chi-square.
** Significant at the 0.01 level.

Table 5 presents the result of the forward selection process used to determine the most parsimonious log-linear model to describe the data. Here the criterion used is a significant increase in the 'goodness of fit' of the hierarchical model when additional effects are added to the base model comprised of the terms identified as 'necessary' in Table 4. Since no effect added to the base model significantly improved the 'goodness of fit' of the model, the best choice of a model to describe the data structure is the base model. Graphically, the interactions sampling strip×glare, sampling strip×taxonomic group, and Beaufort sea state×taxonomic group are presented in Figs 5, 6 and 7, respectively.

The sighting data were examined for the effects of sea state and glare on the frequency of sightings made per track km (sighting density). The results of the ANOVA tests are presented in Tables 6, 7 and 8 and these data are graphically presented in Fig. 8.

Table 5

Forward selection fitting of log-linear models

Model[a]	DF	G^2[b]	Probability	Difference due to	DF	G^2[b]	Probability
SG, ST, BT	146	93.88	0.9997				
SB, SG, ST, BT	134	77.50	<0.9999	SB	12	16.38	0.1744
BG, SG, ST, BT	140	90.34	0.9996	BG	6	3.53	0.7394
GT, SG, ST, BT	142	87.69	0.9999	GT	4	6.19	0.1853

[a] The interaction terms are: BT, Beaufort sea state×taxonomic group; ST, sampling strip×taxonomic group; SG, sampling strip×glare amount; SB, sampling strip×Beaufort sea state; BG, Beaufort sea state×glare amount; and GT, glare amount×taxonomic group.
[b] Likelihood ratio chi-square.

Table 6

Analysis of variance results for regression model on whale sighting data

Source	DF	Sum of squares	Mean square	F	P(F)[a]	R^2
Model	5	30.8088	6.1618	23.46**	0.0003	0.9433
Sea state	1		22.8352	86.95**	0.0001	
Glare	1		0.6814	2.59	0.1512	
Sea state×glare	1		0.0181	0.07	0.8002	
Glare × glare	1		2.9603	11.27**	0.0121	
Sea state×sea state	1		4.3137	16.43**	0.0049	
Error	7	1.8383	0.2626			
Total	12	32.6471				

[a] P (F) represents the probability of having a greater F-value due to chance alone.
** Significant at $\alpha=0.01$
* Significant at $\alpha=0.05$

Table 7

Analysis of variance results for regression model on dolphin sighting data

Source	DF	Sum of squares	Mean square	F	P(F)[a]	R^2
Model	5	475.3962	95.0792	4.77*	0.0324	0.7730
Sea state	1		208.9327	10.48*	0.0143	
Glare	1		164.3950	8.24*	0.0240	
Sea state×glare	1		51.4118	2.58	0.1524	
Glare×glare	1		47.1684	2.36	0.1680	
Sea state×sea state	1		3.4883	0.17	0.6883	
Error	7	139.6156	19.9451			
Total	12	615.0118				

[a] P(F) represents the probability of having a larger F-value due to chance alone.
* Significant at $\alpha = 0.05$

Table 8

Analysis of variance results for regression model on turtle sighting data

Source	DF	Sum of squares	Mean square	F	P(F)[a]	R^2
Model	5	94.8661	18.9732	21.59**	0.004	0.9391
Sea state	1		76.2290	86.75**	<0.0002	
Glare	1		1.7170	1.95	0.2049	
Sea state×glare	1		0.2398	0.27	0.6175	
Glare×glare	1		1.4235	1.62	0.2437	
Sea state×sea state	1		15.2568	17.36**	0.0042	
Error	7	6.1511	0.8787			
Total	12	101.0172				

[a] P(F) represents the probability of having a greater F-value due to chance alone.
** Significant at $\alpha=0.01$.

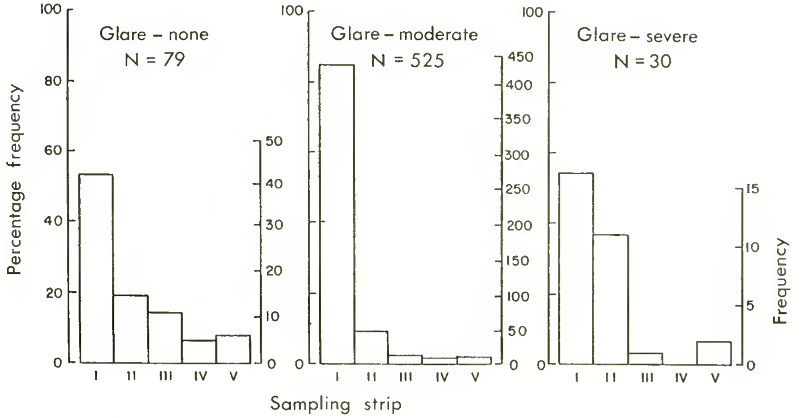

Fig. 5. The effect of amount of glare on the distribution of sightings by right angle distance. The distance intervals are: I, 0–0.463; II, >0.463–0.926; III, >0.926–1.389; IV, >1.389–1.852; V, >1.852 km from the track line.

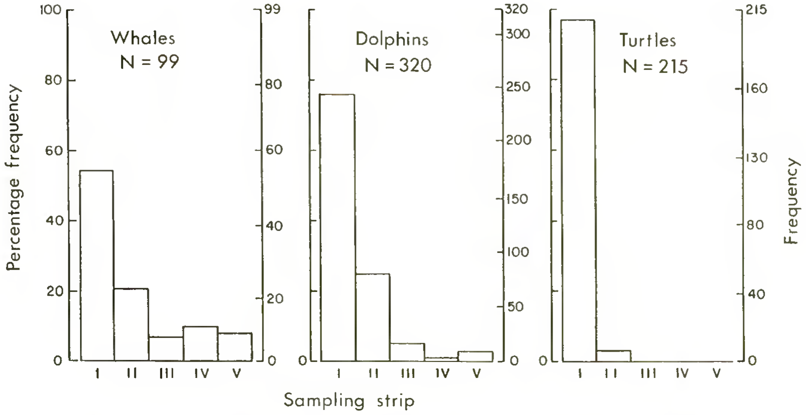

Fig. 6. The distribution of sightings by taxonomic group and sampling strip. Sampling strips represent I, 0–0.463; II, >0.463–0.926; III, >0.926–1.389; IV, >1.389–1.852; V, >1.852 km from track line.

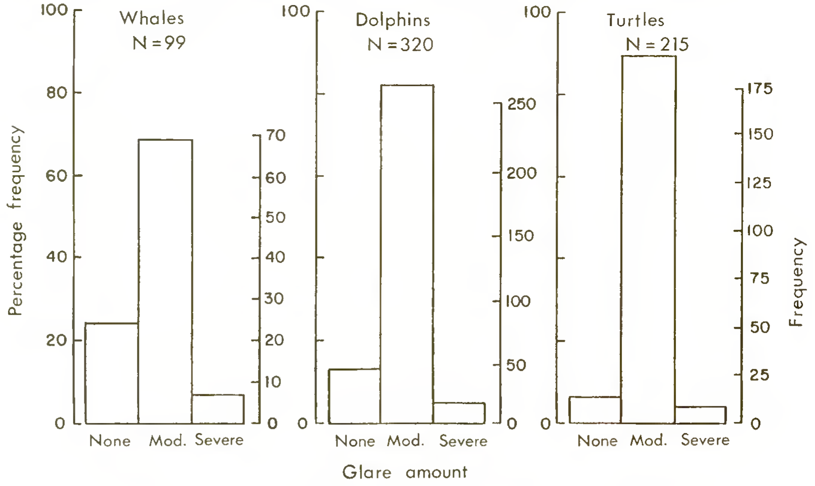

Fig. 7. The distribution of sightings by taxonomic group and Beaufort sea state.

In Fig. 8 it is apparent that the whale and turtle sighting density response curves are similar, but the dolphin data follow a different pattern. Indeed, the dolphin data were found to vary significantly with both sea state and glare conditions as well as glare × sea state and glare^2 interactions. The whale and turtle data, on the other hand, were found to vary predominantly with sea state. (The turtle data also vary significantly with the sea state×glare interaction, but this may be attributable to the domination of sea state.)

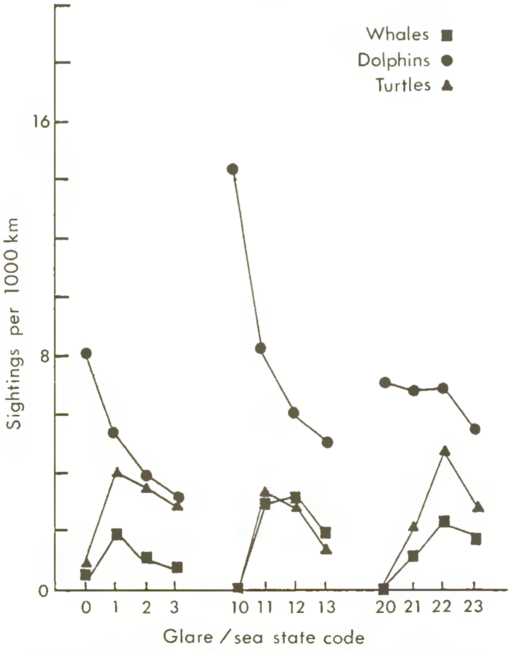

Fig. 8. The sighting density response curves to varying glare and sea state conditions for whales, dolphins and turtles. The glare/sea state codes are: 0, no glare/sea state 0; 1, no glare/sea state 1; 2, no glare/sea state 2; 3, no glare/sea state 3; 10, moderate glare/sea state 0; 11, moderate glare/sea state 1; 12, moderate glare/sea state 2; 13, moderate glare/sea state 3; 20, severe glare/sea state 0; 21, severe glare/sea state 1; 22, severe glare/sea state 2; and 23, severe glare/sea state 3.

Density estimation

The value of $\hat{f}(0)$ was obtained using the data presented in Fig. 4. Letting $C_1 = C_2$ (or $\triangle$)=0.926 km for whales and dolphins and 0.463 km for turtles, the estimates of $\hat{f}(0)$ were as follows:

Taxonomic group	$\hat{f}(0)$	Effective half swath (km)
Whales	1.2120	0.8251
Dolphins	1.4736	0.6786
Turtles	3.0989	0.3227

Note that since $\hat{D} = nf(0)/2L$, then $1/f(0)$ is the effective half swath of the transects.

Estimating abundance

Average densities, variance and average number estimates are presented in Tables 9 through 14 for selected species sampled during the first year's sampling effort. These estimates should be considered preliminary since they are not adjusted for differential sighting frequency due to glare/sea state conditions or for submergence times. The estimates are presented to give the reader an idea of the relative abundances of the different species sampled in the study area. The reader should also note that in a number of cases, estimates are presented for sightings not classified to species.

[Discussion begins on p. 598]

Table 9

Cox-Eberhardt method density estimates for *B. acutorostrata*

Survey	Block A	B	C	D	E	F	G	H	I
A1	0.0000			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0			0	0	0	0	0	0
	0			0	0	0	0	0	0
	± 0			0	± 0	± 0	± 0	± 0	± 0
A2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A4	0.0006	0.0007	0.0039	0.0000	0.0007	0.0000	0.0009	0.0000	0.0000
	2.8E–07	5.7E–07	3.9E–06	0	4.8E–07	0	7.2E–07	0	0
	24	26	136	0	24	0	24	0	0
	± 20	± 33	± 110	± 0	± 39	± 0	± 38	± 0	± 0
A5	0.0009	0.0008	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000
	1.2E–06	7.0E–07	0	0	0	6.8E–07	0	0	0
	33	30	0	0	0	27	0	0	0
	± 49	± 37	± 0	± 0	± 0	± 44	± 0	± 0	± 0
A6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	± 0	0	± 0	± 0	± 0	± 0	± 0	± 0
A7		0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0		0	0	0	0	0	0
		0		0	0	0	0	0	0
	±	± 0	±	± 0	± 0	± 0	± 0	± 0	± 0
A8	0.0008	0.0000			0.0000		0.0000	0.0000	0.0000
	7.9E–07	0			0		0	0	0
	28	0			0		0	0	0
	± 40	± 0			± 0		± 0	± 0	± 0

The values listed are average density, variance, number and +/− 95% CI estimates. Densities are given as whales/km**2.
No sample was taken in the following cells: A1B, A1C, A7A, A7C, A8C, A8D, A8F.

Table 10

Cox-Eberhardt method density estimates for *B. borealis*

Survey	Block A	B	C	D	E	F	G	H	I
A1	0.0000			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0			0	0	0	0	0	0
	0			0	0	0	0	0	0
	± 0			± 0	± 0	± 0	± 0	± 0	± 0
A2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A4	0.0000	0.0000	0.0031	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	9.6E–06	0	0	0	0	0	0
	0	0	109	0	0	0	0	0	0
	± 0	± 0	± 173	± 0	± 0	± 0	± 0	± 0	± 0
A5	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	4.3E–07	0	0	0	0	0
	0	0	0	32	0	0	0	0	0
	± 0	± 0	± 0	± 28	± 0	± 0	± 0	± 0	± 0
A6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A7		0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0		0	0	0	0	0	0
		0		0	0	0	0	0	0
		± 0		± 0	± 0	± 0	± 0	± 0	± 0
A8	0.0000	0.0000			0.0000		0.0000	0.0000	0.0000
	0	0			0		0	0	0
	0	0			0		0	0	0
	± 0	± 0			± 0		± 0	± 0	± 0

The values listed are average density, variance, number and +/− 95% CI estimates. Densities are given as whales/km**2.
No sample was taken in the following cells: A1B, A1C, A7A, A7C, A8C, A8D, A8F.

Table 11

Cox-Eberhardt method density estimates for *B. physalus*

	Block								
Survey	A	B	C	D	E	F	G	H	I
A1	0.0000			0.0000	0.0000	0.0024	0.0000	0.0000	0.0000
	0			0	0	5.7E–06	0	0	0
	0			0	0	81	0	0	0
	± 0			± 0	± 0	± 128	± 0	± 0	± 0
A2	0.0000	0.0000	0.0000	0.0000	0.0005	0.0063	0.0000	0.0000	0.0000
	0	0	0	0	3.8E–07	3.7E–05	0	0	0
	0	0	0	0	18	213	0	0	0
	± 0	± 0	± 0	± 0	± 20	± 328	± 0	± 0	± 0
A3	0.0000	0.0000	0.0007	0.0046	0.0005	0.0010	0.0008	0.0000	0.0000
	0	0	6.0E–07	2.1E–05	1.4E–07	8.4E–07	6.8E–07	0	0
	0	0	25	156	19	33	23	0	0
	± 0	± 0	± 43	± 248	± 22	± 49	± 37	± 0	± 0
A4	0.0181	0.0007	0.0016	0.0129	0.0000	0.0000	0.0000	0.0079	0.0000
	6.6E–05	5.7E–07	7.9E–07	5.3E–05	0	0	0	1.9E–05	0
	660	26	54	436	0	0	0	221	0
	± 310	± 33	± 50	± 394	± 0	± 0	± 0	± 151	± 0
A5	0.0292	0.0000	0.0010	0.0005	0.0024	0.0088	0.0009	0.0000	0.0000
	6.3E–04	0	1.3E–06	2.5E–07	5.5E–06	6.5E–05	6.6E–07	0	0
	1066	0	36	16	86	297	24	0	0
	± 1138	± 0	± 64	± 21	± 133	± 432	± 36	± 0	± 0
A6	0.0000	0.0000	0.0007	0.0000	0.0015	0.0000	0.0014	0.0000	0.0000
	0	0	4.9E–07	0	2.1E–06	0	2.1E–06	0	0
	0	0	24	0	52	0	41	0	0
	± 0	± 0	± 39	± 0	± 82	± 0	± 51	± 0	± 0
A7		0.0000		0.0000	0.0000	0.0019	0.0000	0.0000	0.0000
		0		0	0	4.0E–06	0	0	0
		0		0	0	63	0	0	0
		± 0		± 0	± 0	± 108	± 0	± 0	± 0
A8	0.0008	0.0000			0.0000		0.0000	0.0000	0.0000
	3.9E–07	0			0		0	0	0
	28	0			0		0	0	0
	± 28	± 0			± 0		± 0	± 0	± 0

The values listed are average density, variance, number and +/− 95% CI estimates. Densities are given as whales/km**2.
No sample was taken in the following cells: A1B, A1C, A7A, A7C, A8C, A8D, A8F.

Table 12

Cox-Eberhardt method density estimates for B.p., B.m., B.b., or B.e.

	Block								
Survey	A	B	C	D	E	F	G	H	I
A1	0.0000			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0			0	0	0	0	0	0
	0			0	0	0	0	0	0
	± 0			± 0	± 0	± 0	± 0	± 0	± 0
A2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	±
A7		0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0		0	0	0	0	0	0
		0		0	0	0	0	0	0
		± 0		± 0	± 0	± 0	± 0	± 0	± 0
A8	0.0000	0.0000			0.0000		0.0007	0.0000	0.0000
	0	0			0		5.3E–07	0	0
	0	0			0		20	0	0
	± 0	± 0			± 0		± 25	± 0	± 0

The values listed are average density, variance, number and +/− 95% CI estimates. Densities are given as whales/km**2.
B.p. is *Balaenoptera physalus*, B.m., *B. musculus*, B.e., *B. edeni*, B.b., *B. borealis*.
No sample was taken in the following cells: A1B, A1C, A7A, A7C, A8C, A8D, A8F.

Table 13

Cox-Eberhardt method density estimates for *B. glacialis*

	Block								
Survey	A	B	C	D	E	F	G	H	I
A1	0.0000			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0			0	0	0	0	0	0
	0			0	0	0	0	0	0
	± 0			± 0	± 0	± 0	± 0	± 0	± 0
A2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A3	0.0000	0.0008	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
	0	6.1E–07	0	4.5E–07	0	0	0	0	0
	0	29	0	22	0	0	0	0	0
	± 0	± 44	± 0	± 36	± 0	± 0	± 0	± 0	± 0
A4	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	4.8E–07	0	0	0	0
	0	0	0	0	24	0	0	0	0
	± 0	± 0	± 0	± 0	± 39	± 0	± 0	± 0	± 0
A5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	±
A7		0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0		0	0	0	0	0	0
		0		0	0	0	0	0	0
		± 0		± 0	± 0	± 0	± 0	± 0	± 0
A8	0.0000	0.0000			0.0000		0.0000	0.0000	0.0000
	0	0			0		0	0	0
	0	0			0		0	0	0
	± 0	± 0			± 0		± 0	± 0	± 0

The values listed are average density, variance, number and +/– 95% CI estimates. Densities are given as whales/km**2.
No sample was taken in the following cells: A1B, A1C, A7A, A7C, A8C, A8D, A8F.

Table 14

Cox-Eberhardt method density estimates for *M. novaeangliae*

	Block								
Survey	A	B	C	D	E	F	G	H	I
A1	0.0000			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0			0	0	0	0	0	0
	0			0	0	0	0	0	0
	± 0			± 0	± 0	± 0	± 0	± 0	± 0
A2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A3	0.0000	0.0000	0.0014	0.0007	0.0011	0.0000	0.0000	0.0000	0.0000
	0	0	6.1E–07	4.3E–07	5.6E–07	0	0	0	0
	0	0	51	22	39	0	0	0	0
	± 0	± 0	± 44	± 36	± 42	± 0	± 0	± 0	± 0
A4	0.0187	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
	52.E–05	0	0	1.7E–06	0	0	0	0	0
	684	0	0	46	0	0	0	0	0
	± 275	± 0	± 0	± 71	± 0	± 0	± 0	± 0	± 0
A5	0.0173	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	1.9E–04	0	0	0	0	0	0	0	0
	633	0	0	0	0	0	0	0	0
	± 626	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0
A6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	± 0	± 0	± 0	± 0	± 0	± 0	± 0	± 0	±
A7		0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0		0	0	0	0	0	0
		0		0	0	0	0	0	0
		± 0		± 0	± 0	± 0	± 0	± 0	± 0
A8	0.0008	0.0000			0.0000		0.0000	0.0000	0.0000
	5. 8E–07	0			0		0	0	0
	28	0			0		0	0	0
	± 34	± 0			± 0		± 0	± 0	± 0

The values listed are average density, variance, number and +/– 95% CI estimates. Densities are given as whales/km**2.
No sample was taken in the following cells: A1B, A1C, A7A, A7C, A8C, A8D, A8F.

DISCUSSION OF RESULTS

Effects on sightability

The log-linear model found to most adequately describe the cross-classified data structure included the interactions of sampling strip and taxonomic group (ST), sampling strip and glare (SG) and Beaufort sea state and taxonomic group (BT). Inclusion of these terms in the model implies an interdependence between those variables. The implications of these terms are discussed below.

The sampling strip × glare term implies that the overall sighting-response-function (all groups combined) varies with the amount of glare in the observer's field of view. This response, however, appears not to be a linear function of the amount of glare in the field of view. In Fig. 5 it is evident that sightings are made more frequently in the tail region of the curve than under moderate glare conditions. But, in severe glare conditions, this trend appears reversed. Although fewer sightings are made in the tail region under severe glare conditions than zero glare, there is a higher tail percentage than under moderate glare. The causality of this response remains unknown, although a small sample anomaly can not be ruled out.

The effect of glare on density estimation in this case remains unclear. Since there is an obvious difference in sighting-response-curves for whales, dolphins and turtles (Fig. 6) one would expect the third order interaction glare×strip×taxonomic group to be significant. Scott and Winn (1980) found glare to cause significant variability in the sighting-response-curve for a single species sample (*Megaptera novaeangliae*). Examination of the data by taxonomic grouping may prove more enlightening on this point.

The interaction of taxonomic group × sampling strip has obvious implications. This is, since the response-functions are obviously different (Fig. 6), no single, general sighting-response-curve model should be applied to estimate the abundance of all three taxonomic types. This point has been made on a finer scale by numerous authors who have asserted that there are likely as many response curves as species to sample (e.g. Eberhardt, 1978; Gates 1979). One must assume, therefore, that there is a degree of bias in the approach of using taxonomic groupings for defining species specific sighting functions. However, given the large number of species sampled and the relatively small sample size for each, few options are left open.

The remaining effect in the log-linear model (Beaufort sea state × taxonomic group) has little, if any, direct effect on the sighting response curve. However, this relationship may result from a generalized decrease in sightability in calm seas. One hypothesis is that the animals sampled are less active in very calm seas (Beaufort 0) and, therefore, cause less surface commotion, thus being harder to distinguish. Scott and Winn (1980) have, in fact, found a positive correlation between the degree of activity in humpback whales (*Megaptera novaeangliae*) and Beaufort sea state.

It is of interest to note that for both the whale and turtle data, the highest average sighting density was observed in a sea state of Beaufort 1–2 while the highest average relative density for the dolphin data was found for Beaufort 0 (see Fig. 8). This result leads one to hypothesize that both whales and turtles have lower sightability values in calm seas than rougher ones. This relationship seems not to hold for dolphins, however, which appear to have higher sightability values in calm seas.

One may infer from the results presented (Fig. 6; Tables 6, 7, and 8) that there is no interaction between sea state and glare on the sighting density of whales and turtles. Glare appears not to be a significant factor in the sighting density response-curves for turtles. Glare and sea state (both 1st and 2nd order terms) affect the sighting density response-curve for dolphins and whales.

The implications of a significant effect of either glare or sea state on sighting frequency is that estimates of abundance may need to be adjusted to account for the variability. Scott and Winn (1980) found glare and sea state to significantly affect average density estimates of humpbacks. As in this study (for large whales) Scott and Winn (1980) found no interaction between glare and sea state. Contrary to this study, however, the highest average density was found in calm seas. The sea state classification in the study of Scott and Winn (1980) was not by Beaufort value, but only by the percent of whitecaps in the field of view. Thus, under no whitecap conditions would be included Beaufort values of 0–2. It is possible that the response-function seen in Fig. 8 was masked by the scale used in the Scott and Winn (1980) study.

An additional variable which may alter sighting frequency but has not been investigated with these data is inter-observer variability. Observer variation has been found to be a significant effect in both terrestrial sampling surveys (eg. Caughley, 1974) and marine mammal surveys (Leatherwood *et al.*, 1978). It is likely that inter-observer variability may be a function of both level of experience (Scott and Winn, 1980) and aptitude.

Density estimation

As previously mentioned, the estimates presented must be considered minimal and used only as indices of relative abundance. Additionally, estimates of abundance may be biased due to the assumption that all species in a taxonomic group have the same sighting response curve. For instance, minke whales (*Balaenoptera acutorostrata*) and fin whales (*Balaenoptera physalus*) may have quite different response curves. Species of dolphins which form large herds such as the *Stenella* spp. may also have considerably different sighting response curves than a relatively solitary species such as some of the beaked whales.

Perceived problems

There are a number of problems in collecting, analyzing, and interpreting aerial sampling survey data, especially for sampling surveys protracted in both space and time. The CETAP surveys in particular are difficult to deal with for a number of reasons. Among these are the facts that (1) the survey is a multispecies one, (2) distance information is difficult to collect, (3) sampling within a single survey effort is not synoptic, (4) the relatively small sample size makes analysis difficult, (5) adjustment factors for dive times and visibility conditions are required, and (6) the study itself is geographically specific rather than species specific.

In the first case, the fact that the survey is a multispecies rather than single species one implies that any sampling design cannot be considered 'optimal' for each species. For example, the search image and methods of searching for a turtle are quite different from that of a large whale or a porpoise herd.

An altitude of 1,500 m may be quite well suited for large whale surveys, but nearly impossible for small dolphins or turtles. Lowering the survey altitude has the desirable quality of increasing image size and, presumably, lowering the probability of missing an animal at the surface on or near the transect line. Lowering the survey altitude, however, has the undesirable property of increasing the apparent angular acceleration of the water's surface, thereby giving an observer far less time to search an area, especially the nearfield where a great number of sightings are made. The obvious solution is to lower ground speed, however, open ocean survey efforts leave little margin for error and this should be kept in mind when assigning both altitude and ground speed values to survey conditions. The altitude at which CETAP surveys are conducted (229 m) is the result of a trade-off between what was considered more favorable for large whales, dolphins and turtles. The speed at which the samples are taken (222 km/hr) is considered to allow sufficient margin for safety in the AT-11 craft.

Distance information required for line transect (in the spirit of Gates 1979, line transect sampling is meant to include 'strip' transects as well) estimation is difficult to gather due to the tangential relationship between distance and declination. In order to minimize the effort and errors involved in measuring distances, sightings are classified by distance intervals. The Cox-Eberhardt method (Eberhardt, 1978) and that of Crain *et al.* (1979, i.e. Fourier model) allow one to deal with data that have been 'pooled' in this manner.

The third point mentioned is that the CETAP study area is not sampled in synoptic fashion. It is possible for two sampling blocks within a single survey to be sampled as much as 1 or 2 months apart. Thus animal migratory and localized movements may not be neglected. One must consider the estimates presented representative of the day(s) on which sampling took place and not of the sampling survey window period.

Sampling is restricted by weather, time, and logistical constraints. The result of these constraints, especially over an area as large as the one described, is in many cases, a small sample (ie. a low percentage of surface area is covered). In the first year's effort, sampling was at about the 5% level (assuming an effective swath of 1.85km). Preliminary comparisons of sightings made by the POP (Hain *et al.*, 1981) and the dedicated aerial sampling program indicate that unbiased estimates of abundance and of species distribution are not always possible due to small sample sizes. Often POP effort resulted in sightings in areas where species abundance was estimated to be zero.

Based on the results of analysis of the first year's data it is apparent that the estimates need to be adjusted for varying survey conditions. There are problems in this approach in that the data used for estimating abundance are also used to estimate adjustment factors (an independence problem). One solution may be a jack-knife approach (Scott and Winn, 1980).

One major adjustment factor has not been addressed. This involves corrections for animals missed due to diving behavior. The theoretical ground work for adjusting estimates for diving behavior has been established (Eberhardt 1978, Eberhardt *et al.*, 1979) and the technology for gathering the large amounts of data required for these adjustments is available (i.e. radio telemetry, Ray *et al.*, 1978; Watkins, 1978; B. Mate, pers. comm.). The remaining step is to apply the available technology to develop sufficient data bases for the species in question.

One final point regarding the estimates presented is that since the study area is rather arbitrarily defined and we are dealing with a multispecies program, one cannot legitimately project the density estimates derived to total population estimates. In a few special cases, where the study area is known to encompass all of a species population area throughout the year or during a portion of the year, sampling within the area defined may allow estimating total abundance. However, until the approach of species specific rather than geographically specific studies is used, estimates of total abundance for most species will not be possible.

Perceived progress

The CETAP aerial sampling program is the only large scale sampling effort designed and implemented to estimate the spatio-temporal distributions and abundances of the cetacean and marine turtle species occurring in waters over the eastern US OCS. The sampling design and data collection methods have the attributes of being consistent with the most current models for estimating species abundance. The data management system is flexible and responsive enough to allow revisions of sampling design when revisions are inferred (eg. the stratified design was based on the results of the first year's effort). Environmental data are collected in such a manner to allow correlative analyses between species distributions and physical factors such as depth and surface water temperature. Continuation of the sampling effort will enable the development of a sufficient time-series data base for analysis of trends in seasonal abundance and distribution.

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REFERENCES

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 71: 202pp.

Caughley, G. 1974. Bias in aerial survey. *J. Wildl. Mange.* 38(4): 921–1,133.

Crain, B. R., Burnham, K. P. Anderson, D. R. and Laake, J. L. 1978. *A Fourier Series Estimator of Population-Density for Line Transect Sampling.* Utah St. Univ. Press, Logan, Utah. 25pp.

Eberhardt, L. L. 1978. Transect methods for population studies. *J. Wildl. Manage.* 42(1): 1–31.

Eberhardt, L. L., Chapman, D. G. and Gilbert, J. R. 1979. A review of marine mammal census methods. *Wildlife Monographs* 63: 46pp.

Edel, R. K., Hyman, M. A. M. and Tyrell, M. F. 1981. Chapter 1, Introduction. *In: A Characterization of Marine Mammals and Turtles in the Mid- and North-Atlantic Areas of the US Outer Continental Shelf.* Annual Report for 1979 by the Cetacean and Turtle Assessment Program, University of Rhode Island. BLM Ref. No. AA551-CCT-48, Washington, D.C.

Fienberg, S. E. 1977. *The Analysis of Cross-Classified Categorical Data.* The MIT Press, Cambridge, MA. 151pp.

Gates, C. E. 1979. Line transect and related issues. pp. 75–154. *In*: Cormack, R. M. Patil, G. P. and Robson, D. S. (eds.). *Sampling Biological Populations* Int. Coop. Publ. House, Fairland, MD.

Hain, J., Edel, R., Hays, H., Katona, S. and Roanowicz, J. 1981. Chapter II: General distribution of cetaceans in the continental shelf waters of the northeastern United States. *In: A Characterization of Marine Mammals and Turtles in the Mid- and North-Atlantic Areas of the US Outer Continental Shelf.* Annual Report for 1979 by the Cetacean and Turtle Assessment Program, University of Rhode Island. BLM Ref. No. AA551-CT8-48, Washington, D.C.

Hyman, M. A. M. 1980. *Report of research operations.* CETAP First Year Draft Final Report to the BLM.

Leatherwood, S. J., Gilbert, J. R. and Chapman, D. G. 1978. An evaluation of some techniques for aerial censuses of bottlenosed dolphins. *J. Wildl. Manage.* 42(2): 239–50.

Ray, G. C., Mitchell, E. D., Wartzog, D., Kozicki, V. M. and Maiefski, R. 1978. Radio tracking of a fin whale (*Balaenoptera physalus*). *Science* 202(436): 521–24.

Scott, G. P. and Winn, H. E. 1980. *Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of humpback whales* (*Megaptera novaengliae*). Final Report to Marine Mammal Commission Contract No. MM7AC029.

Scott, G. P., Gilbert, J. R., Kenney, R. D. and Edel, R. 1981. Chapter IV. Estimates of cetacean and turtle abundance in the CETAP study area with an analysis of factors affecting them. *In: A Characterization of Marine Mammals and Turtles in the Mid- and North-Atlantic Areas of the US Outer Continental Shelf.* Annual Report for 1979 by the Cetacean and Turtle Assessment Program, University of Rhode Island. BLM Ref. No. AA551-CT8-48, Washington, D.C.

Seber, G. A. F. 1979. Transects of random length. pp. 183–192 *In*: Cormack, R. M., Patil, G. P. and Robson D. S. (eds.). *Sampling Biological Populations.* Int. Coop. Publ. House, Fairland, MD.

Watkins, W. A. 1978. A radio tag for big whales. *Oceanus* 21(2): 48–54.

SC/33/O 11

Respiration Patterns and 'Sightability' of Whales

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INTRODUCTION AND METHODS

From 11 through 13 September 1980 an International Whaling Commission workshop was held in Seattle, Washington to discuss the design of sightings surveys which are intended to provide data for population estimates or density indices of cetaceans (IWC, 1982). Among the important issues, participants agreed that treatments of such sightings data should account for whales which were diving, and therefore undetected, when the platform was within theoretical viewing range. Previous attempts to correct estimates for whales missed for this reason (Doi, 1971; 1974; 1982) have been hampered by the limited amount and generally poor quality of data on cetacean respiration and diving patterns. This paper summarizes available data and suggests a format for collection of future data on sightability of great whales, killer whales and bottlenose whales.

Responses were received from 54 of 93 persons receiving questionnaires. Recipients had been asked to summarize—for each species, geographical region and method of data collection identified—ranges and average number of respirations per 'surfacing' interval (the period of hyperventilation between longer dives); time between respirations for surfacing intervals; ranges and means of long or 'sounding' dives; and other data or comments on surfacing behavior of a whale species which might affect its sightability. The scientific literature was examined for information on the same questions.

RESULTS AND DISCUSSION

All relevant data assembled are summarized in Appendix I. Forty-seven of the questionnaires were not returned nor were follow-up letters answered. Some respondents acknowledged having relevant data but were unable to provide them for this report. Some of those not responding have conducted recent in-depth studies of whale behavior. Therefore, we know that Appendix I is incomplete.

Despite the considerable research on whales over the years their respiratory patterns continue to be poorly documented. The information available is variable in method, quality, extent and format. Much of it is anecdotal and hardly adequate to support a numerical correction term. Furthermore, from published comments and statements of respondents to questionnaires in the present study one is struck by the variability in diving behavior of all species studied. Overall, the diving patterns of whales appear to vary significantly by time of day, season, geographical area, environmental conditions, number of individuals present, dominant behavior of the group, age composition of the group, presence of the survey platform, and perhaps other factors as well. Consider, for example the discussion below of the complexity of interpreting the time a whale spends at the surface and its effect on sightability.

Clearly the major evidence for the presence of a whale in a survey area is a blow or a portion of the body visible at the surface. The frequency with which whales respire, the time spent doing so, and the visibility of the animals near the surface between the blows for best known species apparently vary significantly at least by group size, whale behavior at the time of observations, and environmental conditions.

Group size

Although whales in a pod often respire nearly synchronously, surface cycles of groups are generally longer than surface cycles for individuals (e.g. see Joyce, 1982) and present more potential glimpses of blows and body parts. At least gray whales tend to be solitary or occur in small groups on feeding grounds but travel in larger groups (24 or more) during migration. Bowhead whales, on the other hand, apparently occur in larger groups on feeding grounds than they do during migration. Similar unquantified differences in group size at different seasons and locations probably exist for other species, as well. That this factor affects visibility is clear.

Behavior

Resting and travelling whales generally spend more time at the surface than feeding or disturbed whales. Gray and bowhead whales make regular, predictable and often protracted surfacings during migrations but make longer dives with more erratic surface intervals when feeding. The longest dives reported for any species are escape dives of harassed or harpooned individuals.

Daily cycles in behavior, like seasonal cycles, apparently exist. They, too, affect sightability. Gray whales in the breeding lagoons are most active near dawn and dusk and often have long rest periods near mid-day (Swartz and Jones, 1979). A migrating radio-instrumented calf made longer dives at night and rested and travelled slowly during the daytime (Evans, 1974).

Sperm whales remain at the surface for long periods after long dives. The often quoted Ashley's rule states that a 60 ft sperm whale, weighing 60 tons, stays down 60 minutes, and spouts 60 times between long dives. The first blow or series of blows following a long dive is the most visible. Similar relationships between dive and surface time and dive length and visibility of blow can be expected for other species.

Revised slightly since presentation at the thirty-third meeting of the International Whaling Commission.

Environmental conditions

Gray whales make short work of respiring and rapidly submerge out of sight on rough weather days but often linger at the surface during respiration on calm days (Leatherwood, unpublished observations). Sperm whales similarly submerge rather than 'raft' when weather is rough (Lockyer, 1977). Within the range of conditions acceptable for conduct of sightings surveys such effects of environmental conditions on surface time and, therefore, on visibility of whales may be significant.

Obtaining required data

The above, are, of course, only a few of the factors that may confound attempts to employ simple treatments of limited respiration data to characterize whales missed during sightings surveys. From the problems they present, we consider it imprudent to construct a correction factor on any species at this time. Much more information is required. It might be obtained in various ways.

Radiotelemetry is being used with increasing frequency in studies of free-ranging cetaceans (see Leatherwood and Evans, 1980 for review; Watkins, 1981 and Mate and Harvey, in press, for updates). As there are improvements in attachment longevity and effects on whales, transmitter placement, range and performance, and understanding of relationships of apparent behavior (indicated by received signals) and actual behavior of whales, radiotelemetry will, no doubt, become one of the most useful tools in studies of free-ranging whales. For the present, however, considerable problems persist in performance of instrumentation and interpretation of results. Of relevance to the questions of this study, for example, signals are not necessarily highly correlated with overall respiration patterns. Signals are often not received even when the tagged animal is blowing and are sometimes received when the whale is surfacing but not blowing (Watkins, 1981; Watkins and Moore, 1980 pers. comm.). Further, it is still often argued that the tagged whales may be significantly affected by the tags and may therefore not represent 'normal' behavior for the species. To be of maximum use in preparing a correction index, radiotelemetric data must be correlated with observed surfacing behavior. In particular, length of transmitted signal must be correlated with observed lengths of blows and surface cycles.

For the present, direct observation continues to yield data most directly relevant to a correction index. Most reports currently available consider only the blow characteristics and time at the surface of the whale itself. Using only that information will likely produce too high a correction factor and, therefore, excessive estimates of numbers since a whale's presence is not infrequently detected by sighting cues other than the blow or the body at the surface (Fig. 1).

We suggest that future sightings surveys routinely collect information on whale visibility along sample segments of the survey route. One method, which would consider contributions to sightability of all sighting cues indicated in Fig. 1, would be to select a whale (or group of whales), pursue it at a distance suitable to collect data without apparent disturbance to the animal(s), and for some predetermined time period score the presence or absence of each identified sighting cue at the start of each sample time segment (eg., 5, 10, 15 or 20 seconds). The process should be repeated for that species until samples are obtained for various group sizes, behaviors, times of day, seasons, and weather conditions for which sightings data are collected. Over long periods of observation, with suitable replication and with recognition of the behaviors that are present, patterns may be recognized and dive and surfacing times may be averaged for individual species. Without such information, however, it is unlikely that a meaningful correction factor can be calculated or estimates corrected accurately for whales missed because they were diving.

REFERENCES

Andrews, R. C. 1909. Observations on the habits of the finback and humpback whales of the Eastern North Pacific. *Bull. Amer. Mus. of Nat. Hist.* 26 (14): 213–16.

Andrews, R. C. 1914. Monographs of the Pacific Cetacea, I, The California Gray Whale (*Rhachianectes glaucus* Cope) its history, habits, external anatomy, osteology, and relationship. *Mem. of Amer. Mus. of Nat. Hist.* N.S. 1(5): 227–87.

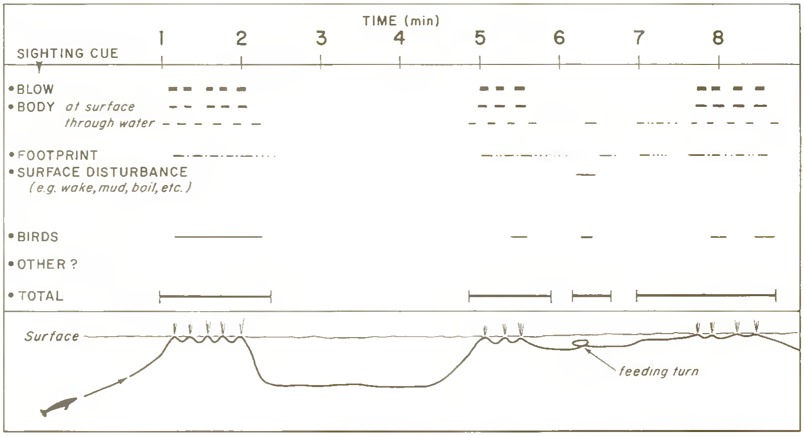

Fig. 1. Stylized surfacing pattern of gray whale, showing the relative contributions of potential sighting cues to the total visibility of the whale to a surface observer.

Benjaminsen, T., Berlund, J., Christensen, D., Christensen, I., Huse, I. and Sandnes, O. 1976. Merking, observasjoner og adferdsstudier av hval i Barentshavet og ved Svalbard i 1974 and 1975. (Marking, sightings and behavior studies of whales in the Barents Sea and at Svalbard in 1974 and 1975). *Fisken Hav.* 76 (2): 9–23.

Benjaminsen, T. and Christensen, I. 1979. The natural history of the bottlenosed whale, *Hyperoodon ampullatus*. pp. 143–64. *In:* H. E. Winn and B. L. Olla (eds) *Behavior of Marine Mammals. Vol. 3: Cetaceans.* Plenum Press, New York. 438 pp.

Bennett, F. D. 1840. *Narrative of a Whaling Voyage Around the Globe From Year 1833 to 1836.* (2 vols). Richard Bently Publ., London. 395 pp.

Berzin, A. A. 1972. *The Sperm Whale* (Kashalot) Israel Program for Scientific Translations, Jerusalem. 394 pp.

Best, P. B. 1970. Exploitation and recovery of right whales of the Cape Province. *Investl. Rep. Div. Sea Fish. S. Afr.* 80: 1–20.

Braham, H., Krogman, B., Leatherwood, S., Marquette, W., Rugh, D., Tillman, M., Johnson, J. and Carroll, G. 1979. Preliminary Report of the 1978 Spring Bowhead Whale Research Program Results. *Rep. int. Whal. Commn* 30: 291–303

Caldwell, D. K., Caldwell, M. C. and Rice D. W. 1966. Behavior of the sperm whale, *Physeter catodon* L. pp. 677–717. *In:* K. S. Norris (ed.) *Whales, Dolphins and Porpoises,* Univ. of California Press, Berkeley. 789 pp.

Carroll, G. M. and Smithhisler, J. R. 1980. Observations of bowhead whales during spring migration. *Mar. Fish. Rev.* 42(9–10): 80–5.

Christensen, I. 1980. Observations of large whales (minke not included) in the North Atlantic 1976–78, and markings of fin, sperm and humpback whales in 1978. *Rep. int. Whal. Commn* 30: 205–8.

Cummings, W. C., Fish, J. F. and Thompson, P. O. 1972. Sound production and other behavior of southern right whales, *Eubalena glacialis. Trans. San Diego Soc. Nat. Hist.* 17(1): 1–14.

di Sciara, G. N., Leatherwood, S. and Evans, W. E. 1981. Cetaceans off eastern Venezuela. Hubbs/Sea World Research Institute, San Diego, Ca., Tech. Rept. submitted to Boeing Marine Systems Seattle, Wa. 68 pp.

Davies, J. L. and Guiler, E. R. 1957. A note on the pygmy right whale, *Caperea marginata* Gray. *Proc. Zool. Soc. Lond.* 129: 578–89.

Davis, R. A. and Koski, W. R. 1980. Recent observations of the bowhead whale in the eastern Canadian High Arctic. *Rep. int. Whal. Commn* 30: 439–44.

Doi, T. 1974. Further development of whale sighting theory. pp. 359–68. *In:* W. E. Schevill (ed.) *The Whale Problem; a Status Report.* Harvard Univ. Press, Cambridge, Mass. 419 pp.

Doi, T., Kasamatsu, F., and Nakano, T. 1982. A simulation study on the sighting survey of minke whales in the Antarctic. Paper SC/Jn81/MiS29, published in this volume.

Erickson, A. W. 1978. Population studies of killer whales (*Orcinus orca*) in the Pacific Northwest: A radiomarking and tracking study of killer whales. Preliminary report to US Marine Mammal Commission. No. MMC 75–10. US Nat. Techn. Inf. Ser. PB285615. 65 pp.

Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpublished manuscript. Geogr. Dep., McGill Univ., Montreal, Quebec, Canada. 3 pp.

Gambell, R. 1968. Aerial Observations of Sperm Whale Behavior. *Norsk Hvalfangst tid.* 6: 126–38.

Gambell, R. and Lockyer, C. 1973. Observations on the birth of a sperm whale calf. *S. Afr. J. Sci.* 69: 147–8.

Gaskin, D. E. 1964. Recent observations in New Zealand waters on some aspects of behavior of the sperm whale (*Physeter macrocephalus*). (Tuatara) *J. Biol. Soc.* Victoria Univ. 12(2): 106–14.

Gilmore, R. M. 1961. *The Story of the Gray Whale.* 2nd ed. (Privately published). 16 pp.

Heezen, B. C. 1957. Whales entangled in deep-sea cables. *Deep-Sea Res.* 4: 105.

Herman, L. M. 1977. Humpback whales in the Hawaiian breeding waters, II: Behaviors. 40 pp. *In:* K. Norris and R. Reeves (eds) Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. Final report to U.S. Marine Mammal Commission on contract MM7AC018. US Nat. Tech. Inf. Ser. PB280794. 90 pp.

Ivashin, M. V., Shevchenko, V. I. and Yukov, V. L. 1972. Karlikovyi gladkii kit *Capera marginata* (Cetacea). *Zool. Zh.* 51(11): 1715–23.

Joyce, G. 1982. Preliminary results on the examination of blow patterns as sighting cues for minke whales in the Antarctic. Paper SC/Jn81/MiS6, published in this volume.

Jurasz, C. M. and Jurasz, J. 1981 (Unpublished manuscript). Humpback whales in southeastern Alaska. Draft report to the US National Parks Service. Washington D.C. (complete report not seen).

Kimura, S. and Nemoto, T. 1956. Note on a minke whale kept alive in aquarium. *Sci. Rep. Whales Res. Inst.,* Tokyo 11: 181–9.

Koski, W. R. and Davis, R. A. 1980. Studies of the late summer distribution and fall migration of marine mammals in NW Baffin Bay and E Lancaster Sound, 1979. Unpubl. Rep. by LGL, Ltd., Toronto for Petro-Canada Explorations, Calgary. 214 pp.

Krogman, B., Sonntag, R. M., Rugh, D. J., Grotefendt, R. A. and Priebe, G. W. 1981. Population estimation of the Western Arctic stock of the bowhead whale. Paper SC/33/PS4, presented to the IWC Scientific Committee, June 1981.

Kukenthal, W. 1888. Berichtiiber eine Reise en das Eismeer und nach Spetzbergen in Jahre 1886, *Geograph. Blatter.* 11(1): 1–43.

Laurie, A. 1933. Some aspects of respiration in blue and fin whales. *Discovery Rep.* 7: 363–406.

Leatherwood, S. and Evans, W. E. 1980. Some recent uses and potentials of radiotelemetry in field studies of cetaceans. pp. 1–31 *In:* H. E. Winn and B. L. Olla (eds) *Behavior of Marine Mammals, Vol. 3. Cetaceans.* Plenum Press, New York, London, 438 pp.

Leatherwood, S., Thomas, J. A. and Awbrey, F. T. 1981. Minke whales off northwestern Ross Island. *Ant. J. U.S.* 16(5): 164–5.

Lockyer, C. 1976. Growth and energy budgets of large baleen whales from the southern hemisphere. ACMRR/MM/SC/38. FAO Scientific Consultation on Marine Mammals, Bergen, Norway. 31 Aug—9 Sept., 1976. 33 pp.

Lockyer, C. 1977. Observations on diving behavior of the sperm whale, *Physeter catodon.* pp. 591–609. *In:* M. Angel (ed.) *A Voyage of Discovery* George Deacon 70th anniversary volume. Pergamon Press Ltd., Oxford. 694 pp.

Mate, B. and Harvey, J. 1981. Unpublished manuscript. Respiration and diving behavior of California gray whales. 38 pp.

Munsterhjelm, L. 1915. Anteckningar on Hyperoodon rostratcis (Mull.) gjorda under en eshavaresa sommaren 1910, *Tromso Mus. Arsh.* 37: 1–13.

Norris, K. S., Goodman, R. M., Villa-Ramirez, B. and Hobbs, L. 1977. Behavior of the California gray whale, *Eschrichtius robustus,* in Baja California, Mexico. *Fish. Bull.* (US) 75(1): 159–72.

Ohsumi, S. 1980. Population Study of the Brydes whale in the Southern Hemisphere under scientific permit in the three seasons, 1976/77–1978/79. *Rep. int. Whal. Commn* 30: 319–31.

Ohsumi, S. 1981. Estimation of the population size of the minke whale in Antarctic Area VI by means of whale sightings. *Rep. int. Whal. Commn* 31: 323–6.

Payne, R. 1972. Swimming with Patagonia's right whales. *Nat. Geog.* 142(4): 576–87.

Payne, R. 1978. Behavior and vocalizations of humpback whales (*Megaptera* sp.). pp. 56–63. *In:* K. S. Norris and R. R. Reeves (eds) Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. Final Report to US Marine Mammal Commission. US Nat. Tech. Inf. Ser. PB280794. 90 pp.

Rice, D. W. 1968. Right whales in the southeastern North Pacific. *Norsk Hvalfangsttid.* 579(5): 1–16.

Rice, D. W. and Wolman, A. A. 1971. *The Life History and Ecology of the Gray Whale (Eschrichtius robustus).* Special Publ. No. 3, Amer. Soc. of Mammal., Stillwater, Okla. 142 pp.

Rice, D. W. 1979. Brydes whales in the equatorial eastern Pacific. *Rep. int. Whal. Commn* 30: 321–4.

Richardson, W. J. (ed). 1981. Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1980. Report to the US Bureau of Land Management by LGL Ecological consultants, Inc. 273 pp.

Ross, G. J. B., Best, P. B. and Donnelly, B. G. 1975. New records of the pygmy right whale (*Capera marginata*) from South Africa, with comments on distribution, migration, appearance and behavior. *J. Fish. Res. Bd Can.* 32(7): 1,005–17.

Rugh, D. J. and Braham, H. W. 1979. California gray whale (*Eschrichtius robustus*) fall migration through Unimak Pass, Alaska. 1977: A preliminary report. *Rep. int. Whal. Commn* 30: 315–20.

Rugh, D. J. and Cubbage, J. C. 1980. Migration of bowhead whales past Cape Lisburne, Alaska. *Mar. Fish. Rev.* (Special Issue) 42(9–10): 45–51.

Scammon, C. M. 1874. *The Marine Mammals of the Northwestern Coast of North America Together with an Account of the American Whale Fishery.* J. H. Carmany, San Francisco, 319 pp. (Reprinted 1968 in paperback, NY, Dover).

Scoresby, W., Jr. 1820. *An Account of the Arctic Regions with a history and description of the northern whale-fishery: Vol. I. The Arctic.* 551 pp. Vol. 2. *The Whale-Fishery.* 574 pp. Newton Abbot, Eng. David and Charles Reprints.

Scheffer, V. B. and Slipp, J. W. 1948. The whales and dolphins of Washington state with a key to the cetaceans of the west coast of North America. *Am. Midland. Nat.* 39: 257–337.

Scholander, P. F. 1940. Experimental investigations on the respiratory function in diving mammals and birds. *Hvalrad. Skr.* 22: 131.

Singarajah, K. V. 1981. Observations on the occurrence and behavior of minke whales off the coast of Brazil. Paper SC/Jn81/MiS1. presented to the IWC Scientific Committee, June 1981.

Slijper, E. J. 1958. *Whales.* Basic Books, Inc. New York. 511 pp.

Sumich, J. L. 1981. Swimming speeds and breathing rates of migrating gray whales, *Eschrichtius robustus.* Unpublished manuscript. 16 pp.

Tomilin, A. G. 1967. *Mammals of the USSR and Adjacent countries. Vol. IX. Cetacea.* Moscow. (Transl. from Russian by Israel Program for Sci. transl., Jerusalem, No. 1124).

Walker, L. W. 1949. Nursery of the grey whales. *Nat. Hist.* 58(6): 246–56.

Winn, W. E., Perkins, P. J. and Winn, L. 1970. Sounds and behaviour of the northern bottle-nosed whale. pp. 53–9. *In: Proceedings of the 7th Annual Conference of Biological Sonar and Diving Mammals.* Palo Alto, Ca. Stanford Univ.

Wyrick, R. F. 1954. Observations on the movements of Pacific gray whale, *Eschrichtius glaucus* (Cope). *J. Mammal.* 35: (4) 596–8.

Yablokov, A. V., Bel'kovich, V. M. and Borisov, V. I. 1974. *Whales and dolphins. Part I.* JPRS-62150–1, Washington, DC (Translation of Russian-language book *Kity y Del'finy.* 1972. Signal Press 15 Dec. 1971. Nauka, Moscow. 472 pp.)

Zenkovich, B. A. 1936 (a). *Nablyudeniya nad kitami del' nevostochnykh more i* (Observations on the Whales of the Far Eastern Seas). Trudy Dal' nevostochnogo filiala Akademii Nauk SSSR, Vol. I.

Zenkovich, B. A. 1936(b). Vokrig svetazakitami-Izdatel'stvo. *Molodaya Guardiya,* pp. 63–161.

Zimushko, V. V. and Ivashin, M. V. 1980. Some results of Soviet investigations and whaling of gray whales. *Rep. int. Whal. Commn* 30: 237–46.

Appendix I

SUMMARY OF DATA AVAILABLE TO AUTHORS ON RESPIRATION PATTERNS AND DIVING BEHAVIOR OF GREAT WHALES, KILLER WHALES AND BOTTLENOSE WHALES

(Unless otherwise noted, n= number of dives represented by data presented.)

Source	Region	Diving behavior	Remarks
Bowhead whale			
Scoresby (1820)	N. Atlantic	Durations of dives = 30, 40 and 60 min.	Harpooned whales.
Scammon (1874)	N. Pacific	Maximum duration of dive = 80 min.	Harpooned whale.
Foote (1964)	Pt. Hope, Alaska	Maximum duration of dive = 1.25 hrs.	Injured whale.
Tomilin (1967)	Unspecified	Duration of dive = 5–10 or 15–20 min.	
		Surface time = 1–3 min.	
		Migrating whales breathe at regular intervals.	
Payne (1972)	Patagonia, Argentina	Resting whales maintain a vertical position, surfacing every 20 min to breath.	
		Blow interval = 2–3 min during normal activity.	
Yablokov *et al.* (1974)	Unspecified	Duration of dives: usual = 8–20 min; maximum = 80 min.	
Braham *et al.* (1979)	Cape Lisburne, Alaska	Surface time: n (surface intervals) = 15; total = 105 min for 180 surfacings; $\bar{x}$ = 8 sec (for 101 blows) and $\bar{x}$ = 5 sec (for 36 breaches).	
		Duration of dives: (within a surface interval). n = 144; $\bar{x}$ = 18.4 sec; median = 11 sec; range (between blows) = 1 min 39 sec to over 28 min, with no regularity.	
Davis (1979)	Lancaster Sound and NW Baffin Bay, Canada	Duration of dive: n = 16; $\bar{x}$ = 9.6 min; range = 2–20 min.	Observations from Cape Adair, Canada.
		Surface time (at or near surface): $\bar{x}$ = 1.2 min; range = 2–6 min. During this time whale sank below surface 2–7 times. ($\bar{x}$ = 3.8 times) for periods of 3–32 sec. ($\bar{x}$ = 6.6 sec.).	
Carroll and Smithhisler (1980)	Pt. Hope and Pt. Barrow, Alaska	Duration of dive = Sounding — n = 63; $\bar{x}$ = 15.6 ± 5.0 (SD) min; range = 3.0–26.7 min. Times for cows and calves shorter: n = 3; $\bar{x}$ = 6.6 min; range = 5.9–7 min.	US NMFS data, 1975–8.
		Surface time: time at or near surface for 8 whales, n = 31 timed periods; $\bar{x}$ = 4.7 ± 2.0 (SD) sec. Total time visible per dive sequence was 30.9 sec.	US NMFS data, 1978 only.
		Whale visible above surface 3.1% of time. Whales above or near surface between sounding dives 8.4% of time. Whales below surface and not visible from ice level 96.9% and from aircraft 91.6% of the time.	US NMFS data, 1975–8.
		Respiration pattern: Whales surfaced 2–14 times in a dive sequence.	US NMFS data, 1975–7.
		For n = 63 observations, $\bar{x}$ = 6.57 ± 3.08 (SD) surfacings per dive sequence, whales ventilated 7–9 times per dive sequence.	1978 data.
		For n = 41 dive sequences, $\bar{x}$ = 6.53 ± 2.84 (SD) blows per rise.	US NMFS data, 1978.
Davis and Koski (1980)	Eastern Arctic of Canada	Duration of dives: n = 16; $\bar{x}$ = 9.6 min; range = 2–20 min.	1978 fall migration.
		Surface time: n = 16; $\bar{x}$ = 1.2 min; range = 0.2–6.0 min. Whales at or near surface 1% of the time.	
Koski and Davis (1980)	Baffin Island	Duration of dive: n = 88; $\bar{x}$ = 8.65 ± 2.73 min; range = 1.03 – 27.50 min.	
	Eastern Arctic of Canada	Surface time: n = 93; $\bar{x}$ = 1.69 ± 1.01 (SD) min; range = 0.02 – 6.25 min.	
		Blow interval: n = 399; $\bar{x}$ = 16.11 ± 2.29 (SD) sec; range = 4–68 sec.	

Appendix I (*continued*)

Source	Region	Diving behavior	Remarks
Rugh and Cubbage (1980)	Cape Lisburne, Alaska	Duration of dive: Series dives — n = 145; $\bar{x}$ = 17.9 ± 2.3 (SD) sec; range = 1.3 – 67.8 sec. Underwater time (no breaching); range = 2.3 – 53.5 sec; $\bar{x}$ = 11.6 ± 2.4 sec. Sounding dives = 395, 437 and 529 sec. Surface time: (breaching): n = 36; $\bar{x}$ = 9.1 – 0.6 (SD) sec; range = 1.9 – 10.3 sec. (Non breaching): n = 112; $\bar{x}$ = 6.1 ± 0.55 (SD) sec; range = 1.6 – 16.5 sec.	
Krogman *et al.* (1981)	Pt. Barrow, Alaska	Duration of dive (Maximum): n = 47; $\bar{x}$ = 24.11 ± 16.31 (SD) min. Duration of dive: n = 36; $\bar{x}$ = 3.0 ± 2.8 (SD) min; range = 0.03 – 9.0 min.	
Richardson (ed.) (1981)	Mackenzie Delta Northwest Territories, Canada	Surface time: n = 158; $\bar{x}$ = 1.09 ± 0.62 (SD) min. For longer dives, mean surface time was >2 times the surface time after short dives (t = 3.82; df = 22; $p > 0.001$). Surface times and number of blows peak at midday due to concurring rises in social behavior. Overall whales spent 25% of their time at the surface during period of observation, summer 1980. Respiration pattern: respirations per surfacing and surface times more closely related to duration of dive and time of day, than are the blow intervals. Blow interval: Calves, females, and skim-feeding animals exhibit longest blow interval times.	
Right whale			
Scoresby (1820)	North Atlantic	Surface time: 2 min usually but sometimes up to 5–15 min.	'sleeping whales'
Scammon (1874)	North Pacific	Duration of dive: 12–15 min; up to 80 min if wounded. Respiration pattern: Often very unstable, 1 breath every 1 to 10–15 min.	
Tomilin (1967)	Greenland	Duration of dive: 5–10 min or up to 20 min in food rich area. Surface time: 1–3 min. Respiration pattern: not regular; 1–15 breaths per surfacing, usually 4–9 breaths per surfacing.	
Rice (1968)	Punta Abreojos, Baja Calif. Mexico	Duration of dive: 4–5 min. Number of blows per surfacing = 3–5.	Recorded from 2 slow moving whales.
Best (1970)	Clifton Bay Cape Peninsula, South Africa	Duration of dive: n = 19; $\bar{x}$ = 55 sec. Blow intervals: 15 sec – 2.05 min.	Whales largely inactive.
Cummings (1972)	Bahia Lanca, Argentina	Duration of dive: range = 0.5 – 4.3 min; max = 8.0 min. Blow interval: 1 blow 10–20 sec in presence of other whales; 1 blow per min (swimming slowly at surface); 1 blow per 2–3 min (more active).	In deep water.
Payne (1972)	Patagonia, Argentina	Blow interval: usually 1 per 2–3 min. 'Sleeping' whales maintain vertical position surfacing every 20 min to breathe.	
Doi (1974)	Antarctica	Duration of dive: n = 65; $\bar{x}$ = 3.7 min.	Data from 1969/70 season sightings.
Yablokov *et al.* (1974)	Unspecified	Duration of dive: usual = 5–13 min; max = 50 min.	

Appendix I (*continued*)

Source	Region	Diving behavior	Remarks
Watkins (1980)	Northeastern United States	Dive times related to total behavior pattern Duration of dive: 3–4 min (when feeding near surface); 10–20 min (other activity); 1–7 min (spring and early summer feeding dives). Respiration pattern: 5–20 blows per surfacing, depending on exertion.	
Pygmy right whale			
Davies and Guiler (1957)	Ralph Bay, Tasmania, Australia	Suggests species spends 'long' periods underwater.	
Ivashin *et al.* (1972)	Southwestern Australia	Duration of dive: 3–4 min. Surface time $\geq$ 4–5 sec.	Blows small and inconspicuous.
Ross *et al.* (1975)	South Africa	Respiration pattern: regular — For n = 5, $\bar{x}$ = 1 blow every 49 sec, range = 40–55 sec. For n = 5, $\bar{x}$ = 1 blow every 60 sec.	Blows small 'hardly distinguishable'. Surfacing habits make species inconspicuous at sea.
Gray whale			
Andrews (1914)	Unspecified	Duration of dive: Individuals cruising along shore submerged for 10 min; groups submerged up to 15–20 min; one large female submerged for 4–5 min with regular blow intervals. Respiration pattern: number of respirations between dives fairly regular.	
Zenkovich (1936)	Unspecified	Duration of dive: 6–8 min.	
Walker (1949)	Unspecified	Duration of blows = 3–4 per surfacing.	
Wyrick (1954)	California	Duration of dive: $\bar{x}$ = 1.51 min. Surface time: = $\bar{x}$ = 4.9% of total time; range = 2.2% – 8.9% of total time.	
Wyrick (1954)	California	Respiration pattern: 3 quick blows followed by a long dive occupied 7–8 min. when cruising. For females on straight course same behavior occupied 4–5 min.	
Gilmore (1961)	California	Duration of dive: usually 3–7 min; max = 12.7 min; shallow dives = usually 3–4 min; deep dives = usually 7–8 min. Surface time: 15% of total time spent at or near surface. Respiration pattern: approximately 1 breath for each min. diving; breath takes 2–3 sec.	
Tomilin (1967)	Unspecified	Duration of dive: 1–3 min to 5.6 min when chased; 3–5 min when feeding; sometimes only 0.5 min. Blow intervals variable: n = 3, time = 3, 10 and 15 sec; range = 10–20 sec.	
Rice and Wolman (1971)	California	Duration of dive: 3–5 min (shallow dives during migration). Number of blows per surfacing: 3–5.	
Yablokov *et al.* (1974)	Chukotskii Peninsula Siberia, USSR	Duration of dive: usual = 0.5–6 min.; max = 20 min. Groups submerged for 2–3 min.	
Norris *et al.* (1977)	Baja Calif. Mexico	Surface time: for female and calf in nursing sequence, $\bar{x}$ = 16 sec per min; for travelling young, $\bar{x}$ = 3 sec per min. Mother and calf surface much more frequently than other whales. Respiration pattern: female = 0.97 breaths per min; calf = 1.5 breath per min.	From radiotelemetry of calf.

Appendix I (*continued*)

Source	Region	Diving behavior	Remarks
Rugh and Braham (1978)	Unimak Pass, Cape Sarichef, Alaska	Surface time: $\bar{x} = 4.98$ sec. Number of blows per surfacing: $\bar{x} = 3.93$. Median number of blows per surfacing increases with size of pod.	
Rugh and Braham (1979)	Unimak Pass, Cape Sarichef, Alaska	Surface time: $n = 292$; $\bar{x} = 5.0 \pm 0.1$ sec; range = 1.4–2.9 sec. Respiration pattern: $n = 247$; mean number of blows per whale per surface interval = 3.9 ± 0.3.	
Swartz and Jones (1979–1980)	San Ignacio Lagoon, Baja California, Mexico	Respiration pattern: females = 0.89 breaths per min; calves = 1.21 breaths per min.	
Mate and Harvey (1980, unpublished MS)	San Ignacio Lagoon, Baja California, Mexico	Duration of dive: Females: $\bar{x} = 1.15$–3.44 (SE) min; 35% of dives = 16–30 sec; 93% of dives = <3.0 min; max = 8.07 min. Calves: $\bar{x} = 0.57 \pm 1.38$ (SE) min; 38% of dives = 0–15 sec; 99% of dives = <3.0 min; max = 4.08 min. Surface times: Females $n = 577$; $\bar{x} = 3.6$ sec or 4% of the time; range = 0.6–1.88 min. Calves: unrecorded.	
Mate and Harvey 1980, unpublished MS)	San Ignacio Lagoon, Baja California, Mexico	Respiration pattern: Females: $\bar{x} = 0.83$ breaths/min or 1 breath every 1.20 min. Calves: $\bar{x} = 1.67$ breaths/min or 1 breath every 36 sec. Respiration classified as clumped = 2–9 surfacings spaced <1 min apart followed by long dive from 1–20 min; regular = surfacings approximately evenly spaced; irregular = inconsistent patterns. Female: clumped occurred 71% of the time; regular occurred 15%; irregular occurred 9%, logging or resting at surface occurred 4%. Calves: same as female but no logging. Longer respiration patterns associated with milling animals.	Respiration patterns and duration of dives for females and calves at San Ignacio Lagoon appear somewhat shorter and more regular than migrating whales due perhaps to their limited activity.
Zimushko and Ivashin (1980)	Bering Sea, Chukotka, Siberia USSR	Duration dive: When feeding = <15 min; when lactating = 1 min 25 sec — 5 min 19 sec; $\bar{x} = 2.7$ min. When chased = 1+ min –4 min 58 sec; $\bar{x} = 2.28$ min.	
Sumich (1980 unpublished MS)	Point Loma, California	Surface time: near surface for 1 min and occasionally up to 2 min.	
Sumich (1981 unpublished MS)	Point Loma, California	Respiration pattern: $n = 15$; $\bar{x}$ 0.08 breaths per min. Correlation between breathing rate and swimming velocity.	
Blue whale Bennett (1940)	Unspecified	Length of respiration: exhalation and inhalation together occupy approximately 2 sec.	
Laurie (1933)	Unspecified	Duration of dive: generally = 10 min but if chased or harpooned will submerge up to 0.5 hrs. Respiration pattern: normally only one breath per surfacing but after long dive may breath twice, with interval of 1 min per surfacing.	
Zenkovich (1936)	'Far Eastern Seas'	Duration of dive: 10–35 min. Blow intervals: 10–20 sec. Number of blows per surfacing: 10–12.	
Tomlin (1967)	Off Kamchatka Peninsula, USSR	Duration of dive: Long dive of 40–50 min; preceded by shallow dives. Surface time: 6–7 sec.	
	N. Atlantic	Duration of dive: 10–18 min.	Recorded by Millais.
Doi (1974)	Antarctic	Duration of dive: $n = 172$; $x = 5.67$ min.	From 1969/70 Antarctic season sightings.
		Surface time: Breathing time at surface = 5.08 sec. Real rate of sightings (P) = 0.141.	From special sighting data 1969/70.
Yablokov *et al.* (1974)	Unspecified	Duration of dive: Usual = 2–5 min; max = 50 min.	

Appendix I (*continued*)

<table>
<tr><th>Source</th><th>Region</th><th>Diving behavior</th><th>Remarks</th></tr>
<tr><td>Lockyer (1976)</td><td>Unspecified</td><td>
<table>
<tr><th>Body Length (ft.)</th><th>Dive duration (min)</th><th>Av. no. and duration of blows after dive</th><th>Av. no. of blows per min. when not diving</th></tr>
<tr><td>58</td><td>—</td><td>—</td><td>2–3; 3–4</td></tr>
<tr><td>60</td><td>4–4.5</td><td>5–10 in 2 min</td><td>—</td></tr>
<tr><td>60</td><td>2–3</td><td>—</td><td>1–3</td></tr>
<tr><td>70</td><td>3–9</td><td>—</td><td>0.7–2.0 (resting)
3–6 (chased)</td></tr>
<tr><td>75</td><td>3–7</td><td>7–11 in 12.5 min</td><td>3.5–6</td></tr>
</table>
</td><td></td></tr>
<tr><td>Fin whale
Andrews (1909)</td><td>Pacific Coast, USA</td><td>Duration of dive: Groups of 3 whales submerged for 4–23 min; solitary individuals submerged for 5–6, 5.5–8, 7–8 and 3–10 min.
Respiration pattern: Inspiration = 2–4 sec.
Blow interval: 15 sec.
Number of blows per surfacing: 4 (before sounding).</td><td></td></tr>
<tr><td>Laurie (1933)</td><td>South Georgia</td><td>Duration of dive: calculations from lung capacity (72ccm) indicate a 22 m whale could submerge for 39 min.</td><td></td></tr>
<tr><td>Slijper (1958)</td><td>Unspecified</td><td>Depth of dive: 84–230 m.</td><td></td></tr>
<tr><td>Tomilin (1967)</td><td>Kamchatka Seas and Chukotskii Peninsula, USSR</td><td>Pattern of diving: after first surfacing 4–7 brief shallow dives.
Blow interval: 10–20 sec (relaxed animal).
Number of blows per surfacing: 5–8 (relaxed animal).</td><td></td></tr>
<tr><td>Doi (1974)</td><td>Antarctic</td><td>Duration of dive: n = 1,066; x̄ = 4.87 min.
Surface time: Breathing time at surface = 4.57 sec. Real rate of sighting (P) = 0.24.</td><td>Data from 1969/79 season sightings.
From special sightings data.</td></tr>
<tr><td>Yablokov <i>et al.</i> (1974)</td><td>Unspecified</td><td>Duration of dive: Usual = 2–5 min; max = 30 min.</td><td></td></tr>
<tr><td>Lockyer (1976)</td><td>Unspecified</td><td>
<table>
<tr><th>Body length (ft)</th><th>Dive duration (min)</th><th>Av. no. and duration of blows after dive</th><th>Av. no. and blows per min. when not diving</th></tr>
<tr><td>47</td><td>3–4</td><td>—</td><td>1–2</td></tr>
<tr><td>65</td><td>4–6
before chase</td><td>—</td><td>6–8</td></tr>
<tr><td>75</td><td>6–9</td><td>3–5 in 1 min</td><td>—</td></tr>
</table>
</td><td></td></tr>
<tr><td>Christensen (1980)</td><td>North Atlantic</td><td>Duration of dive: 2–8 min.
Surface time: 4–6 sec.</td><td></td></tr>
<tr><td>Watkins (pers. comm., Dec. 1980)</td><td>Unspecified</td><td>Pattern of diving. During summer (1) short, 1–6 min during foraging (2) may suddenly shift to 7–15 min dives.</td><td></td></tr>
<tr><td>Sei whale
Andrews (1916)</td><td>Japan</td><td>Duration of dive: One whale observed to submerge 40.25 sec and 125 sec. Another whale submerged for 4 min surfaced with 2 spouts and submerged again for 2.5 min. The whale surfaced again with 2 spouts at 4 sec intervals. The following short dives occupied 14, 18, 20 and 20 sec. The whale then blew 3 times at 10 sec intervals then sounded for 2 min.
Blow intervals: Intervals mentioned above = 4 and 10 sec; usual range = 4–22 sec.
Number of blows after long dive: 2–3.</td><td></td></tr>
</table>

Appendix I (*continued*)

<table>
<tr><th>Source</th><th>Region</th><th>Diving behavior</th><th>Remarks</th></tr>
<tr><td>Zenkovich (1936)</td><td>'Far East'</td><td>Duration of dive: 10–12 min.</td><td></td></tr>
<tr><td></td><td></td><td>Blow intervals: 18–22 sec.</td><td></td></tr>
<tr><td>Doi (1974)</td><td>Antarctic</td><td>Duration of dive: n = 2,252; x̄ = 4.21 min.</td><td>Data obtained from 1969/70 season sightings.</td></tr>
<tr><td></td><td></td><td>Surface time: Breathing time at surface = 3.66 sec. Real rate of sighting (P) = 0.197.</td><td></td></tr>
<tr><td>Yablokov et al. (1974)</td><td>Unspecified</td><td>Duration of dive: Usual = 0.5–5.0 min. Max = 12 min.</td><td></td></tr>
<tr><td>Lockyer (1976)</td><td>Unspecified</td><td>
<table>
<tr><th>Body length (ft)</th><th>Average no. of blows per minute when not diving</th></tr>
<tr><td>48</td><td>0.7 before chasing</td></tr>
<tr><td></td><td>1.3 after chasing</td></tr>
<tr><td>43</td><td>1.4 before chasing</td></tr>
<tr><td></td><td>2.0 after chasing</td></tr>
<tr><td>47</td><td>0.8 before chasing</td></tr>
<tr><td></td><td>1.0 after chasing</td></tr>
</table>
</td><td></td></tr>
<tr><td>Bryde's whale</td><td></td><td></td><td></td></tr>
<tr><td>Lockyer (1976)</td><td>Unspecified</td><td>Respiration pattern: Average number of blows per min when not diving = 0.5–1.0 (39 ft whale zig-zagging after fish).</td><td></td></tr>
<tr><td>Rice (1979)</td><td>Coast of Mexico</td><td>Duration of dive: x̄ = 5 min, range = 1–11 min.</td><td></td></tr>
<tr><td></td><td></td><td>Blow interval: x̄ = 15 sec; range = 12–18 sec.</td><td></td></tr>
<tr><td></td><td></td><td>Number of blows per surfacing x̄ = 5.</td><td>Diving and blowing rhythm</td></tr>
<tr><td>di Sciara et al. (1981)</td><td>Eastern Caribbean off Venezuela</td><td>Surface time: Time between dives: for n = 90, x̄ = 618.7 sec. For n = 93, x̄ = 647.5 sec.</td><td></td></tr>
<tr><td></td><td></td><td>Blow interval: For n = 90, x̄ = 58.3 sec. For n = 28, x̄ = 102.6 sec.</td><td>Cow and calf feeding; only cow timed.</td></tr>
<tr><td>Ohsumi (1980)</td><td>Southern Indian & Pacific Oceans</td><td>Duration of dive: x̄ = 40 min.</td><td></td></tr>
<tr><td></td><td></td><td>Surface time: Breathing time at surface x̄ = 3.7 sec.
Blow/dive sequence: For n = 90, x̄ = 9.5 blows.</td><td></td></tr>
<tr><td>Minke whale</td><td></td><td></td><td></td></tr>
<tr><td>Kimura and Nemoto (1956)</td><td>Japan</td><td>Surface times: longer after longer dives.</td><td>Whale captive 37 days.</td></tr>
<tr><td></td><td></td><td>Blow interval: x̄ = 2–3 min.</td><td></td></tr>
<tr><td></td><td></td><td>Blow intervals: variable.</td><td></td></tr>
<tr><td></td><td></td><td>Inter-respiratory intervals: ranging from 10 sec–6.0 min. Respiration rate: decreases throughout afternoon, then increases to peak at 0100 hrs.</td><td>Significance not reported.</td></tr>
<tr><td>Tomilin (1967)</td><td>Bering Strait, Siberia, USSR</td><td>Duration of dive: 3–5 min.</td><td>Duration of respiratory pause varies according to food, position to shore, dive depth and state of animal.</td></tr>
<tr><td></td><td></td><td>Surface time: 2–2.5 sec.</td><td></td></tr>
<tr><td></td><td></td><td>Blow interval: 0.7–1.0 sec.</td><td></td></tr>
<tr><td>Doi (1974)</td><td>Antarctic</td><td>Duration of dive: n = 99; x̄ = 1.30 min.</td><td>Data from 1969/70 sightings.</td></tr>
<tr><td></td><td></td><td>Surface time: Breathing time at surface = 3.23 sec. Real rate of sighting (P) = 0.112.</td><td></td></tr>
<tr><td>Yablokov et al. (1974)</td><td>Unspecified</td><td>Duration of dive: Usual = 0.5–3 min, max = 6 min.</td><td></td></tr>
</table>

Appendix I (*continued*)

Source	Region	Diving behavior	Remarks
Benjaminsen *et al.* (1976)	Barents Sea and Svalbard	Whales followed (but not chased) by ships are exposed to air for only 3–4 sec and dive between 12 sec and 10 min.	Suggested by cruise observations.
Lockyer (1976)	Unspecified	Body length (ft) — Average number of blows per minimum net diving 28 — 0.5 12 — 1.0	
Doi *et al.* (1982)	Antarctic	Duration of dive: $\bar{x}$ Dive times less for whales in pods than for individuals. For n = 45, $\bar{x}$ = 1 min 56 sec (solitary whales timed), n = 142, $\bar{x}$ = 1 min 26 sec (2–3 whales in pod timed), n = 420, $\bar{x}$ = 1 min 31 sec (4 and more whales in pod timed). Average overall dive cycle (including blowing time) equals 2 min. Without blow time, net dive time = 117.7 sec. Blow time: For solitary whales, $\bar{x}$ = 1.95 sec. For > 2 whales $\bar{x}$ = 2.7 sec. Overall, $\bar{x}$ = 2.3 sec.	
Joyce (1982)	Antarctic	Blow interval: For n = 22, $\bar{x}$ = 1.50 ± 1.56 (SD) min, max = 6.15 min; For n = 18, $\bar{x}$ = 0.82 ± 1.30 (SD) min, max = 7.73 min; For n = 17, $\bar{x}$ = 0.16 ± 0.25 (SD) min, max = 1.67 min; For n = 6, $\bar{x}$ = 0.14 ± 0.28 (SD) min, max = 1.67 min. Number of blows greatest in the morning. Dive profile affected by pod size.	
Leatherwood *et al.* (1982)	McMurdo Sound, Antarctica	Duration of dive: for n = 30, $\bar{x}$ = 9.7–10.8; max = 14 min. For n = 8, $\bar{x}$ = 7.2–8.9 min. Surface time: For dives of 9.7–10.8 min, $\bar{x}$ surface time = 1.3–3.5 min with 2–15 blows.	
Ohsumi (1981)	Antarctic	Minke whale is smaller in size and has smaller blow and surface time than the fin whale — 3.23 sec compared to 4.57 sec.	
Singarajah (1982)	Unspecified	Minke whales remain near surface on moderately windy days.	
Slijper (1958)	Alaska	Dive depth: 110 m.	
Tomilin (1967)	Olytorskii Bay, Chukchi Sea, Bering Strait	Duration of dive: Usually = 2.6 min; longer dives = 6–7 min.	
Humpback whale			
Doi (1974)	Unspecified	Duration of dive: n = 20; $\bar{x}$ = 8.13 min.	Data from 69/70 sighting expedition.
Yablokov *et al.* (1974)	Unspecified	Duration of dive: Usual = 1.7 min; max = 30 min.	
Lockyer (1976)	Antarctic	Duration of dive: 2 3 min. Overall duration and number of blows after dive = 4–6. Blow interval = 1–1.5 min. Average number of blows/min when not diving = 1.7.	
Herman (1977)	Hawaii	Duration of dive: shallow and intermediate dives > 15 min; sounding duration = 4–6 min.	For shallow dives whale may surface inconspicuously and respire, then sink slowly.
Payne (1978)	Hawaii	Duration of dive: Average = 5 min with 5–6 blows. Rarely submerged > 15 min. Great variability in number of blows and rate.	
Jurasz and Jurasz (1981, unpublished MS)	Glacier Bay, Southeast Alaska	Duration of dive: Downtimes 3< $\bar{x}$ <5 min occurred 3.4% of time (n = 68 down times, no vessel close). Downtimes <5 min. Occurred 0.4% of time (no vessel close). Respiration pattern: Range = 1 breath per 31.4–82.8 sec.	

Appendix I (*continued*)

Source	Region	Diving behavior	Remarks
	Bartlett Cove	Downtime: $\bar{x}$ sec(s^2) 1979: stimulus present: 68.4 ± 8 1976–8: stimulus present: 86.3 ± 10 1976–8: stimulus not present: 62.9 ± 10	
		65% of downtimes occurred when vessel present (stimulus), 35% when no vessel.	Significance; vessel/no vessel difference significant at 99% confidence level.
		Dives erratic and variable from approximately 25 min to 2.75 min. Length of respiratory sequence significantly affected by whale behavior.	
Sperm whale			
Caldwell *et al.* (1966)	Unspecified	Duration of dive: Female submerged for approx. 20 min. Surface time: Female at surface for approx. 4 min. Respiration pattern: pattern of diving and respiration for bulls extremely constant with 1 respiration for approx. each min. diving. Each respiration interval approx. 11 sec. Females are constant. Limits of duration and depth of dive determined largely by size of whale.	
Tomilin (1967)	Kronotskii Bay	Duration of dive: Solitary whales submerged for 90–100 min.	Data apply only for large individuals.
		Blow intervals = 10–15 sec.	
	Unspecified	Duration of dive: 50–70 min with 35–40 and 45 spoutings.	
		Duration of dive: Sounding is followed by a number of intermediate shallow dives just under surface, with duration up to 15 min.	
		Respiration pattern: Whales breathed 20–70 times in 10–15 min. Reported long respiratory pauses of 15–60 min.	
		Blow intervals: 5–15 sec.	
	Kamchatka, USSR	Max. respiratory pause: 75 min.	
Gambell (1968)	Off Durban, South Africa	1 whale < 45 ft long sounded for 52 min. Six large and 5 medium whales feeding stayed submerged for 35 min.	Based on observations, notes and comments by K. J. Pinkerton.
Berzin (1972)	Unspecified	Duration of dive: small whales usually dive for $\leq$ 20 min. Respiration pattern: A more constant respiratory rhythm is characteristic of large animals.	
Gambell and Lockyer (1973)	South Africa	Duration of dive: New born calf dived up to 7 min, other whales accompanying calf dived longer but remained just below surface.	
Doi (1974)	Antarctica	Duration of dive: n = 630 whales; $\bar{x}$ = 8.56 min. Surface time = 2.72 sec. Real rate of sighting (P) = 0.138	
Yablokov *et al.* (1974)	Unspecified	Duration of dive: usual = 1–10 min, max = 15–90 (120 min).	
Lockyer (1976)	Unspecified		

Body length (ft)	Dive duration (min)	Ave. number of blows when not diving
30	<6	4–6 (obs. from aircraft)
	<45	6–7 (obs. from ship)
45	<6	3–4 (obs. from aircraft)
	<65	6 (obs. from ship)

Appendix I (*continued*)

Source	Region	Diving behavior	Remarks
Lockyer (1977)	South Africa	Duration of dive: 70–80% of dives during chase were < 10 min. Time at surface related to length of previous dive. If dive < 10 min, surface time $= 1.42 \pm 0.01$ ($n = 149$). If dive 10–20 min, surface time $= 2.46 \pm 0.04$ ($n = 41$).	
		Respiration rate between dives = 4–7.	
Christensen (1980)	North Atlantic	Duration of dive: Chased whale dived for 34.5 and 33.5 min.	
		Blow interval: Before chase = 18, 32 and 16 sec. After chase = 9, 10, 15, 10, 14, 17, and 9 sec.	
di Sciara *et al.* (1981)	Eastern Caribbean Sea off Venezuela	Blow intervals: $n = 7$ blows; $\bar{x} = 28$ sec between blows; blow/dive quasi regular intervals = 10–20 sec. Total blowing observation time = 196 sec.	Visible areas: body, footprints flukes up. 13+ individuals many cows and calves, probably traveling.
Leatherwood *et al.*, (1981 unpublished MS)	Baja California	Diving time: Males = 92, 80, 75, 60, 65, 62, 6 min. Females = 20 min.	
		Max depth of up to 2,500 m.	
Killer whale			
Scheffer and Slipp (1948)	Commencement Bay, Tacoma Washington	3–5 shallow dives at 5 sec intervals.	
Tomilin (1967)	Unspecified	Duration of dive: Sounding duration 1–2 to 5–6 min. Single individuals submerged 1–3 min; packs submerged 5–6 min.	
		Surface time = 1–5 sec.–30 sec.	
	Bering Strait	Surface time = 3 min near shore.	
		Respiration pattern: Breathing less regular near shore.	
Erickson (1976)	Puget Sound, Washington and British Columbia	Surface time: $n = 2$; $\bar{x} = 3.5$ sec.	
		Blow interval: 3–4 consecutive blows over 30–40 sec every 6–8 min.	
Bottlenose whale			
Kukenthal (1888)	Unspecified	Wounded bottlenose submerged for 45 min.	
Munsterhjelm (1915)	Unspecified	Duration of dive: between 10 and 45 min.	
Scholander (1940)	Unspecified	Perhaps longest dives of all cetaceans. Whalers recorded dives of 30–45 min and 1 harpooned whale remained under 2 hrs.	
Tomilin (1967)	Unspecified	Duration of dive usually 10–20 min with brief blow intervals.	No accurate observations on respiratory movements; probably similar to *Hyperoodon planifrons* in Antarctic (Racovitza [1903] and Liouville [1913]).
Winn *et al.* (1970)	Nova Scotia	Three groups of 2, 5 and 4 individuals: blew 3–5 times, then dived for 13, 7, 9, 5, 3, 8, 3.8, 3.7, 10 and 15.1 min.	
Yablokov *et al.* (1974)	Unspecified	Duration of dive: usually = 5–15 min.	
Christensen (1980)	Northeastern Iceland and Labrador	Duration of dive: = 14, 19, 21, 25, 31, 31, 33, 37, 50 and 70 min.	

SC/33/Rep4

Report of the Workshop on Identity, Structure and Vital Rates of Killer Whale Populations, Cambridge, England, June 23–25, 1981

1. PARTICIPANTS AND AGENDA

Members (M) of the Scientific Committee of the IWC, invited experts (E) and observers (O) attending were G. Anderson (M), K. Balcomb (E), P. Best (M), M. Bigg (E), R. Borodin (M), H. Braham (M), I. Christensen (M), M. Dahlheim (E), W. Evans (E), L. Fleischer (M), J. Ford (E), M. Ivashin (M), S. Leatherwood (E), C. Lockyer (M), S. Ohsumi (M), T. Øritsland (M), W. Perrin (M), Y. Riazantsev (M), T. Smith (M), P. Spong (O) and R. Walker (E). Some participants did not attend all sessions of the meeting.

Perrin chaired the meeting and edited the report. Bigg, Dahlheim, Ford and Balcomb acted as rapporteurs.

The draft Agenda was discussed and approved with some additions (Appendix 1). The scope of the meeting was broadened to include consideration of vital rates.

2. BACKGROUND OF THE MEETING

During attempts at the 1980 meeting of the IWC Scientific Committee to assess the status of recently exploited stocks of killer whales, it became apparent that information available to the meeting was not adequate to allow delineation of management units with confidence. For this reason it was decided to convene a meeting of experts on killer whales for the purposes of reviewing all relevant information and making recommendations for definition of management units. A brief review of recent developments in the major killer whale fisheries follows.

2.1 The Northeastern Atlantic

After a 5-year period of very low catches (0–7 per year), in 1978 Norway took 63 killer whales under a license-subsidy system occasioned by the belief that concentrations of killer whales in certain fjord areas were doing harm to depleted but recovering herring stocks. The 1979 take was 221. The killer whales were taken by 'small-type whaling' vessels that usually take minke whales. The catches were processed for oil and animal food. As no stock assessment had been made, the Scientific Committee recommended in 1979 that Norway be urged to provisionally limit its take in 1980 to 52 whales (the average annual coastal take over the 10-year period 1969–78) and be requested to produce at the 1980 meeting the information necessary for an assessment. The recommendation was not acted on by the Commission, but Norway voluntarily limited its take in 1980 to 52 whales, all taken in January. No data on abundance and stock structure were made available at the 1980 meeting, however, and the Committee recommended that the stock(s) be classified provisionally as Sustained Management Stock(s) (on the grounds that there has been a long history of sustained catches), that the catch be limited to 52 whales, and, again, that Norway be asked to conduct research that would make possible a stock assessment. The Committee was especially concerned that the historical catches may not have been all from the same population(s) presently being fished.

2.2 The Southern Hemisphere

Pelagic catches of killer whales by the USSR in the Southern Hemisphere in the 1950s were as high as 110 per season (1958/59 season), but from the mid-1960s until recently they ranged from 0 to 48 per season. Takes of 78 whales were reported in the 1977/78 season and 49 in the 1978/79 season. In 1979 the Committee recommended that the USSR be requested to provide at the 1980 meeting the information necessary for a stock assessment and that the take during the 1979/80 season be provisionally limited to 24 whales, the average season's take over the period 1969–78. The Commission did not act on the recommendation, and the USSR took 916 killer whales during the 1979/80 season. The USSR did not provide information at the 1980 meeting adequate for a stock assessment, but abundance estimates for portions of the Southern Hemisphere (Statistical Areas III and IV) were made based on sightings data from IDCR minke whale cruises in 1978/79 and 1979/80. Data and hypotheses suggestive of the existence of several stocks of killer whales in the Southern Hemisphere were available, but it was felt that there was insufficient evidence on which to base geographical stock boundaries which would be of long-term use for assessments. Because of the uncertainty over stock identities and a lack of knowledge about population parameters and the effects of exploitation on social structure, the Committee recommended that the catch limit for Antarctic killer whales be set at zero. The Commission adopted this recommendation and broadened the existing moratorium on factory-ship whaling (for other than minke whales) to include killer whales.

3. REVIEW OF EXISTING INFORMATION

3.1 Distribution and Migration

3.1.1. North Atlantic

Killer whales in the North Atlantic occur with varying density in different areas. They are frequently observed off Greenland, Iceland, in the Barents and White Seas, and off Novaya Zemlya. Norwegian data indicate that killer whales occur in coastal waters all year round and that there are concentrations in the Lofoten, Møre, and Finnmark areas (SC/Jn81/KW1). Little is known about killer whale movements there, although it was suggested that they migrate in response to movements of their prey. Killer whales are also reported off Great Britian, Iceland, Denmark and France.

In the northwest Atlantic, killer whales remain in the cold waters of the Arctic until driven out by ice. Sergeant and Fisher (1957) reported killer whales off the eastern

and Areas 2 and 4, and between Areas 1 and 2. They pointed out, however, that the samples had not been stratified by age. Also, Ivashin cautioned that some selectivity for large animals may exist in the fisheries. The same caution applies to the Norwegian data.

No useful analyses of geographical skeletal variation exist, but Braham reported that series of osteological specimens that would possibly allow such analysis exist at the US National Marine Mammal Laboratory, Seattle and elsewhere. The group agreed that a first step in this direction should be to compile a list of available materials.

3.2.1.2. Meristics

As is the case with skeletal variation, no useful analyses of geographical variation in meristic characters exist, but accumulating material may now make possible analyses such as those carried out by Soviet scientists (Yablokov, Berzin and others) on phalangeal counts in *Delphinapterus leucas* and *Physeter macrocephalus*. Evans reported (pers. comm. from A. Yablokov) that data collected in the Antarctic during the 1979/80 season included toothcounts.

3.2.1.3. Colouration

The group discussed the work of Yablokov and Evans (SC/Jn81/KW11) on variation in colour pattern. Statistically significant geographical variation was found in four of fourteen catalogued *Orcinus* colour-pattern components. Antarctic specimens have a distinct dorsal cape; those from the Northern Hemisphere, South Pacific and South Atlantic lack such a cape. Differences in shape and position of post-ocular patches were observed between specimens from McMurdo Sound – Ross Sea – Antarctic Peninsula and specimens from IWC Areas III, IV and V. These colour-pattern differences support the conclusion that regional groups exist in the Antarctic. However, for some areas the samples represent as few as 5–20 individuals, possibly drawn from single pods (SC/Jn81/KW11).

Detailed examination of colouration of 110 males and 106 females taken by the Soviet whaling fleet in 1977–78, 78–79 and 79–80 further distinguishes animals collected in Area I from those taken in III and IV combined and suggests existence of separate 'in-ice' and 'open water' forms. No significant sexual dimorphism in colouration was found in this sample.

The results of these analyses are consistent with the existence of at least two forms in Antarctic waters but are inconclusive with respect to the 6–8 longitudinally-defined stock divisions proposed by Mikhalev *et al.* (1981).

In British Columbia there are distinct differences in colouration between pods (SC/Jn81/KW4 and KW9). The apparent differences between 'in-ice' and 'open water' forms noted for the Antarctic may be sufficient to mask such pod or area differences there (Table 4 SC/Jn81/KW11). Therefore, there is concern that photographic sample sizes must be substantially increased to ensure that pod-level differences are not misinterpreted as population-level differences or vice-versa.

3.2.2. Sound production

Reports submitted to the meeting describe variation in the vocal patterns of killer whales related to pod and population identity and geographical location. A study of the acoustic behaviour of killer whales in British Columbia (SC/Jn81/KW8) has shown that the predominant social signals are repetitious, pulsed calls which can be organised into discrete, non-overlapping categories. Repeated encounters with 15 photographically-identified pods in this region during 1978–80 demonstrated that each pod has a limited repertoire of 8 to 15 ($\bar{x} = 11.9$) discrete call types. These repertoires are consistent regardless of changes in behavioural context. Recordings obtained from captive animals of known pod origin indicate that pod repertoires are highly stable for periods of at least 15 years (1965–80), and that each pod member produces most or all of the group's calls.

Significant differences exist between the discrete-call repertoires of different pods in British Columbia. Individual pods can be reliably identified solely on the basis of dialectal variation. The degree of similarity in dialects is also a reliable index of the degree of association of pods. Pods which associate and travel together (a pod 'community') tend to share certain calls in their repertoires, while those that do not associate (different communities) produce entirely different calls. Pods which associate most often within a community have the greatest dialectal similarity.

Two of the three pod communities off Vancouver Island, B.C., have separate, well-defined ranges, while the third is widely distributed on the coast and occurs within the other community ranges. Since each pod community is acoustically unique, major dialectal differences in this case exist in both geographically separated and socially isolated (but sympatric) communities.

Variation in killer whale vocalisation is also apparent on a larger geographical scale. Studies on the sounds of Antarctic killer whales have noted differences in the frequency structure, timing, and pattern of calls from those recorded in the North Atlantic (SC/Jn81/KW5) and North Pacific (SC/Jn81/KW6 and SC/Jn81/KW7). Vocalisations recorded in the Ross Island area of the Antarctic were reported to be similar in 1980 and 1981 (SC/Jn81/KW6).

It is apparent from these studies that the examination of killer whale sounds represents a potentially important technique for identifying populations and determining their social organisation. The degree of difference in dialects may correlate with the degree of breeding isolation. If so, the pod will be even more useful in identifying populations. While acoustical studies in other areas have identified geographical variation between widely separated regions (SC/Jn81/KW5, KW6, KW7), it is likely that dialectal variation on a local scale also exists within these regions, and the caution stated above with respect to interpretation of colour-pattern data applies here.

3.2.3. Behaviour

There is no evidence of significant geographical variation in the basic behaviour patterns of killer whales, with the exception of that in sound production (Section 5.2.2) and feeding habits, which probably reflect availability of prey (Section 5.2.5). Group sizes and composition are similar in the North Pacific (SC/Jn81/KW2, KW3, KW4, KW9: Dahlheim, 1981), the Bering Sea (Ivashin and Votrogov, 1981), the coast of Norway (SC/Jn81/KW1), the South Atlantic (Budylenko, 1981), and the Antarctic (Budylenko, 1981; Mikhalev *et al.*, 1981). These sources generally report groups of 1 to 100 individuals, with the majority containing between 5 and 20 individuals. In the coastal waters of Washington and British Columbia, groups with less than 20 animals typically represent primary social units, or pods, with stable membership

(SC/Jn81/KW4, KW9; Section 5.5). Stable groups have also been documented in other areas of the world (SC/Jn81/KW9).

There are several reports of large aggregations containing 100 or more killer whales, primarily in the Antarctic (SC/Jn81/KW7; Budylenko, 1981; Doroshenko, 1978), Alaskan (SC/Jn81/KW2) and Norwegian waters (Christensen, 1978), all high-latitude areas. These large groups probably result from the temporary joining of a number of pods and may be related to seasonal peaks in prey density in certain areas. Killer whales in the Antarctic are frequently observed in the company of other cetaceans (Mikhalev *et al.*, 1981), but this may reflect the fact that the sightings have been made from whaling vessels. However, the participants reported that such associations also occur in several other areas.

Opportunistic feeding behaviour associated with human activities is known to have developed in killer whales in various localities. Among these is the unusual relationship between killer whales and shore-based whalers at Eden, Australia during the later 1800s and early 1900s (reviewed by Mitchell and Baker, 1980), a recently developed interaction between killer whales and a drop-line fishery off Tasmania (*Rep. int. Whal. Commn* 31: 147) and similar interactions with a long-line fishery near Iceland (SC/Jn81/KW1). Such occurrences appear to be localized phenomena and may, as in the case at Eden, Australia, involve only one or a few pods. That these behaviours do not seem to spread is suggestive of little exchange of animals between local areas.

3.2.4 Biochemical and chromosomal characters

Polymorphism has been described in the C-banded karyotype of the killer whale (Árnason, Lutley and Sandholt, 1980), and studies are presently underway to compare chromosomes of killer whales from different locations (D. Duffield, pers. comm. to Dahlheim, June 1981). There is preliminary chromosomal and biochemical evidence that certain pods may be genetically isolated (Duffield and Cornell, 1979). The group agreed that while this area of research is promising for future studies of stock identification, it has not yet progressed sufficiently far to be of use in the present exercise.

3.2.5. Feeding habits

Food items found in the stomachs of killer whales encompass a wide range of species (Appendix 4). The list presented is incomplete and does not represent a comprehensive review of the literature or a complete listing for any geographic area. Fish prey from stomach contents may be less likely to be identified to species and thus may be under-represented in the table. Composition of diet varies among areas and within areas, both seasonally and between individuals sampled.

The broad range of diet items is reflected in diverse feeding behaviours associated with different prey. These behaviours have been described by the authors listed in the table.

The present data do not suggest systematic geographical variation in feeding habits not related to distribution of prey.

3.3 History of catches with respect to geographical sub-areas

3.3.1 North Atlantic

As noted above, there has been concern that the long history of take of killer whales by Norway may not pertain to a single breeding population. Christensen reported that all killer whales taken in recent years have been taken in Norwegian fjords and coastal inshore waters. Data in Jonsgård [Christensen (1975) and in catch records (*fide* Christensen)] indicate that about 70% of the killer whales taken by Norway since 1938 were taken from Norwegian coastal waters. In recent reports (see, for example, Christensen, Jonsgård and Rørvik, 1981) the statistics indicate that the take has been from a portion of the coastline, centred about Lofoten.

Christensen reported (SC/33/KW1) the existence of several (7–8) areas of concentrations of killer whales along the coast of Norway. The whales are found in these areas in large numbers throughout the year; there is no evidence of seasonal migration. The coastal statistical reporting areas in Christensen *et al.*, 1981, correspond roughly to the reported areas of concentration of killer whales. Considering these facts and the limited ranges and long-term stability of local populations observed in the Northeastern Pacific (the only areas where killer-whale movements have been intensively studied for long periods of time) the group thinks it likely that the Norwegian fishery may be exploiting one or a few local breeding populations.

3.3.2. Southern Hemisphere

Mikhalev *et al.* (1981), presented catch statistics for the Southern Hemisphere for the period 1969/70–1978–79 by 10-degree square. The catches were concentrated in roughly 3 regions: southeast of Africa, southeast of Australia, and southwest of South America. These areas correlate roughly with the Areas 1, 2 and 3 defined in the same paper for purposes of analysis of geographical variation in length (discussed above). The authors concluded that at least two populations are probably involved. These analyses do not include data from the 916 killer whales taken during the 1979/80 season. To date, the 1979/80 catch statistics have been reported only by expedition (SC/33/ProgRep USSR).

3.3.3 Other Areas

No detailed information on distribution of catch by sub-areas is available for other fisheries.

3.4 Age and structure of catches

3.4.1 Live capture for display

Killer whales taken for display (about 100) in Washington, British Columbia and Iceland have been young males and females, with selection against large bulls. Pods were enclosed, one or more individuals were selected and removed, and the remainder were released. No information was available on catches for display off Iceland.

3.4.2. Soviet pelagic catches in the Southern Hemisphere

Two sets of data giving length composition are available—one for the period 1961/62 to 1978/79 (Mikhalev *et al.*, 1981) and the other for 1979/80 (IWS LVXXXI) and are shown in Table 1.

Size composition of the earliest catches indicates that there was selection for larger animals, with more males than females taken, and some selection for large animals may

Table 1

Length-frequency data for Soviet takes of killer whales in the Antarctic

	Length																				
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Totals
1961/62–1978/79																					
Males							2	7	10	21	17	14	27	31	33	24	13	5	1		205 males
Females							4	10	11	20	19	26	15	5	2	—	—	—	—		118 females
																					323
1979/80																					
Males			1	1	4	6	6	13	39	32	52	69	72	45	41	24	9	14	21	1	450 males
Females	1	1	3	6	9	25	66	46	60	85	88	56	17	2	1	—	—	—	—	—	466 females
																					916

also have occurred in the later catches. Ivashin and Evans reported that the 1979/80 catch of 916 killer whales may incorporate an open-water form and an ice-edge form of different sizes. The relationship of those forms to the dwarf form proposed by Mikhalev and Ivashin is not clear, but it is apparent that detailed consideration of the data from the 1979/80 catch will require further analysis of its possible components.

There is little information on the way in which the killer whales were taken, i.e., whether an attempt was made to take all members of a pod or only a small number of individuals selected at random. If possible, the information will be obtained and presented to the Scientific Committee next year. It is understood that there are no data available on the age composition of the recent Soviet catches.

3.4.3 Other coastal catches

Nishiwaki and Handa (1958) gave details of coastal Japanese killer whale catches for the period 1948–57, in which 567 animals were taken:

	1948		1949		1950		1951		1952		1953		1954		1955		1956		1957		Totals	
	no.	size	no.	size	no.	size	no.	size	no.	size	no.	size	no.	size	no.	size	no.	size	no.	size	no.	size
♂	12	19.4	19	21.6	11	22.5	40	21.9	33	21.8	39	21.7	66	22.5	43	20.2	22	21.0	35	21.2	320	21.5
♀	15	18.6	24	18.3	7	20.1	27	19.1	21	20.7	26	21.7	43	21.9	34	19.8	16	21.0	34	18.4	247	20.0

It is clear that there was selection for males, with more males than females taken in all years but 1948 and 1949. The mean lengths of males taken are greater than mean lengths of females in years other than 1953 and 1956, when the mean lengths were equal. Total coastal Japanese catches in the period 1948–80 were 1,452 animals. Detailed information was not available for the period 1958–80 for the Japanese coastal fishery. Similarly, no information beyond that presented by Dahlheim (1981) was available for Denmark, Peru, South Africa, USA or the West Indies.

3.5 Definition of breeding unit

3.5.1 Size

In British Colombian waters, at least, the primary social unit (in which calves are reared) is a pod, and the basic breeding unit is demonstrably no larger than a 'community' composed of several pods (SC/Jn81/KW4; SC/Jn81/KW9). The pod sizes range from 1 to 50 whales. Periodically pods join with others to form larger aggregations of up to 80 individuals. Pods around Vancouver Island form three communities whose individuals associate with one another but not with individuals of other communities. One, a resident community off southern Vancouver Island, contains three pods totalling 79 whales that are seen year round. The second, resident off northern Vancouver Island, contains 12 pods with about 136 whales. At least one of these 12 pods is seen year round. A third community is made up of transient whales which range in a loose network around Vancouver Island, incorporating the ranges of the other communities. This group contains 15 pods and 47 individuals, which are seen infrequently. The transient pods differ from resident pods in swimming and feeding behaviour. They also range farther than do the other two communities.

In other regions, aggregations of several hundred are commonly reported, and in one instance a group of 2,500 was noted in Alaska (SC/Jn81/KW2). There was discussion about the difficulty in counting cetaceans in large groups.

3.5.2 Structure

Pods typically contain individuals of mixed ages and sexes (SC/Jn81/KW4; SC/Jn81/KW9; Grieg, 1889). Based on 30 pods containing 260 whales in British Columbia and Washington, the average pod contains 23.0% bulls, 34.1% cows, 38.5% juveniles and 4.4% young of the year. Solitary whales can be male or female. Some small pods (<7 whales) in British Columbia contain no adult males. Such pods can contain calves and thus must breed with males of other pods. At the opposite extreme is a pod of eight whales of which five are bulls.

3.5.3 Stability

Pods are long-term association of the same individuals (SC/Jn81/KW4; SC/Jn81/KW9; Wellings, 1944). Associations within entire pods have been recorded for seven years in British Columbia and Washington. Four individuals in one pod are known to have associated for 13 years. Based on observed annual changes in pod size, these pods increase at an average rate of 2.52%. One suggestion for new pod formation is that it occurs through the gradual splitting of established pods over perhaps several decades. Related sub-pods would gradually spend less time in association with one another. Evidence is now accumulating to indicate that mothers and their accumulated young form subgroups within pods. Such maternal associations may well be the basis on which pods eventually divide. There have been no instances observed of individuals moving out of one pod and into another on a permanent basis, although temporary associations across pods within a community do occur.

3.6 Vital parameters

3.6.1. Age at sexual maturity

Based upon catches of killer whales by Norway reported by Jonsgård and Lyshoel (1970) and Christensen (SC/Jn81/KW1) and by the USSR in 1979/80 (IWS LXXXVI and Table 1), few pregnancies occur among females less than 16 ft long, and a marked increase in pregnancies occurs among females 16 ft long and larger. These data indicate that most first pregnancies occur at about that length. Age at first pregnancy is not directly known. However, based on rates of growth of captive killer whales (SC/Jn81/KW4) it is at least 7 years. Based on growth layers in the teeth of whales taken in the Norwegian fishery (SC/Jn81/KW1, Fig. 9), both sexes attain the length of 16 ft at an age of about 8 years.

Based upon testes weight and the presence of sperm, as well as the onset of dimorphism of the dorsal fin, males reach sexual maturity at about 19 ft (SC/Jn81/KW4). Age at sexual maturity is not directly known, but based on captive whale growth rates (SC/Jn81/KW4), it is at least 10–12 years. Growth layers in the teeth (SC/Jn81/KW1) indicate that this length is attained at about 16 years.

There are no data on changes in the age at sexual maturity with level of exploitation.

3.6.2 Pregnancy rate

Reported pregnancy rates for adult females ⩾ 16 ft vary from 14.8% to 42.3% (SC/Jn81/KW4). However, if gestation is more than 12 months, annual pregnancy rates calculated without allowing for foetuses from more than one breeding season will be too high. As shown in Appendix 5, there is definite bimodality in the length frequencies of foetuses from Antarctic catches. Pregnancy rates (including known pregnancies for females of less than 16 ft) recalculated to provide an annual rate corrected for a 15-month gestation period are given in Table 2.

There may be decreased reproductive activity in older females. Data from Antarctic 1979/80 catches indicate a decreasing proportion of pregnant females over 20 ft. There are in addition data on known pods in which adult females are known to have calved at three-year intervals while others have calved much less frequently or not at all in 7–10 years of observation. It appears that there may be social control maintaining relatively low levels of pregnancy.

3.6.3 Birth rates

Studies in British Columbia (SC/Jn81/KW4) and Greater Puget Sound (SC/Jn81/KW9) provide estimates of birth rate for calves which survived to an age of at least six months. Over the same seven-year study period, both studies yielded identical birth-rate information for pods studied in common, but the British Columbia study included more pods and is used here for a best estimate. Table 3 summarizes their data. The birth rate in cropped pods was slightly higher than that for uncropped pods. The estimated population birth rates correspond well with the observed ratio of 7.45% calves-and-juveniles to other ages noted by Best (1980) in Antarctic sighting cruises. Also, they are close to 2.99% ratio of newborn to other ages observed in aerial surveys in the Ross Sea and McMurdo Sound (SC/Jn81/KW6), although some field observations of higher proportions exist, e.g., Christensen (1978) reported a pod of 4–6 animals with one newborn calf and another pod of 15–20 with 5 small calves. However, while it had been considered that the birth rates for adult females were much lower than the pregnancy rates from some whaling records, a re-examination of pregnancy-rate data indicates a much closer correlation of birth and pregnancy rates (Appendix 6). The Committee discussed the discrepancy in rates but could not establish the cause. It could be due to some selection of pregnant whales by whalers, which could happen if females with calves are more difficult to capture, or due to high mortality of calves in the first six months of life.

3.6.4 Natural mortality rate

Natural mortality rates were estimated based on the disappearance of identifiable individuals in pods in the Vancouver Island study (SC/Jn81/KW4). Bulls, cows and juveniles all exhibited low overall rates. These data are presented in Table 3. In each case the cropped pods had a slightly lower rate than the uncropped pods. Further studies are needed to confirm the rates.

3.6.5 Net annual change in pod size

The annual net pod change was determined by following the sizes of individual pods over several years. The data are given in Table 3. The cropped pods have a slightly higher rate than the uncropped pods (SC/Jn81/KW4 and 9).

3.6.6 Length of gestation

The commonly quoted range for duration of gestation is 12–16 months (Nishiwaki and Handa, 1958). The duration is probably more than 12 months. A bimodal peak in foetal lengths occurred during January-March 1979/80 in the Antarctic (Appendix 6), indicating two developmental stages of foetal growth occurring at the same time. Additional data are available from captive animals. The conception time of a female at Marineland of the Pacific was determined to be at about mid-March 1979, based on progesterone levels (Dahlheim, pers. comm. 25 June 1981) and a calf was born prematurely on 1 April 1980, suggesting a gestation close to 15 months.

3.6.7 Length of lactation

There are no direct observations on the duration of lactation in killer whales, although the calf remains in close association with the mother for about a year after birth.

3.7 Species identity

The group discussed the new species, *Orcinus nanus*, proposed by Mikhalev, *et al.* (1981) based on data and specimens collected in the Southern Hemisphere, 1972–79.

Ivashin explained that the description is based on modal

Table 2

Killer whale pregnancy rates from catch data

Source		Length in feet																			Corrected % annual	
		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
Norway	♀					39	48	55	83	72	53	29	28	9	6	4	2	1	1	430		
(Jonsgård & Lyshoel, 1970)	pregnant					1	8	9	12	10	4	4	5	3	2	0	0	0	1	59	51.6[1]	
	% of mature ♀					2.6	16.7	16.4	14.5	13.9	7.5	13.8	17.9	33.3	33.3	—	—	—	1.00	13.72%	12.00%	
Norway (SC/Jn81/KW1)	♀					9	23	37	35	26	23	5	2	1						161		
(i) foetus present	pregnant					1	11	16	15	6	5	1	0	1						56	46.7[2]	
	% of mature ♀					11.1	47.8	43.2	42.9	23.1	27.7	25	0	100						34.87%	28.9%	
(ii) ovarian examination	♀				7	4	3	16	13	8	8	2								61		
	mature ♀				0	2	2	16	13	8	8	2								51		
	pregnant				—	1	1	7	7	2	2	0								20	16.7[2]	
	% of mature ♀					50.0	50.0	43.1	53.9	25.0	25.0	—								39.22%	32.8%	
Antarctic	♀							4	10	11	20	19	26	15	5	3				118		
(Mikhalev *et al.*, 1981)	mature ♀							2	8	7	15	16	21	15	4	3				91	(50% of total)	
	pregnant								4	2	4	2	7	4	1	1				25	12.5	
1961/62 to 1978/79	% of mature ♀								50.0	28.6	26.7	12.5	33.0	26.7	25.0	33.3				27.47%	13.74%	
(IWS LXXXVI)	♀	1	1	3	6	9	25	66	46	60	85	88	56	17	2	2				466		
	estimated mature ♀	—	1	—	4	—	25	66	46	60	85	88	56	17	2	1				448	small	large
	pregnant		1		1		11	14	15	21	35	32	10	3	—	—				143	57	85
	% of mature ♀	100			25.0	44.0	21.2	32.6	33.0	41.2	36.4	17.9	17.7	—	—					31.92%	12.72%	18.97%

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[1] Where corrected value = No. pregnant −0.5 × 3/12 (No. pregnant)

[2] Where corrected value = No. pregnant −0.5 × 6/18 (No. pregnant)

Table 3

Rates of birth, natural mortality and net pod change in cropped, uncropped and combined pods off British Columbia and Washington, 1973–81

Parameter	Source	Cropped (%)	Uncropped (%)	Combined (%)
Birth rate				
Adult females[1]	SC/Jn81/KW4	11.64	8.02	10.30
	SC/Jn81/KW9	8.90	—	—
Population[2]	SC/Jn81/KW4	4.56	3.15	3.90
	SC/Jn81/KW9	2.60	—	—
Natural mortality rate				
Bulls	SC/Jn81/KW4	2.50	3.06	2.81
Cows	SC/Jn81/KW4	0.46	1.52	0.70
Juveniles	SC/Jn81/KW4	1.99	4.35	2.30
Total	SC/Jn81/KW9	0.80	—	—
Net pod change	SC/Jn81/KW4	3.01	1.67	2.52
	SC/Jn81/KW9	2.30	—	—

[1] $\geq$ 16 ft

[2] $= \frac{\text{No. calves}}{\text{No. all other ages}}$

differences between a dwarf form and the ordinary killer whale in external proportions, weight of gonads, length at attainment of sexual maturity and maximum length. The dwarf form on the average has relatively larger anterior measurements, a higher and longer-based dorsal fin placed closer to the head, larger flippers placed closer to the head, larger flukes and a shorter peduncle than does the ordinary killer whale. The weight of the testes in the dwarf form at 6.1–6.5 m is the same as in the ordinary killer whale at 7.1–7.5 m. The ovaries of dwarf females 18–19 ft long weigh the same as those of 25 ft long ordinary females, and dwarf females 5.6–6 m long have the same number of ovarian corpora as do ordinary females 7.5–8 m long. Maximum length for the dwarf form is 7.5 m in males and 6.5 m in females, as opposed to 9.0 m and 7.7 m in the ordinary form. Ivashin emphasised that further data and analyses are desirable to adequately delineate the differences between the two forms and settle the question of whether a new species or sub-species is involved. He suggested that studies of colour-pattern differences and of sound production may be helpful in this regard. Ongoing studies of 1979/80 data and specimens by Berzin of TINRO, Vladivostok may also contribute to description of variation of killer whales in the Antarctic.

The group believes that the data are more suggestive of sub-specific-level differentiation than of existence of an unrecognised species, as the differences are modal rather than absolute. In any case, under the international rules of zoological nomenclature, the name *Orcinus nanus* Mikhalev *et al.* 1981 is at this point a *nomen nudem*, because it is not accompanied by figure, diagnosis and designation of a holotype specimen. These items will presumably be included in the final description of the dwarf form.

4. SUMMARY OF CONCLUSIONS

4.1 Nearly every area of the world's ocean that has been examined contains killer whales, but there are obvious concentrations of abundance, mainly within a few hundred miles of coasts and in high latitudes.

4.2 There is not a strong case for extensive migrations, with the exception of migration with the retreating ice edge in polar areas. This suggests the existence of local populations.

4.3 There is good evidence for a high degree of isolation over a few hundred miles for coastal animals, but the data are inadequate to define larger units. Pelagic animals may have larger ranges. Some members of the group believe that while the existence of broader regional groupings has been proposed, the application of a broader-scale concept of stock areas for management by analogy with species such as sperm and baleen whales is not appropriate for this species.

4.4 The sorts of population units (groups of pods or 'communities') that can be defined with present methods probably contain only tens or hundreds of animals.

4.5 Given the extreme stability of local populations and the low reproductive rates evidenced by the available data, any exploitation can be expected to have long-term impacts on population size and structure.

5. RECOMMENDATIONS FOR RESEARCH

5.1 Noting that a large sample (916) of killer whales was taken in 1979/80 by the USSR and not yet fully reported upon, the meeting recommends that the USSR be asked to provide a report at next year's meeting of the Scientific Committee detailing the specimens and data available, including analysis of sightings per effort. Also, specific questions were raised about hunting strategy of the whalers which may have biased the age structure and size structures of the catch; these should be addressed by the report.

5.2 Noting that the question of number of stock(s) of killer whales in the waters near Antarctica remains unresolved, the meeting recommends that studies be continued on existing data bases concerning colour patterns and morphology of killer whales taken and that acoustic methods of distinguishing pods and populations by their vocalisations be further explored.

5.3 Noting that the social and breeding population structure of Southern Hemisphere killer whales has not been studied and might be different from that of eastern North Pacific killer whales reported here, the meeting recommends that reports be solicited from other researchers in the Southern Hemisphere to ascertain whether differences exist.

5.4 Noting that specimen materials exist in public museums and various institutions that have not been examined and described in the literature and that they potentially could yield valuable data on age and morphological variation, the meeting recommends that these materials be inventoried and that their study be encouraged.

5.5 Noting that inadequate information exists for stock definition of the killer whale population in Norwegian coastal waters, the meeting recommends that research be carried out to provide this and other information necessary for adequate stock assessment. The programme of marking to study movements should continue. The possibility of using natural marks should be investigated. Considering the existence of a live-capture fishery in Icelandic waters, the same recommendation should be made to Iceland.

5.6 Noting that teeth for age determination have not been consistently collected for all killer whales taken commercially or found stranded, the meeting recommends that in the future every effort be made to collect and examine such materials, as well as gonads, stomach contents, morphometric and meristic data, and other biological materials whenever possible.

5.7 Precise data on locality and date of capture for the live-capture fishery in Iceland and elsewhere should be provided to the Scientific Committee.

5.8 Noting that chromosomal and biochemical studies may yield information concerning stock and populations of killer whales, the meeting recommends that such studies be undertaken for all killer whales currently in captivity, and, whenever opportunity exists, to conduct such studies on stranded and harvested whales and whales in the wild.

5.9 Noting that field studies of killer whales in waters around Vancouver Island and in Greater Puget Sound have produced significant new information concerning vital parameters, as well as precise assessments of the local populations, the meeting recommends that such studies be continued, in order to accurately determine: (1) at what age killer whales become adult, (2) age-specific birth and mortality rates, and (3) immigration/emigration rates for the local population, especially as they may correlate with changes in the habitat. It is further recommended that similar studies be encouraged in other areas of the world for comparative purposes.

5.10 Existing data on dates and localities of take of killer whales in Japanese coastal waters should be made available and analysed to elucidate patterns of distribution and abundance in that area.

REFERENCES

Aguayo, A. L. 1975. Progress report on small cetacean research in Chile. *J. Fish. Res. Bd Can.* 32: 1123–43.

Anon. 1981. Japan progress report on cetacean research, June 1979–May 1980. *Rep. int. Whal. Commn* 31: 195–200.

Árnason, Ú., Lutley, R. and Sandholt, B. 1980. Banding studies on six killer whales: an account of C-band polymorphism and G-band patterns. *Cytogenet. Cell Genet.* 28: 71–8.

Balcomb, K. C., Boran, J. R., Osborne, R. W. and Haenel, N. J. 1980. Observations of killer whales (*Orcinus orca*) in Greater Puget Sound, State of Washington. Final Report to the Marine Mammal Commission. Contract No. MM1300731–7.

Barr, N. and Barr, L. 1972. An observation of killer whale predation on a Dall porpoise. *Can. Field-Nat.* 86(2): 170–71.

Best, P. B. 1971. Order Cetacea. Part 7. *In*: J. Meester and H. W. Setzer (Eds.). *The Mammals of Africa. An Identification Manual.* Washington, D.C. Smithsonian Institution. ISBN 0 87474 116 5.

Best, P. B. 1980. Notes on abundance of killer whales in Antarctic Areas III and IV. Paper SC/32/SM10 presented to the IWC Scientific Committee, June, 1980 (unpubl.).

Blokhin, S. A. 1981. The results of the cruise of the whaler *Recordniy* in the coastal waters of Australia in March, 1979. *Rep. int. Whal. Commn* 31: 723–7.

Brown, D. H. and Norris, K. S. 1956. Observations of captive and wild cetaceans. *J. Mamm.* 37(3): 311–26.

Brownell, R. L. Jr. 1974. Small odontocetes of the Antarctic. *Am. Geogr. Soc., Antarctic Map Folio* 18: 13–19, pls. 8–9, 11.

Budylenko, G. A. 1981. Distribution and some aspects of the biology of killer whales in the South Atlantic. *Rep. int. Whal. Commn* 31: 523–5.

Caldwell, D. K. and Caldwell, M. C. 1969. Addition of the leatherback sea turtle to the known prey of the killer whale. *Orcinus orca. J. Mamm.* 50(3): 636.

Caldwell, D. K. and Caldwell, M. C. 1975. Dolphin and small whale fisheries of the Caribbean and West Indies: occurrence, history and catch statistics—with special reference to the Lesser Antillean Island of St Vincent. *J. Fish. Res. Bd Can.* 32: 1105–10.

Christensen, I. 1975. Preliminary report on the Norwegian fishery for small whales: expansion of Norwegian whaling to Arctic and northwest Atlantic waters, and Norwegian investigations of the biology of small whales. *J. Fish. Res. Bd Canada* 32: 1083–94.

Christensen, I. 1978. Spekkhoggeren (*Orcinus orca*): i det Nordøstige Atlanterhav. (The killer whale in the northwest Atlantic). *Fisken Hav. 1978* (1): 23–31.

Christensen, I., Jonsgård, A. and Rørvik, C. 1981. Catch statistics for minke whales (*Balaenoptera acutorostrata*) and killer whales (*Orcinus orca*) caught by Norway in 1979. *Rep. int. Whal. Commn* 31: 635–7.

Clarke, R. 1981. Whales and dolphins of the Azores and their exploitation. *Rep. int. Whal. Commn* 31: 607–15.

Cook, J. H. 1926. *Pursuing the Whale: A Quarter Century of Whaling in the Arctic.* Houghton Mifflin, New York. 344 p.

Dahlheim, M. E. 1981. A review of the biology and exploitation of the killer whale, *Orcinus orca*, with comments on recent sightings from Antarctica. *Rep. int. Whal. Commn* 31: 541–50.

Doroshenko, N. V. 1978. On the relationship (predator-prey) between the killer whale and the minke whale in the Antarctic. pp. 107–109. In: *Marine Mammals. Abstracts of Reports to the 7th All-Union Meeting*, Moscow.

Duffield, D. and Cornell, L. 1979. Observations on population structure and dynamics in *Orcinus orca*. Third Bien. Conf. Biol. Mar. Mammals (Abst.). October 7–11, 1979. Seattle, Wa.

Evans, W. E. and Yablokov, A. V. 1982. Geographic variation in the color pattern of killer whales (*Orcinus orca*). Paper SC/Jn81/KW11 (published in this volume).

Fay, F. H., Shultz, R. M. and Djeterich, R. A. 1979. Natural mortality of marine mammals in Alaskan waters. (Abstr), *Amer. Assoc. Advan. Sci., Proc. 29th Alaskan Sci. Conf.*

Grieg, J. A. 1889. Cetologiske notiser. (Cetacean notes). *Bergens Mus. Årb.* 4: 1–25. (In Norwegian.)

Ivashin, M. V. 1981. USSR Progress report on cetacean research June 1979–May 1980. *Rep. int. Whal. Commn* 31: 221–28.

Ivashin, M. V. and Votrogov, L. M. 1981. Killer whales, *Orcinus orca*, inhabiting inshore waters of the Chukotka Coast. *Rep. int. Whal. Commn* 31: 521.

Jehl, J. R., Evans, W. E., Awbrey, F. T. and Drieschmann, W. S. 1980. Distribution and geographic variation in the killer whale (*Orcinus orca*) populations of the Antarctic and adjacent waters. *Arct. J.* 15(5): 161–3.

Jonsgård, A. and Lyshoel, P. B. 1970. A contribution to the knowledge of the biology of the killer whale, *Orcinus orca* (L.) *Norweg. J. Zool.* (Nytt mag. Zool.) 18(1): 41–8.

Kasuya, T. 1971. Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based upon aerial sighting record. *Sci. Rep. Whales Res. Inst., Tokyo* 23: 37–60.

Leatherwood, J. S. and Dahlheim, M. E. 1978. Worldwide distribution of pilot whales and killer whales. NOSC Tech. Rep. 295, Naval Ocean System Center, San Diego, Ca. 92152. 39 p.

Martinez, D. R. and Klinghammer, E. 1970. The behaviour of the whale, *Orcinus orca:* a review of the literature. *Z. Tierpsychol.* 27: 828–39.

Mikhalev, Yu. A., Ivashin, M. V., Savusin, V. P. and Zelenya, F. E. 1981. The distribution and biology of killer whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 551–65.

Mitchell, E. 1975. Porpoise, dolphin and small whale fisheries of the world. *IUCN Mono. No. 3.*

Mitchell, E. and Baker, A. N. 1980 [1981]. Age of reputedly old killer whale, *Orcinus orca*, 'Old Tom' from Eden, Twofold Bay, Australia. *Rep. int. Whal. Commn* (special issue 3): 143–54.

Nikulin, P. G. 1941. Chukotskii morzh (Chukotsky walrus), Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. (TINRO) 20: 21–59. (In Russian.) [Transl. by Bur. Commer. Fish., Seattle, Wa., 1953, 52 p.]

Nishiwaki, M. and Handa, C. 1958. Killer whales caught in the coastal waters off Japan for recent 10 years. *Sci. Rep. Whales Res. Inst., Tokyo.* 13: 85–96.

Norris, K. S. and Prescott, J. H. 1961. Observations on Pacific cetaceans of California and Mexican waters. *Univ. of Cal. Publ. Zool.* 63(4): 291–402.

Pike, G. C. and MacAskie, I. B. 1969. Marine mammals of British Columbia. *Fish. Res. Bd Can. Bull.* 171: 1–54.

Rice, D. W. 1968. Stomach contents and feeding behavior of killer whales in the eastern North Pacific. *Norsk Hvalfangsttid*, 57(2): 35–8.

Richardson, W. J. (ed.) 1981. Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1980. Report to the U.S. Bureau of Land Management by LGL Ecological Consultants.

Scammon, C. M. 1872. The orca. *Overland Monthly* 9(1): 52–7.

Scheffer, V. B. and Slipp, J. W. 1948. The whales and dolphins of Washington State. *Amer. Midl. Nat.* 39: 257–337.

Sergeant, D. C. and Fisher, H. D. 1957. The smaller Cetacea of eastern Canadian waters. *J. Fish. Res. Bd Can.* 14: 83–115.

Sleptsov, M. M. 1961. Nablyudeniya nad melkimi kitoobraznymi v Dal'Nevostochnykh moryakh i severo-zapadnoy chasti tikhogo okeana (Observations of small cetaceans in far eastern seas and northwest Pacific). *Tr. Inst. Morf. Zhiv.* 34: 136–43. (In Russian.) (Transl. U.S. Naval Oceanographic Office, Washington, D.C. 20390, 1970. Transl. 482).

Smith, T. G., Siniff, D. B., Reichie, R. and Stone, S. In press. Coordinated behaviour of killer whales, *Orcinus orca*, hunting a crabeater seal, *Lobodon carcinophagus*. *Can. J. Zool.*

Tarpy, C. 1979. Killer whale attack. *Nat. Geog.* 155(4): 540–45.

Tomilin, A. C. 1957. *Kitoobraznye* (Cetacea). Vol. IX of *Zveri SSSR i prilezhashchikh stran* (Mammals of the USSR and Adjacent Countries). Izd. Akad. Nauk SSSR, Moskva, 756 pp. (In Russian.) (Transl. by Israel Program Sci. Transl., 1967, 717 pp., avail. Natl. Tech. Inf. Serv., Springfield, Va.).

Wada, S. 1981. Japanese whaling and whale sighting in the North Pacific 1979 season. *Rep. int. Whal. Commn* 31: 783–86.

Wang, P. 1979. Investigations on the medium and small size tooth whales of the Yellow Sea and Bohai Sea. *Zool. Mag.* 2: 31–3.

Wellings, C. E. 1944. Killer-whales of Twofold Bay, NSW Australia Grampus area. *Aust. Zool.* 10(3): 291–3.

Zenkovich, B. A. 1938. O kosatke ili kite-ubiitse (On the grampus or killer whale, *Grampus orca* Lin.). *Priroda, Acad. Sci. USSR* 4: 109–112 (In Russian.). (Engl. transl. avail. through Natl. Mar. Mammal Lab., Seattle, Wa 98115).

Appendix 1

AGENDA

1. Participants and agenda
2. Background of the meeting
    2.1. The northeastern Atlantic
    2.2. The Southern Hemisphere
3. Review of existing information
    3.1. Distribution and migration
        3.1.1. North Atlantic
        3.1.2. Southern Hemisphere
        3.1.3. North Pacific
    3.2. Geographical variation in:
        3.2.1. Morphology
            3.2.1.1. External and skeletal size and shape
            3.2.1.2. Meristics
            3.2.1.3. Colouration
        3.2.2. Sound production
        3.2.3. Behaviour
        3.2.4. Biochemical and chromosomal characters
        3.2.5. Food habits
    3.3 History of catches with respect to geographical sub-areas.
        3.3.1. North Atlantic
        3.3.2. Southern Hemisphere
        3.3.3. Other areas
    3.4. Age and sex structure of catches
        3.4.1. Live capture for display
        3.4.2. USSR pelagic catches in the Southern Hemisphere
        3.4.3. Other coastal catches
    3.5. Definition of breeding unit
        3.5.1. Size
        3.5.2. Structure
        3.5.3. Stability
    3.6. Vital parameters
        3.6.1. Age at sexual maturity
        3.6.2. Pregnancy rate
        3.6.3. Birth rate
        3.6.4. Natural mortality rate
        3.6.5. Net annual change in pod size
        3.6.6. Length of gestation
        3.6.7. Length of lactation
    3.7. Species identity
4. Summary of conclusions
5. Recommendations for research
6. Literature cited
7. Other business
    7.1 Production of the meeting report
    7.2 Publication of the meeting documents

Appendix 2

LIST OF DOCUMENTS SUBMITTED TO THE MEETING

SC/Jn81/KW1*	Christensen, I. Killer whales in Norwegian coastal waters.
SC/Jn81/KW2*	Braham, H., Dahlheim, M. and Consiglieri, L. Killer whales in Alaska from at sea sightings documented in the U.S. Platforms of Opportunity Program.
SC/Jn81/KW3*	Dahlheim, M., Leatherwood, J. S. and Perrin, W. F. Distribution of killer whales in the warm temperate and tropical eastern Pacific.
SC/Jn81/KW4*	Bigg, M. An assessment of killer whale, *Orcinus orca*, stocks off Vancouver Island, British Columbia.
SC/Jn81/KW5	Jehl, J. R., Evans, W. E., Awbrey, F. T. and Dreischman, W. S. Distribution and geographic variation in the killer whale, *Orcinus orca*, populations in the Antarctic and adjacent waters.
SC/Jn81/KW6	Thomas, J. A., Awbrey, F. T., Leatherwood, J. S. Evans, W. E. and Jehl, J. R. Ross Sea killer whale, *Orcinus orca*, distribution, behaviour, colour pattern and vocalizations.
SC/Jn81/KW7*	Awbrey, F. T., Evans, W. E., Thomas, J. A., and Leatherwood, J. S. Comparison of Ross Sea and Pacific northwest killer whale vocalizations.
SC/Jn81/KW8*	Ford, J. K. B. and Fisher, H. O. Killer whale, *Orcinus orca*, dialects as an indicator of stocks in British Columbia.
SC/Jn81/KW9*	Balcomb, K. C. III., Boran, J. R. and Heimlich, S. L. Killer whales in Greater Puget Sound, a population ideally suited for statistical modelling.
SC/Jn81/KW10	Ohsumi, S. Distribution and abundance of killer whales in the Southern Hemisphere.
SC/Jn81/KW11*	Yablokov, A. V. and Evans, W. E. Geographic variation in the color pattern of killer whales (*Orcinus orca*).

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* Published in this volume.

Appendix 3

LITERATURE CITATIONS DOCUMENTING KILLER WHALE SIGHTINGS CORRESPONDING TO GEOGRAPHIC AREAS OF DISTRIBUTION DEPICTED IN TEXT AND FIGURES 1 AND 2

Area	Literature citations
Atlantic Ocean	
Northeast (including Greenland and Barents Seas)	Geptner (1936) and Chapskii (1941) cited in Tomilin (1957); Jonsgård and Lyshoel (1970); Christensen *et al.* (1981); SC/Jn81/KW1.
Northwest	Sergeant and Fisher (1957).
Central	
Caribbean	Caldwell and Caldwell (1975).
Azores	Clark (1981).
West Africa	Bourne (1965) cited in Mitchell (1975); Evans and Yablokov (In ms).
Southern	
South America	Aguayo (1975); Budylenko (1981).
Africa	Budylenko (1981).
Pacific Ocean	
Northeast	
Alaska	Wada (1981); SC/Jn81/KW2.
North America and Mexico	Scheffer and Slipp (1948); Norris and Prescott (1961); Pike and MacAskie (1969); Balcomb *et al.* (1980); SC/Jn81/KW3, SC/Jn81/KW4; SC/Jn81/KW9.
Northwest	
Japan–China	Nishiwaki and Handa (1958); Kasuya (1971); Wang (1979); Anon. (1981); Wada (1981).
Pacific Ocean (continued)	
USSR	Zenkovich (1938); Nikulin (1941); Tomilin (1957); Sleptsov (1961); Ivashin and Votrogov (1981).
Central	
Eastern	SC/Jn81/KW3.
Hawaii	Richards (1952) cited in Leatherwood and Dahlheim (1978). SC/Jn81/KW3.
Southern	
South America	SC/Jn81/KW10.
Western	Blokhin (1981); SC/Jn81/KW10.
Indian Ocean	
Africa	Best (1971).
Australia	Blokhin (1981).
Arctic Ocean (US)	Cook (1926); Sleptsov (1961); Richardson (1981).
Antarctic Ocean	
Atlantic	Brownell (1974); Jehl *et al.* (1980); Dahlheim (1981).
Pacific	Brownell (1974); Jehl *et al.* (1980); Dahlheim (1981).
Indian	Brownell (1974); Best (1980).

Appendix 4

FOOD ITEMS OF KILLER WHALES BY GEOGRAPHIC AREAS

Area	Food Items	References
Atlantic Ocean		
Northeast	Herring (*Clupea spp.*) cod and squid, 'seal', birds (Norway), salmon (England).	Lepekhin (1805) cited in Tomilin (1957); Pike and MacAskie (1969); Jonsgård and Lyshoel (1970); Norman and Fraser (1949) cited in Martinez and Klinghammer (1970); SC/Jn81/KW1.
Northwest	Minke whale (*Balaenoptera acutorostrata*), seals (harp seal? *Phoca groenlandica*).	Sergeant and Fisher (1957).
Caribbean (St Vincent)	Leatherback turtle (*Dermochelys coriacea*), pygmy sperm whale (*Kogia breviceps*), *Stenella spp.*, sperm whale (*Physeter macrocephalus*), squid.	Caldwell and Caldwell (1969); R. V. Walker (unpublished).
Southern	Dolphins, fishes, pinnipeds.	Shevchenko (1975) cited in Budylenko (1981).
Pacific Ocean		
Arctic and Sub-Arctic	Walrus (*Odobenus rosmarus*), bearded seal (*Erignathus barbatus*), ringed seal (*Phoca hispida*), salmon (*Oncorhynchus spp.*), northern sea lion (*Eumetopias jubatus*), Alaskan fur seal (*Callorhinus ursinus*), gray whale (*Eschrichtius robustus*), bowhead whale (*Balaena mysticetus*), white whale (*Delphinapterus leucus*).	Scammon (1872); Cook (1926); Zenkovich (1938); Nikulin (1941); Nishiwaki and Handa (1958); Fay *et al.* (1979); SC/Jn81/KW2.
Northeast	Calfornia sea lion (*Zalophus californianus*), elephant seal (*Mirounga angustirostris*), Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), striped dolphin (*Stenella coeruleoalba*), salmon, Pacific halibut (*Hippoglossus hippoglossoides*), merganseropah (*Mergus serrator*), harbor seal (*Phoca vitulina*), deer (*Odocoileus sp.*), squid (moon fish), carcharhinid shark, minke whale, blue whale (*Balaenoptera musculus*), ray (*Torpedo californica*), common dolphin (*Delphinus delphis*), greenling (*Hexagrammidae sp.*), Ling cod (*Ophiodon elongatus*).	Scheffer and Slipp (1948); Brown and Norris (1956); Nishiwaki and Handa (1958); Norris and Prescott (1961); Rice (1968); Barr and Barr (1972); Tarpy (1979); Balcomb *et al.* (1980);
Northwest	Cod (*Gadus* spp.), flatfish, sardine, salmon, tuna, mackerel, Atka mackeral, bonito, cephalopods (squid and octopus), Dall's porpoise, striped dolphin, Baird's beaked whale (*Berardius bairdii*), goose-beaked whale (*Ziphius cavirostris*), sei whale (*Balaenoptera borealis*), pilot whale (*Globicephala macrorhynchus*), finless porpoise (*Neophocaena phocaenoides*), harbor seal.	Nishiwaki and Handa (1958).
Southern	No data.	

Appendix 4—*continued*

Area	Food Items	References
Indian Ocean	Pygmy sperm whale (*Kogia* spp.), minke whale (*Balaenoptera acutorostrata*), elephant seal (*M. leonina*).	P. Best (unpublished).
Antarctic	Antarctic cod (*Dissostichus mowsoni*), adelie penguin, crabeater seal (*Lobodon carcinophagus*), minke whale, pinnipeds, squid, fish, leopard seal (*Hydrurga leptonyx*), southern elephant seal (*M. leonina*).	Ivashin (1981); Mikhalev *et al.* (1981); Siniff and Bangston (1977) and Carrick and Ingham (1962) cited in Smith *et al.* (1981); SC/Jn81/KW6.
Other	Skate, smelt, capelin, herring (*Clupea harengus*), right whale (*Balaena glacialis*), humpback (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*), narwhal (*Monodon monoceros*), Weddell seal (*Leptonychotes weddelli*), sea otter (*Enhydra lutris*), white winged scoter (*Melanitta fisca leglandi*), black brant (*Branta nigricans*).	Tomilin (1957); Martinez and Klinghammer (1970).

Appendix 5

A RE-EXAMINATION OF PREGNANCY RATES AND CALF RATIOS IN *ORCINUS ORCA*

G. R. V. Anderson

INTRODUCTION

Estimates of pregnancy rates, and hence of expected numbers of young-of-year, observed birth rates and calf ratios have been reported as ranging from 5–42%. Variations of such magnitude may arise from extreme bias in sampling or for other reasons, and some resolution is required. Data from the 1979/80 USSR catch of killer whales in the Antarctic have been re-examined and pregnancy rates and expected numbers of young-of-year recalculated with account taken of a gestation period of 15 months.

PREGNANCY RATE DATA FROM ANTARCTIC CATCHES

Deriving estimated numbers of young-of-year from pregnancy rate data is relatively simple where gestation periods are 12 months or less and there is strong seasonality in breeding. Where a gestation period of greater than 12 months is expected, however, samples may include months in which both young to be born in that year and young conceived in that year are represented. Inflated estimates of birth rates may be produced. The tendency would be most marked in samples taken over a short period in which overlap may be expected.

Fig. 1 is a schematic representation of a strongly seasonal reproduction pattern with a 3 month breeding season and a 15 month gestation period—one pattern which may be considered for Antarctic killer whales. Killer whales were taken in January, February and March in 1980.

The distribution of 143 foetus lengths is given in Fig. 2. It is clearly bimodal.

Fig. 2b gives % frequency of pregnant females in the 1979/80 Antarctic killer whale catch by length. The significant number of pregnant females below 16 ft should

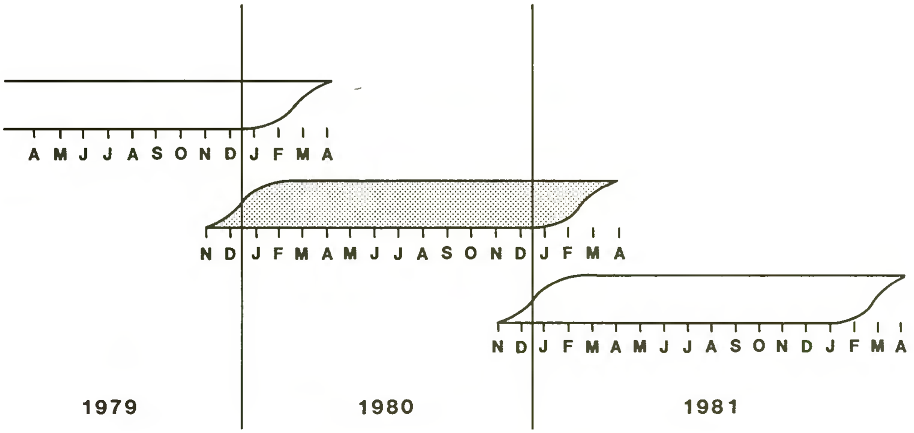

Fig. 1. 3-month breeding period and 15-month gestation.

Similar considerations apply to the data on pregnancy rates given by Mikhalev and Ivashin (1981) for 123 killer whales taken between November and March in the period 1961/62 to 1978/79. Two hundred and five males and 118 females were taken, 92 of which were examined for pregnancy; one was immature. Without foetal length distributions, it is assumed that only half of the pregnancies would lead to calves in the year of capture and the overall pregnancy rate has been halved to obtain the expected corrected pregnancies and the rate for an individual year per mature female (see Table below).

1961/62–1978/79

Total	Total ♀	Total examined	Mature	Pregnant	Overall rate/female	Corrected pregnancy of year/mature female
323	118	92	91	25	0.274	0.137

NORTHERN HEMISPHERE KILLER WHALE CATCHES

Estimates of pregnancy rates from Norwegian catches of killer whales for the period 1938/67 are given in SC/Jn81/KW4, Table 5 as 13.7%. Pregnancy rates were obtained from whales taken in most months of the year, unlike for the Antarctic catches. Correction of pregnancy rates to avoid the incorporation of more than one cycle of impregnation is less straightforward. As a first approximation, however, a correction may be made by reducing the overall pregnancy rate in proportion to months in which there is likely to be an overlap.

$$Pc = Po - 0.5\,\frac{(G - 12)\,Po}{12}$$

Pc = corrected pregnancy rate.
Po = observed pregnancy rate.
G = gestation period in months (15 months).

$$Pc = 59/430 - 0.5\;3/12\;(59/430)$$
$$= 0.120 \text{ pregnancies/mature female}$$

Data presented in SC/Jn81/KW1 are difficult to partition for the two years in question; foetuses over 100 cm given as occurring in the later September/February period do not appear in the earlier September/February period in Fig. 6. Conversely, foetuses under 100 cm in length are not reported for the second September/February period. As an approximation, however, if breeding is considered to be seasonal to a degree, with a peak in October/December for conception, then 6 of the 18 months listed will be months in which overlap in reproduction cycles occurs and

$$Pc = 51/129 - 0.5 \times 6/18\;(51/129)$$
$$= 0.33 \text{ pregnancies/mature female}$$

It is clear, however, that catches are not distributed evenly throughout the 18 months given in Fig. 6 of SC/Jn81/KW1, and the pregnancy/mature female can be expected to be less than the initially corrected figure.

No account has been taken in the foregoing of the possibility of proportional over-representation of pregnant females in catches through selection or through avoidance by females with calves of catch vessels. Should that occur, it would further depress the corrected pregnancy rate/mature female.

OBSERVED BIRTH RATES AND CALF RATIOS

Available observed birth rates and calf ratios for the northern Pacific and the Antarctic and their sources are given below

Birth rates			Source
0.089	calves/female/year		SC/Jn81/KW9
0.098	,, ,, ,,	cropped pods	SC/Jn81/KW4
0.069	,, ,, ,,	uncropped pods	

Calf ratios

Calves	(Mature?) females	Calves/ female	All other ages		
5	37	0.135	94	cropped pods	SC/Jn81/KW4
3	33	0.091	—	uncropped pods	
6	58?	0.102	147		
51 (7–12 ft)	274	0.186	736	(Antarctic)	SC/32/SM10

In examining the Antarctic data in SC/32/SM10, it is clear that some of the calves present would have been more than one year old on the basis of length. It is also likely that all 1980 calves were not yet born at the time of the survey, and the figure has not been reduced to remove 1+ juveniles. Mature females were taken as 40% of the total number of whales other than calves sighted.

SC/Jn81/KW1

Killer Whales in Norwegian Coastal Waters

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ABSTRACT

Observations reported by whalers and fishermen indicate that killer whales are present in all areas of the Norwegian coast throughout the year. No migration pattern has been discovered, but killer whales occur in greatest numbers in the Lofoten and Møre areas and off the southern west coast. A mean catch of 57 killer whales per year over the period 1938–1980 has not changed the length distribution in the catch. Decreasing fatness from 1951 to 1968 may have been caused by a decreasing availability of food. Reported weights indicate that meat constitutes 40% of total body weight, blubber 29%, bones 22%, and viscera 9%. Feeding behaviour and pod organization is described from recorded observations.

Female killer whales seem to reach sexual maturity at a length of 15 feet, and an age of about 6 years. Matings occur throughout the year, with a maximum in October-December. A gestation period of 12 months and one birth every second year is indicated.

Preliminary age determinations indicate continued growth in groups of body length up to 20–25 years and a life span of at least 35 years.

INTRODUCTION

An increasing number of observations of killer whales, *Orcinus orca,* in Norwegian coastal waters, has caused concern about interactions between killer whales and fisheries. The fishermen and their organizations particularly fear that an increasing number of killer whales may slow down the recovery of the Atlanto-Scandian herring. Catches of killer whales have been small compared to the take of minke whales, and in the period 1973–77 only negligible catches (0–7 per year) were taken. In order to promote the harvest of killer whales, the Norwegian Government in 1978 gave permission to catch this species outside the regular whaling season.

Jonsgård and Lyshoel (1970) analyzed data collected by whalers in the period 1938–67. The following report is based on corresponding data and on teeth and reproductive organs collected by whalers in the years 1978–80.

MATERIALS AND METHODS

Catch data are available in annual whaling reports (Anon. 1938–80). Additional information is available in reports given by whalers for 173 female and 143 male killer whales caught in the Lofoten and Vesterålen areas in 1978–80. The report for each whale includes date and position caught, sex and length, and weight of meat and blubber. If a foetus is present the length of this is also given. Body lengths in English feet are estimated by the whalers. These estimates do not differ significantly from true lengths (Jonsgård and Lyshoel, 1970).

The whalers also collected teeth from 68 females and 53 males, and reproductive organs from 47 females and 45 males, in 1979 and 1980. A reward was paid for each set of teeth and organs. For some of the whales, however, only one of the paired reproductive organs had been collected.

Ovaries were sliced in about 3 mm thick sections, and all *corpora* were classified and counted. Testes have not yet been examined. Teeth were cut in longitudinal sections, ground and etched for 30 hours in 10% formic acid. The growth layers were counted in reflected light under a binocular dissecting microscope (×6).

Questionnaires were sent to local fisheries administrations requesting reports on sighted killer whales. Marking has been carried out using 0.410 marks.

DISTRIBUTION

Fig. 1 shows the general distribution of killer whales along the coast of Norway. The figure is based on reports from whalers and fishermen. The observations cannot be used as a measure of numbers, but they do indicate areas of relatively high and low abundance. Killer whales are found all along the coast with concentrations on the southern west coast, at Møre, Lofoten and Finnmark. The whales have been observed throughout the year in all areas.

Only one brief marking cruise for killer whales has been organized (Christensen, 1978). However, a few killer whales marked on minke whale catchers and on herring surveys are listed in Table 1. No recovery of marked killer whales has yet been reported.

Table 1

Killer whales marked by Norway in the period 1977–81.

Mark no.	Date	Area	Position	Remark
N 1125	16 June 77	Svalbard	76°45′N 15°00′E	
N 1065	19 Jan. 78	Møre	63°10′N 07°50′E	
N 1131	18 Jan. 78	"	" "	
N 1296	19 Jan. 78	"	" "	Possible hit
N 1516	14 Oct. 80	Lofoten	68°14′N 14°45′E	
N 1514	16 Oct. 80	"	68°12′N 14°33′E	
N 1513	25 Feb. 81	Runde, Møre	62°29′N 05°45′E	
N 1518	25 Feb. 81	"	" "	
N 1519	2 Mar. 81	Fausken, Møre	62°35′N 05°35′E	
N 1517	3 Mar. 81	Buagr., Møre	63°09′N 06°41′E	

Fig. 2. Blubber weight of killer whales in percent of meat weight compared to overall average.

Table 3

Weight of meat, blubber and bones from some killer whales landed by Norwegian small type whalers.

Season	No. of whales	Weight in kg		
		Meat	Blubber	Bones
1943	2	630	406	520
1944	5	2,569	1,528	1,228
1946	1	1,320	610	470
1947	4	2,340	1,995	1,485
1948	4	2,399	2,026	1,344
1950	1	150	170	70
1952	2	3,600	2,610	1,325
1964	2	1,166	1,000	1,423
Total	21	14,174	10,345	7,865
Mean		675	493	375

schools are then concentrated. Pods of killer whales have also been observed circling over deep swimming shoals of herring, apparently to wait for the herring to come up to the surface. It has also been observed that killer whales pick herring one by one when they eat.

Whaling for killer whales is much more laborious and difficult than whaling for other small whales. Because of the way the killers organize themselves when they are frightened, 5–6 whaling vessels usually have to cooperate during the hunt. When a scattered pod of killer whales is frightened they always come together before they run away. This seems to be organized by the old males. Females with calves run first, and then the rest of the whales side by side. Small calves follow their mothers closely and appear to ride on the wave from the mother, but they have to blow more often. During the flight the whales dive and surface synchronously. If the whalers succeed in splitting a pod or killing the big male, the organization often collapses. Killer whales also seem to be able to distinguish between individual ships as demonstrated during a marking cruise in 1978 (Christensen, 1978). Before marking the killers showed no fear of the vessel, but after the first hit it was impossible to approach the pod again, while other vessels did not seem to frighten the whales.

STOMACH CONTENTS

Whalers have reported stomach contents from 95 killer whales caught in the Lofoten area. Of these, one had codfish mixed with herring, two had cephalopods and herring, eight had empty stomachs and the rest, 84 animals, had eaten only herring. The volumes of the stomach contents were estimated for 41 of the whales. These varied between 15 litres and 150 litres with a mean of 70 litres per stomach.

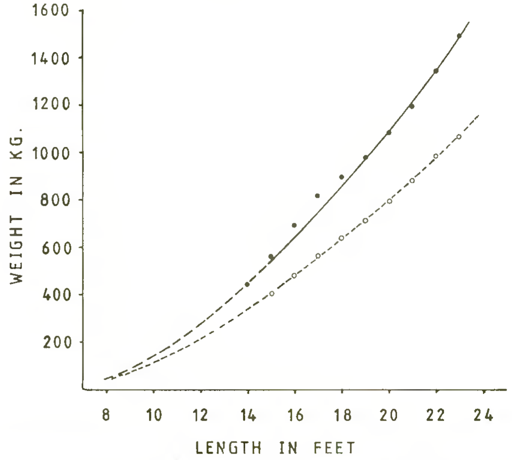

Fig. 3. Mean weight of meat (•——•) and blubber (○----○) of killer whales in relation to body length.

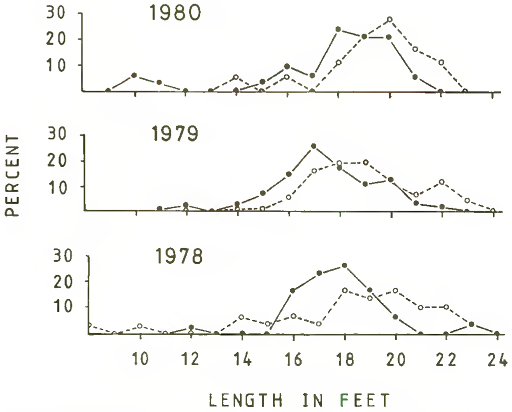

Fig. 4. Length distribution in catches of females (•——•) and male (○——○) killer whales taken by Norwegian whalers 1978–80).

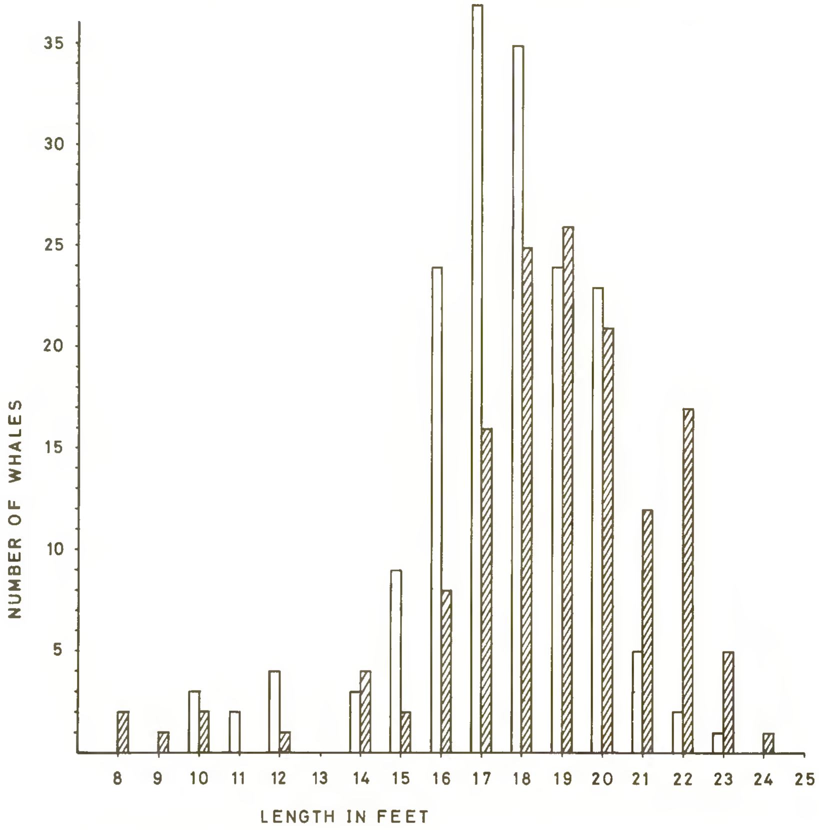

Fig. 5. Combined length distributions of female (☐) and male (▨) killer whales taken by Norwegian whalers in the Lofoten area in 1978–80.

REPRODUCTION

The length distributions of pregnant, lactating and all female killer whales taken in 1978, 1979 and 1980 are given in Table 4. The smallest pregnant whale was 15 feet long, and nearly half of the 16 feet long or longer females were either pregnant or lactating (43.4%).

From the ovaries collected by whalers in 1979–80 no female smaller than 15 feet was found to be sexually mature. Two of four 15 feet long females, two of three 16 feet females and 15 of 16 females in length group 17 feet were mature. These data suggest a median length at sexual maturity of about 15 feet for female killer whales in Norwegian waters. In Table 5, sexually mature females are classified from ovary analyses as pregnant, lactating or resting. The basic data available for individual whales are listed in the Appendix (Table IA and B). Excluding seven whales which could not be classified (marked with asterisks in Table 1A and B, unknown in Table 5), the data show that 43.2% of the females were pregnant, 22.7% were lactating and 34.1% were resting. When compared to the number of females classified as pregnant from ovary analysis, the number of reported foetuses suggests that nine foetuses (47%) may have been overlooked by the whalers (Table 1A and B).

AGE AND GROWTH

Lengths of 107 foetuses reported by whalers in the period 1938–67 and 1978–80 are plotted against date (ten-day periods) in Fig. 6. One foetus reported to be 10 feet (305 cm) long has been omitted in the figure, as there can be no doubt that a mistake was made. Two other, reported to be 250 cm and 256 cm long, are also omitted because either the lengths are overestimated or they represent extreme plus-variants. The foetus lengths show great variation within each month, and it is therefore difficult to construct a curve describing foetal growth.

Assuming a constant foetal growth rate and a pregnancy of 12 and alternatively 15 months, the estimated months of conception for the respective foetuses in Fig. 6 are shown in Fig. 7. Both of the two alternatives show that the majority of pairing occurs from September to January with a maximum in December.

An acid-etching of the ground half of a bisected killer whale tooth shows clear ridges and grooves in the dentine (Fig. 8). The initial axial growth of the tooth is rapid, and the layers are deposited as a series of elongated nested cones. The most recent growth layer groups (GLGs) in the occluded teeth of old whales are compressed and show up as very narrow ridges and grooves.

Table 4

Length distributions of pregnant, lactating and all female killer whales caught by Norwegian whalers in 1978, 1979 and 1980.

Length (feet)	10–14	15	16	17	18	19	20	21	22	23	Total
No. pregnant	0	1	11	16	15	6	5	1	0	1	56
No. lactating	0	0	1	6	2	2	0	0	0	0	11
Total no.	12	9	23	37	35	26	23	5	2	1	173

Table 5

Reproductive status of mature female killer whales based on analysis of ovaries collected by Norwegian whalers in 1979–80.

Length (feet)	15	16	17	18	19	20	21	Total	%
Mature	2	2	15	13	9	8	2	51	100.0
Pregnant	1	1	7	6	2	2	0	19	37.3
Lactating	0	1	5	2	2	0	0	10	19.6
Resting	1	0	3	2	3	5	1	15	29.4
Unknown	0	0	0	3	2	1	1	7	13.7

For the purposes of this study a GLG is defined as the distance from the bottom of one main groove in the etched surface to the bottom of the subsequent main groove. Accessory layers sometimes are numerous and can obscure the annual pattern of growth layers, but the readability is quite good in most of the teeth. The distance between accessory layers and main layers is considerably smaller than the distance between adjacent main groups.

The cementum layer on the teeth is extremely thin and therefore no attempt has been made to examine cemental growth layers. The growth of killer whales from the Lofoten area is illustrated in Fig. 9 by the relationship between total length and the number of groups of dentine growth layers. The female age at sexual maturity using this growth curve and a length at sexual maturity of 15 feet, is 6 GLGs.

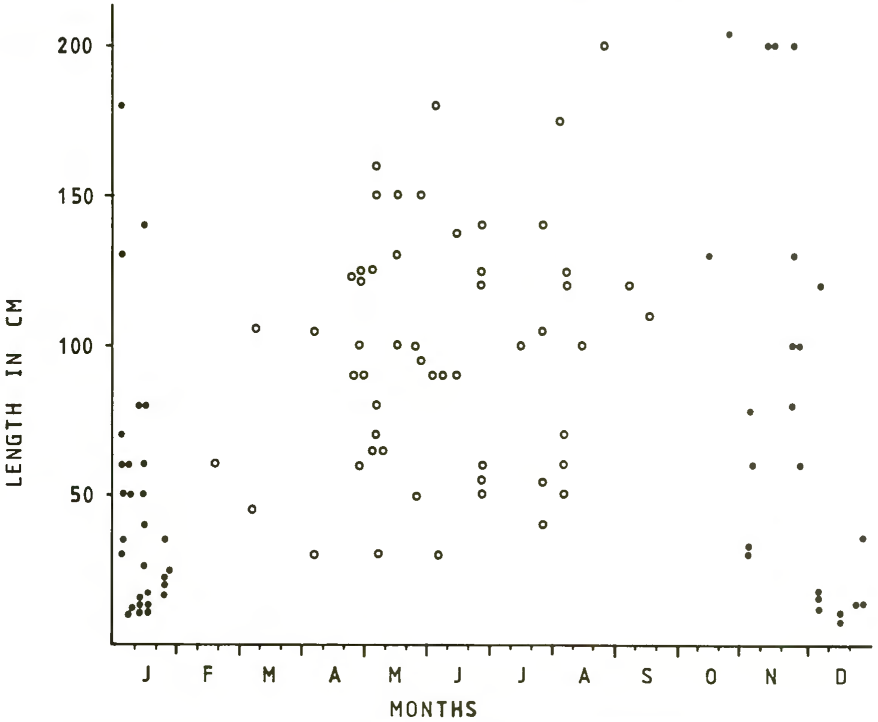

Fig. 6. Lengths of foetuses plotted against date of capture as reported by Norwegian whalers in 1938–67 (○) and 1978–80 (●).

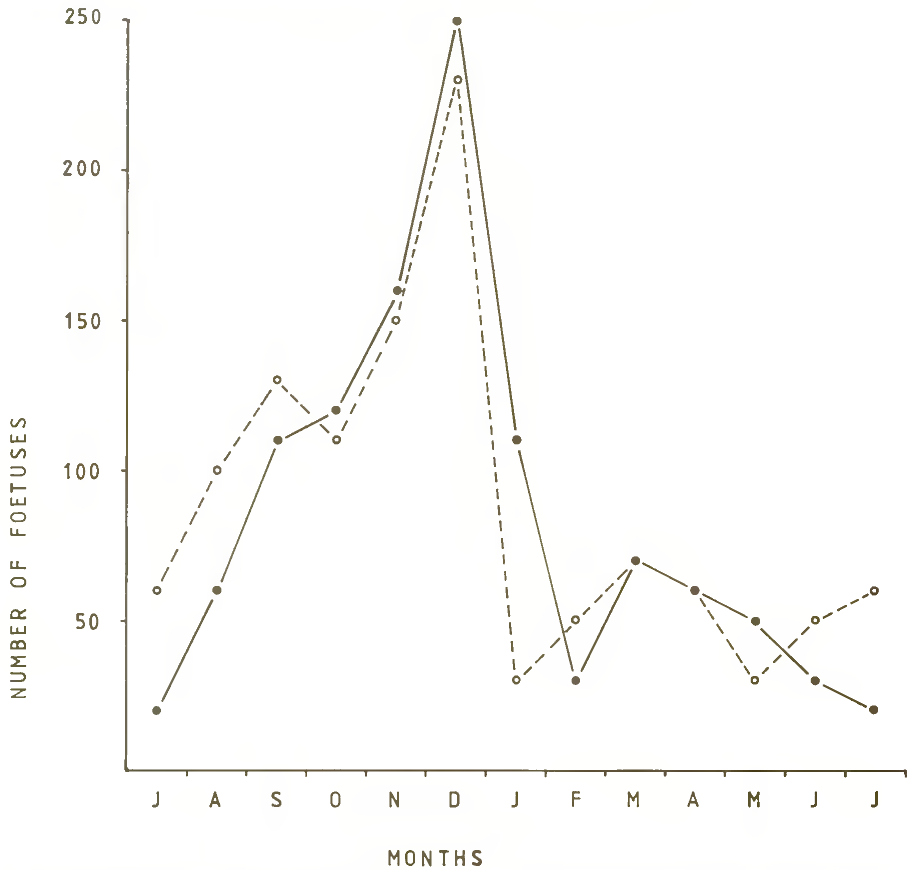

Fig. 7. Estimated month of conception for killer whale foetuses reported by Norwegian whalers 1938–67 and 1978–80. Assumed gestation 12 months (●——●) and 15 months (○---○).

DISCUSSION

The highest numbers of killer whales (Fig. 1) have been reported from the same areas as shown by Jonsgård and Lyshoel (1970) to be the main hunting areas in the period 1938–67. Also Collett (1877) reported that killer whales are often seen, and he (Collett, 1883) assumed that they were stationary along the coast. Our observations support Collett's (1883) assumption and indicate that killer whales are present in all areas of the Norwegian coast throughout the year. Numerous Norwegian vernacular names of the species also show that the killer whale is well known along the coast (Christensen, 1978). To date, none of the marked killers have been recaptured, and our knowledge of its migrations is limited.

Except for a few seasons with particularly high or low weights, the mean weight of meat per animal has remained about the same over the years (Table 2). This suggests that the length distribution of the catch has been about the same over the whole period from 1938 to 1980. This is also supported by the present length distributions (Fig. 4 and Fig. 5) when compared to length distributions given by Jonsgård and Lyshoel (1970). About 70% of the total number of killer whales caught by Norwegian whalers in the period 1938–1980 have been taken in Norwegian coastal waters, the rest in different areas in the North Atlantic (Christensen, 1975).

If the weight of the viscera is assumed to be about 10% of the combined weights of meat, blubber and bones, the total weight of the mean killer whale in Table 3 is about 1,700 kg. The weight proportions of the different parts of the body then are 40% meat, 29% blubber, 22% bones and 9% viscera. These proportions seem to fit well with what Lockyer (1976) found for other whales. The average total weight of all killer whales caught in the period 1938–80 (Table 2) then would be about 2,350 kg. This estimated total weight also fits well with published body length-weight data (Bigg and Wolman, 1975).

The main food item of killer whales along the Norwegian coast is herring, and the highest concentrations of whales are found in areas with herring. This is in accordance with Collett (1912), who stated that killer whales followed the great herring schools towards the coast of Norway. Also other fishes and cephalopods were recorded by the whalers. Nishiwaki and Handa (1958) reported Pacific halibut, moonfish and sharks as stomach contents in killers from the North Pacific. Eschricht (1863) also mentioned salmon and skate.

One fisherman has reported that when he was fishing for halibut west of Iceland in 1976–79, killer whales came

APPENDIX

Table IA

Data on the reproductive condition of mature female killer whales collected in Sept., Oct., Nov. and Dec. 1979.

Date	Length of female	Length of foetus	No. of corpora Graviditatis	No. of corpora Albicans	Lactating	Comments
3/11	15	0	0	1	—	
5/11	15	250	1	1	—	—
3/11	16	Not found	1	2	—	—
6/10	17	0	0	6	—	—
9/10	17	0	0	9	Milk	—
16/10	17	130	Not collected		—	—
6/10	17	Not found	1	5	—	—
24/10	17	0	0	13	—	—
29/10	17	Not found	1	5	—	—
3/10	17	0	0	5	Milk	—
3/10	17	0	0	8	Milk	—
3/10	17	60	1	14	—	—
2/11	17	0	0	0	Milk	½ ovary
2/11	17	35	1	5	—	—
2/11	17½	Not found	1	2	—	½ ovary
22/11	17½	0	Not collected		Milk	—
21/9	18	0	0	5	Milk	—
8/10	18	256	Not collected		—	—
8/10	18	Not found	1	3	—	—
29/10	18	?	?	4	—	½ ovary*
2/11	18	0	0	6	—	—
9/11	18	0	0	8	—	—
19/10	19	0	Not collected		Milk	—
19/10	19	0	Not collected		Milk	—
2/11	19	78	Not collected		—	—
3/11	20	0	0	7	—	—
5/11	20	0	0	13	—	—
19/12	20	?	?	2	—	½ ovary*

* Incomplete data, classification not possible.

Table IB

Sexual condition of mature female killer whales collected in January and February 1980.

Date	Length of female	Length of foetus	No. of corpora Graviditatis	No. of corpora Albicans	Lactating	Comments
29/1	16	0	0	1	Milk	
9/1	17	50	Not collected		—	
16/1	17	0	0	6		
23/1	18	?	?	2	—	½ ovary*
17/1	18	40	1	0	—	½ ovary
9/1	18	10	1	5	—	½ ovary
18/1	18	0	0	5	Milk	
23/1	18	Not found	1	3	—	
1/2	18	Not found	1	5	—	
25/1	18	?	?	3	—	½ ovary*
11/1	19	0	0	6	—	
21/1	19	?	?	1		½ ovary*
21/1	19	0	0	16	—	
25/1	19	Not found	1	9	—	
23/1	19	?	?	2	—	½ ovary*
31/1	19	0	0	8	—	
25/1	20	0	0	7	—	
21/1	20	0	0	7	—	
17/1	20	0	0	10	—	
15/1	20	Not found	1	8	—	
23/1	20	25	1	1	—	½ ovary
29/1	21	?	?	7	—	½ ovary*
14/1	21	0	0	6	—	

* Incomplete data, classification not possible.

SC/Jn81/KW2

Killer Whales in Alaska Documented in the Platforms of Opportunity Program

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ABSTRACT

Sighting records of over 1,100 killer whale (*Orcinus orca*) groups from Alaskan waters obtained from 1958 to 1980 are now in the National Marine Mammal Laboratory's Platforms of Opportunity Program data base. From a preliminary analysis, and with as yet no correction for sighting effort, killer whales are distributed primarily over the continental shelf in water less than 200 m deep in the eastern North Pacific (southeast Alaska to the eastern Aleutian Islands) but seem to concentrate near the 200 m contour over the shelf slope in the southeastern Bering Sea. In the Gulf of Alaska over 60% of our sightings were within 20 km of shore, while in the North Pacific from Kodiak Island to Unimak Pass they were uniformly distributed from shore to beyond 56 km. Pod size ranged from 1–100 animals, with only 1% of the groups containing 20 or more individuals. From a review of the literature, and in light of our sightings of concentrations near areas of known high productivity of fishes and other marine mammals, killer whales appear to feed upon fish when locally abundant and to switch to marine mammals when fish are less available.

INTRODUCTION

Killer whales (*Orcinus orca*) are one of the most readily identifiable cetaceans in the world. Although they occur in all oceans, little is known about their seasonal distribution, abundance or habitat use patterns. There is no estimate of worldwide abundance. Recent summaries of the literature on world distribution (Leatherwood and Dahlheim, 1978), in tropical and subtropical waters (Dahlheim, Leatherwood, and Perrin, 1982), on distribution (Dahlheim, 1981) and abundance in Antarctic waters (Allen, 1981) and inland waters of the Pacific Northwest (Bigg, MacAskie, and Ellis, 1976; Balcomb, 1978), review occurrence on a regional basis.

Literature documenting the occurrence of killer whales in United States, Canadian, and Soviet waters adjacent to the State of Alaska (Severinghaus, 1979) contains only anecdotal accounts. Since 1975, as a result of NOAA's Alaska Outer Continental Shelf Environmental Assessment Program, we have assembled a burgeoning data base of sightings of killer whales in Alaskan waters as part of our Platforms of Opportunity Program (Consiglieri, Braham and Dahlheim, in press).

This paper extends the summarized sightings previously reported by Fiscus *et al.* (1976) for the Gulf of Alaska and Braham *et al.* (1977) for the Bering Sea.

LITERATURE REVIEW

Killer whales are reported to be seasonal residents from the high Arctic and northwestern Alaska (Bailey and Hendee, 1926; Cook, 1926; Bee and Hall, 1956; C. Fiscus, observation 92 km north of Point Barrow), the western Chukchi Sea (Sleptsov, 1961a) and Bering Strait (Nikulin, 1946), the eastern Aleutian Islands especially near Unalaska Island (Murie, 1959; Kawamura, 1975; Braham *et al.*, 1977), the North Pacific Ocean (Scammon, 1874; Ohsumi, Masaki, and Wada, 1976), near Kodiak Island and in Prince William Sound, Gulf of Alaska (Pitcher, 1975; Fiscus *et al.*, 1976; Hall and Tillman, 1977).

The movements or migration patterns of killer whales may be in part related to availability of prey (Mitchell, 1975; Dahlheim, 1981). In-shore migration of fin fish, such as salmon (*Oncorhynchus* spp.) and other shoaling fish, are common killer whale prey in southeast Alaska, Prince William Sound and along the north side of the eastern Aleutian Islands and Alaskan Peninsula (Sleptsov, 1961b; Rice, 1968; Hall, 1981). The relative occurrence and density of other marine mammals that are potential prey for killer whales change from southeastern Alaska to northern Alaska.

Predation on gray whales (*Eschrichtius robustus*), walrus (*Odobenus rosmarus*) (Nikulin, 1941; Fay, Schults, and Dieterich, 1979), is believed to be common in the Bering, Chukchi, and Beaufort Seas. Belukha (*Delphinapterus leucas*) and bowhead whales (*Balaena mysticetus*) (Scammon, 1872; Cook, 1926) may occasionally be pursued by killer whales, however, the levels of predation on these two species is unknown.

Northern and California sea lions (*Eumetopias jubatus* and *Zalophus californianus*), elephant seals (*Mirounga angustirostris*), minke whales (*Balaenoptera acutorostrata*), Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), and striped dolphins (*Stenella coeruleoalba*) are commonly taken by killer whales near the Aleutian Islands, Gulf of Alaska and/or eastern North Pacific (Nishiwaki and Handa, 1958; Rice, 1968; Barr and Barr, 1972). Sleptsov (1961c) stated that killer whales in the western North Pacific switch to marine mammal prey species in summer when fish are less abundant or not available, and in winter months when fish descend to deep water. Hall (1981) observed similar prey selection behavior in Prince William Sound. Sleptsov (1961c) and Hall (1981) also reported that when fish are abundant, killer whales appear to exclude marine mammals from their diet. Balcomb (pers. comm.) observed killer whales in Washington State's Puget Sound waters take one Dall's and one harbor porpoise when pink salmon (*Oncorhyncus gorbuscha*) were abundant. Dall's porpoise and northern sea lions have been frequently seen near and on occasion directly interacting with killer whales without direct aggression by the killer whales (personal observations by authors).

Movements of killer whales in the North Atlantic are reported to be related to the migrations of rorquals, seals, and herring (*Clupea* spp) (Sergeant and Fisher, 1957;

Year-round occurrence is documented within Alaskan waters. However, at present we know little about their movements. In the Chukchi and northern Bering Seas the whales move south with the advancing pack ice and thus under such circumstances long-range movements occur. In the southern Bering Sea, Aleutian Islands and Gulf of Alaska waters, more restricted movements may prevail. In Prince William Sound, for example, summer-resident groups have ranges of approximately 20 km in length (Hall, 1981). In comparison, resident groups of killer whales in Puget Sound, Washington, are known to travel 140 km while foraging (Balcomb *et al.*, 1979), and transient pods are known to travel up to 610 km (Bigg *et al.*, 1976).

Group size ranged from 1 to 100. Only 1% of all groups observed contained 20 or more animals. Of special note are two groups estimated at 500 (Middleton Island) and 2,500 animals (Unimak Pass)[3]. Large aggregations have been reported for other geographical areas; several hundred were observed from the USCGC *Northwind* enroute to McMurdo sound in the Antarctic (Awbrey *et al.*, 1982). The biological significance of these large aggregations is unknown.

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REFERENCES

Allen, R. 1981. Abundance estimates for killer whales in Antarctic Areas III and IV. *Rep. int. Whal. Commn* 31: 151–2 (Appendix 2).

Awbrey, F. T., Thomas, J. A., Evans, W. E., Jehl, J. J. and Leatherwood, S. 1982. Ross Sea killer whale vocalizations: preliminary description and comparison with those of Pacific Northwest killer whales. Paper SC/Jn81/KW7 (published in this volume).

Bailey, A. M. and Hendee, R. W. 1926. Notes on the mammals of northwestern Alaska. *J. Mammal.* 7(1): 9–28.

Bakkala, R. G. and Smith, G. B. 1978. Demersal fish resources of the eastern Bering Sea: Spring 1976. NWAFC. Processed report, 404 pp.

Balcomb, K. 1978. Orca Survey 1977: Final report of a field photographic study conducted by the Moclips Cetological Society in collaboration with the U.S. National Marine Fisheries Service on killer whales (*Orcinus orca*) in Puget Sound. Unpub. report to Marine Mammal Division, Natl. Marine Fisheries Serv., Seattle, Wash., 10 pp.

Balcomb, K. C., Boran, J. R., Osborne, R. W. and Haenel, J. 1979. Observations of killer whales (*Orcinus orca*) in Greater Puget Sound, State of Washington. Marine Mammal Commission Report: NTIS, Washington, D.C.

Barr, N. and Barr, L. 1972. An observation of killer whale predation on a Dall porpoise. *Can. Field-Nat.* 86(2): 170–1.

Bee, J. W. and Hall, E. R. 1956. Mammals of northern Alaska on the Arctic slope. *Univ. Kans. Mus. Nat. Hist., Misc. Publ.* 8: 309 pp.

Bigg, M. A., MacAskie, I. B. and Ellis, G. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island with comments on management. Prelimin. unpub. rept, Arctic Biol. Sta., Ste. Anne de Bellevue, Quebec. 21 pp.

Braham, H. W., Everitt, R. D., Krogman, B. D., Rugh, D. J. and Withrow, D. E. 1977. Marine mammals of the Bering Sea: a preliminary report on distribution and abundance, 1975–76. U.S. Commer., Natl. Oceanic Atmos. Admin., NMFS, NWAFC, Mar. Mammal. Div., Seattle, Wash., Proc. Rep., 90 pp.

Consiglieri, L., Braham, H. W. and Dahlheim, M. E. in press. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. NWAFC Tech. Memo.

Cook, J. H. 1926. *Pursuing the Whale: a Quarter Century of Whaling in the Arctic.* Houghton Miffline (Boston, New York), 344 pp.

Dahlheim, M. E. 1981. A review of the biology and exploitation of the killer whale, *Orcinus orca*, with comments on recent sightings from the Antarctic, *Rep. int. Whal. Commn* 31: 541–6.

Dahlheim, M. E., Leatherwood, S. and Perrin, W. F. 1982. Distribution of killer whales in the warm temperate and tropical eastern Pacific. Paper SC/Jn81/KW3 (published in this volume).

Fay, F. H., Shults, L. M. and Dieterich, R. A. 1979. Natural mortality of marine mammals in Alaskan waters. Amer. Assoc. Advan. Sci., Proc. 29th Alaskan Sci. Conf., Abst.

Fiscus, C. H., Braham, H. W., Mercer, R. W., Everitt, R. D., Krogman, B. D., McGuire, P. D., Peterson, C. E., Sonntag, R. M. and Withrow, D. E. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. U.S. Dept. Commer., Natl. Oceanic Atmos. Admin., NMFS, NWAFC, Mar. Mammal Div., Seattle, Wash., Proc. Rep., 238 pp.

Hall, J. D. 1981. Aspects of the natural history of cetaceans of Prince William Sound. Ph.D. dissertation, Univ. of Calf., Santa Cruz, 153 pp.

Hall, J. D. and Tillman, M. F. 1977. A survey of cetaceans of Prince William Sound and adjacent vicinity, their numbers and seasonal movements. *Environ. Assess. Alask. Cont. Shelf.* 1: 681–708.

Jonsgård, A. and Lyshoel, P. B. 1970. A contribution to the knowledge of the biology of the killer whale *Orcinus orca* (L). *Nybt. Mag. Zool.* 18: 41–8.

Kawamura, A. 1975. Whale distribution in Bering Sea and northern North Pacific in the summer of 1974: results of a visual sighting study aboard the University of Hokkaido training vessel *Oshoro Maru. Bull. Japan. Soc. Fish. Oceanogr.* 25: 119–28.

Leatherwood, J. S. and Dahlheim, M. E. 1978. Worldwide distribution of pilot whales and killer whales. Naval Ocean Systems Center, Tech. Note 433, 39 pp.

Mitchell, E. (ed.). 1975. Review of biology and fisheries for small cetaceans—report and papers from a meeting of the IWC Subcommittee on Small Cetaceans, Montreal, April 1–11, 1974. *J. Fish. Res. Bd. Canada*, 32(7): 875–1,240.

Murie, O. J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. *North Am. Fauna.* 61: 1–364.

National Marine Mammal Laboratory. 1981. Report on studies of the incidental take of marine mammals, particularly Dall's porpoise, *Phocoenoides dalli*, in the Japanese salmon fishery. U.S. Dep. Commer., NOAA, NMFS, National Marine Mammal Laboratory, Seattle, Wash., 70 pp (unpubl.).

Nikulin, P. G. 1941. Chukotskii morzh [Chukotsky walrus]. *Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr.* [TINRO] 20: 21–59. [In Russian.] (Transl. by Bur. Commer. Fish., Seattle, Wash., 1953, 52 pp.)

Nikulin, P. G. 1946. O rospredelenii kitoobraznykh v moryakh, omyvayushchikh Chukotskiy poluostrov [Distribution of cetaceans in seas surrounding the Chukchi Peninsula]. *Izv. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr.* [TINRO] 22: 255–7. [In Russian] (Transl. by U.S. Nav. Oceanogr. Off., Washington, D.C., 1969, Transl. 428, 3 pp].

Nishiwaki, M. and Handa, C. 1958. Killer whales caught in coastal waters off Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 13: 85–96.

Ohsumi, S., Masaki, Y. and Wada, S. 1976. A note on the distribution of some smaller cetaceans in the North Pacific. Paper L20 presented to the IWC subcommittee on Small Cetaceans, London, June 1976.

Pitcher, K. W. 1975. Distribution and abundance of sea otters, Steller sea lions, and harbor seals in Prince William Sound, Alaska. Appendix A, *In:* D. G. Calkins, K. W. Pitcher and K. Schneider, *Distribution and abundance of marine mammals in the Gulf of Alaska.* Unpubl. manuscr., Alaska Dep. Fish Game, 333 Raspberry Rd., Anchorage, Alaska, 31 pp.

Rice, D. W. 1968. Stomach contents and feeding behavior of killer whales in the eastern North Pacific. *Norsk Hvalfanstid.* 57(2): 35–8.

Scammon, C. M. 1872. The orca. *Overland Monthly* 9(1): 52–7.

Scammon, C. M. 1874. *The Marine Mammals of the Northwestern Coast of North America.* John H. Carmany and Co: San Francisco, Calif. 320 pp.

Sergeant, D. E. and Fisher, H. D. 1957. The smaller Cetacea of eastern Canadian waters. *J. Fish. Res. Bd Can.* 14(1): 83–115.

Severinghaus, N. C. 1979. Selected annotated references on marine mammals of Alaska. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., NMFS, NWAFC, Natl. Mar. Mammal Lab., Seattle, Wash., Proc. Rep. 79–15. 178 pp.

---

[3] J. Branson, NMFS, Anchorage, Alaska, pers. comm. to Dahlheim, June 1980.

Sleptsov, M. M. 1961a. O kolebanii chislennosti kitov v Chukotskov more v raznyye gody [Fluctuations in the number of whales of the Chukchi Sea in various years]. *Tr. Inst. Morfol. Zhivotnykh* 34: 54–64. [In Russian.] (Transl. by U.S. Nav. Oceanogr. Off., Washington, D.C., 1970, Transl. 478, 18 pp.).

Sleptsov, M. M. 1961b. Raiony nagula kitov v Beringovom more [Feeding regions of whales in the Bering Sea]. Akad. Nauk SSSR, *Tr. Inst. Morfol. Zhivotnykh* 34: 65–78. [In Russian.] (Engl. abstr;. *Biol. Abstr.* 43(1), entry 551).

Sleptsov, M. M. 1961c. Nablyudeniya nad melkimi kitoobraznymi v dal'nevostochnykh moryakh I severo—zapadney chasti tikhogo okeana [Observations of small cetaceans in Far Eastern Seas and Northwest Pacific]. Tr. *Inst. Morfol. zhivotnykh* 34: 136–43. [In Russian] (Transl. No. 482, U.S. Naval Oceanogr. Off., Wash., D.C. 1970, 11 pp.).

SC/Jn81/KW3

Distribution of Killer Whales in the Warm Temperate and Tropical Eastern Pacific

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ABSTRACT

Records of killer whale occurrence for the warm temperate and tropical eastern Pacific Ocean are summarized from 11 strandings/collections and 581 observations. Levels of sighting effort are identified and used to interpret trends in distribution and movement. Killer whales occur from the Gulf of California more or less continuously along the Pacific Coast from 35°N to just below 5°S. Nearly all records off California and western Baja California were within 150 nm of the coast. North of 20°N, there were only four widely scattered offshore sightings beyond 150 nm. South of 20°N, 56.6% of all sightings were within approximately 300 nm of the coast and 78.4% within 600 nm. Two offshore clusters of sightings occurred, (1) 7° to 14°N, 127° to 139°W and (2) within a band between the equator and 5°N from the Galapagos Islands to 115°W. Herds contained up to 75 animals, with a mean of 5.3 animals per herd. An estimated 91% of the herds contained fewer than 10 animals.

INTRODUCTION

Killer whales, *Orcinus orca,* are cosmopolitan in distribution. There are records of their occurrence from virtually all oceans and major seas and from all ocean zones (for review see Leatherwood and Dahlheim, 1978; Dahlheim, 1981). Concerning their relative abundance by habitat, Mitchell (1975) states that although reported from tropical waters and the open sea, killer whales appear to be most prevalent in the colder waters of both hemispheres, with centers of greatest abundance within 800 km of major continents. Details adequate to support summary statements about the species' distribution and relative abundance, however, have only been reported for four areas: northeast Atlantic (Jonsgård and Lyshoel, 1970); northwest Atlantic (Sergeant and Fisher, 1957); inland marine waters of Washington State, US and British Columbia, Canada in the northeast Pacific (Bigg, MacAskie and Ellis, 1976; Chandler, Goebel and Balcomb, 1977); and coastal Japan (Nishiwaki and Handa, 1958; Kasuya, 1971). Beyond the odd sighting record there is little or no published information currently available on such populations in other regions. This paper reviews the data available from 1907 through 1979 on killer whale occurrence in the eastern Pacific Ocean from latitude 15°S and longitude 160°W, north to latitude 35°N and east to the coastline (Fig. 1).

MATERIALS AND METHODS

Data collection and methods of analysis were the same as those used by Leatherwood, Perrin, Kirby, Hubbs and Dahlheim (1980) for Risso's dolphin, *Grampus griseus*. We reviewed all previously published and unpublished strandings and collections of killer whales in the study area. These data were summarized and their locations plotted and examined for distributional patterns (Fig. 2). All previously published data on sightings of killer whales were reviewed and tabulated.

We examined 306 unpublished observations of free-ranging killer whales from the National Marine Fisheries Service (NMFS) tuna-dolphin observer program (1974–79). An additional 275 unpublished at-sea sightings were available from our files and from the files of other individuals and agencies. We carefully examined these unpublished sighting records for reliability of identification. Interviews with observers and/or the use of photographs assured us of the accuracy of many records. Descriptions of animals with striking black and white coloration, a white oval eye patch, and prominent erect dorsal fin (all diagnostic field characteristics of *Orcinus orca*) aided in verification of the remainder. We discarded questionable records.

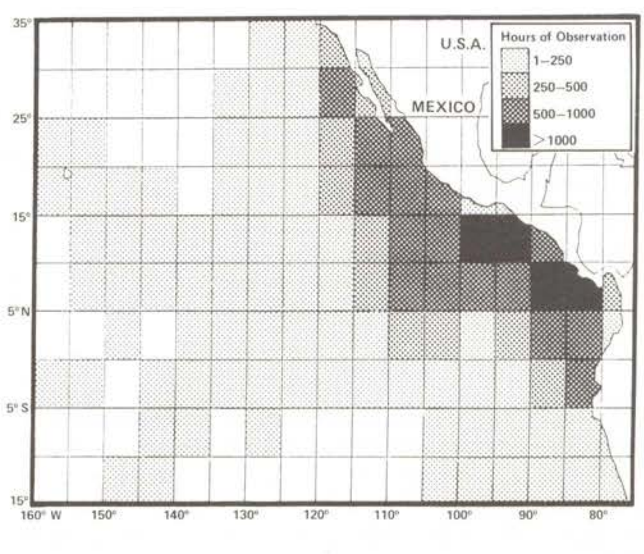

Fig. 1. Survey effort by NMFS dolphin-tuna observer program (1974–79), in hours of ship time by 5° square.

[1] National Marine Fisheries Service, National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, 7600 Sand Point Way, N.E., Seattle, Washington 98115, USA; [2] Hubbs Sea World Research Institute, 1700 South Shores Road, San Diego, California 92109, USA; [3] National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California 92038, USA.

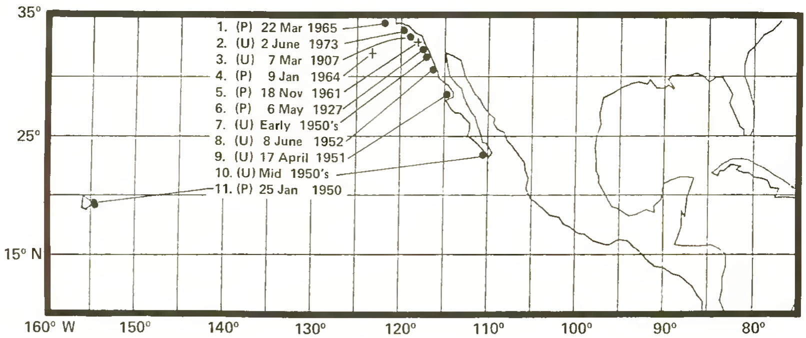

Fig. 2. Strandings (●) and collections (+) of killer whales (1907–79). (P) = Published record and (U) = Unpublished record. Numbers (1–11) refer to numbered paragraphs in the text.

Table 1

Principal sources of unpublished sighting records of killer whales in the study area. The two programs marked * maintained records of survey effort and are discussed in text

Institution/Activity	Approximate portion of study area covered	Approximate period and effort
I. US National Marine Fisheries Service		
A. Southwest Fisheries Center (Figs 1 and 3)		
1a. Dolphin-tuna observer program and associated research cruises	Principally lats 35°N to 15°S, coast to approximately long 160°N	1968–73—heavy effort nearshore Jan–Feb, declining and moving seaward throughout year, some coastward research Qtr. 4.
*1b. As above	As above	1974–79—generally as above, but effort data available as number of ship survey hours per 5° square (see Fig. 1).
B. National Marine Mammal Lab (Fig. 4)		
1. Research cruises	Lats 25°N to 35°N within 150 nm of shore¹	1960s—sporadic coverage.
2. Pelagic Fur Seal Program	N of lat 32°N and E of long 130°W¹	1960s—sporadic coverage.
II. Naval Ocean Systems Center (Fig. 3)		
A. Ship surveys	Within 100 nm of coast, So. Calif. & Baja Calif. and throughout Gulf of Calif.	1965–75—misc. cruises all seasons but principally winter and spring.
*B. Aerial surveys	Southern California Bight, above lat 32°N	1968–75—29,000 nm surveyed, representing all seasons (see Leatherwood and Walker, 1979).
III. Scripps Institution of Oceanography (Fig. 4)		
A. Research cruises	Principally within 100 nm of coast of California and Baja Calif, and in Gulf of California	1950–79—misc. cruises with no indication of survey effort by area or season.
IV. Smithsonian Institution Pacific Ocean Biological Survey (Fig. 4)	Lat 27°N to lat 35°N, coast to long 120°W	1967–68—unable to quantify effort by area or season.

¹ Principal program effort was farther north; effort in areas indicated was peripheral.

Additional sources include: The University of Southern California, the Natural History Museum of Los Angeles County, San Diego Museum of Natural History, Marineland of the Pacific, and numerous colleagues (Fig. 4).

Principal institutions contributing unpublished sighting records and statements of their effort in the area are listed in Table 1. Additional sources are referenced in acknowledgements. Records were grouped into two categories: (1) those sightings from the two programs in which effort has been quantified (NOSC aerial surveys, 1968–1975, and NMFS dolphin-tuna observer programs, 1974–79) and (2) miscellaneous sightings, including those for which there was no evidence of associated level of effort and those from programs for which effort could be only subjectively described.

For the NMFS dolphin-tuna observer program, 1974–79, effort—as number of ship survey hours per 5° square—and locations of sightings were plotted by quarter and examined for patterns of occurrence. All effort (Fig. 1) and sightings (Fig. 3) from all quarters were then combined and re-examined. For the years represented by this analysis, survey effort was sufficient at all seasons and latitudes for us to have detected major trends in distribution of cetacean fauna if they existed. Miscellaneous records were plotted (Fig. 4) and their distribution examined for evidence of patterns in killer whale occurrence.

Many of the sighting records included estimates of herd or group size. For those estimates stated as ranges (e.g. 10–20 animals), we used the midpoint for group size. If the midpoint was a half number, we rounded down.

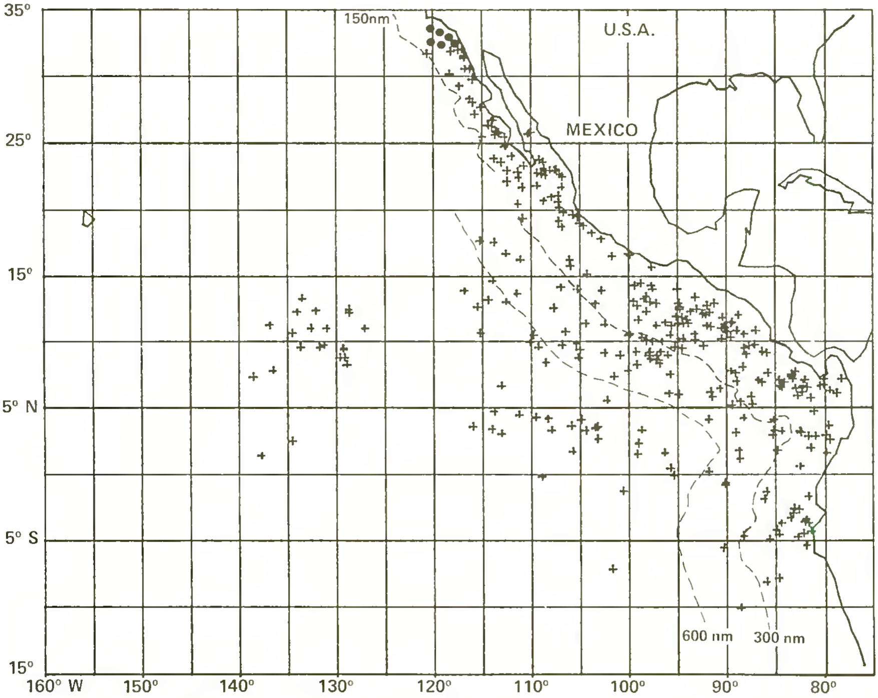

Fig. 3. Observations of killer whales by NOSC (●) and NMFS (+) programs (1968–79).

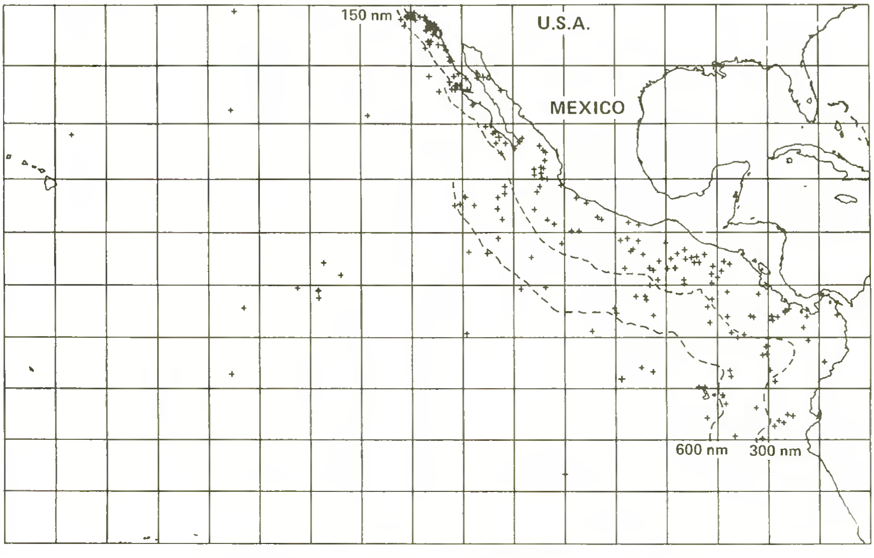

Fig. 4. Miscellaneous observations of killer whales (1939–76).

RESULTS

Strandings and collections

We were able to find data for only 11 specimens of the killer whale in the study area: nine strandings, one live-capture, and one killed (Fig. 2). The letters in parentheses below indicate whether the record has (P) or has not (U) been previously published. Specimens are discussed below in chronological order:

3. (U) On 7 March 1907 the US National Museum, Smithsonian Institution catalogued a water-worn earbone (USM 49909) collected on an unspecified date by B. Traske at Avalon, Santa Catalina Island, California (James G. Mead, pers. comm., 16 June 1980).
6. (P) On 6 May 1927 a 'juvenile' killer whale of unreported sex and length was collected at Hermosa Beach, Los Angeles County, California (33°50′N, 118°25′W). The skull is in the collection of the Museum of Natural History of Los Angeles County—LACM 30461 (Caldwell and Brown, 1964).
11. (P) On 25 January 1950 an estimated 6.09 m (20 ft) male killer whale washed ashore on Ka Lae, South Point, Kau District, Island of Hawaii. No materials were collected and we have been unable to locate the photographs or additional data reportedly collected. This account constitutes the first published record of a killer whale from the Hawaiian Islands (Richards, 1952).
9. (U) On 17 April 1951 a partial skull was collected by W. Mayer at Viscaino Bay, Baja California, Mexico. This specimen is in the Los Angeles County Museum—LACM 22791 (John Heyning, pers. comm., 3 Oct. 1980).
8. (U) On 8 June 1952 Carl L. Hubbs uncovered a weathered skull of a killer whale at Punta Cabras, Baja California, Mexico, at approximately lat 31°20′N (Hubbs' field notes, 1952).
7. (U) On an unspecified date, thought to have been in the early 1950s (Laura Hubbs, pers. comm., 1978), a killer whale was found dead on the beach at Del Mar, California. We were unable to locate data or specimen material from the stranding.
10. (U) On an unspecified date, though to have been in the mid-1950s (Laura Hubbs, pers. comm., 1978), a killer whale was found dead on the beach at 23°25′N, 109°20′W. Apparently, no materials were collected.
5. (P) On 18 November 1961 a 5.21 m (17 ft) female killer whale was taken alive in a turning basin in the harbor of Newport, California (33°58′N, 117°55′W) and transported to Marineland of the Pacific, Palos Verdes, California, where it died two days later. Details of the capture, behavior, and postmortem examination of the whale are included in the account of the stranding (Caldwell and Brown, 1964). The complete skeleton of the specimen is in the Museum of Natural History of Los Angeles County (LACM No. 52455).
4. (P) On 9 January 1964 a free-swimming 5.65 m (18.54 ft) female killer whale was collected at 35°50′N, 120°31°W. The stomach contained remains of 2 moonfish and 2 carcharinid sharks. The skull is in the collection of the National Marine Mammal Laboratory—NMML No. 9860 (Rice, 1968).
1. (P) On 22 March 1965 a 7.4 m (24.28 ft) male killer whale was collected at 34°23′N, 121°16′W. The stomach contained baleen and blubber of a minke whale, *Balaenoptera acutorostrata*. The skull is in the collection of the National Marine Mammal Laboratory—NMML 1965–4 (Rice, 1968).
2. (U) On 2 June 1973 a 3.30 m (10.83 ft) immature male killer whale was found dead on the beach at Willow Cove, Santa Cruz Island, California. This animal was estimated to have been less than 1.5 years old. The stomach contained miscellaneous remains of a young California sea lion, *Zalophus californianus*. The entire skeleton was collected and taken to the Natural History Museum of Los Angeles County—LACM No. 54444 (Leatherwood field notes, 1973).

At-sea sightings

We observed 19 published articles containing records or summaries of observations of free-ranging killer whales in the study area (Table 2). In addition we assembled 581 reliable previously unpublished sighting records (a complete list is available from the senior author).

The distribution of the 581 sightings, from sources dating 1939–79, can be summarized as follows. The six records from NOSC aerial surveys, 1968–75, and the 306 from NMFS dolphin-tuna observer program, 1974–79, are shown in Fig. 3. No significant differences were apparent in distribution by quarter which could not readily be explained by variable effort. Therefore, all effort (Fig. 1) and all sightings (Fig. 3) from this program were displayed as cumulative summaries for all years and months combined. In this form, the distribution of the sightings is very similar to that from the 269 miscellaneous records (Fig. 4). Records from both sources extend from the Gulf of California more or less continuously along the Pacific Coast from 35°N to just below 5°S. Nearly all records off California and western Baja California were within 150 nm of the coast. Above 20°N, there are only four widely scattered pelagic records beyond 150 nm. Below 20°N, 56.6% (223 of 394) of all records were within approximately 300 nm of the coast and 78.4% (309 of 394) of the records were within 600 nm of the mainland coast.

Of particular interest, however, are the two clusters of sightings which occurred, one in the same general offshore area where miscellaneous sightings were concentrated (7° to 14°N, 127° to 139°W), and a second within a band between the equator and 5°N from the Galapagos Islands to 115°W. There was no seasonal pattern apparent in occurrence of animals in either of these zones which could not be readily related to variable effort.

Of the 581 unpublished sighting records, 508 provided usable estimates of herd sizes. Distributions of estimated herd sizes from the two data sets were compared. Because they were not significantly different (ANOVA; $P = 0.05$) the herd size data were pooled and grouped by 5° latitudinal belts and by seasons. Number of animals sighted within a herd ranged from 1 to 75, with a mean of 5.3 animals per herd. About 91% of the herds observed contained fewer than ten animals (Fig. 5). No differences could be demonstrated among herd sizes from different areas (5° bands of latitude) or among seasons (ANOVA; $P = 0.05$).

Table 2

Previously published at-sea observations of killer whales in the eastern North Pacific.

Source	Date	Location	Number in herd
Lacépède (1804)	Unreported	08°15′N, 79°00′W	Unreported
Scammon (1874)	Unreported	Off southern Calif. and the Baja Peninsula	Unreported
Banks (1931)	Unreported	24°45′N, 110°34′W	2
Allen (1939)	Unreported	32°51′N, 117°19′W	Unreported
Anonymous (1951)	9 May 1951	32°35′N, 117°15°W	Unreported
Brown & Norris (1956)	29 Oct 1954	34°10′N, 119°50′W	5
	3 Nov 1954	34°25′N, 119°40′W	7
	4 Nov 1954	33°45°N, 118°30′W	2
	18 Dec 1954	33°45′N, 118°30′W	11
	28 Dec 1954	33°45′N, 118°30′W	10
	14 Dec 1955	33°45′N, 118°30′W	1
	Unreported	25°00′N, 141°45′W	Unreported
Harder & Johannessen (1960)	Unreported	03°30′N, 141°45′W	Unreported
Van Gelder (1960)	Unreported	30°30′N, 116°06′W	4
Anonymous (1961)	28 Oct 1961	32°50′N, 117°19′W	10
Norris & Prescott (1961)	1940	Estero de Punta Banda, Baja California, Mexico	Unreported
	? May 1949	33°45′N, 118°30′W	3
	? Apr 1952	24°30′N, 111°45′W	5–7
	? Aug 1955	33°30′N, 119°00′W	6
	25 Nov 1956	33°36′N, 118°03′W	6
	1 Dec 1956	32°38′N, 117°17′W	8
	26 Nov 1958	Iron Bound Bay, Catalina Island	5
Lévèque (1963)	Unreported	Galapagos Islands	Unreported
Stephens (1963)	Unreported	Point Dume, Calif.	1
	? Mar 1959	28°20′N, 115°39′W	1
	? June 1960	La Jolla Cove, Calif.	4
	? Jan 1962	33°00′N, 117°10′W	1
	? Apr 1963	33°00′N, 117°00′W	4
Burrage (1964)	26 Jan 1964	32°50′N, 117°18′W	Unreported
Fiscus & Niggol (1965)	19 Mar 1958	34°05′N, 120°25′W	1
	6 Feb 1959	35°15′N, 121°54′W	2
	20 Feb 1959	34°39′N, 122°21′W	2
Leatherwood, Evans & Rice (1972)	Unreported	Notes distribution off So. California; Baja California, Mexico; and in pelagic tropical Pacific	Unreported
Gilmore (1976)	2 Sept 1953	La Jolla, California	3
	12 Apr 1954	La Jolla, California	16
	28 May 1954	La Jolla, California	4
	? July 1954	La Jolla, California	Unreported
	4 Sept 1954	La Jolla, California	3
	? Sept 1955	La Jolla, California	2
	25 Sept 1955	La Jolla, California	2
	20 Mar 1956	La Jolla, California	1
Norris et al. (1976)	Jan–Dec 1975–76	Southern California Bight	Unreported
Aguayo (1975)	Unreported	Notes distribution off Chile	Unreported
Leatherwood & Dahlheim (1978)	Unreported	Notes distribution California coast, around islands of Baja California, Mexico, and in the Gulf of California	Unreported

DISCUSSION

From the available data, strandings of killer whales in the study area would appear uncommon. The low frequency with which killer whales strand along the heavily populated and well-patrolled shores of southern California and extreme northwestern Baja California may be related to the apparent scarcity of killer whales in that area (see discussion of NOSC aerial surveys above; Norris, Dohl, Guero, Hobbs and Honig, 1976) or to a generally low tendency of this species to strand even when it is present in substantial numbers. For example, in the waters of Puget Sound, Washington, and British Columbia, where a population which numbers at least 216 individuals (and is seasonally supplemented by other emigrants) is carefully monitored (Bigg *et al.*, 1976) and well known to the public (Chandler *et al.*, 1977), only nine strandings have occurred in the last eight years (Michael Bigg, 20 May 1981, pers. comm.). Strandings of killer whales appear to be equally rare in other parts of the world.

Killer whales were seen frequently in near-shore parts of the study area south of southern California. However, few strandings were reported for that area. One cannot rule out the possibility that the low number of stranding records in most of the study area simply reflects the inaccessibility of much of the shoreline of Baja California, Mexico, Central America, and northwestern South America and the infrequency with which these shores are visited by scientists and others who take note of such events. Certainly, no seasonal or geographical patterns can be ascertained from the data currently available.

The overall concentration of records nearshore clearly reflects a concentration of effort in those areas by the fishery on which these data depended. In 1974–78, alone, most coastal zones were surveyed from 500 to over 1000 hours. Those coastal zones were fringed by a band of zones which were surveyed for 250 to 500 hours. Outside of those, westward and southward, there was little or no effort. Effort was heaviest in the early months of the year,

Burrage, B. 1964. An observation regarding gray whales and killer whales. *Trans. Kans. Acad. Sci.* 67(3): 550–1.

Caldwell, D. K. and Brown, D. H. 1964. Tooth wear as a correlate of described feeding behavior by the killer whales, with notes on a captive specimen. *Bull. South Calif. Acad. Sci.* 63(5): 128–40.

Chandler, R., Goebel, G. and Balcomb, K. 1977. Who is that killer whale? *Pacific Search* 11(7): 25–35.

Dahlheim, M. E. 1981. A review of the biology and exploitation of the killer whale, *Orcinus orca,* with comments on recent sightings from Antarctic. *Rep. int. Whal. Commn.* 31: 541–6

Fiscus, C. H. and Niggol, K. 1965. Observations of cetaceans off California, Oregon, and Washington. *U.S. Fish Wildlife Serv., Spec. Sci. Rep. Fish.* 498. 27 pp.

Fiscus, C. H., Braham, H. W., Mercer, R. W., Everitt, R. D., Krogman, B. D., McGuire, P. D., Peterson, C. E., Sonntag, R. M. and Withrow, E. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. Northwest and Alaska Fisheries Center, Processed rep. Seattle. Wa. October 1976. 238 pp.

Gilmore, R. M. 1976. Killer whales in the San Diego area, Del Mar to the Coronado Islands. Newsletter of the American Cetacean Society, San Diego, Calif., pp. 4–5.

Hall, E. R., and Kelson, K. R. 1959. pp. 806–32. In: *Mammals of North America. Vol. 2,* Ronald Press, New York.

Harder, J. A. and Johannesen, C. L. 1960. Sustained swimming speeds of dolphins. *Science* 32, (3439): 1550–1.

Jonsgård, Å., and Lyshoel, P. B. 1970. A contribution to the knowledge of the biology of the killer whale, *Orcinus orca* (L). *Nytt Mag. Zool.* 18: 41–8.

Kasuya, T. 1971. Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based on aerial sighting records. *Sci. Rep. Whales Res. Inst., Tokyo* 23: 37–60.

Lacépède, B. 1804. p. 298. In: *Histoire Naturelle des Cetacea.*

Leatherwood, S., Evans, W. E. and Rice, D. W. 1972. *The Whales, Dolphins, and Porpoises of the Eastern North Pacific. A Guide to their Identification in the Water.* Naval Underseas Center, Tech. Publ. 282, 175 pp.

Leatherwood, J. S., and Dahlheim, M. E. 1978. Worldwide Distribution of Pilot Whales and Killer Whales. Naval Ocean Systems Center, Technical Note 443, 39 pp.

Leatherwood, S. and Walker, W. A. 1979. The northern right whale dolphin, *Lissodelphis borealis* Peale, in the eastern North Pacific. pp. 85–141. *In:* H. E. Winn and B. L. Olla (eds), *Behavior of Marine Animals. Vol. III,* Natural history of cetaceans, Plenum Press, N.Y.

Leatherwood, S., Perrin, W. F. Kirby, V. L., Hubbs, C. L. and Dahlheim, M. 1980. Distribution and movements of Risso's dolphin, *Grampus griseus,* in the eastern North Pacific. *Fish. Bull.* 77(4): 951–63.

Lévèque, R. 1963. *Orcinus orca,* orque. *Mammalia* 27(4): 609.

Mitchell, E. 1975. Report on the meeting on smaller cetaceans, Montreal, Apr 1–11, 1974. *J. Fish. Res. Bd Can.* 32(7): 914–16.

Nishiwaki, M., and Handa, C. 1958. Killer whales caught in coastal waters off Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 13: 85–96.

Norris, K. S., and Prescott, J. H. 1961. Observations of Pacific cetaceans of Californian and Mexican water. *Univ. Calif. Pub. Zool.* 63(4): 330–4.

Norris, K. S., Dohl, T. P., Guero, R. C., Hobbs, L. H. and Honig, M. W. 1976. Cetacea: Numbers, Distribution and Movements in the Southern California Bight. Section II: pp. 270–441. *In:* (Regents of the Univ. of Cal., ed.). Marine Mammals and Seabird Survey of the So. Calif. Bight Area. Vol. III. Draft Final Rep. 1975–1976. For BLM Contract No. 08550-CT5-28.

Reilly, S. B. 1977. The distribution of pilot whales, *Globicephala macrorynchus,* Gray, 1846, in the eastern Tropical Pacific. Master's thesis, California Polytechnic State University, San Luis Obispo, California. 80 pp.

Rice, D. W. 1968. Stomach contents and feeding behavior of killer whales in the eastern North Pacific. *Norsk Hvalfangsttid.* 57: 35–8.

Richards, L. P. 1952. Cuvier's beaked whale from Hawaii. *J. Mammal.* 33: 255.

Scammon, C. M. 1874. *The Marine Mammals of the North-Western Coast of North America, Described and Illustrated: Together with an Account of the American Whale-Fishery.* John H. Carmany and Co., San Francisco, Ca. 319 pp.

Sergeant, D. E., and Fisher, H. D. 1957. The smaller Cetacea of eastern Canadian waters. *J. Fish. Res. Bd Can.* 14(1): 83–115.

Stephens, W. M. 1963. The killer. *Sea Frontiers* 9: 262–73.

Van Gelder, R. G. 1960. Results of the Puritan-America Museum of Natural History expedition to western Mexico. *Bull. Am. Mus. Nat. Hist.* 1992: 5.

Walker, W. A. 1981. Geographical variation in morphology and biology of bottlenose dolphins (*Tursiops*) in the Eastern North Pacific. N.O.A.A., NMFS. Southwest Fisheries Center Administrative Report No. LJ-81-03C, 52 pp.

SC/Jn81/KW4

An Assessment of Killer Whale (*Orcinus orca*) Stocks off Vancouver Island, British Columbia

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ABSTRACT

A study of photographically identifiable individual killer whales was undertaken during 1973–81. In all, 30 pods were found, containing about 260 whales. A pod is a long term family or kinship group which periodically joins with others to form communities. Around Vancouver Island there are two resident communities and one transient community. The three communities do not associate with one another. Resident and transient killer whales differ in pod size and behaviour. The coastal range of movements for most resident pods is probably about 300 nm. Transient pods appear to range further. Births occur mainly during fall and winter. At birth, lengths average about 8 ft. First pregnancies generally occur at 16 ft, or at an age of at least 6.7 years. Sexual maturity occurs in males at 19 ft, or at an age of at least 12 yrs. A long term stability in pod composition permits direct measurement of vital statistics. The rate of calf production to an average age of six months is 10.30% per cow. The minimum interval between calving is three years. Many cows apparently rarely give birth. Annual natural mortality rates average 2.80% for bulls, 0.70% for cows and 2.30% for juveniles. Pods increase at an average net rate of 2.52% per year. Exploited pods have a slightly higher productivity than unexploited pods.

INTRODUCTION

A small live-capture fishery for killer whales occurred in British Columbia and Washington during 1962–77 to supply oceanaria (see Bigg and Wolman, 1975). This resulted in the need for an assessment of stocks in local inshore waters. Although the species was known to be relatively common here, no estimates were made of abundance or other population parameters. Prior to the live-capture fishery the species was unexploited in this region.

During 1973–81 a study was undertaken to determine abundance, movements and population biology of the species around Vancouver Island. As will be shown later, most of the whales inhabiting waters of British Columbia and Washington are probably seen here at various times of the year. The study was based on observations recorded while following photographically identifiable individual whales. Such individuals were encountered repeatedly.

The study began at the end of the live-capture fishery and thus monitors pod changes following exploitation as well as those in pods which were not exploited. Most pods cropped prior to the start of the study have now been identified from early photographs and tape recordings of vocalizations taken at the site of the live-captures. Ford and Fisher (1982) show that vocalizations of local killer whales exhibit unique features for each pod.

Bigg, MacAskie and Ellis (1976) prepared a preliminary report on abundance and movements of the species in local waters. K. C. Balcomb, J. Boran and co-workers (Orca Survey, Friday Harbor, Washington) have also conducted studies of the population biology and behaviour of some of the same whales using photographic identification of individuals. Two reports concerning their findings from 1976 to 1980 are available (Balcomb, Boran, Osborne and Haenel, 1980; Balcomb, Boran and Heimlich, 1982).

This report is a summary of analyses which are still in progress. Emphasis is placed on estimating the age at sexual maturity and comparing birth rates, natural mortality rates and changes in population size between exploited and unexploited pods. Only brief treatment is given for three basic findings of the study on individual identification and behaviour. These findings are now well established in the form of unpublished data at the Pacific Biological Station and to some extent in the preliminary reports by Bigg *et al.* (1976) and Balcomb *et al.* (1980, 1982). Detailed supporting data will be provided at a later date. The first finding is that each killer whale is uniquely marked and thus identifiable from a good photograph. This fact permits a count of all individuals within a pod. Secondly, pods are discrete long term breeding units which are composed of the same individuals. The absence of movement by individuals between pods permits an estimation of birth and mortality rates within each pod. Finally, the species in this region is non-migratory and thus the environmental controls which act on the population dynamics of pods occur within local waters.

METHODS

Killer whales were located primarily by volunteer observers who live or travel along the shore. Such people relayed by telephone, information on the location, time of sighting and direction of pod travel. Pods were intercepted using a 16 ft boat equipped with a 50 hp motor. As many as possible of the whales present were photographed and counted. Encounters were also made by waiting in areas frequently used by killer whales.

Photographs were taken with a 35 mm SLR camera and a 300 mm telephoto lens mounted on a shoulder brace. The film used was *Kodak* Tri X Pan taken and developed at 1200 ASA. Typically the shutter speed was 1/1000 sec. The most useful photographs were taken within 100 ft of the whale, at a right angle to the dorsal fin.

About 24,000 photographs were taken. J. Ford (University of British Columbia) took an additional 4,000 photographs while studying the acoustic behaviour of the species. These data are included in the current study. Several thousand other photographs were examined which were taken by a variety of people such as observers at the live-capture sites and boaters who encountered whales incidentally to marine activities. Individual whales were identified from negatives examined with a dissecting microscope. Some whales were so distinctively marked as to be identifiable by eye without a photograph.

The individual composition of pods J, K and L off southern Vancouver Island was determined from an exchange of information and photographs with K. C. Balcomb, J. Boran and co-workers (Orca Survey). The individual whale composition of these pods are the only data from this research group which are incorporated into the current study.

RESULTS AND DISCUSSION

1. Study area

The main study area was eastern Vancouver Island (Fig. 1). This was the most easily studied region in British Columbia because of the greater abundance of whales, the relatively protected waterways and the large number of observers here compared to other localities. Additional areas studied include Puget Sound, Washington, western Vancouver Island and the inshore coast north of Vancouver Island. No field studies were done on the Queen Charlotte Islands. Apparently there are few killer whales to be found there, according to fishermen.

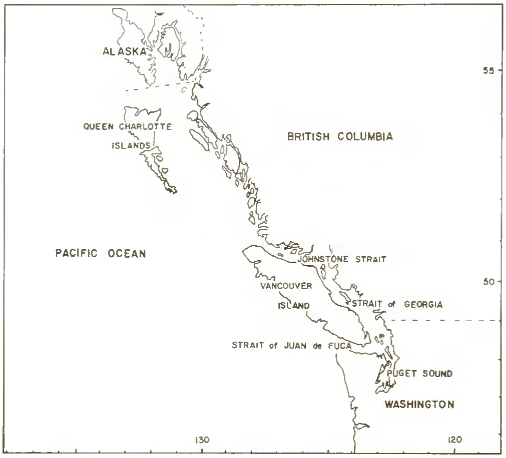


Fig. 1. Geographical locations mentioned in the text.

2. Number of encounters

Based on early photographs and current data, killer whales were recorded on 359 days during 1965–81. Generally whales were observed on 25–40 days during each year from 1973–80, except in 1974–75 when they were encountered on 58 and 80 days respectively. There were five encounters from early 1981 included in this study. Approximately 40% of encounters occurred during July–August with the remaining proportion from all other months of the year.

3. Individual identification

The features used for identification include shape and size of the dorsal fin, shape of the saddle patch, nicks and tears in the dorsal fin and scars on the saddle patch and back. Figure 2a–d shows examples of identifying features. The shape of the dorsal fin varies considerably from falcate to erect and from rounded at the apex to pointed. Numerous subtle differences exist when the fin is viewed in silhouette from the side. Relative size can usually be estimated by comparison with that of other killer whales. The fins of adult females do not change in shape or size with increasing age. Those of adult males seem to develop structural weaknesses eventually, which result in curling at the tip, less rigidity of the fin and, in three cases, complete collapse of the fin to lie flat along the side of the body.

The shape of the saddle patch is variable from closed, or horizontal tear drop pattern, to open as in the form of a thin S shape, with many intermediate patterns. Its shape on the left and right sides of the body is generally slightly different in detail, but it can differ substantially. Newborn calves do not have a pigmented saddle pattern for several months. Once formed the pattern does not change.

Nicks and tears occur most frequently on the posterior edge of the dorsal fin. These injuries range from barely noticeable to major tissue loss. In one case about two thirds of the fin was gone. Nicks and tears are permanent markings which do not fill with replacement tissue. Thus the shape and location of injuries are characteristic for individuals. This was shown to be true experimentally in an adult male. On 23 October 1973, a bull (K1) which had been captured by Sealand of the Pacific, Victoria, was surgically marked with two nicks, as shown in Fig. 3a–b, and then released. Since then the whale has been photographed each year up to 1980. The marks remained essentially unchanged. An important point to note concerning the shape of injuries on a growing fin is that these tend to elongate slightly and become more shallow.

Scars frequently occur on the saddle patch either as dark or white lines. If a scar remains for about two years it will become a permanent and useful mark. Some scars are not injurious enough to last a year. Nevertheless, such scars are still useful for identifying calves and young individuals which often have few other unique features.

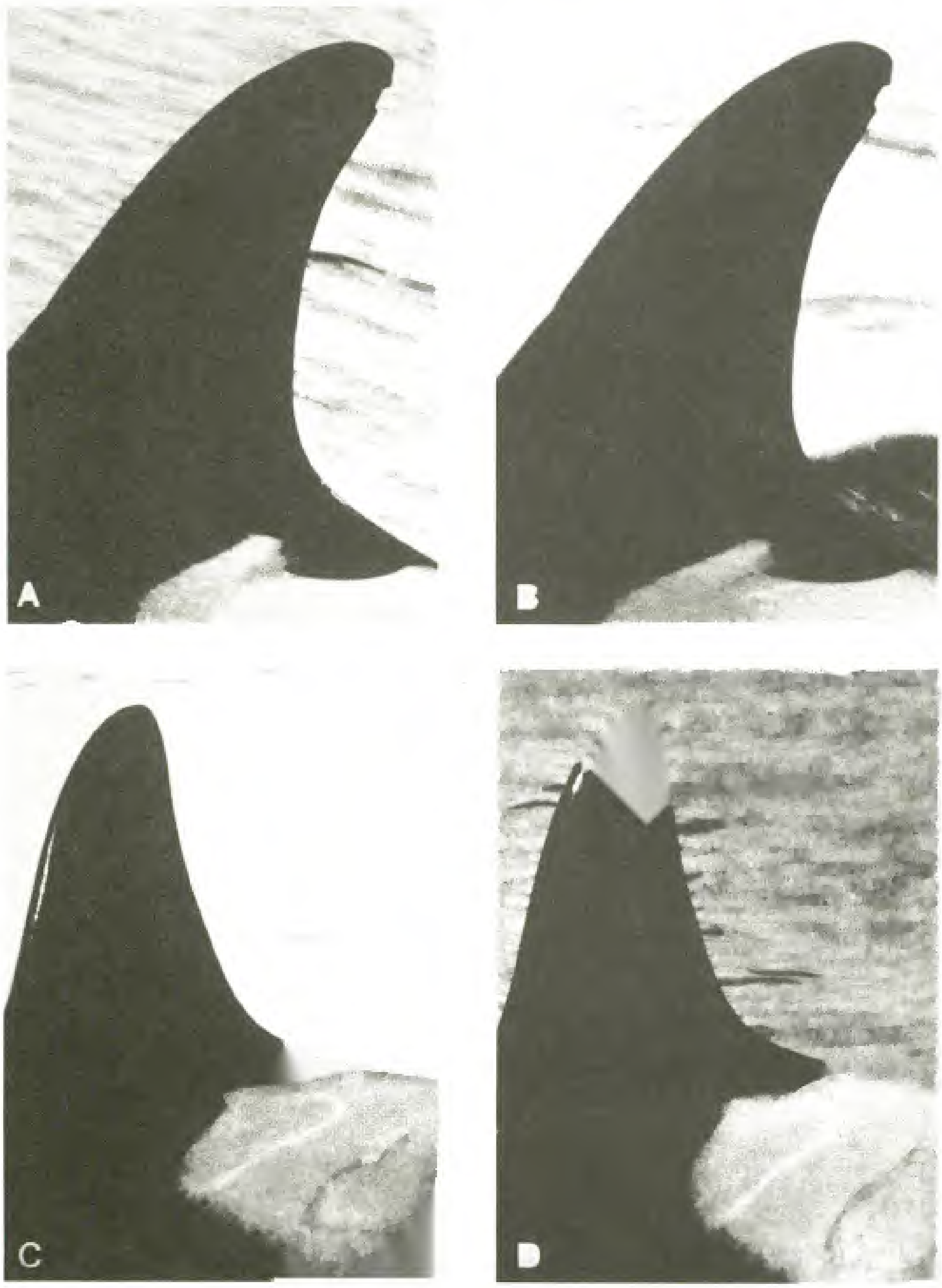
4. Recognition of sex and maturity

Adult males are the most easily recognized category, having an erect dorsal fin generally 3.5–5.5 ft in height. The identification for most bulls is probably certain. Some subjectivity exists when designating the year in which a maturing male should be called a bull when it is followed for several years.

Adult females are distinguished by a dorsal fin 1.5–2.5 ft in height which does not change in size or shape over several years. The shape for individuals varies considerably from falcate to triangular. Individuals which are accompanied by a calf are assumed to be adult females.

Most juveniles are distinguished by their obviously small fin and body size. Changes in dorsal fin size and subtle changes in shape are apparent each year as the whale grows. Difficulties in identification of this category arise when females approach maturity and the fin changes only slightly each year. Some cows are probably included in the juvenile category. Juvenile males and females cannot be distinguished from the shape of the dorsal fin or saddle patch.

Calves, during their first year, are recognizable by their very small size and close association with their mothers. The fin is short and usually falcate in shape. Calves do not have a saddle patch for the first few months.


A
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C
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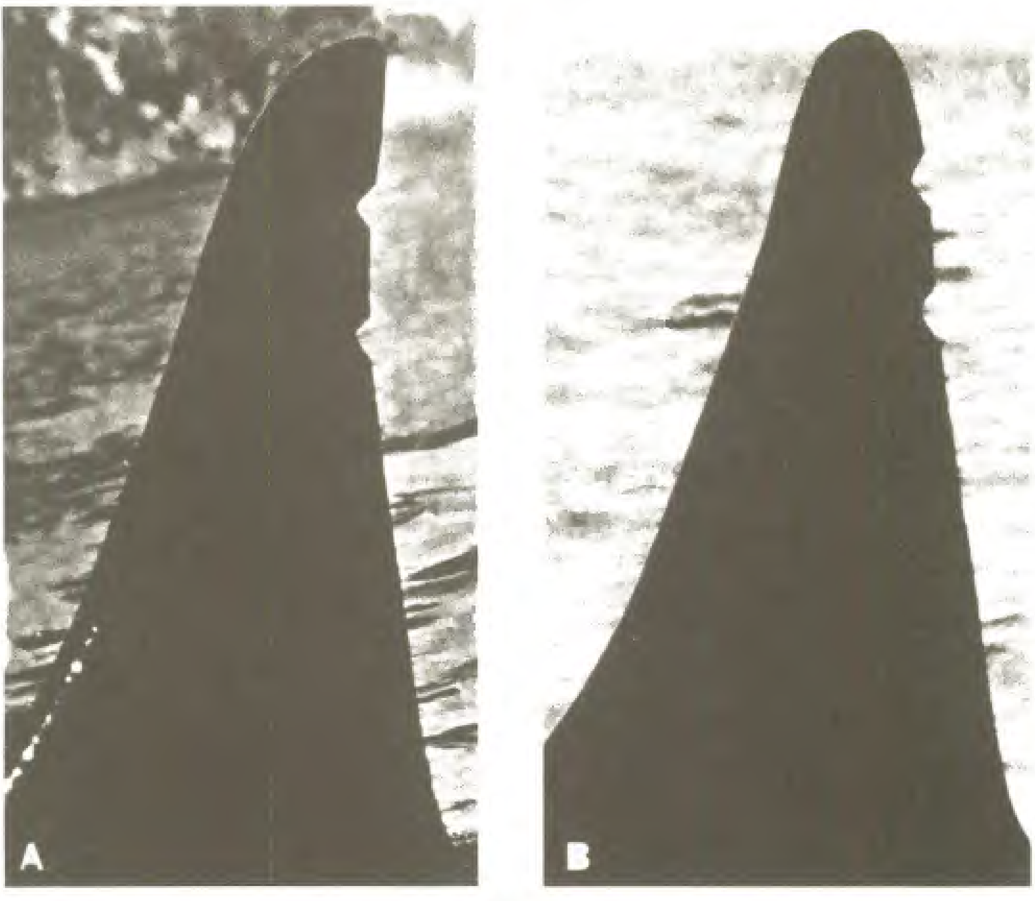
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Table 1

Pod size and composition from the most recent or most accurate count off Vancouver Island.

Pod	Size	Number of bulls	Number of cows	Number of juveniles	Number of calves
A1	14	5	4	5	0
A4	7	1	3	2	1
A5	12	1	4	6	1
B	8	5	1	2	0
C	9	4	3	2	0
D	10	4	2	4	0
E	5*	1+	?	?	?
F	1	1	0	0	0
G	19*	4	5	11	1
H	6	1	2	3	0
I1	16*	4	5	6	1
I11	6	0	3	3	0
J	19	3	8	7	1
K	10	2	5	3	0
L	50*	9	16	24	2
M	3	1	1	0	1
N	1	1	0	0	0
O	5	1	3	1	0
P	2*	1	?	?	0
Q	5	0	3	2	0
R	19*	3	?	?	1
S1	4	0	?	?	0
S8	1	0	1	0	0
T	4*	2	?	?	?
U	4	0	1+	?	1
V	2	1	?	?	0
W	9*	3	?	?	0
X	5	0	1+	?	1
Y	3	1	1	1	0
Z	2	1	?	?	0
Total	261	60	72	82	11

* Size accuracy is probably within one individual; all other pod sizes are thought to be exact. The juvenile category excludes calves but may include a few cows.

confined year round to Georgia Strait and Puget Sound, about 230 nm (425 km). Pods K and L travel throughout the range of J pod and also into Juan de Fuca Strait and to areas of unknown extent off the west coast of Vancouver Island and Washington. However, these two pods occur off eastern Vancouver Island during all months of the year and thus do not range far beyond the study area. Their range is at least 300 nm (556 km).

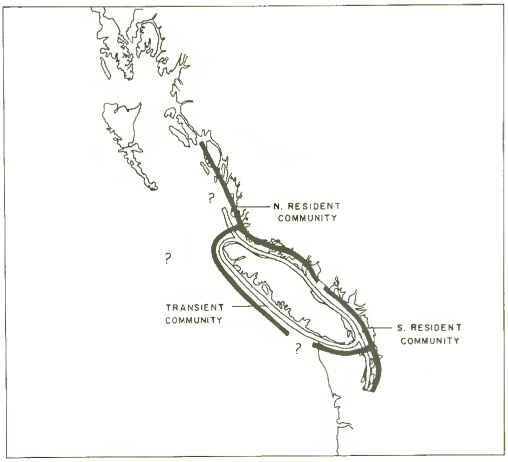

Fig. 4. The usual ranges of two resident communities and one transient community of killer whales around Vancouver Island.

The northern community consists of 12 pods, A1, A4, A5, B, C, D, G, H, I1, I11, R, and W, with about 135 whales. Its coastal range is about 300 nm (556 km) from northern Georgia Strait to about 100 nm (185 km) south of the northern border of British Columbia. Summer studies indicate that killer whales rarely occur off the northern border. Pod A5 is known to range along the coast for at least 270 nm (497 km). As with the southern community the range of individual pods varies. Some pods (G, I11) are known to frequent the west coast of Vancouver Island. The extent of travel to offshore areas is unknown. The coastal range of most resident pods is probably about 300 nm.

The geographical discreteness of the two resident communities suggests a territorial division of the waters off eastern Vancouver Island. Only on rare occasions do pods from one community travel into the range of the other. About 210 nm (390 km) separate the central areas of summer abundance of the two communities along eastern Vancouver Island. This is only 2.5 days travelling time at an average speed of 3.5 knots.

The transient pods form a community similar to that of the residents. Of the 15 transient pods identified ten are known to associate with one another. Unlike the resident pods, they comprise a single community which forms a loose network of associations encircling Vancouver Island. The transient pods do not respect the boundary line of resident pods. The largest range of a transient pod (Q) is 340 nm (630 km). The ranges of other pods vary. The extent of movement offshore is not known.

(e) Pods cropped

The identity of pods which were cropped during the live-capture fishery was determined from photographs and tape recordings of vocalizations. The photographs used were those of distinctively marked individuals which were caught and later released or were not captured but remained near the entrapped whales. Generally only a few useful photographs were available for most captures. Because pods sometimes travel together it is possible that some other captured pods were also present but not photographed. J. Ford (pers. comm.) identified several pods which were captured, by recognizing the unique vocalizations of each. He used tape recordings obtained at the capture site or from whales which had been taken to oceanaria.

Table 2 gives data on the number, sex and length of whales removed from pods identified as having been cropped. From 1962 to 1977, a total of 65 killer whales was removed from pods around Vancouver Island. Of these, the pods for 53 whales were identified. A total of 14 whales in 3–4 pods were removed from the northern resident community, 34 whales in three pods from the southern resident community and five whales from two transient pods. An additional 12 whales were removed from pods which have not yet been identified. Data on these latter captures are given in Table 3. Only one whale came from northern Vancouver Island, ten came from southern Vancouver Island and one from the west coast of Washington.

Of the 30 pods recorded around Vancouver Island only nine are known to have been cropped. By far the largest number (34) were removed from the three pods in the

Table 2

Number, sex and length of individuals removed from pods known or suspected of having been cropped.

			Immature					Mature	
			8–11 ft			12–15 ft	12–18 ft	16 ft+	19 ft+
Pod	Capture date	Number removed	F	M	?	F	M	F	M
N. Resident									
C[1,2]	June/65	1							1
I11[1]	July/67	1					1		
A(A5)[2]	Apr/68	6		1		1	1	3	
A5[1,2]	Dec/69	6	1			2	2	1	
		14	1	1		3	4	4	1
S. Resident									
J or K or L[2]	July/64	1					1		
J or K or L[2]	Oct/65	2				1		1	
K[1,2]	Feb/67	8	1	2		1	2	1	1
J[1], L[2]	Oct/68	5		1			3		1
J, K, L[1,3]	Aug/70	11	1	4	2	1	2	1	
L[1]	Aug/71	3				2	1		
J[1]	Mar/72	1					1		
K[1]	Aug/73	1						1	
L[2]	Aug/73	2					1	1	
		34	2	7	2	5	11	5	2
Transient									
M[1]	Mar/70	3	1			1		1	
Q[1]	Aug/75	2				1		1	
		5	1			2		2	
Total		53	4	8	2	10	15	11	3

[1] Evidence of pod identification from photographs.

[2] Evidence of pod or identification from vocalizations provided by J. Ford (pers. comm.).

[3] J not identified but almost certainly present due to the large number captured (80 whales) and the fact that these three pods often travel together and with no other pods.

southern resident community. Most, if not all, of the ten whales taken from the as yet unidentified captured pods off southern Vancouver Island probably also came from the same three pods. These are by far the most accessible for capture in this area. Assuming that the southern resident community was cropped of 44 whales it is possible to determine the likely extent of reduction. In 1974, which was essentially the end of the cropping period, these three pods contained 67 individuals (J = 14; K = 10; L = 43). It will be shown later that cropped pods have an annual net increase of 3.01%. By back calculating the population level to 1967, using the annual increase less annual cropping, a reduction in total abundance of about 27% (89 to 65) occurred from 1967 to 1973. These pods were thus moderately reduced and were included as cropped pods in the following comparisons between cropped and uncropped pods.

Within the northern community probably only one pod, A5, was cropped to any extent. In 1968–69, at least six and probably 12 whales were removed. Not until 1973 was a count of the pod made, at which time it contained ten individuals. As this is a substantial reduction it was included as a cropped pod in subsequent analyses. The removal of single individuals from pods C and I11 in 1965 and 1967 can probably be considered as having a negligible effect on productivity of these pods during 1973–80. Thus, for purposes of subsequent analyses, these pods were considered uncropped. The two transient pods which were cropped both experienced large proportional reductions (although small in numbers) and were included as cropped pods.

The sex ratio of whales removed from pods was about equal (31 females, 30 males). All sizes were taken although most were immature.

6. Body growth

(a) Birth size

Nishiwaki and Handa (1958, p. 91) examined records kept by whalers off Japan and concluded that birth occurred at about 9 ft. Based on the same type of data, Jonsgård and Lyshoel (1970, p. 47) suggested that off Norway birth lengths were close to 7 ft. Lengths taken from five newly born stranded calves in British Columbia indicate a birth size of about 8 ft. Four males were examined by staff of the Pacific Biological Station and found to be 7 ft 4.5 in, 7 ft 5 in, 8 ft 0 in and 8 ft 2.5 in. Carl (1946, p. 27) reported a newly born female killer whale at Cherry Pt., Vancouver Island of length 8 ft 1 in.

(b) Postnatal growth

Males attain an average maximum length of 29.2 ft and females an average of 25.6 ft based on records of whalers. The maximum lengths given for males and females, respectively, in five separate studies were as follows: 31 ft and 27 ft off Japan (Nishiwaki and Handa, 1958, p. 91); 32 ft and 28 ft off Norway (Jonsgård and Lyshoel, 1970, p. 48); 24 ft and 23 ft off Norway (Christensen, 1980, p. 12); 29 ft and 25 ft in the Southern Hemisphere

Table 3

Number, sex and length of individuals removed from captures for which no pod identity has yet been assigned.

				Immature					Mature	
				8–11 ft		12–15 ft		12–18 ft	16 ft+	19 ft+
Region	Capture date	Number removed	?	F	M	F	?	M	F	M
NE Vancouver Is.	July/68	1						1		
S. Vancouver Is.	Sept/62	2							1	1
	July/66	1						1		
	Feb/68	2			1				1	
	Apr/69	1								1
	Oct/69	1	1							
	Feb/70	1					1			
	Aug/70	1		1						
	Aug/77	1		1						
		11	1	2	1		1	2	2	2
W. Washington	Mar/73	1							1	
Total		12	1	2	1		1	2	3	2

(Mikhalev, Ivashin, Savusin and Zelenaya, 1981, p. 556); and 30 ft and 25 ft in the Antarctic (Ivashin, 1981, p. 225).

The body growth rate recorded in captive killer whales provides a guide to the growth rate potential in the wild. Fig. 5 depicts the likely growth pattern of males and females from 9.5 ft to 23 ft based on three captive males and five captive females. The growth curves for individual whales have been aligned approximately, to show the general growth pattern for each sex. Up to about 16 ft in length males and females grow at similar linear rates averaging 1.2 ft/yr for the five year period required to increase from 10 ft to 16 ft. There are data on only two males and one female longer than 16 ft. Growth after 16 ft appears to slow in both sexes with the female ceasing growth after 19 ft while the two males continue to grow.

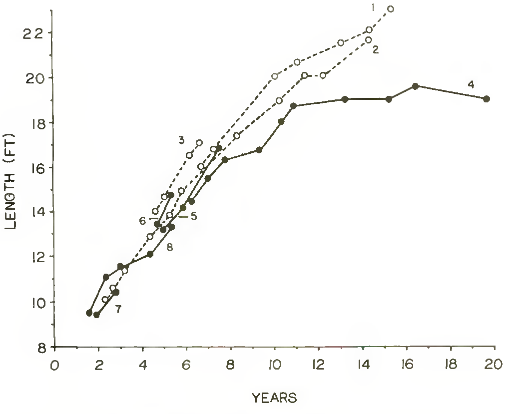

Fig. 5. Body growth in three captive male and five captive female killer whales. Open circles = male; solid circles = female; 1 = Haida (Sealand of the Pacific); 2 = Hyak (Vancouver Public Aquarium); 3 = Orky (Marineland of the Pacific); 4 = Skana (Vancouver Public Aquarium); 5 = Corky I (Marineland of the Pacific); 6 = Shamu (Sea World); 7 = Patches (Marineland of the Pacific); 8 = Miracle (Sealand of the Pacific).

7. Reproduction

(a) Length and age at sexual maturity

Most females appear to become pregnant for the first time at 16 ft in length. Jonsgård and Lyshoel (1970, p. 46) report length frequencies for 59 pregnant females taken off Norway (Table 4). The smallest pregnant female was 15 ft. A marked increase in the number of pregnancies occurred at 16 ft. Data collected by Christensen (1980), also off Norway, confirm these findings (Table 4). Mikhalev *et al.* (1981, p. 559) observed that all females 17–25 ft in length taken in the Southern Hemisphere were mature (Table 4). Only one smaller female was examined, it being 12 ft and immature. Assuming that births occur at 8 ft, most first pregnancies at 16 ft and the annual growth rate is 1.2 ft/yr, then females mature at about age 6.7 yr. However, this figure is probably too low for killer whales in the wild as the latter probably grow more slowly than captive whales.

Available data suggest that males mature at about 19 ft in length. Jonsgård and Lyshoel (1970, p. 46–47) examined the testes of three males taken off Norway and found that two, of body lengths 22 ft 10 in and 21 ft 8 in, were sexually mature while one, of 18 ft 4 in, was approaching maturity. They concluded that maturity occurs at 19 ft. Mikhalev *et al.* (1981, p. 557) recorded the weight of one testis from each of 57 males of body lengths 18–28 ft taken in the Southern Hemisphere. Weights increased sharply from 18 ft (4.4 kg, $n = 2$) to 19–20 ft (7.0 kg, $n = 6$), increased slightly at 21 ft (8.8 kg, $n = 6$) and again at 22–28 ft (11.5 kg, $n = 43$). On the basis of increases in testis weight, these authors felt that sexual maturity probably begins at 21 ft. However, these data could also be interpreted to suggest maturity at 19–20 ft.

Length at sexual maturity in males can be indicated by the body length at which the dorsal fin of the male is clearly longer than that of the female as the large size of the dorsal fin in the male is a secondary sex characteristic. Fig. 6 shows the relationship between dorsal fin height and body length in both sexes. The data come from measurements of three captive whales, 17 stranded killer whales reported by Carl (1946, p. 23) and from unpublished data collected by the Pacific Biological Station. The dorsal fin of the adult female (≥16 ft) reaches 1.5–2.5 ft in height. In males the fin reaches 3 ft in height beginning at about 17–18 ft in body length. By 19 ft the fin averages about 3.5 ft. In field observations of the current study, a whale with a dorsal fin of about this height would be classified as a young bull.

Assuming maturity to occur at 19 ft, then the age at sexual maturity would occur at about 10 yrs according to the growth curve of two captive males in Fig. 5. However, as the growth rate in wild killer whales is probably slower, the age at maturity would be later. Based on photographs, a preliminary examination of the growth rate in the dorsal fin of males suggests an age at sexual maturity of at least 12 yrs. For this method the shape and size of the fin was observed in males from calves to age 6–7 yrs and in those which were encountered as medium sized juveniles and then followed annually into adulthood. Juveniles were sexed occasionally from the appearance of the external genitalia which were photographed when the whale jumped clear of the water.

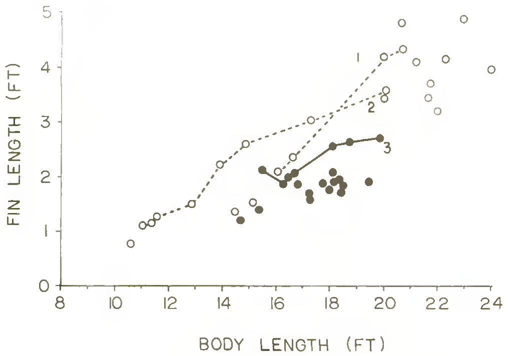

Fig. 6. Relationship between body length and dorsal fin height in males (open circles) and females (solid circles). 1 = Haida (Sealand of the Pacific); 2 = Hyak (Vancouver Public Aquarium); 3 = Skana (Vancouver Public Aquarium); for the source of other points see text.

(b) Pregnancy rate

Data collected by whalers produce conflicting results on the incidence of pregnancy in adult females (≥16 ft) off Norway, in the Southern Hemisphere and in the Antarctic. Pregnancy rate can be estimated for Norway during 1938–67 using data derived from two histograms presented by Jonsgård and Lyshoel (1970, p. 46–47). These authors note (p. 41) that whalers provided data on body lengths and pregnancy for each whale caught. The number pregnant at each length can be accurately taken from their Fig. 4 and the total number of females killed for each length closely approximated from their Fig. 5. These data are given in Table 4. From this the pregnancy rate for mature females is 14.8%.

This rate is much lower than that derived from similar data provided by Christensen (1980) for Norway during 1978–79, by Mikhalev *et al.* (1981) for the Southern Hemisphere during 1961/62–1978/79 and by Ivashin (1981) for the Antarctic in 1979/80. These data are also presented in Table 4. However, unlike the data from Jonsgård and Lyshoel (1970), theirs are based on samples of the total kill. At this time it is unclear if these samples were collected randomly. Their results indicate that mature females have a pregnancy rate of 40.5% off Norway, 27.5% in the Southern Hemisphere and 42.3% in the Antarctic. Reasons for the diversity of values remain unclear particularly for the two studies off Norway. It is important to note here that the rates given assume a gestation length of 12 months or less. If the gestation length is greater than 12 months then the pregnancy rate will be lower. At present the duration is unknown. There are no data on pregnancy rates for killer whales around Vancouver Island.

(c) Birth rate

An estimate of birth rate in cows from exploited and unexploited pods can be made from the incidence of calving in individual cows followed for consecutive years off Vancouver Island. This rate was calculated from the proportion of the summed number of consecutive years for

Table 4

Pregnancy rates, by length and maturity from four studies.

	Length (ft)														
Study	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Total
Jonsgård and Lyshoel (1970)															
Number females	39	48	55	83	72	53	29	28	9	6	4	2	1	1	430
Number pregnant	1	8	9	12	10	4	4	5	3	2	0	0	0	1	59
% pregnant—by length	2.6	16.7	16.4	14.5	13.9	7.5	13.8	17.9	33.3	33.3	0.0	0.0	0.0	100.0	13.7
—≥16 ft = 14.8															
Christensen (1980)[1]															
Number of females	8	20	35	26	17	16	3	3	1						129
Number pregnant	1	11	15	12	5	4	1	0	1						50
% pregnant—by length	12.5	55.0	42.9	46.2	29.4	25.0	33.3	0.0	100.0						38.8
—≥16 ft = 40.5															
Mikhalev *et al.* (1981)															
Number females			2	8	7	15	16	21	15	4	3				91
Number pregnant			0	4	8	4	2	7	4	1	1				25
% pregnant—by length			0.0	50.0	28.6	26.7	12.5	33.3	26.7	25.0	33.3				27.5
—≥16 ft = 27.5															
Ivashin (1981)															
% pregnant for mature females = 42.3 (141/333)															

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[1] One 19 ft female omitted due to uncertain pregnancy.

which all cows were followed against the total number of calves born during these 'cow years'. The year in which a cow was first observed was designated as year 1. The use of 'cow year' in this instance required knowing whether a cow gave birth in the preceding year, or year 0. Thus, for the calculation, if a cow was observed for five consecutive years after year 0 and was seen to give birth once during this time, then the annual birth rate would be 20.0%. Table 5 gives these data for cropped, uncropped, and combined pods. The average birth rate for cropped pods is 9.77%, for uncropped pods 6.94% and for combined pods 9.17%.

Table 5

Annual birth rate for female adult killer whales off Vancouver Island.

Pod	Number Cows	Number Cow yrs	Number Calves	Birth rate (%)
Cropped				
A5	5	37	4	10.81
J	8	64	7	10.94
K	5	35	1	2.86
L	16	112	11	9.82
M	1	6	1	16.67
Q	2	12	2	16.67
	37	266	26	9.77
Uncropped				
A1	5	35	3	8.57
A4	3	24	2	8.33
O	3	13	0	0.00
	11	72	5	6.94
Total	48	338	31	9.17

An estimate of birth rate for cows can also be made more directly from the ratio of calves to cows as given in the most recent or most accurate census for each pod in Table 1. This method would give the same results as that preceding if the same pods and individual whales were involved in both methods. However, while there is some overlap, the data are different enough to allow a second interpretation from more of the data base. Using the second method, the proportion of calves to cows in exploited pods A5, J, K, L, M and Q is 13.51% (5 calves, 37 cows) while for unexploited pods A1, A4, B, C, D, G, H, I1, I11, O, S8, and Y it is 9.09% (3 calves, 33 cows). The average for combined pods is 11.43%. When the two methods are averaged the birth rate for cows in cropped pods is 11.64%, in uncropped pods 8.02% and in combined pods 10.30%. Thus, exploited pods have a higher birth rate than unexploited pods.

Table 6

The calving interval based on consecutive year observations of 26 cows.

	Years						
	1	2	3	4	5	6	7
1. Completed interval							
Cropped pods			5	1			
2. Minimum interval							
Cropped	2	4	7	4	2	9	4
Uncropped		1		1	1		4

The birth rate in exploited pods is slightly less than the pregnancy rate derived from Jonsgård and Lyshoel (1970) for the species off Norway. The latter population can also be considered exploited as it has been hunted for many years. It should be noted that the birth rate for whales off Vancouver Island is actually the production of calves to an average age of about six months rather than to birth. Births occur mainly during the fall and winter in this region while most field observations are during the summer. The pregnancy rate is likely to be higher than the birth rate as some mortalities would be expected between birth and six months of age.

The net recruitment rate of calves, expressed as a percent of calves against all other whales in the pod, can be determined from Table 1. Here the average rate for exploited pods A5, J, K, L, M and Q is 5.32% (5 calves, 94 other ages) and the rate for the unexploited pods, which consist of all other pods except E and T, is 4.08% (6 calves, 147 other ages). The average rate for all pods is 4.56%. The rate can also be determined by applying the birth rate from cows to the percentage composition which cows comprise in the population. The birth rates for cows has already been calculated and the percentage of cows in the population can be taken from Table 11. The result, when adjusted for the proportion of calves against other ages, is 3.79% in cropped pods, 2.21% in uncropped pods and 3.23% for combined pods. The averages for the two methods are 4.56%, 3.15% and 3.90%. These figures are in general agreement with the International Whaling Commission (1981, p. 142) which reported 6.95% calves and small juveniles (7–12 ft long) travelling with 734 individuals of other ages in the Antarctic. The proportion of calves only would be less.

(d) *Calving interval*

The interval between successive births in individual cows off Vancouver Island was recorded on six occasions. For most cows, only the minimum calving interval could be noted. This is the period for which a cow was followed and either did not produce another calf or the date for the preceding birth could not be established because it occurred prior to the start of the study. These data are given in Table 6. The shortest interval recorded between births in cropped pods was three years. No complete intervals were recorded in uncropped pods. An interesting finding is that there were many cows for which the minimum birth interval was 6–7 years. These cows were either barren, which seems unlikely for such a large component of the cow population, or did not breed, perhaps for social reasons.

An average annual birth rate of 11.64% for cows from cropped pods indicates an average calving interval of 8.59 years. For cows in unexploited pods with a birth rate of 8.02% the interval is 12.47 years. These intervals are very long when compared to the minimum observed completed interval of three years (Table 6). The species is clearly breeding at a much lower rate than its potential even within the exploited pods.

8. Natural mortality rates

Ohsumi (1979, p. 403) provides the only estimate of natural mortality rate for the species. To do this, he established the relationship between length, natural mortality rate, maximum life span and maximum body length for various species of toothed and baleen whales which were studied and used these relationships to derive mortality rates for the unstudied species. He concluded that the natural mortality coefficient for male and female killer whales was 0.094–0.095 (= annual mortality rate of 8.97–9.06%).

Mortalities recorded in pods off Vancouver Island were those which resulted from natural causes as there was essentially no fishery for the species during the study. An estimate of the average annual natural mortality rate for bulls, cows and juveniles was made using the 'whale year' unit, as with the estimate for birth rates. Here the mortality rate is the proportion of the number of years in which all individuals of a category were followed against the number of individuals of that category which died during these years. Death was assumed to have occurred when a whale was recorded as missing from its pod, as there is no evidence that killer whales leave their pod permanently under any other circumstances. The individuals used in deriving mortality rates were those which were relatively well marked to ensure that their absence from the pod was noticeable. The year in which a whale was first observed is designated as year 0. Application of the 'whale year' unit to mortality rates, unlike birth rates, requires knowledge of events (deaths) following the initial encounter. Thus, for this calculation, if a whale was observed to be alive for four consecutive years after year 0 and then was observed to die (i.e. was missing) in year five, the annual mortality rate would be 20.0%.

(a) Bulls

Table 7 lists the number of 'bull years' and mortalities in cropped and uncropped pods. Only those males which were identified as bulls when first encountered were included. Juvenile males which became adults during the course of the study were omitted. Bulls in cropped pods had a slightly lower mortality than those in uncropped pods. The average annual rate for all pods was 2.80%. This is considerably less than that suggested by Ohsumi (1979) for the species and is also lower than for other cetaceans noted by him. Converting the average annual mortality rate to life span indicates that males live for an average of 36 yrs as adults. When the estimated maturation period is added, which is at least 12 yrs, bulls live for an average of at least 48 yrs.

Table 7

Annual natural mortality rate of adult males off Vancouver Island.

Pod	Number bulls	Number bull yrs	Number bulls dead	Annual mortality rate (%)
Cropped				
A5	1	7	0	0.00
J	3	21	0	0.00
K	3	12	1	8.33
L[1]	6	35	1	2.86
M	1	5	0	0.00
	14	80	2	2.50
Uncropped				
A1	3	20	1	5.00
A4	1	7	0	0.00
B	2	14	0	0.00
C	4	28	0	0.00
D	2	12	0	0.00
H	1	7	0	0.00
O	1	4	1	25.00
Y	1	5	0	0.00
I11	1	1	1	100.00
	16	98	3	3.06
Total	30	178	5	2.81

[1] Excludes one bull (L8) which apparently drowned accidentally from entanglement in a fishing net (Orca Survey, pers. comm., 9 May 1981).

(b) Cows

Table 8 reports the number of cows which died within exploited and unexploited pods. Only females which were considered to have been adults throughout the study were included.

Table 8

Annual natural mortality rate of adult female killer whales off Vancouver Island.

Pods	Number cows	Number cow yrs	Number cows dead	Annual mortality rate (%)
Cropped				
A5	5	32	1	3.13
J	8	56	0	0.00
K	5	30	0	0.00
L	16	96	0	0.00
M	1	5	0	0.00
	35	219	1	0.46
Uncropped				
A1	5	30	1	3.33
A4	3	21	0	0.00
O	3	10	0	0.00
Y	1	5	0	0.00
	12	66	1	1.52
Total	47	285	2	0.70

Only two cows were recorded as dying during 285 cow years observed. The average annual rate for cows in all pods was 0.70% which implies an average life span of 143 years as an adult. This appears to be an unrealistically low mortality rate although no obvious bias is apparent and the sample is large. The rate for cows should be lower than that for bulls as there are more cows than bulls. The low rate could be a random error as the death of only 2–3 cows by the next year of sampling would raise the mortality rate to a more realistic level.

(c) Juveniles

Table 9 gives the natural mortality rates for juveniles by pod. Males and females are combined. Here juveniles

Table 9

Annual mortality rate of juvenile killer whales off Vancouver Island.

Pod	Number juveniles	Number juvenile yrs	Number juveniles dead	Annual mortality rate (%)
Cropped				
A5	7	28	1	3.57
J	8	39	1	2.56
K	3	15	0	0.00
L	13	66	0	0.00
M	1	3	1	33.33
	32	151	3	1.99
Uncropped				
A1	4	17	1	5.88
A4	2	6	0	0.00
	6	23	1	4.35
Total	38	174	4	2.30

Results of this study suggest that the recent cropping of killer whales off Vancouver Island has increased their productivity, although not substantially. Cropped pods have slightly higher rates of birth and net annual increase and slightly lower rates of natural mortality than uncropped pods. Few data are currently available on the mechanism by which this has occurred. Birth rates can be elevated by reducing the age at sexual maturity and by increasing individual fertility. At this point comment can only be made on the latter which is a reasonable possibility. The large number of nonbreeding adult females in the population suggests that the species might be controlling its birth rate in a manner similar to that of wolves and African wild dogs. In these species only a few selected adult females breed. Perhaps a reduced population size induces more adult female killer whales to breed.

The manner by which survival is increased through cropping is only speculative at present. It could involve greater food availability for other members of the cropped pod. Each pod has its own range which, while overlapping with those of others, is sufficiently different to perhaps have its own food base. A reduction in the size of a pod would allow for more food and thus greater survival for remaining members.

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REFERENCES

Balcomb, K. C., Boran, J. R. Osborne, R. W. and Haenel, N. J. 1980. Observations of killer whales (*Orcinus orca*) in greater Puget Sound, State of Washington. Rep. MMC-78/13 to U.S. Marine Mammal Commission, Washington, D.C. 41 pp.

Balcomb, K. C. III, Boran, J. R. and Heimlich, S. L. 1982. Killer whales in greater Puget Sound, a population ideally suited for statistical modelling. Paper SC/Jn81/KW9 (published in this volume).

Bigg, M. A. and Wolman, A. A. 1975. Live-capture killer whale (*Orcinus orca*) fishery, British Columbia and Washington, 1962–73. *J. Fish. Res. Bd Can.* 32: 1213–21.

Bigg, M. A., MacAskie, I. B. and Ellis, G. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island, with comments on management. Unpub. Rep., Arctic Biol. Stn., Ste. Anne de Bellevue, Quebec. 21 pp.

Carl, G. C. 1946. A school of killer whales stranded at Estevan Point, Vancouver Island. B. C. Provincial Museum. Rep. (1945): 21–8.

Christensen, I. 1980. Miscellaneous data of killer whales caught in Norwegian coastal waters, 1978–79. Paper SC/32/SM14 presented to the IWC Scientific Committee Cambridge, June 1980.

Ford, J. K. B. and Fisher, H. D. 1982. Killer whale (*Orcinus orca*) dialects as an indicator of stocks in British Columbia. Paper SC/Jn81/KW8 (published in this volume).

International Whaling Commission. 1981. Report of the sub-committee on small cetaceans. (Annex H.) *Rep. int. Whal. Commn* 31: 140–53.

Ivashin, M. V. 1981. USSR, Progress report on cetacean research June 1979–May 1980. *Rep. int. Whal. Commn* 31: 221–6.

Jonsgård, A. and Lyshoel, P. B. 1970. A contribution to the knowledge of the biology of the killer whale *Orcinus orca* (L). *Norw. J. Zool.* 18: 41–8.

Mikhalev, Y. A., Ivashin, M. V., Savusin, V. P. and Zelenaya, F. E. 1981. The distribution and biology of killer whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 551–66.

Nishiwaki, M. and Handa, C. 1958. Killer whales caught in the coastal waters off Japan for recent 10 years. *Sci. Rep. Whales Res. Inst., Tokyo* 13: 85–96.

Ohsumi, S. 1979. Interspecies relationships among some biological parameters in cetaceans and estimation of the natural mortality coefficient of the Southern Hemisphere minke whale. *Rep. int. Whal. Commn* 29: 397–406.

SC/Jn81/KW7

Ross Sea Killer Whale Vocalizations: Preliminary Description and Comparison with those of some Northern Hemisphere Killer Whales

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ABSTRACT

Vocalizations of free-ranging killer whales (*Orcinus orca*) were recorded in Antarctic waters in 1979–81. Peak energies in a wide variety of clicks, click trains, pulsed vocalizations, screams, cries and tonal sounds ranged from below 1 kHz to over 30 kHz. To the human ear, Antarctic killer whale cries sound higher pitched than those of northern populations. Broadband clicks emphasized a wide range of frequencies and often were very similar to the clicks we recorded from British Columbian whales. Antarctic killer whale sounds generally tended to resemble those of other regions in timing characteristics but to emphasize somewhat higher frequencies.

INTRODUCTION

Information on relationships among 'populations' and 'stocks' of exploited cetaceans is essential to effective management. Following preliminary work by Yablokov (1974), Evans and Yablokov (1978) and Yablokov and Evans (1982) classified killer whale, *Orcinus orca* populations into five distinct regional groups based on geographic variation in the color pattern, particularly the size and orientation of the postocular patch and the characteristics of other light areas. Dorsal fin shape and size, and individual markings have been sufficient to permit identification of pods and even individual killer whales in the coastal marine waters of Washington and British Columbia (Bigg, MacAskie and Ellis, 1976; Chandler, Goebel and Balcomb, 1977).

Free-ranging killer whale pods (Ford, 1980; Ford and Fisher, 1982) and captive killer whale individuals (Dahlheim, 1980) from the Pacific northwest can also reliably be distinguished by differences in vocalizations. Preliminary results suggested that differences in vocalizations also might be used to distinguish among killer whales from different geographical areas (Jehl, Evans, Awbrey and Drieschman, 1980). This paper reports on preliminary analysis of vocalizations of Antarctic killer whales 1979–81, and compares those vocalizations with sounds of Pacific Northwest and North Atlantic killer whales.

MATERIALS AND METHODS

Field recordings of Antarctic killer whales were obtained in Gerlache Strait (64°38′S, 62°45′W), Dallmann Bay (64°28′S, 63°02′W) in 1979, on Pennell Bank (74°45°S, 178°35′W) in 1980, and in McMurdo Sound, Antarctica in 1980 and 81) (IWC, 1982, Figs 1 and 2). Recordings were made using: ANSQS41B sonobuoys deployed from R/V *Hero* in 1979; ANSQS41-A sonobuoys deployed from USCGC *Northwind* (1980) and USCGC *Glacier* (1981) or dropped from helicopters operating from McMurdo Station (1980); and various hydrophones placed directly in the water from ice-edge sites (1980–81). The five systems used to obtain these recordings are detailed in Table 1.

Pacific Northwest killer whales were recorded during August 1979 at Hansen Island, British Columbia, Canada using system 5 (Table 1) and in captivity by Dahlheim (1980). Except where noted, recordings illustrated in this report were made with system 4 or 5. Clicks, click trains and buzzes were described from oscillograms and spectra made with a Spectral Dynamics 345 FFT spectrum analyzer. Screams, cries and whistles were described from sonograms made with a Kay Electric model 6061B Sound Spectrograph with a model 6083 counter and scale magnifier. To facilitate analysis, tapes were usually slowed down for playback.

RESULTS

A wide variety of clicks, click trains, pulsed vocalizations, screams, cries and whistle-like tonal sounds have been recorded from McMurdo Sound killer whales. Peak energies in these sounds range from below 1 kHz to over 30 kHz.

Clicks, click trains and buzzes

The Antarctic whales examined to date produced broad band clicks with energy concentrated in frequencies ranging from near 500 Hz (Fig. 1) to over 30 kHz (Fig. 2). Most clicks were doublets with pulses spaced about 1.5 ms apart (Fig. 2a). An expanded view of one pulse of a pair is shown in Fig. 3a. It is a strongly damped 23.25 Hz oscillation. The first cycle of the pulse is negative-going and frequency decreases during the pulse, implying that killer whales click by popping open a resonant cavity. The spectrum of this doublet (Fig. 3b) has harmonics about 650 Hz apart, as determined by the interpulse interval. These are probably different from the doublets reported by Steiner, Hain, Winn and Perkins (1979), which had interpulse intervals of 40–60 ms.

Most McMurdo Sound killer whale clicks emphasized frequencies higher than those reported by Dahlheim

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* Revised slightly since presented at the meeting. This revision incorporates review comments by M. E. Dahlheim and W. W. Steiner.

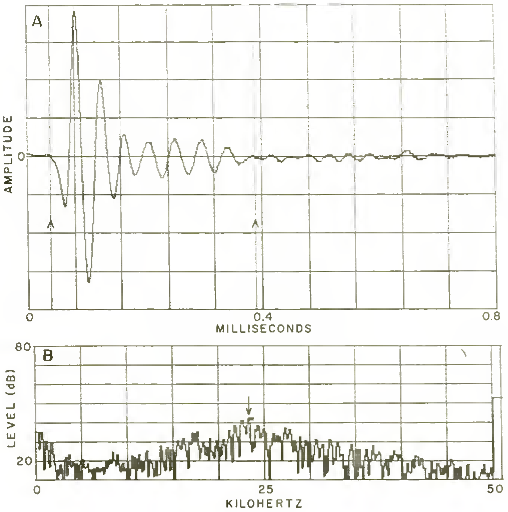

Fig. 3. (A) Expanded waveform of one pulse of a doublet. Time between arrows is 0.35 ms. Note the frequency decrease during the 8 cycles between the arrows. Period of the maximum amplitude peak is about 42.5 μs (≃ 23.5 kHz). Time resolution 0.8 μs. (B) Spectrum of a pulse doublet including that shown in A. Maximum amplitude is at 23.25 kHz, (arrow), with harmonics about 650 Hz apart. Reference level is arbitrary. Effective filter bandwidth 125 Hz.

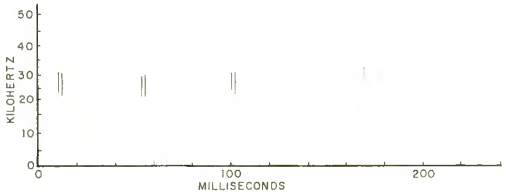

Fig. 4. Part of the pulse trains produced by at least two individuals. The sonagram was produced by setting the Sona-Graph Scale Magnifier for a 5 kHz bandwidth and playing the tape at 1/10 speed to expand the frequency bandwidth to 50 kHz and reduce time to 200 ms. The wideband filter was used to improve time resolution of the clicks. Effective filter bandwidth is 3 kHz. Repetition rate for these slow clicks was very irregular but averaged about 20 per second.

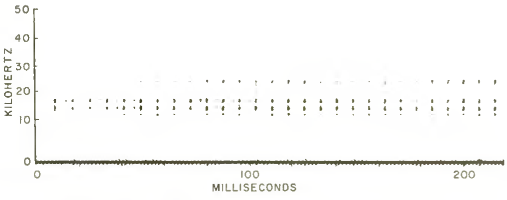

Fig. 5. Sonagram of a 200 ms segment of a 'buzz' made up of doublet clicks. Intradoublet interval ≃ 2.7 ms (550 Hz). Click repetition interval ≃ 8 ms (125 Hz). The second pulse in each doublet has greater amplitude than the first but both have the same frequency and energy distribution. Made at 1/10 speed with the narrowband filter. Effective filter bandwidth = 450 Hz.

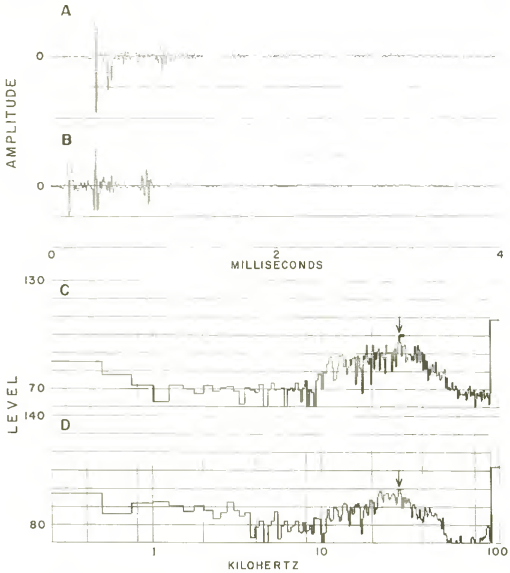

Fig. 6. (A) Oscillogram of click triplet from killer whale pod near Hansen Is., British Columbia; (B) Oscillogram of click triplet from McMurdo Sound; (C) Spectra of (A), Arrow = 29 kHz; (D) Spectrum of (B), Arrow = 28.5 kHz. Amplitudes were not calibrated so scale is arbitrary. Peak frequency was set at 100 dB. Effective filter bandwidth of C and D = 250 Hz.

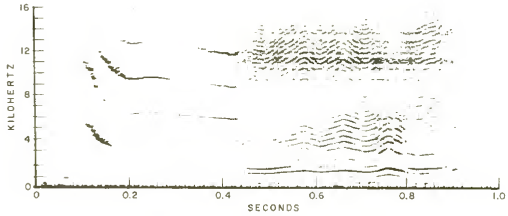

Fig. 7. Sonogram of a downswept 'scream' that suddenly shifts to a vocalization frequency modulated at 400 Hz with stressed harmonic at 1.5 kHz and considerable energy to beyond 16 kHz. Effective filter bandwidth = 90 Hz.

Tonal Calls

These near pure tone sounds are characteristic of delphinids (Evans, 1969) but are rare in killer whales. Dahlheim (1980) recorded a delphinid-like frequency modulated whistle from a captive killer whale. Steiner *et al.* (1979) reported over 50 tonal calls and showed that tonal vocalizations sometimes precede or accompany pulsed sounds. In recordings at Pennell Bank on 1 January 1980 (System 2, table I), only clicks and delphinid-like whistles were heard (Fig. 8). A group of several hundred killer whales was encountered en route to McMurdo. Because of tight schedules and excessive ship noise, only about 10 minutes of satisfactory recordings were made.

The whistles appear not to be pulse modulated and fall well within the reported frequency range of killer whale whistles. Whether this group of whales produced substantial sound at higher frequencies is not known because of the sonobuoy's 10 kHz upper frequency limit.

Additional recordings of Antarctic killer whales made by M. J. White and J. Holbrook aboard the R/V *Hero* in Gerlache Strait on 24 March 1979 using System 1 (Table 1). Signal-to-noise ratio on the tapes is so poor that only a few vocalizations could be analyzed. These few sounds appear similar to those of McMurdo Sound killer whales in pulse rates, stressed harmonics, and frequency modulation (Fig. 8).

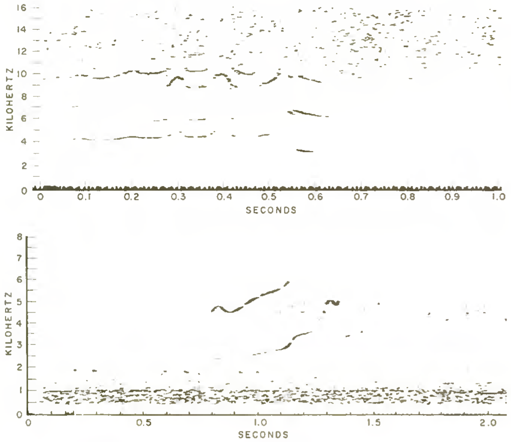

Fig. 8. Sonagrams of tonal vocalizations. These vocalizations are frequency modulated whistles reminiscent of small delphinids. No harmonic structure is evident but sonobuoys limited bandwidth to < 10 kHz. Effective filter bandwidth = 45 Hz.

DISCUSSION

Killer whale vocalizations recorded in different locations sound noticeably different. Even so, the human listener has no difficulty recognizing each of them as killer whale sounds. The bases for this species-specificity have not been determined. All killer whales have upswept, downswept and 'warbled' sounds, but the sounds differ widely among populations in emphasized frequencies, amplitude modulation and frequency modulation rates, sweep rates, duration, beginning and ending frequencies and other characteristics. Analysis of these differences is beyond the scope of this paper.

Nevertheless, individuals (Dahlheim, 1980) and pods (Ford, 1980) can be recognized unequivocably from their vocalizations. Pod-specific sound patterns are stable over at least a decade, even in captive animals. (Dahlheim, pers. comm.; Ford and Fisher, 1981). If this pod-specificity extends to killer whales in general, it offers management agencies a new tool. If the technique proves to be valid, combined with color pattern and dorsal fin comparison it can help to answer some fundamental questions about killer whale movements, distributions and abundance.

REFERENCES

Bigg, M. A., MacAskie, I. B. and Ellis, G. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island with comments on management. Prelim. Unpub. rep., Arctic Biol. Sta., Ste. Anne de Bellevue, Quebec. 21 pp.

Chandler, R., Goebel, C. and Balcomb, K. C. 1977. Who is that killer whale? *Pacific Search*. 11 (7): 25–35.

Dahlheim, M. E. 1980. A classification and comparison of vocalizations of captive killer whales (*Orcinus orca*). M.S. Thesis, San Diego State University, San Diego, California. 79 pp + 2 pgs. unnumbered abstract.

Evans, W. E. 1967. Vocalizations among marine mammals. pp 159–86. *In:* W. N. Tavolga (ed.) *Marine Bio-Acoustics*. Vol. 2, Pergamon Press, New York.

Evans, W. E. and Yablokov, A. V. 1978. Intraspecific variation of the color patterns of the killer whale (*Orcinus orca*). *In:* V. E. Sokolov and A. V. Yablokov (eds). *Advances in pinniped and cetacean research*. Moscow, Akademia Nauk (In Russian).

Ford, J. K. B. 1980. Group specific vocalizations of the killer whale (*Orcinus orca*). Abstract of the papers presented at the 146th National Meeting of the AAAS; 3–8 Jan 1980; San Francisco, CA.

Ford, J. K. B. and Fisher, H. D. 1982. Killer whale (*Orcinus orca*) dialects as an indicator of stocks in British Columbia. Paper SC/Jn81/KW8 (published in this volume).

International Whaling Commission. 1982. Report of the workshop on identity, structure and vital rates of killer whale populations. SC/33/Rep 4 (published in this volume).

Jehl, J. R. Jr, Evans, W. E., Awbrey, F. T., and Drieschman, W. S. 1980. Distribution and geographic variation in the killer whale (*Orcinus orca*) populations of the Antarctic and adjacent waters. *Ant. J. of U.S.* 15(5): 161–3.

Steiner, W. W., Hain, J. H., Winn, H. E., and Perkins, P. J. 1979. Vocalizations and feeding behavior of killer whales (*Orcinus orca*). *J. Mammal.* 60(4): 823–7.

Yablokov, A. V. 1968. 'Popyalyatsionnaya morfulogiya zhivotnykh' ('Population Morphology of Animals') *Zool. Zh.* 47: 1749–65.

Yablokov, A. V. 1974. *Variability in Mammals. New Delhi.* American Publishing Co. 350 pp.

Yablokov, A. V. and Evans, W. E. 1982. Geographic variation in the color pattern of killer whales (*Orcinus orca*). Paper SC/Jn81/KW11 (published in this volume).

SC/Jn81/KW8

Killer Whale (*Orcinus orca*) Dialects as an Indicator of Stocks in British Columbia

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ABSTRACT

Underwater vocalizations were recorded from killer whale pods (stable kin groups) off Vancouver Island, British Columbia, during 1978–80. We report here preliminary results of analyses which are still underway. Vocal exchanges in killer whale pods are dominated by repetitious, pulsed calls which can be organized into discrete, non-overlapping categories. Repeated encounters with 15 photographically-identified pods demonstrate that each pod has a limited repertoire of 8 to 15 ($\bar{X} = 11.9$) discrete call types. Recordings obtained from captive animals of known pod origin indicate that pod repertoires are highly stable for periods of at least 15 years (1965–80) and that each pod member produces most or all of the group's calls. Significant differences exist among the discrete call repertoires of different pods in British Columbia. The degree of similarity in dialects generally reflects the degree of association of pods. Pods which associate and travel together tend to share discrete calls, while those that do not associate produce entirely different calls. Non-associating pods can be either geographically or socially isolated. The killer whale dialect system represents a potentially useful technique for identifying populations and determining their social organization.

INTRODUCTION

In recent years, a number of new techniques have been developed to aid studies of the distribution, behaviour and social structure of cetacean populations. Among these is a method of photographically identifying individual killer whales (*Orcinus orca*) in the field, which was developed and used in a long-term study of this species in the coastal waters of British Columbia (Bigg, MacAskie and Ellis, 1976; Bigg, 1982). This study has resulted in a great deal of new information concerning the abundance, distribution and structure of the population.

In 1978 we began a study of the acoustic behaviour of killer whales in British Columbia. Our objectives were to gain some understanding of this apparently important aspect of the animal's behaviour and its possible role in the maintenance of killer whale social structure. With the application of Bigg's (1982) photo-identification technique, we have been able to record and compare the vocalizations of different killer whale social groups, or pods. Although the study is not yet complete, preliminary results indicate that each pod produces a limited number of discrete calls, and that there are consistent differences, or dialects, in the call repertoires of most pods. In this report, we present a general summary of the dialects of 15 killer whale pods recorded in the waters off Vancouver Island, B.C., and interpret their similarities and differences with respect to the observed social organization and distribution of the killer whale population. We feel that the acoustic dialects of killer whales also represents a useful tool in stock analysis.

THE STUDY ANIMALS

The following summary of killer whale abundance and distribution in the study area is based on information collected by Bigg *et al.* (1976) and Bigg (1982). For more detailed information, the reader is referred to the latter paper.

Killer whales in British Columbian coastal waters live in highly stable groups or pods containing up to 50 individuals. Pods usually include immature and mature animals of both sexes. The permanence of these groups suggests that pods are family or kinship units. Although no permanent exchange of individuals between pods has been observed, pods often travel together for periods of up to a few weeks.

A population comprising approximately 30 pods occurs in the waters surrounding Vancouver Island. This population is divided into three distinct communities. Two of the communities each consist of a number of pods which are present year-round in two separate ranges and are thus termed 'residents'. The range of one resident community, referred to here as the 'southern community', includes the waters of Georgia Strait, Juan de Fuca Strait and Puget Sound (maps showing geographic locations and ranges of the killer whale communities are shown in Figs 1 and 4, respectively, of Bigg (1982)). This community consists of three pods, totalling about 80 animals. The second, or 'northern community' of resident pods is largely confined to waters north of Georgia Strait. The northern community includes 12 pods with a total of about 136 whales. Since there is generally no overlap in the ranges of the two resident communities, pods from each do not associate. However, pods within each community frequently travel together.

The third community consists of a group of 15 pods, totalling 47 individuals, which does not appear to have a well-defined range. The movements of these 'transient' pods are unpredictable and some have been observed only rarely. Transients may be seen within the ranges of the two resident communities, but they do not associate with resident pods. However, different transient pods frequently join and travel together.

The killer whale pods discussed in this paper are identified alphabetically or, in some cases, alphanumerically according to the system developed by Bigg (1982). These names are arbitrary and are not meant to imply degrees of association or relationship.

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METHODS

Killer whales were encountered and recorded acoustically in a number of localities near Vancouver Island in 1978–80. All observations and recordings were made from a 5 m, outboard-powered boat. Upon encountering a group of killer whales, we photographed the dorsal fins of as many individuals as possible for identification. Black and white photographs were taken using a 35 mm SLR camera with a 300 mm lens mounted on a shoulder brace. Individual whales in these photographs were subsequently identified by M. A. Bigg. The group was then observed and recorded acoustically for as long as conditions would permit. For recording we used a calibrated system consisting of a *Nagra* IV-SJ instrumentation recorder, *Celesco* BC-10 or BC-50 hydrophones, and a specially designed preamplifier/filter unit. Frequency response was limited by the recorder and high-pass filter to 100 Hz–35 kHz (±3 dB) at a tape speed of 38 cm/s. Concurrent observations of the whales' behaviour and spatial arrangement were recorded on a second channel of the recorder. In addition to our recordings, a number of early and recent recordings made by other people were examined.

A simple shorthand technique, involving symbols which reflect the pitch contours of killer whale signals, was used to transcribe the recorded vocalizations from the tapes. The vocalizations were analyzed using a *Kay Elemetrics* 7029A spectrum analyzer. All spectrograms illustrated in this report have a linear frequency bandwidth of 80–8,000 Hz and were produced using a narrowband (45 Hz) analyzing filter.

RESULTS

The following results are based on information gathered from 174 pod encounters[1] involving 15 different killer whale pods during 1978–80 and several recordings made of both captive and wild killer whales by other individuals.

Characteristics of killer whale vocalization

At certain times, killer whales are extremely vocal. As noted by previous authors, these whales produce three basic types of sounds. The first type is a very short (0·8 to 25 ms) pulse containing energy over a wide range of bandwidths (Schevill and Watkins, 1966; Steiner, Hain, Winn and Perkins, 1979). Usually termed clicks, or click trains when emitted in series, these pulses are believed to function as echolocation signals (Schevill and Watkins, 1966). We have observed click trains with repetition rates of 1 or 2 to over 300 clicks/s, and click energies as high as 35 kHz, the upper limit of our recording equipment. The second type of sound consists of tonal signals having a continuous or non-pulsed waveform. Spectrographically, these 'whistles' are characterized by a dominant, narrowband component with little or no harmonic or sideband structure. Tonal sounds were generally emitted between 6 and 12 kHz, although occasional whistles went as low as 1·5 kHz and as high as 18 kHz. Tone durations varied from 50 ms to as long as 10–12 s.

The third and most characteristic form of killer whale vocalization is a sound made up of rapidly-pulsed or burst-pulsed emissions. These sounds are intense and have unusual aural qualities, having been described as 'scream' like (Schevill and Watkins, 1966) or as having a 'harsh, strident or metallic quality' (Steiner *et al.*, 1979). We recorded a wide variety of pulsed calls, most of which showed a complex physical structure. Pulsed calls contained energy as high as 25 kHz in frequency and had pulse repetition rates of up to 5000/s. Most pulsed calls were between 0·5 and 1·5 s long, although they ranged from less than 50 ms to over 10 s in duration.

Behavioural contexts of vocal activity

The type and amount of vocal activity within killer whale groups is not constant. Killer whale behaviour can be organized into two broad categories, 'active' and 'inactive'. Vocal activity is, in most cases, directly related to the vigour of whale movements and general activity.

The 'active' category includes beach-rubbing, play, travelling and, most commonly, foraging. While foraging, whale pods break into a number of smaller sub-groups which disperse widely, often over areas as large as 10 km². Each sub-group moves at roughly the same pace and in the same direction but dives independently. In general, vocal activity during foraging behaviour is high; within a single foraging pod, pulsed calls typically are given at rates of 5 to 30 or more per minute, either continuously or in bouts of varying duration. Echolocation clicks can be heard throughout periods of activity, while whistles occur less frequently. The 'inactive' behaviour category is represented by group-resting behaviour. All members of a pod join together in a tightly-knit group, usually with animals lined up abreast. Movement slows, and the whales carry out a series of long (4–8 min), synchronous dives, during which they travel distances of 150 m or less. Between these long dives, the whales make several shallow dives, surfacing every 10–30 s to breathe. Group-resting behaviour may continue for up to several hours at a time. Whales become comparatively quiet while resting, but on occasion they emit a variety of low-intensity whistles and low-frequency pulsed calls.

Pulsed calls: discrete and variable

The majority of killer whale pulsed calls can be arranged into discrete, non-overlapping categories based on their physical structure seen in spectrographic analysis and from aural impression. Although some variability exists within each discrete call category (Fig. 1), intermediates between any two categories are rare. In addition to discrete pulsed calls, killer whales also emit a complex array of highly variable pulsed signals which cannot be placed in any clearly defined categories. These variable, or 'miscellaneous' calls cover a broad range of sounds, from very short squeaks and trills to long, raucous squawks lasting up to 12 s in duration. In general, 70% to 95% of the social signals of killer whales are discrete pulsed calls, with the remainder made up of variable calls and whistles. The remainder of this paper deals solely with these discrete calls.

Recordings obtained during repeated encounters with identified killer whale pods have shown that each pod emits a limited number of discrete call types. Pods have repertoires of 8 to 15 discrete calls, with a mean of 11·9 calls per pod (calls of three pods have not yet been fully analysed and are not included in this calculation). Not all discrete calls in a pod's repertoire are heard with equal regularity. Certain calls are highly repetitious and

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[1] One pod encounter is the interception and identification of one pod on one day. When two pods were observed together, this was recorded as two pod encounters.

1. Northern Resident Community. Acoustic recordings were collected from 147 pod encounters involving 9 different resident pods in the northern community during 1978–80. The identity of these pods, their size, the number of times each was encountered either alone or together with other pods, and the pods observed to associate with each, are given in Table 1. A total of 30 discrete call types were determined from these recordings. Four of these calls have from 2 to 4 variant forms. Table 2 lists the call identification numbers and the pods observed to produce them. The pattern of call sharing among the northern community pods clearly shows that certain pods are more closely associated acoustically than are others. These associations are displayed graphically in Fig. 2, based on the number of calls and call variants shared by different pods.

Some degree of call sharing occurs among all but 1 of the 9 northern community pods. Pod I11, with a repertoire of 8 unique calls, is acoustically unrelated to the rest of the community. The remaining 8 pods, A1, A4, A5, B, C, D, H and I1, share 5 discrete call types. These pods can be further subdivided by additional unique calls in their repertoires and by call variants which are given only by certain pods or groups of pods (Table 2, Fig. 2). Because of the considerable similarities in their repertoires, pods A1, A4 and A5 clearly form a distinct acoustic unit. They share 6 calls and 2 call variants which are given by no other pods (an additional call and 2 call variants are also produced by certain other pods). Spectrograms of the call repertoire of the A-pods are shown in Fig. 3. Pod A5 can be differen-

Table 1

Summary of pod encounters in the northern community. Included are the number of animals in each pod, the number of times each pod was encountered alone or in the company of other pods, and the number of times each pod associated with others in the community.

Pod[1]		Number of encounters										
				Pods associated								
ID	No.	Total	Alone	A1	A4	A5	B	C	D	H	I1	I11
A1	14	30	6	—	13	21	2	2	4	5	1	3
A4	7	22	1	13	—	20	3	4	6	3	1	3
A5	12	41	6	21	20	—	3	6	13	3	1	3
B	8	12	4	2	3	3	—	1	1	0	0	4
C	9	8	2	2	4	6	1	—	3	0	0	1
D	10	14	1	4	6	13	1	3	—	1	0	1
H	6	7	1	5	3	3	0	0	1	—	0	3
I1	16	4	3	1	1	1	0	0	0	0	—	0
I11	6	9	0	3	3	3	4	1	1	3	0	—

[1] Pod identifications are the same as those in Bigg (1982). For further details on identification methods and pod composition, see this report.

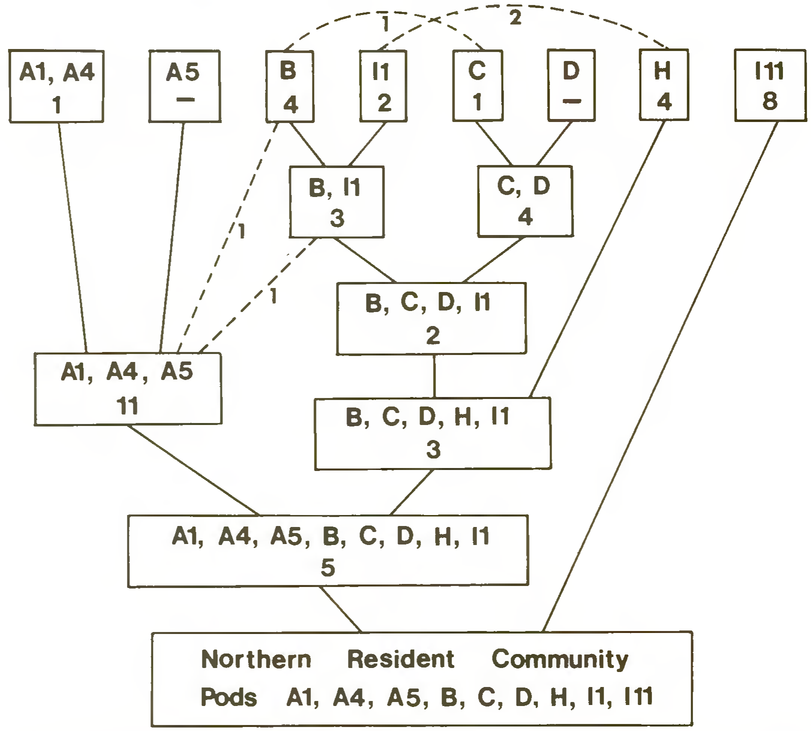

Fig. 2. Diagram illustrating acoustic relationships between 9 resident pods of the northern community, based on data in Table 2. Figures within each box indicate the number of call types and call variants shared by the pods listed or by each pod alone. Broken lines join pods which share calls but which are considered separate because of other, more significant differences in their repertoires. The number of calls or call variants involved in such cases are placed adjacent to each broken line. Not indicated in this diagram is a link between pod H and pods A1, A4 and A5, which share call variant N7II. This variant occurs only rarely in the repertoire of the three A-pods.

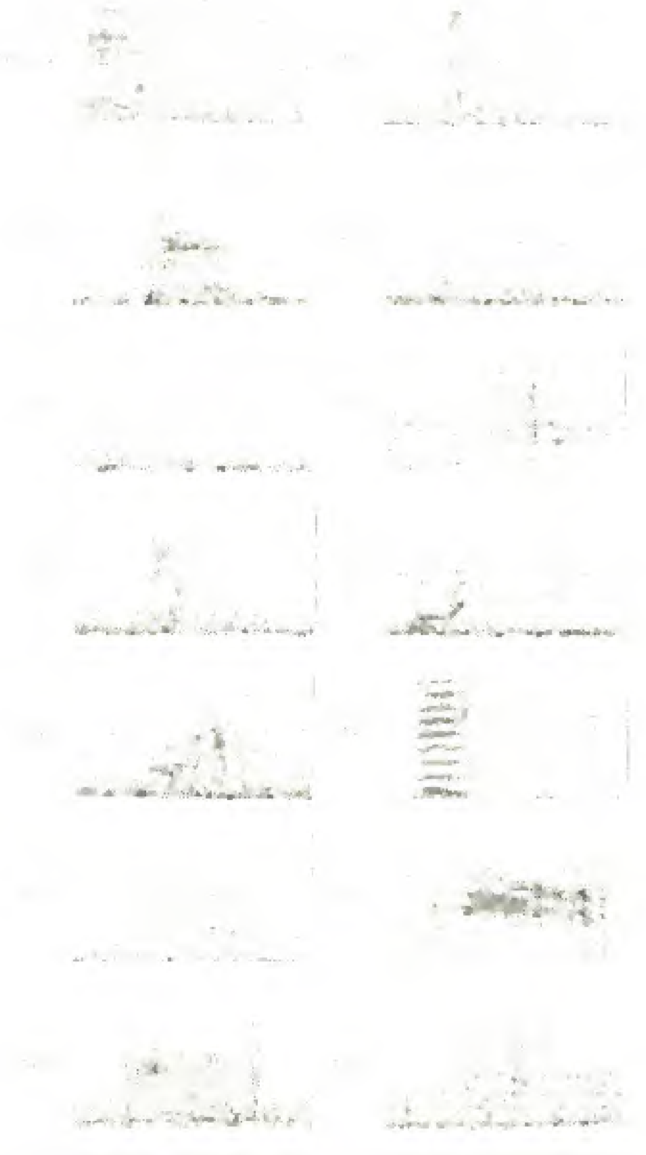

Table 3

Discrete calls recorded from southern community killer whales, and the pods observed to produce them.

	Pods				Pods		
Calls	J	K	L	Calls	J	K	L
S1	×	×	×	S18			×
S2	×			S19			×
S3	×			S22			×
S4	×	×		S31		×	
S5	×	×		S33			×
S6	×	×	×	S36			×
S7	×	×		S38			×
S8	×			S39	×		
S9	×			S40			×
S10	×	×	×	S42	×	×	×
S12	×			S44	×		
S13	×			S45			×
S16		×	×	S46			×
S17		×	×				
				Total	15	10	15

June through September). On 48 of the 84 occasions we intercepted killer whales (57%), two or more pods were travelling in association. The overall mean number of pods present per encounter was 2.09, with a range of 1 to 6.

Recordings obtained from multi-pod associations typically contain calls characteristic of each pod present at the time. The only exceptions were when a pod was group-resting and therefore non-vocal while accompanying pods were active and vocal.

We have a good deal of evidence indicating that when pods travel in association, each pod produces only those calls characteristic of its own repertoire. On many occasions, pods travelling together remained some distance apart, allowing the recorded calls to be attributed to one pod or the other on the basis of relative signal intensity. At no time was one pod observed to emit calls characteristic of another pod with which it was travelling, unless those pods shared the same calls. When pods are closely intermixed, it is more difficult to ascertain the source of calls. However, individual whales frequently passed close to our hydrophone, and the loud vocalizations recorded at such times were always from the repertoire of the animals' pod.

DISCUSSION

Discrete calls of killer whales

The predominant social signals of killer whales are discrete, pod-specific pulsed calls. Discrete signals, either tonal or pulsed in nature, have been described in several other odontocetes, and it has been suggested that some may be individually-specific (Caldwell and Caldwell, 1971; Watkins and Schevill, 1977; Ford and Fisher, 1978). There is also evidence that the whistles of some delphinids comprise a graded rather than discrete system (Taruski, 1976; Herman and Tavolga, 1980). Whether group-specific signals exist in other odontocetes is unknown. However, recent field studies of delphinid social organization indicate a great fluidity in group structure and composition in a variety of species (Würsig, 1978; Saayman and Tayler, 1979; Wells, Irvine and Scott, 1980; Norris and Dohl, 1980). Group-specific signals such as those given by killer whale pods would not be expected within such open societies.

Although the actual functions of killer whale communication signals are unknown, the strident nature and unique physical structure of discrete calls make them well suited for reception and identification over long distances. Discrete calls very likely provide an effective and reliable means for pod members to maintain contact and possibly coordinate movements and spacing while dispersed and foraging. The use of loud, discrete calls in the maintenance of group spacing has been described in arboreal primates which, like the killer whale, live in habitats where visual contact is often restricted (Marler, 1972; 1977; Waser, 1977).

Killer whale dialects: interpretation and application

Any consistent differences in the vocal patterns of different groups or populations of the same species can be described as dialects (Le Boeuf and Peterson, 1969). Although dialects are well known in birds, they appear to be quite rare among the mammals (Nottebohm, 1972; Green, 1975). In the literature on bird song a distinction is often made between true dialects, which involve differences in the songs of neighbouring populations which can potentially interbreed, and geographic variation in songs, which appears in widely separated populations and likely results from genetic isolation (Grimes, 1974). Dialects in birds are thought to reduce gene flow between breeding populations thereby allowing more efficient and rapid adaptation to locale-specific conditions (Nottebohm, 1972; Baker and Mewaldt, 1978).

Among the cetaceans, geographic variation in vocalization has been suggested for a few species (e.g. Taruski, 1976; Cummings and Thompson, 1977; Thompson, Winn and Perkins, 1979), but has been demonstrated only in the humpback whale, *Megaptera novaeangliae*. Payne (1979) and Winn, Thompson, Cummings, Hain, Hudnall, Hays and Steiner (1981), have found that the songs of humpbacks in the North Atlantic are significantly different from those in the North Pacific. However, songs recorded from different breeding grounds within each ocean are essentially identical. In a study of the acoustic signals of captive killer whales, Dahlheim (1980) was able to discriminate between individuals, sex and geographic origin of the animals on the basis of vocalization. Her results suggested that geographic variations exist in killer whale signals.

The differences in the vocal patterns of killer whale pods described here represent true dialects, since they exist in groups which are not geographically isolated and can potentially interbreed. The function of killer whale dialects is as yet unknown. It is possible, however, that they serve to maintain the identity and discreteness of pods. It is unknown whether killer whale dialects are genetically encoded (i.e. result from reproductive isolation of dialect groups) or result from behavioural traditions which are passed from parent to offspring through cultural transmission. However, the latter would appear more likely since the ability to mimic and learn new sounds, while rare in most mammals, is well known among delphinids (Herman, 1980). Furthermore, dialects in birds consistently have been found to involve vocal learning (Nottebohm, 1972).

Killer whale dialects are useful as a means of assessing the identity and structure of killer whale populations. The results of our acoustic analyses are consistent with Bigg's (1982) observations on the social organization and distribution of killer whales in British Columbia. An examination of the dialects of 15 killer whale pods off Vancouver Island indicates that virtually every pod has some unique features in its vocal repertoire which allow it to be identified acoustically. This, in addition to the apparent stability of pod dialects over time, supports Bigg's (1982) conclusion that killer whale pods are long-term, discrete social units.

Bigg (1982) has discovered that there are three distinct communities of killer whale pods in the waters off Vancouver Island. Two communities have well-defined ranges which generally do not overlap, while the third is widely distributed and occurs throughout the ranges of the other communities. Pods within each community frequently associate and travel together, but pods from different communities do not.

We have found that the three communities are also distinct acoustically. Each community has dialects unlike those in any other community. However, typically there are considerable similarities in the dialects of pods within each community. There is also evidence that pods which associate most often tend to have the greatest acoustic similarities. There are several possible reasons for these similarities. One is that pods simply incorporate into their own repertoires certain calls given by the pods with which they most often associate. Another possibility, which we consider more likely, is that pods with similar call repertoires originated from the same ancestral kinship group which split into smaller groups as it grew. As each subgroup became more independent, its acoustic repertoire changed as a result of behavioural or genetic isolation and drift. Old calls gradually became modified or were lost and replaced with entirely new signals. Perhaps the three A-pods of the northern community, which share almost the same call repertoire yet spend considerable amounts of time apart, represent an early stage in such a process.

Killer whale pods appear to represent distinct breeding units (Bigg, 1982). If true, pod-specific dialects can be viewed as an indicator of reproductively isolated groups. However, it is possible that mating occurs between pods within a community, and that groups of pods having similar dialects represent breeding units. In general, pods which have no calls in common may be considered to be socially and reproductively distinct groups.

The study of killer whale dialects is thus a useful technique for identifying populations and determining their social organization. We feel that the technique could be applied successfully in analyses of killer whale stocks in other parts of the world, especially in cases where long-term observational studies using photo-identification techniques are not practical.

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REFERENCES

Baker, M. C. and Mewaldt, L. R. 1978. Song dialects as barriers to dispersal in white-crowned sparrows, *Zonotrichia leucophrys nuttalli*. *Evolution* 32: 712–22.

Bigg, M. A. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Paper SC/Jn81/KW4 (published in this volume).

Bigg, M. A., MacAskie, I. B. and Ellis, G. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island with comments on management. Unpubl. MS, Arctic Biological Station, Ste. Anne de Bellevue, Quebec, Canada. 21 pp.

Caldwell, M. C. and Caldwell, D. K. 1971. Statistical evidence for individual signature whistles in Pacific whitesided dolphins, *Lagenorhynchus obliquidens*. *Cetology* 3: 1–9.

Cummings, W. C. and Thompson, P. O. 1977. Long 20-Hz sounds from blue whales in the northeast Pacific. Proc. 2nd Conf. Biol. Mar. Mammals Abstr. 73.

Dahlheim, M. E. 1980. A classification and comparison of vocalizations of captive killer whales (*Orcinus orca*). Unpubl. MSc. thesis, San Diego State Univ. 76 pp.

Ford, J. K. B. and Fisher, H. D. 1978. Underwater acoustic signals of the narwhal (*Monodon monoceros*). *Can. J. Zool.* 56: 552–60.

Green, S. 1975. Dialects in Japanese monkeys: vocal learning and cultural transmission of locale-specific vocal behavior? *Z. Tierpsychol.* 38: 304–14.

Grimes, L. G. 1974. Dialects and geographical variation in the song of the splendid sunbird *Nectarinia coccinigaster*. *Ibis* 116: 314–29.

Herman, L. M. 1980. Cognitive characteristics of dolphins. pp. 363–429 *In:* Herman, L. M. (ed.) *Cetacean Behavior: Mechanisms and Functions*. John Wiley and Sons, New York, 463 pp.

Herman, L. M. and Tavolga, W. N. 1980. The communication systems of cetaceans. pp. 149–209 *In:* Herman L. M. (ed.) *Cetacean Behavior: Mechanisms and Functions*. John Wiley and Sons, New York, 463 pp.

Le Boeuf, B. J. and Peterson, R. S. 1969. Dialects in elephant seals. *Science* 166: 1654–56.

Marler, P. 1972. Vocalizations of east African monkeys. II: Black and white colobus. *Behaviour* 62: 175–97.

Marler, P. 1977. The evolution of communication. p. 45–76 *In:* Sebeok, T. A. (ed.) *How Animals Communicate*. Indiana Univ. Press, Bloomington.

Norris, K. S. and Dohl, T. P. 1980. Behavior of the Hawaiian spinner dolphin, *Stenella longirostris*. *Fish. Bull.* 77: 821–49.

Nottebohm, F. 1972. The origins of vocal learning. *Amer. Nat.* 106: 116–40.

Payne, R. 1979. Humpback whale songs as an indicator of 'stock'. *Abstr. 3rd Bienn. Conf. Biol. Mar. Mammals 46.*

Saayman, G. S. and Tayler, C. K. 1979. The socioecology of humpback dolphins (*Sousa* sp.) pp. 165–226 *In:* H. E. Winn and B. L. Olla (eds.). *Behavior of Marine Animals, Vol. 3: Cetaceans*. Plenum Press, New York, 438 pp.

Schevill, W. E. and Watkins, W. A. 1966. Sound structure and directionality in *Orcinus* (killer whale). *Zoologica* 51: 70–6.

Steiner, W. W., Hain, J. H., Winn, H. E. and Perkins, P. J. 1979. Vocalizations and feeding behavior of the killer whale (*Orcinus orca*). *J. Mammal.* 60: 823–7.

Taruski, A. G. 1976. Whistles of the pilot whale (*Globicephala* spp.): variations in whistling related to behavioral/environmental context, broadcast of underwater sound, and geographic location. Unpubl. Ph.D. thesis, Univ. of Rhode Island. 89 pp.

Thompson, T. J., Winn, H. E., Perkins, P. J. 1979. Mysticete sounds. pp. 403–431 *In:* H. E. Winn and B. L. Olla (eds). *Behavior of Marine Animals, Vol. 3: Cetaceans.* Plenum Press, 438 pp.

Waser, P. M. 1977. Individual recognition, intragroup cohesion and intergroup spacing; evidence from sound playback to forest monkeys. *Behaviour* 60: 28–74

Watkins, W. A. and Schevill, W. E. 1977. Sperm whale codas. *J. Acoust. Soc. Amer.* 62: 1485–90.

Wells, R. S., Irvine, A. B. and Scott, M. D. 1980. The social ecology of inshore odontocetes. pp. 263–317 *In:* L. M. Herman (ed.). *Cetacean Behaviour: Mechanisms and Functions.* John Wiley and Sons, New York, 463 pp.

Winn, H. E., Thompson, T. J., Cummings, W. C., Hain, J., Hudnall, J., Hays, H. and Steiner, W. W. 1981. Song of the humpback whale—population comparisons. *Behav. Ecol. Sociobiol.* 8: 41–6.

Würsig, B. 1978. Occurrence and group organization of Atlantic bottlenose porpoises (*Tursiops truncatus*) in an Argentine bay. *Biol. Bull.* 154: 348–59.

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Killer Whales in Greater Puget Sound

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ABSTRACT

From 1974 to 1980 killer whales (*Orcinus orca*) in a previously exploited population in Greater Puget Sound, North America increased in number at a rate of 2.3% per year. The average adult female reproductive rate was observed to be 0.089 calves per year, and the average mortality rate for all whales was calculated to be 0.010 per year.

INTRODUCTION

The population of killer whales (*Orcinus orca*) in Greater Puget Sound and around Vancouver Island in the Pacific Northwest of North America has been significantly harvested in recent years for live animals to be used in public display and research (Bigg and Wolman, 1975; Asper and Cornell, 1977). Studies of animals remaining in this population were initiated by Bigg in 1972 and have continued to date (Bigg, 1982; Balcomb *et al.*, this report), resulting in detailed knowledge of its status and many aspects of killer whale biology and social structure. This paper reports upon the results of studies on the Puget Sound whales with particular emphasis on dynamic features that are useful inputs for population models used in management schemes.

METHODS

For a seven year study period, 1974 to 1980 inclusive, the population of killer whales in Greater Puget Sound was extensively photodocumented each summer and during all months of some years. The technique involved 'encountering' whales with a small motor boat and taking high resolution photographs of as many whales as possible during an encounter period. The photographs were subsequently analysed and individual whales were identified by characteristic scars and pigmentation patterns on the dorsal fin and back. Many whales were recognized by eye during an encounter, in which case field notes were made of their presence and associations with other whales. The photographs and field notes from each encounter were then tabulated to document the occurrence of individuals and associations of individuals, with particular attention to females with calves. The encounter summaries for the entire study period were tabulated to yield information on patterns of association, calving interval, mortality, and seasonality of occurrence. Adult female reproductive rates were calculated using 1974 as year 1, 1980 as year 7, and including only females known or reliably presumed to be mature. Mortality rates were calculated using 1974 or the year of first appearance as year 0 and 1980 as year 6. Continued absence of previously identified whales was taken as evidence of mortality.

RESULTS

Social structure and population dynamics

From 272 encounters with killer whales in Greater Puget Sound it is apparent that there are consistent associations of three main groups of pods which we have designated alphabetically as 'J', 'K', and 'L' pods with 18, 10, and 50 whales respectively as of 1980. These three pods frequently associate with one another, but when they dissociate the individuals involved consistently return (with a few exceptions noted below) to their own pod. These pod associations have been remarkably cohesive over the seven year history of extensive documentation (Tables 1–3), and they strongly suggest that the pod is the fundamental social unit in a breeding population.

The pod designated 'J' is the most cohesive and frequently occurring group of killer whales in the study area. During the study period it was encountered 200 times, 105 (52%) of which were of J pod alone, and the remainder were with K and/or L pod associated. The first known published photographs identifying this pod were taken in October 1968 during a capture operation in Yukon Harbor, Puget Sound (Ridgeway, 1972, Fig 10–36). Adult whales at the time of capture, J-3, J-4, J-5, and J-8 were identifiable among 25 whales reported present. Five juvenile males were removed for research and educational display and the remaining whales were released (Asper and Cornell, 1977). J pod was photodocumented again in March 1972 at Carr Inlet, Puget Sound when eleven whales including adults J-1, J-2, J-3, J-4, J-7, and J-10 were captured and one young male was removed (*Ibid*; and Bigg and Wolman, 1975). Subsequently, J pod has been encountered every year and every month of recent years. Throughout the study period there have been three adult males and eight adult females in the pod, and there has been a calf born every year except 1980. The only loss during this same time period was in 1980 when one six year old subadult died or emigrated. The pod grew in number from 14 to 18, for a 4.1% annual increase. It is interesting to note that only five of the eight adult females produced calves during the study period, and one of the females had three calves at three year intervals (one was born before the study period and its age was estimated). The observed average female reproductive rate is 0.107 calves per year and the most productive female averaged 0.33 per year. The mortality rate within J pod was 0.014 per year.

The pod designated 'K' is the smallest in number of the three local pods and it is less frequently encountered than J pod, though it does occur in all months. Of 136 encounters with K pod, 30 (22%) were with K pod alone and the remainder were with J and/or L pod. The first known photodocumentation of K pod dates to a capture operation in February 1967 at Yukon Harbor, Puget Sound where an adult male (K-5) was identifiable among fifteen whales, three of which were removed (Asper and Cornell, 1977). At the beginning of the study period there were three adult males and five adult females in the pod, but one male (K-2) disappeared in 1974 and has not been seen since. The only calf born among the five adult females during the study period was in 1977, after the disappearance of K-2, hence the net growth of the pod was zero. The average adult female reproductive rate was 0.029 calves per year, and the reproductive rate of one productive female was 0.143 per year. Apart from pod growth due to natality, there was an apparent immigration of several whales from L pod in recent years, but for purposes of calculating pod dynamics they are included with L pod. The mortality rate within K pod was observed to be 0.024 per year.

The pod designated 'L' is the largest in number of the three local pods, and it frequently dissociates into smaller groupings which may themselves be pods (depending upon how one defines a pod). Of 112 encounters with L pod whales, 25 (22%) were with L pod alone and the remainder were with J and/or K pod, most frequently (57%) with both. The first photodocumentation of L pod whales dates to a capture operation in August 1970 at Penn Cove Whidbey Island, where an adult male (L-8) was identifiable among 80 whales, at least seven of which were removed (Asper and Cornell, 1977). Because of the pod's large size and tendency to travel in subgroups, often with J and K pods, L pod is difficult to assess, but we estimate that it has grown in number from 43 (including two newborn calves) in 1974 to 50 whales as of 1980. The pod growth rate was therefore 2.3% per year. Eleven calves were observed as new born during the study period from among 16 presumed adult females. The average reproductive rate of females was therefore about 0.098 calves per female per year. Two females each gave birth to calves at three year intervals for an average reproductive rate of 0.29 calves per year. As this study continues a consistent three year calving

Table 1

Encounter history for J pod. × = photographed or noted present. 0 = absent. Y = alive but not photographed or noted. I = immature. N = newborn

	First photo	1974	1975	1976	1977	1978	1979	1980	for M
Males									
J-1	1972	×	×	×	×	×	×	×	
J-3	1968	×	×	×	×	×	×	×	18
J-6		×	×	×	×	×	×	×	
Females									
J-2	1972	×	×	×	×	×	×	×	
J-4	1968	×	×	×	×	×	×	×	
J-5	1968	×	×	×	×	×	×	×	
J-7	1972	×	×	×	×	×	×	×	24
J-8	1968	×	×	×	×	×	×	×	
J-9		×	×	×	×	×	×	×	
J-10	1972	×	×	×	×	×	×	×	
J-12		×	×	×	×	×	×	×	
Subadults	Mother								
J-11	J-4	I	×	×	×	×	×	×	
J-13	J-5	N	×	×	×	×	×	0	
J-14	J-12		N	×	×	×	×	×	
J-15	J-4			N	×	×	×	×	32
J-16	J-7	I	×	×	×	×	×	×	
J-17	J-5				N	×	×	×	
J-18	J-10					N	×	×	
J-19	J-4						N	×	

Table 2

Encounter history for K pod (symbols as Table 1).

	First photo	1974	1975	1976	1977	1978	1979	1980	for M
Males									
K-1	1973	×	×	×	×	×	×	×	
K-2		×	0	0	0	0	0	0	12
K-5	1967	×	×	×	×	×	×	×	
Females									
K-3		×	×	×	×	×	×	×	
K-4		×	×	×	×	×	×	×	
K-7		×	×	×	×	×	×	×	15
K-8		×	×	×	×	×	×	×	
K-11		×	×	×	×	×	×	×	
Subadults	Mother								
K-12	K-4	I	×	×	×	×	×	×	
K-13	K-7	I	×	×	×	×	×	×	15
K-14	K-3				N	×	×	×	

interval (0.33 calves per year such as was found for one female in J pod) may be documented for these females. Two whales disappeared from L pod during the study period for a mortality rate of 0.007 per year.

In aggregate, these three local pods may be considered a breeding population which has increased in population size from 67 (including three newborn calves) in 1974 to 78 in 1980 (Table 4), for an average growth of 2.3% per year. The combined average reproductive rate of adult females was 0.089 calves per female per year, and fecundity as high as 0.33 calves per year was observed in one case. It is unknown to what extent earlier exploitation might have altered the social and age structure of the population and thereby have contributed to the differential fecundity observed. The overall mortality rate for the population was 0.010 per year.

Other pods of killer whales were observed from time to time, but they were invariably small in number and transient in occurrence. The J, K and L pods did not travel or intermingle with the transient pods, and they presumably did not interbreed with them. We have no evidence that either the pods or population of transient whales increased during the study period. In fact, they possibly diminished due to two known mortalities and only

Table 3

Encounter history for L pod (symbols as Table 1)

	First photo	1974	1975	1976	1977	1978	1979	1980	for M
Males									
L-1		×	×	×	×	×	×	×	
L-6		×	×	×	×	×	×	×	
L-8	1970	×	×	×	0	0	0	0	
L-10		×	×	×	×	×	×	×	
L-13		×	×	×	×	×	×	×	
L-16	1971	×	×	×	×	×	×	0	
L-17		×	×	×	×	×	×	×	61
L-19		×	×	×	×	×	×	×	
L-20		×	×	×	×	×	×	×	
L-33		×	×	×	×	×	×	×	
L-38		×	×	×	×	×	×	×	
Females									
L-2		×	×	×	×	×	×	×	
L-3		×	Y	×	×	×	×	×	
L-4		×	×	×	×	×	×	×	
L-7		×	×	×	×	×	×	×	
L-11		×	×	×	×	×	×	×	
L-12		×	×	×	×	×	×	×	
L-15		×	×	×	×	×	×	×	
L-18		×	×	×	Y	×	×	×	96
L-21		×	×	×	×	×	×	×	
L-23		×	×	×	×	×	×	×	
L-26		×	×	×	×	×	×	×	
L-28		×	×	×	×	×	×	×	
L-32		×	×	×	×	×	×	×	
L-35		×	×	×	×	×	×	×	
L-37		×	×	×	×	×	×	×	
L-40		×	×	×	Y	×	×	×	
Subadults	Mother								
L-5	?	×	×	×	×	×	×	×	
L-9	?	×	×	×	×	×	×	×	
L-25	?	×	×	×	×	×	×	×	
L-27	?	×	×	×	×	×	×	×	
L-30	?	Y	×	×	Y	×	×	×	
L-45	?	×	Y	Y	Y	×	Y	×	
L-14	L-23	I	×	×	×	×	Y	×	
L-22	L-32	I	×	×	×	×	×	×	
L-39	L-2		N	×	×	×	×	×	
L-41	L-11				N	×	×	×	
L-42	L-11	Y	I	×	×	×	×	×	
L-43	L-37	I	×	×	×	×	×	×	
L-44	L-32		N	×	×	×	×	×	120
L-46	L-18	I	×	×	×	×	×	×	
L-47	L-21	N	×	×	×	×	×	×	
L-48	L-21				N	×	Y	×	
L-49	L-23							N	
L-50	L-35	I	×	×	×	×	×	×	
L-51	L-3	N	×	×	Y	×	×	×	
L-52	L-26							N	
L-53	L-7				N	×	×	×	
L-54	L-35				N	×	×	×	
L-55	L-4	I	×	×	×	×	×	Y	
L-56	L-32					N	×	×	
L-57	?	Y	I	×	×	×	×	×	
		—						—	
		43						50	

Table 4

Pod composition in Greater Puget Sound killer whales from 1974 to 1980

	1974	1975	1976	1977	1978	1979	1980
J males	3	3	3	3	3	3	3
J females	8	8	8	8	8	8	8
J subadults	3	4	5	6	7	8	7
Total	14	15	16	17	18	19	18
K males	3	2	2	2	2	2	2
K females	5	5	5	5	5	5	5
K subadults	2	2	2	3	3	3	3
Total	10	9	9	10	10	10	10
L males	11	11	11	10	10	10	9
L females	16	16	16	16	16	16	16
L subadults	16	18	18	22	23	23	25
Total	43	45	45	48	49	49	50
Males	17	16	16	15	15	15	14
Females	29	29	29	29	29	29	29
Subadult	21	24	25	31	33	34	35
Total	67	69	70	75	77	78	78

one known birth having occurred. The infrequent occurrence of transient whales in the study area makes their accurate assessment difficult. Their pod dynamics are not further considered in this paper, though they may be an important factor in the sociobiology of the species.

Regularity of occurrence

The pods designated J, K and L were each encountered in every month of the year, suggesting they do not travel far, if at all, from the study area. During the study period the average number of encounters per month of these whales ranged from one in March to thirteen in July and August. The encounter data are biased due to weather and observation conditions, but they nonetheless indicate that these whales were in the area year-round and can therefore be considered resident to Greater Puget Sound. A public sighting report system which we initiated and maintained from 1976 through 1980 indicated that killer whales were in the study area for approximately half of the days of the year, with an almost daily occurrence from July through October when salmon (*Oncorhynchus* sp.) are migrating inshore toward rivers to spawn (Balcomb *et al.*, 1980). Similar regularity of occurrence related to abundance of prey species has been reported for other populations of killer whales (Jonsgard and Lyshoel, 1970; Condy *et al.*, 1978).

DISCUSSION

Pods and populations

The existence of pods or gregarious packs of killer whales has been known for centuries by whalers and naturalists, but it has only been in recent years that the cohesiveness of these pods and their recurrence in certain areas over long periods of time have been demonstrated. Mead (1961) relates the story of a pod of killer whales found along the Southeastern shore of Australia that for nearly one hundred years were individually known to whalers operating at Twofold Bay, New South Wales. Lending credence to the whalers' story are photographs of these whales which appeared in *The Australian Zoologist* (Wellings, 1944) which clearly show distinctive features of six adult males that were obviously recognizable by eye. Bigg's pioneering work in the Pacific Northwest of North America (Bigg *et al.*, 1976) revealed that approximately 19 pods totalling about 210 whales regularly occur in the waters around Vancouver Island, where their inshore habits make them accessible for study. Some of these pods are the subject of this report and the entire population is the subject of a report by Bigg (1982). In other parts of the world, Gilmore (pers. comm.) provides evidence of a regularly occurring pod of killer whales off Southern California; Matkin (pers. comm.) describes a regularly occurring pod in Prince William Sound, Alaska; Lopez (pers. comm.) describes a regularly occurring pod near Peninsula Valdez, Argentina; and one of us (Balcomb) has photoidentified a pod that regularly occurs off the East coast of Newfoundland, another pod that regularly occurs in the Bering Sea, and another pod that regularly occurs in the Caribbean Sea. The regular catches off Japan during a ten year period (Nishiwaki and Handa, 1958) imply that killer whales regularly occur there; and, the catches by Norwegian whalers in the northeastern North Atlantic (Jonsgård and Lyshoel, 1970) were concentrated in certain localities, such as off Iceland, Scotland, and four areas near Norway, implying local populations occurred in those areas. In Antarctic waters south of the Indian Ocean the Minke Whale Assessment Program in 1978/79 and 1979/80 logged 73 group sightings of killer whales totalling 1,029 animals, for an average group (pod) size of 14 (Dalheim, 1980). Traditionally each of these regional populations might be considered a stock for management purposes, but wherever the local populations have been studied the fundamental enduring social unit is found to be the pod, which suggests that pod dynamics must be considered in any management scheme. Within a geographic area there may be more than one breeding population of killer whales, each comprised of one or more pods. The situation can become quite complex, requiring foreknowledge of the local situation, before any rational management scheme can be introduced.

Dynamics in the Greater Puget Sound resident population

From 1962 to 1973 at least 58 killer whales were removed from the Greater Puget Sound population, and, in 1974, 67 resident whales remained. It may never be known precisely how many of these whales were removed from the J, K, and L pods, but certainly they were heavily exploited, mostly for immature whales. The reproductive rate of adult females can be expected to have increased as a result of this exploitation, hence the average figure of 0.089 calves per female per year may be higher than that for a population in equilibrium. The evidence for high productivity of a few adult females (e.g. to 0.33 calves per year) probably represents the maximum possible reproductive rate for females of the species. It is difficult to imagine that a fifteen month gestation and at least a year of nursing permit a much shorter reproductive interval. The fact that many females do not have such a high reproductive rate suggests that social or age-dependent factors are operative. The average mortality rate of 0.010 per year is extremely low, suggesting that these animals are exceptionally long-lived and therefore might be expected to exhibit age-dependent variations in fecundity. The overall growth of 2.3% per annum for this previously exploited population can probably be used to calculate the growth potential of other exploited populations, provided the reproductive animals have not been removed or the pod structure destroyed.

This figure is more accurate than population growth estimates based upon whaling catch data by virtue of the fact that the study animals survived and a real increase in population was measured.

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REFERENCES

Asper, E. D. and Cornell, L. H. 1977. Live capture statistics for the killer whale (*Orcinus orca*) 1961–1976 in California, Washington, and British Columbia. *Aquatic Mammals* 5(1): 21–7.

Balcomb, K. C., Boran, J. R. Osborne, R. W. and Haenel, N. J. 1980. Observations of killer whales (*Orcinus orca*) in Greater Puget Sound, State of Washington. Report MM1300731-7, US Marine Mammal Commission, Wash. D.C., USA.

Bigg, M. A. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Paper SC/Jn81/KW4 (published in this volume).

Bigg, M. A., McAskie, I. B. and Ellis, G. 1976. Abundance and movements of killer whales off Eastern and Southern Vancouver Island with comments on management. Preliminary report, Arctic Biological Station, Ste. Anne de Bellevue, Quebec, Canada.

Condy, P. R., Van Aarde, R. J. and Bester, M. N. 1978. The seasonal occurrence and behavior of killer whales, *Orcinus orca*, at Marion Island. *J. Zoology* 184: 449–64.

Dalheim, M. E. 1980. A review of the biology and exploitation of the killer whale, *Orcinus orca*, with comments on recent sightings from Antarctica. *Rep. int. Whal. Commn* 31: 541–46.

Jonsgård, Å. and Lyshoel, P. B. 1970. A contribution to the biology of the killer whale, *Orcinus orca* (L.). *Norwegian Jour. Zool.* 18: 4–48.

Mead, T. 1961. *Killers of Eden.* Angus and Robertson, Ltd., Sydney, London, and Melbourne. 222pp.

Nishiwaki, M. and Handa, C. 1958. Killer whales caught in the coastal waters off Japan for recent ten years. *Sci. Rep. Whales Res. Inst., Tokyo.* 13: 85–96.

Ridgeway, S. H. 1972. Homeostasis in the aquatic environment. pp. 590–747. *In:* S. H. Ridgeway, (ed.) *Mammals of the Sea.* Charles C. Thomas, Springfield, Illinois.

Wellings, C. E. 1944. Killer Whales of Twofold Bay. NSW Australia, Grampus orca. *Australian Zoologist.* 10(3): 291–3.

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Geographic Variation in the Color Pattern of Killer Whales (*Orcinus orca*)

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INTRODUCTION

Evans and Yablokov (1978) proposed a method for analyzing differences in the color pattern of killer whales (*Orcinus orca*). This species' rather complex pattern was divided into several distinct components. Using schemes similar to those proposed by Yablokov (1969), Mitchell (1970), Perrin (1972) and Evans (1975), each component was identified by a descriptive name associated with its anatomical location, e.g. post-dorsal fin saddle, flank field, post-ocular, etc. The observed variants of each component were compiled from illustrations in the literature, photographs taken in the field during various research cruises, and by examination of live specimens at Sea World, San Diego, California, Orlando, Florida and at several other oceanaria in the United States and Canada. These components and the observed variations are presented in Fig. 1. In our original paper (Evans and Yablokov, 1978) it was hypothesized that the pigmentation pattern of *Orcinus* is geographically variable. If this assumption is valid it should then be possible to characterize different regional populations, based on analysis and quantification of color pattern types.

To test this hypothesis we collected samples of *Orcinus* color patterns from as many geographic areas as possible.

MATERIALS AND METHODS

The color pattern samples studied were collected using two different techniques: (1) photographing live specimens at sea and at oceanaria, (2) on-site scoring of color pattern components for specimens collected by the Soviet Antarctic whaling fleet, during 1977–78, 1978–79 and 1979–80 seasons. Samples collected by both techniques were scored using a data sheet based on Fig. 1. Summaries of all data are presented in Appendix Tables A-1 and A-2.

Photographic material

Following the cautions presented by Mitchell (1970), only photographs of live specimens or recently killed specimens (less than 4 hours) were analyzed. In most photographs, only those components dorsally or laterally exposed during a blow or other surface activity were suitable for analysis. The material for analysis consisted of five components: post-ocular patch, sub-ocular notch, shoulder notch, anterior ventral field and post-dorsal fin saddle. The components are illustrated in Fig. 1 as sections 1, 4, 5, 6 and 14. Compared to actual examination of specimens, photographic material is limited by the inability to segregate the sample according to sex and age (size).

Most of the main color pattern components of *O. orca* are symmetrical, and therefore sampling only one side was considered adequate. The post-dorsal fin saddle is an exception, being quite asymmetrical in some individuals. We have compensated for the bias that could result by reducing the number of variants (16) originally suggested to three more generalized patterns not affected by the asymmetries: (a) extensive black in the saddle, (b) small black intrusion, and (c) no black intrusion in the saddle.

Table 1

Orcinus orca samples for color pattern in World Oceans (photographic material)

Locality	Sample size
Northwest Pacific (Puget Sound, Alaskan water, Bering Sea, western Aleutian Islands)	56
East Central Pacific (Baja California, Mexico)	38
North Atlantic (Iceland waters, North Sea)	15
South Atlantic (Argentina, off Punta Norte)	16
Antarctic—open waters (South Shetland Islands, Drake Passage, Weddell Sea)	36
Antarctic—in ice (McMurdo Sound, ice edge)	63

With the cooperation of several colleagues and institutions (see list in Acknowledgements) analyzable material was obtained from several locations in the Pacific, northeastern and southwestern Atlantic and three regions of the Antarctic (Table 1). Material was collected on an opportunistic basis: we cannot, therefore, guarantee that the sample is an unbiased representation of the actual distribution of the various color patterns. We did not attempt to control for homogeneities within pods, although we did obtain samples from as many different areas as possible.

On-site scoring of color pattern

Our data collection forms, patterned after Fig. 1, were used by Dr V. M. Veinger, Dr A. A. Kuzmin and Mr V. L. Vladimirov in the Antarctic during the 1977–78, 1978–79 and 1979–80 seasons to collect color pattern data from *O. orca*. Each specimen was sexed, measured and the color patterns scored as soon as possible after delivery by the

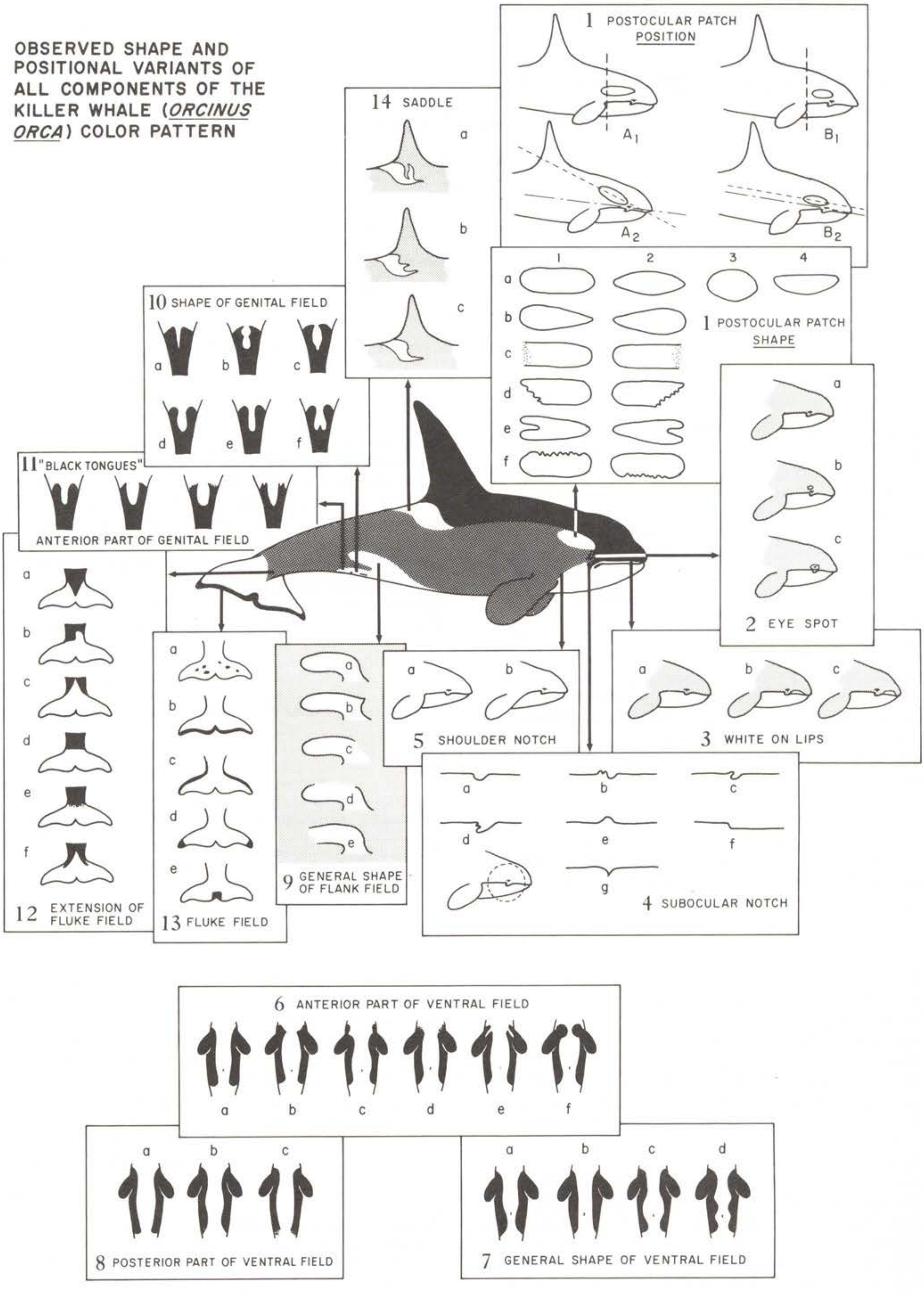

Fig. 1. Components of the *Orcinus orca* color pattern with all observed shape and positional variants of the killer whale color pattern (after Evans and Yablokov, 1978).

catcher boats. The IWC Area where each group of specimens was collected was designated on the data form. The largest sample (n = 177) was collected in Area V. The sample size from Areas III and IV was small (n = 38), and since all the material was collected between 40°E and 90°E, near the dividing line between these Areas, the samples were combined. In addition, it was also indicated whether pods were encountered far into open ice leads or in open water. Details of the numbers of individuals studied by sex and locality of collection are given in Table 2. Since the sample sizes for the longitudinally separate groups for open water were so small they were combined and only the latitudinally separated groups (in ice versus open water) were tested for differences.

Table 2

Orcinus orca sampled for color pattern in Antarctic by Soviet whaling fleets.

	Sex		
Locality	Male	Female	Total*
Area V, 'in ice'	70	65	135
Area V, 'open water'	21	21	42
Area III–IV, 'in ice'	7	7	14
Area III–IV, 'open water'	12	12	24
Total	110	106	216

* 20 samples were from 1977–78 season, 5 from 78–79 and 190 from 79–80 season.

ANALYSIS AND SUMMARY OF RESULTS

General features of *Orcinus* color pattern

In Evans and Yablokov (1978), Guldberg-Nausen's (1894) description of the color pattern of a fetal *Orcinus* was briefly discussed. In their illustration the specimen had all the major components of the *Orcinus* pattern. In addition, their illustrations indicated the presence of a general dorsal cape similar to that described by Perrin (1972) as a general feature of delphinid color patterns. Based on photographic samples from Northern Hemisphere available at the time we considered this was a feature that apparently was not expressed in the adult color pattern. Upon more detailed examination of photographic samples from the Southern Hemisphere several individuals from the area of McMurdo Sound, Antarctic, illustrated a very visible dorsal cape (Fig. 2). The margin of this dorsal cape runs from near the apex of the melon to behind the dorsal fin, passing high over the eye, forming the dorsal margin of the post-ocular patch, and dipping below the dorsal fin to form the lower lateral margin of the post-dorsal fin saddle. On re-examination it was possible to detect this cape in the photographs of all specimens from Antarctic waters and from a few specimens from Argentina. G. M. Vienger (TINRO) also noted that all specimens taken by the Soviet Antarctic fleet had a pronounced cape pattern. This feature is not discernable in photographs of individuals from any of the other geographic areas studied. It is, however, possible with careful scrutiny to detect the margin of a cape in living specimens from Icelandic and Puget Sound waters on display at Sea World, San Diego.

Color pattern component analyses

Because of the previously mentioned differences in our data collection methods, the photographic material and on-site (Soviet Antarctic Whaling Fleet) data were analyzed separately. Depending on the sample size and consistency of the data, some samples from adjoining areas were combined. If the frequency of occurrence of a pattern variant was low for all geographic areas, we dropped the variant out of the analysis. We also assumed that the components of the color pattern varied independently. We would like to caution that in light of the observed connection (dorsal cape) between the post-dorsal fin saddle and post-ocular patch this assumption of independence may not be valid for these two components.

To test for homogeneity among variants of each color pattern component as a function of geographic area Chi-square (χ^2) contingency tests were performed (Sokal and Rohlf, 1969). In 2 × 2 contingency tables where cell size was less than 5, Yates correction was used. All analysis was performed using SPSS (Statistics Package for the Social Sciences, Nie *et al.*, 1975).

Photographic data

All photographic material was segregated by geographic region (see Table 1). Material was pooled from all pods observed within these regions. Due to the gross level of the analysis, no attempt was made to control for interpod differences. Tracings were made of each visible component. These tracings were used to determine which variant of each component (Fig. 1) provided the best match. The frequency of occurrence of component variants for each geographic area was tabularized for comparison.

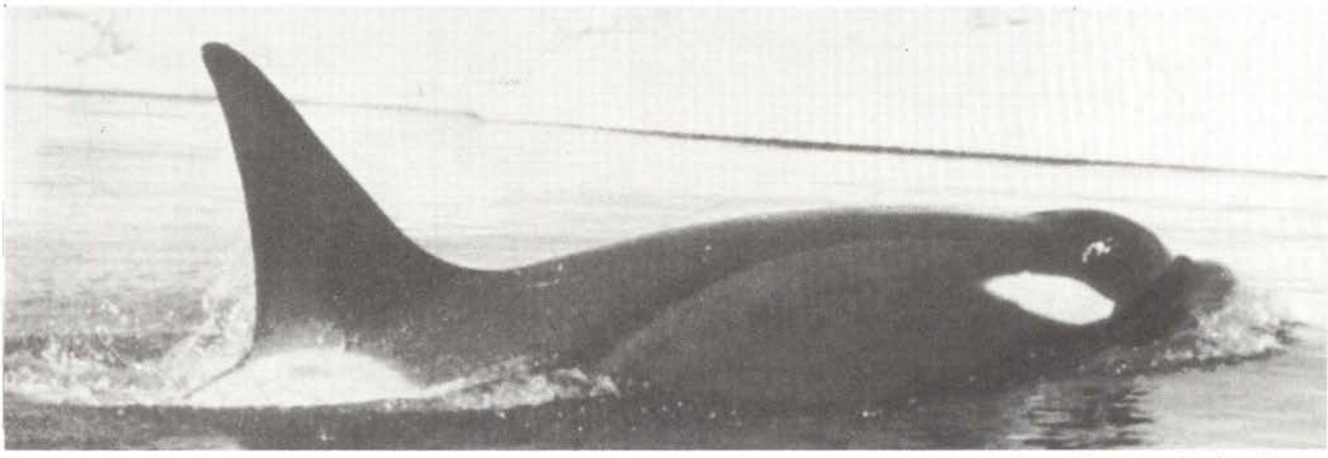

Fig. 2. Expression of dorsal cape pattern was observed in all Antarctic *Orcinus orca* studied. This photo illustrates the dorsal cape configuration of the McMurdo Sound group.

Of the fourteen components originally identified, only 5 could be scored on individuals representing the geographic areas indicated in Table 1. Each of these will be discussed separately. We examined data for only those geographic areas where sample sizes were large enough to insure that most cell sizes were greater than 5. These included the Northwest Pacific (Puget Sound, Gulf of Alaska, Aleutian Is.), East Central Pacific (Baja California, Mexico), North Atlantic (Iceland), South Atlantic (Argentina), Antarctic in-ice leads (McMurdo Sound), Antarctic open water (So. Shetlands, Antarctic Peninsula, and IWC Areas III–V pooled).

Post-ocular patch

Evaluation of the frequency of occurrence data indicated that symmetrical post-ocular patch patterns (a 1–4) were predominant in the sample from the Antarctic Peninsula, Antarctic Areas III–IV, and Iceland. The expression of this component is most variable in the samples from Puget Sound (Pacific Northwest) and McMurdo Sound, Antarctic, with all major variants represented (see Fig. 3). It is possible that this is a function of sample size and the existence of a high degree of individual variation in this component, since the largest samples are from these areas. In order to compensate for absence of some variants or small sample size in some samples all the symmetrical variants and asymmetrical variants were combined. χ^2 values, testing symmetrical versus asymmetrical patterns from four geographical areas are presented in Table 3.

Table 3

Post-ocular patch shape symmetrical vs. asymmetrical for 4 geographic regions (Northwestern Pacific, East Central Pacific, McMurdo in ice, Antarctic open water Areas III–IV)

	Northwest Pacific	East Central Pacific	Antarctic in ice
East Central Pacific	$\chi^2 = 1.3973$ NS $n = 97$		
Antarctic in ice	$\chi^2 = 0.9226$ NS $n = 124$	$\chi^2 = 0.8247$ NS $n = 99$	
Antarctic open water	$\chi^2 = 15.1428$ NS $n = 97$	$\chi^2 = 7.5988$ $p < 0.05$ $n = 72$	$\chi^2 = 11.7862$ $p < 0.05$ $n = 99$

Whole table: $\chi^2 = 16.2652$
$p < 0.05$
$n = 196$

Data from the North Atlantic (Iceland) and South Atlantic (Argentina) were not tested due to small sample size. As discussed above, samples from the Antarctic Peninsula and Areas III–IV (Antarctic open water) were combined. The hypothesis of homogeneity in the post-ocular patch shape by geographic areas was rejected at $p < 0.05$. Interestingly, it appears that this is largely due to a

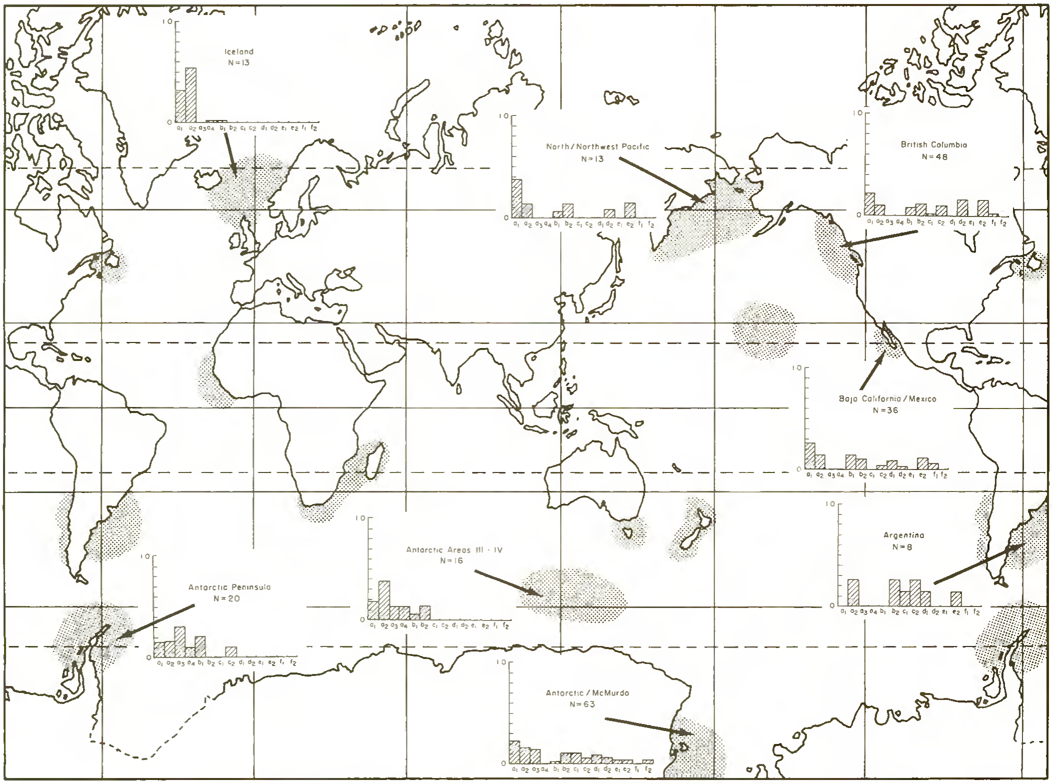

Fig. 3. Frequency of occurrence of post-ocular patch shapes for all geographic areas studied.

difference between McMurdo Sound and all other areas, including the Antarctic open water samples. To a lesser extent, Antarctic open water differs from the Northern Hemisphere and southern Atlantic areas examined.

In addition to variation in shape, the position and size of the post-ocular patch were also variable. The position and size differences were in angular orientation of the patch with the long axis of the body (A_2, B_2, Fig. 1, Section 1) and in posterior extension of the patch past the anterior insertion of the flipper (A_1, B_1). The A_2 variant was found only in high southern and northern latitude samples. Although this type occurs in the Northwest Pacific, it is quite rare. In the Antarctic it occurs with very low frequency in Areas III–V (7%), slightly higher near S. Shetland Islands (36%) and is quite common along the ice edge of McMurdo Sound (68%). The posterior extension of the patch (A1), also shows a marked north-south difference (Table 4). The χ^2 values, levels of significance and sample sizes for the 5 geographical areas tested are presented in Table 5. The hypothesis of homogeneity was rejected at $p > 0.05$, and, as before, Antarctic in-ice was significantly different from all other areas. Northwest Pacific was different from all areas except East Central Pacific (Baja California, Mexico).

Table 4

Occurrence of variations in post-ocular patch position and size as function of geographic location. Variations A_1, A_2, B_1, B_2 appear in Fig. 1. Section 1

	Positions post-ocular patch					
	Patch size			Position		
Location	n	A_1	B_1	n	A_2	B_2
Northwest Pacific	44	2	42	47	12	35
East Central Pacific	17	0	17	9	2	7
North Atlantic	15	0	15	17	16	1
South Atlantic	16	1	15	5	1	4
Antarctic open water	28	7	11	17	16	1
Antarctic in ice	60	41	19	13	10	3

Sub-ocular notch

The expression of the sub-ocular notch is quite variable in all groups, especially the McMurdo Sound samples. The 'a' and 'c' variants predominate in most samples from the Pacific and McMurdo. However, in the Antarctic open water samples the 'b' and 'c' variants were the most frequently observed (Fig. 1, section 4). Table 6 lists χ^2 values for the four geographic areas tested. This component was homogeneous for all areas tested except Antarctic open water versus the Northwest Pacific.

Table 6

Sub-ocular notch (3 variants) versus 4 areas from the photographic data

	North Pacific	East Central Pacific	Antarctic in ice
East Central Pacific	$\chi^2 = 5.03$ NS N = 54		
Antarctic in ice	$\chi^2 = 1.6208$ NS n = 60	$\chi^2 = 1.37290$ NS n = 56	
Antarctic open water	$\chi^2 = 8.99646$ $p < 0.05$ n = 55	$\chi^2 = 5.7616$ NS n = 51	$\chi^2 = 5.5299$ NS n = 57

Whole table: $\chi^2 = 16.3267$
$p < 0.05$
df = 6
n = 111

Anterior part of the ventral field

This component is relatively homogeneous in the Northern Hemisphere groups with variants 'a' and 'b' occurring with equal frequency. The only exception is, again, the Puget Sound sample, which is highly variable. Variants 'a' and 'b' have the highest frequency of occurrence but all variants of this component can be found. This character was non-homogeneous between McMurdo and other

Table 5

Post-ocular patch size (A_1, B_1) and angle (A_{21}, B_2) versus the six geographic areas from photographic data. We did not examine size and angle independently with area. (See Fig. 1, Section 1, and Fig. 3)

	North Pacific	East Central Pacific	North Atlantic	Southern Atlantic	Antarctic open-water
East Central Pacific	$\chi^2 = 3.22657$ NS n = 106				
North Atlantic	$\chi^2 = 24/98\text{-}12\text{-}$ $p < 0.05$ n = 112	$\chi^2 = 15.05431$ $p < 0.05$ n = 58			
Southern Atlantic	$\chi^2 = 9.53457$ $p = < 0.05$ n = 102	$\chi^2 = 6.62338$ NS n = 48	$\chi^2 = 5.08442$ NS n = 54		
Antarctic open-water	$\chi^2 = 29.18966$ $p = < 0.05$ n = 125	$\chi^2 = 19.09272$ $p = < 0.05$ n = 71	$\chi^2 = 5.97552$ NS n = 77	$\chi^2 = 3.81608$ NS n = 67	
Antarctic in ice	$\chi^2 = 64.03040$ $p = < 0.05$ n = 153	$\chi^2 = 33.21820$ $p = < 0.05$ n = 99	$\chi^2 = 32.85516$ $p = < 0.05$ n = 105	$\chi^2 = 19.46268$ $p = < 0.05$ n = 95	$\chi^2 = 21.11264$ $p = < 0.05$ n = 118

Whole table: $\chi^2 = 161.14554$ df = 15
$p < 0.05$ n = 278

populations (Table 7). As in the Northern Hemisphere samples, there is a high frequency of occurrence of variants 'a' and 'b': however, the 'd' variant occurs with the highest frequency in all Antarctic groups (see Fig. 1, Section 6).

Table 7

Chi-square test of anterior part of ventral field (a, b, d variants, Fig. 1, section 4) versus 4 areas from the photographic data

		Northwest Pacific		
East Central Pacific	2	$\chi^2 = 16.4478$ $p < 0.05$ $n = 46$	East Central Pacific	
Antarctic in ice	3	$\chi^2 = 15.3263$ $p < 0.05$ $n = 48$	$\chi^2 = 14.471$ $p < 0.05$ $n = 22$	Antarctic in ice
Antarctic Peninsula III–IV	4	$\chi^2 = 5.2738$ NS $n = 47$	$\chi^2 = 2.4436$ NS $n = 21$	$\chi^2 = 12.4801$ $p < 0.05$ $n = 23$

Whole table: $\chi^2 = 43.8620$
$p < 0.05$
$n = 69$
$df = 9$

Post-dorsal fin saddle

All variants of the post-dorsal fin saddle occur in the Northern Hemisphere. Qualitatively, different geographic groups appeared to be non-homogeneous, however the sample size was not adequate for testing. In contrast, only variant 'c' of this component is observed in Southern Hemisphere samples (Fig. 1, section 4).

On-site whaling fleet data

The data from color pattern scoring forms for each individual examined were consolidated into tables. These data were segregated by the Areas designated in Table 2, by sex, and by the variant of each component observed. The frequency of occurrence of component variants for males and females was examined, and no sexual dimorphism in color patterns was observed for the characters examined in this paper. The data for males and females were then combined for further analysis. It should be noted that black pigmentation bordering the genital areas was not considered in this analysis; where observed it is sexually dimorphic.

Examination of the raw frequency data (Appendix Table A-2 indicated differences between the groups sampled in Area V and Areas III/IV. However, the differences between the 'in ice' samples and 'open water' samples are more pronounced and the sample sizes more balanced. Since this latter difference is also supported by analysis of more traditional morphological characters, such as length at sexual maturity and dentition (A. A. Berzin and V. L. Vladimirov, TINRO, 1981), we chose to test for homogeneity between the in ice and open water groups.

Chi-square contingency tests for homogeneity were made of Area V, III/IV ('in ice'), versus Area V, III/IV ('open water'). Three components, sub-ocular notch, shoulder notch, and the general shape of the ventral field exhibited non-homogeneities and were tested. In the sub-ocular notch 8 variants were tested for in-ice versus open water and the hypothesis of homogeneity was rejected ($\chi^2 = 18.8080$, $n = 220$, $p < 0.05$). The same is true for presence or absence of a shoulder notch for in-ice versus open water ($\chi^2 = 10.8950$, $n = 215$, $p < 0.05$). Finally, three variants of the general shape of the ventral field also showed significant non-homogeneities ($\chi^2 = 9.9476$, $n = 213$, $p < 0.05$). These results were consistent with the previously mentioned differences between in-ice and open water specimens, and with the photographic data. The expression of the variants of these three components appears to be quite complex. For example in the sub-ocular notch, high frequency of occurrence of pairs of variants contribute strongly to the observed non-homogeneity (Table 8).

Table 8

Prominent variants of non-homogeneous components of Antarctic *Orcinus* as a function of location

Component		Area V	Area III/IV
4. Sub-ocular notch	ice	a/f	c/d
	open water	c/f	f/a
5. Shoulder notch	ice	b	b
	open water	a/b	a
6. Anterior part of ventral ice	ice	c/a	c
	open water	a/e	c/d
7. General shape of ventral field	ice	b	c
	open water	a	a/b/c

CONCLUSION AND DISCUSSION

Six of the fourteen components of the color pattern of killer whales examined are geographically variable. There are also significant geographic differences in the position of the post-ocular patch and expression of a dorsal cape. Differences in groups from the Northern and Southern Hemispheres are most pronounced. Fortunately some of the most variable, and therefore useful, components are displayed when individuals surface to blow. These components can be effectively sampled photographically and/or visually. Unfortunately, the photographic sample available from mid-latitude temperate and tropical waters was not large enough to do more than indicate trends. Availability of more data from these areas may make it possible to determine whether post-ocular patch shape and position, post-dorsal fin saddle shape and expression of the dorsal cape are clinal or antitropical in distribution.

It is important to caution that one of the main sources of errors in comparing the color pattern of animals from different areas is the danger of confusing pod (demes) characters with potential population characters. The data collected by two separate methods are supportive of the conclusion that significant geographic variations do occur in the color pattern of *Orcinus orca*. Groups of killer whales from McMurdo Sound (near the ice edge), open water areas near the Antarctic Peninsula, and in IWC Areas III–IV, differ from each other in the expression of several color pattern components. Additional differences also occur between Pacific and Atlantic samples. At the present, the data are not sufficient to determine whether the different color forms observed represent modes in a geographically continuously varying species or several reproductively isolated populations.

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REFERENCES

Evans, W. E. 1975. Distribution and differentiation of stocks and natural history of *Delphinus delphis* Linnaeus in the northeastern Pacific. Ph.D. Diss. UCLA, 1–57.

Evans, W. E. and Yablokov, A. V. 1978. Intraspecific variation of the color pattern of the killer whale (*Orcinus orca*). pp. 102–115. *In:* V. E. Sokolov and A. V. Yablokov (eds). *Advances in Studies of Cetaceans and Pinnipeds*, 'Nauka' Publ., Moscow. (English summary).

Mitchell, E. 1970. Pigmentation pattern evolution in delphinid cetaceans; an essay in adaptive coloration. *Canad. J. Zool.* 48: 717–40.

Nie, N. H. *et al.* 1975. *SPSS: Statistics Package for the Social Sciences.* 2nd ed. McGraw Hill, New York.

Perrin, W. F. 1972. *Color Pattern of Spinner Porpoises* (*Stenella cf. S. longirostris*) *of the Eastern Pacific and Hawaii.* Univ. Calif. Press, Berkeley, Los Angeles, London, 206pp.

Sokal, R. R. and Rohlf, F. J. 1969. *Biometry.* W. H. Freeman, San Francisco.

Yablokov, A. V. 1969. Types of color of the Cetacea. *Fish. Res. Board of Canada, Transl. Ser.*, N 1239, 1–28. (Orig. in Russian 1963).

APPENDIX

Table A-1

Raw data on four color pattern components (see Fig. 1) collected from analysis of photographic material. Not all photos could be scored for all components. Material was available from 12 areas; only those areas where a sample of 5 or more individuals for 2 or more components could be scored are included (8 areas).

Component	Northwest Pacific	Puget Sound (British Columbia)	East Central Pacific (Baja)	Iceland North Atlantic	Argentina S.W. Atlantic	McMurdo	Antarctic Peninsula	II–IV
Post-ocular patch (1)	5,a1 2,a2 1,b1 2,b2 1,d2 2,e2	10,a1 5,a2 4,b1 6,b2 1,c1 5,c2 8,d2 8,e2 1,f1	9,a1 6,a2 6,b1 4,b2 1,c2 3,d1 1,d2 4,e2 2,f1	4,a1 7,a2 1,a4 1,b1	1,a1 2,b2 1,c1 2,c2 1,d1 1,e2	14,a1 9,a2 8,a3 1,b1 6,b2 6,c1 4,c2 5,d1 4,d2 2,e1 2,e2 2,f2	3,a1 3,a2 6,a3 2,a4 4,b1 2,c2	3,a1 6,a2 2,a3 2,a4 1,b1 2,b2
Sub-ocular notch (4)	4,a 4,c 1,d 1,g	5,a 1,b 15,c 5,d	13,a 3,b 9,c 2,g	6,a 1,c 1,d	2,a 1,c	12,a 3,b 16,c 4,d 1,e 4,f 2,g	2,a 1,d 2,g	4,a 9,b 11,c 1,e
Anterior part of ventral field (6)	4,a 4,b	10,a 12,b 2,c 4,d 5,e	1,b	3,a 3,b	2,a 2,b 6,d	1,a 3,b 8,d	—	3,a 5,b 3,d
Post dorsal fin saddle (14)	4,a 1,b 8,c	32,a 43,b 33,c	4,a 38,c	2,a 10,c	16,c	24,c	19,c	5,c

Note: For purpose of analysis Pacific N/NW and British Columbia (Puget Sound) were combined as were Antarctic Peninsula and Areas III–IV.

Table A-2

Raw data on color pattern components (see Fig. 1) found to be non-homogeneous for sample. Collected by Soviet Antarctic whaling fleet, 1977–78,78–79, 79–80.

Component	All in ice	All open water	All Area V	All III Area IV
Sub-ocular notch (4)			57a	6a
	53a*	10a	5b	9b
	5b	1b	53c	7c
	31c	30c	4d	5d
	6d	4d	34g	7g
	30e	12g	24h	4h
	1f	8h		
	13g			
	11h***			
Should notch (5)	116a	36a	131a	16a
	33b	30b	46b	22b
Anterior part ventral field (6)	34a	19a	49a	4a
	32b	10b	36b	6b
	57c	18c	57c	18c
	27d	9d	26d	10d
		10e	10e	
General shape ventral field (7)	55a	39a	79a	11a
	64b	16b	89b	18b
	29c	10c	7c	9c
	N = 150*	*N = 66*	N = 177*	N = 35*

* Not all shapes could be seen due to damage to central areas during tests.

** Variant designations refer to Fig. 1.

*** No detectable sub-ocular notch.

SC/33/Rep 3

Report of the Special Meeting on Southern Hemisphere Minke Whales, Cambridge, 22–26 June 1981

1. CONVENOR'S OPENING REMARKS

The meeting was convened by J. W. Horwood. It was noted that, due to problems documented in *Rep. int. Whal. Commn* 31: 110, the Scientific Committee had recommended a special meeting for assessment of the Southern Hemisphere Minke Whale Stocks prior to the full meeting of the Scientific Committee.

2. APPOINTMENT OF CHAIRMAN

Horwood was appointed as Chairman for the meeting. A list of participants is given in Appendix 1.

3. APPOINTMENT OF RAPPORTEURS

It was agreed that Donovan and Horwood would jointly manage the reporting from the meeting.

4. ADOPTION OF AGENDA

The agenda is shown in Appendix 2.

5. REVIEW OF DOCUMENTS AND REPORTS

Participants' attention was drawn to the fact that a special meeting on sightings theory was held in Seattle in 1980. A report from this meeting was available (SC/33/Rep 1).

A list of documents presented to the meeting is given in Appendix 3.

6. REVIEW OF COMPUTER FACILITIES AND AVAILABLE DATA

Free reported that the computing facility had been greatly expanded since the 1980 meeting and that five terminals were available to be used for contact with the Cambridge University IBM 370 computer. He explained that the University had been very helpful in arranging facilities. Data encoded on the computer consisted of BIWS, on the individual catch records of whales in the Southern Hemisphere and CDW. Free also reported that he was negotiating for the acquisition of ice cover data by 30 km squares from NASA. He will discuss with people at the meeting what the most relevant ice information is likely to be. Clark brought an atlas of weekly estimates of ice cover for the period 1973–80.

Data were also available on tape for the 1979/80 and 1980/81 IWC/IDCR Minke Whale Cruise. Biological data provided by Japan were also available on tape.

Japanese scientists brought three films. The first was a long video film of the behaviour of the top-men on the 1980/81 IWC/IDCR research cruise. The second was a professional video film of the 1980/81 IWC/IDCR cruise and the third was a 16 mm film of the 0.410 test firing experiment on the *Nisshin Maru No. 3* in 1980/81.

7. DEFINITION OF MANAGEMENT AREAS

One of the main reasons for the minke whale sub-committee of last year recommending a special meeting was the lack of agreement over stock boundaries and the inability to use all the suggested combinations in the assessments.

SC/Jn81/MiS3 reviewed the literature on minke whale stock separation in the Southern Hemisphere and considered that there was insufficient evidence from any study for dividing the region into biological populations or stocks. Given the lack of other information the study recommended the use of CPUE or cumulated catch as a basis for splitting the Southern Hemisphere into management areas.

In response to SC/Jn81/MiS3, Appendix 4 describes the results of a new analysis using G-statistics.

It was agreed that on the basis of the biochemical studies from Antarctic catches there was probably more than one biological population in the Southern Hemisphere. The available data suggested a division somewhere between the samples taken in Area IV and V.

Best drew attention to a diminutive form of minke whale found off South Africa (SC/Jn81/MiS4) and apparently also off Brazil SC/33/ProgRep Brazil. This form has a colour pattern atypical of minke whales in the Southern Hemisphere. So far as is known this form has not been recorded from the Antarctic to date.

In response to SC/Jn81/MiS3 Shimadzu explained that Shimadzu and Kasamatsu (*Rep. int. Whal. Commn* 30: 349–56) documented operational information that showed cumulative catch should not be used as a basis for dividing the Antarctic into areas. Ohsumi pointed out that small or no effort in some locations could appear as hiatuses in density distributions as represented by CPUE values. This would be false and CPUE should be used cautiously.

Holt (Appendix 5) looked at catches in Areas III–V before and after the times at which minke whale catch limits were set by Area. He concluded that a more appropriate grouping for management regions would be (1) 0°–100°E and (2) 100°E–180° or 170°W. Shimadzu suggested that Holt's results were sensitive to the pairs of 10° squares selected.

Material was collated which might assist in the division of the Antarctic into management Areas. This included,

1. Total catch by sex, year, month, country and 10° square.
2. Total catch, CSW, catch/CSW summed by 10° of longitude S of 50°S and S of 60°S (Appendix 6).

3. Catch by sex and CSW corrected for weather for Areas III and V and some of VI, and CSW corrected for weather and seasonality for Area IV, for years in which the Japanese expeditions traversed all the 10° squares in any of the Areas (Appendix 7).
4. Marking and recapture results. (SC/Jn81/MiS10, 31, 33).
5. Japanese scouting boat sightings summed by longitude (Ohsumi, *Rep. int. Whal. Commn* 29: 416) and Soviet sightings data (Arsenev, *Norsk Hvalfangsttid.* 49: 380–2).
6. The sightings data and contours from the IWC/IDCR cruises to Areas III, IV and V (SC/Jn81/MiS15, 16 and Best and Butterworth, *Rep. int. Whal. Commn* 30: 257–83).
7. Marr's krill distribution (*Discovery Rep.* 32: 378, 394).
8. A graphical summary of some of the data presented in 1 (Appendix 8).

It was agreed that all the information should be considered together for the purpose of agreeing stock boundaries.

Except for the biochemical studies there was no biological evidence to suggest that any one form of split was likely to be better than any other, however Ohsumi considered that the mark returns tended to support the present stock boundary between Areas III and IV. Attention eventually focused on the various CPUE indices, but as Best pointed out, the major hiatuses in these coincided with the Ross and Weddell Seas in which it is considered too dangerous for the factory ships to operate. High densities of whales were seen in the Ross Sea by the 1980/81 IWC/IDCR cruise.

For assessment purposes it was necessary to divide the Southern Hemisphere into several sub-areas. Further it was discussed how the best set should be decided upon. Although a criterion such as minimum residual sum of squares of observed and expected catches could be used, it was noted that this could be misleading if the model was incorrect. There was no agreement on an *a priori* basis for selection of the best set. Such a subdivision would not prejudice the selection of management areas. It was noted that there was no theory with which to decide the optimal size of the management Areas.

Four sets were proposed.

1. The present six management Areas.
2. Last year's scheme proposed by Holt (SC/32/Mi2 [not published]; *Rep. int. Whal. Commn* 31: 103) and amended slightly by Best to make it more compatible with the design of the IWC/IDCR sightings surveys: A: 40°E–160°E, B: 160°E–160°W, C: 160°W–40°W, D: 40°W–40°E.
3. Last year's scheme based on a synthesis of the data available to that sub-committee (*Rep. int. Whal. Commn* 31: 103): i, 120°W–20°W; ii, 20°W–80°E, iii, 80°E–130°E, iv, 130°E–170°W, v, 170°W–120°W.

It was argued that this year's deliberations might have superseded those of last year, but there was no agreement with the suggestion that that scheme be rejected.

4. A scheme proposed by Chapman based on the CPUE series: α, 30°W–130°E; β, the rest.

It was recognised that it was not possible in the time available to run the assessment program for all these sub-areas, particularly since effort had to be corrected for each new sub-area and that age of recruitment had to be calculated for each sub-area. It was estimated, that this would involve about one week's work. However many regions do not have large sets of effort data and previous experience suggested that attention should be focused on the sector of 0°–180°E. Consequently it was agreed that data would be extracted and assessments undertaken for Areas III, IV, V, A and α.

8. BIOLOGICAL PARAMETERS

8.1 Age

SC/Jn81/MiS4 examined the assumption that one growth layer group (GLG) is laid down per year in the minke whale's ear plug. It was concluded that the ovulation rate of 0.81 per year derived from this assumption was more compatible with the estimated pregnancy rate (0.78) than an ovulation rate of 1.62 derived from 2 GLGs per year. A fair correlation was also shown between puberty and the appearance of the transition phase in the ear plug.

8.1.1 Female ages at maturity (t_m)

No new information was available on the ages at maturity of the early (1934/5–1967/8) age classes and it was agreed that last year's values be retained. Information from SC/Jn81/MiS4 corroborated a decline in age at sexual maturity based on the transition phase, with time. It was agreed that, where possible, the actual ages in the individual Areas should be used but it was noted that there was little difference between Areas.

SC/Jn81/MiS32 presented new data on the actual mean age of maturity in the Japanese catch over the period 1971/72 to 1979/80. There was some evidence for a small increase in t_m over this period. A small increase in age at maturity was noted for the year classes 1965 to 1972.

It was recognised that small changes in t_m over the period 1971/72—1979/80 would have no effect on population estimates and a very small effect on predicted recruitments for the next few years. It was therefore agreed that for all Areas a value for t_m of 6.5 (SC/Jn81/MiS32, Table 3) be used for the years 1971/72 onwards (note this is for the year and not for the year class).

The age at first parturition is given by $t_m + 0.83$ (*Rep. int. Whal. Commn* 31: 104).

8.1.2 Male age at maturity

Information given in SC/Jn81/MiS4 suggested that the criterion for male sexual maturity used in SC/Jn81/MiS32 might be incorrect, and this would account at least partly for the younger ages at sexual maturity estimated for males. Information given in SC/33/ProgRep Brazil, indicates that males as large as 28 ft and with testes weights of up to 2.6 kg may still be classified histologically as immature.

8.2 Pregnancy rates (p)

SC/Jn81/MiS4 (Durban) and 32 (Antarctic) examined ovulation rates and found values over 80%, consistent with previous findings. However, data from Durban were interpreted to give an estimate of true pregnancy rate of 78%. If parameter values in the balance equation are to be considered separately then it was agreed that the pregnancy rate should be about 0.78 rather than the estimated maximum of about 0.86 (i.e. a calving interval of about 15 months).

SC/Jn81/MiS32 reported that no trends in time had been detected in apparent pregnancy rate in the Japanese catch (1971/72–1979/80). SC/Jn81/MiS20 reported on a comparison of observed catch at age with that predicted by last year's model. Various historical changes in life history parameters, including a substantial increase in recruitment rate with time could improve the fit. Such an increase could in part be achieved by an increase in pregnancy rate. However the meeting noted that there was no direct evidence to suggest or deny that the minke whale pregnancy rate had increased since the start of Antarctic whaling. It was agreed, that for use in the assessment programme BALEEN the pregnancy rate would be held constant.

Best pointed out a peculiarity of the reproductive status of the Brazilian minke whales (SC/Jn81/MiS1). Unlike the situation at Durban, whales simultaneously ovulating and lactating were not observed; this is inconsistent with a breeding cycle of one year. Da Rocha reported that ovaries were collected at the Brazilian station. The meeting recommended that an investigation (including histological analysis) of the mammary glands should be instigated to determine the instance of lactating animals in order that this apparent contradiction can be resolved.

8.3 Juvenile mortality (M_j)

If adult natural mortality is specified then the balance equation determines the product of pregnancy rate and juvenile survival. Since estimates of adult mortality were available this product was fixed. SC/Jn81/MiS20 reported that a decline in this parameter was one way to improve the agreement of simulated and observed age compositions.

8.4 Adult mortality (M)

Last year (*Rep. int. Whal. Commn* 30: 104) a value of $M = 0.09\ yr^{-1}$ was agreed from a regression of $\ln(M)$ on maximum length of different whale species. SC/Jn81/MiS20 had reconstituted the 1971/72 age composition with a form of virtual population analysis. The author concluded from simulations that the steep slopes of recent age distributions suggested an M value of 0.04–0.06 with a severalfold increase in recruitment rates between 1930 and 1950, or alternatively that there was a decreasing catchability with age (Grenfell and Beddington, *Rep. int. Whal. Commn* 30: 237) or increasing natural mortality with age. Chapman (Appendix 9) examined the last possibility by fitting a quadratic regression to the data presented in SC/Jn81/MiS20. This estimates that M increases from 0.100 at age 20 to 0.190 at age 50 and explains the deficiencies in the number of older animals in the age composition of SC/Jn81/MiS20. This age composition had been obtained from assuming a constant mortality rate and it was unclear as to whether similar answers would be obtained if an age-varying rate had been assumed in the construction of the age composition. For use in the assessments, three values of M were selected, based on the confidence intervals of last year's regression: M = 0.06; 0.09; and 0.12.

8.5 Age at recruitment

8.5.1. Readability

The percentages of aged animals by sex and by length in the total catch of minke whales by Japanese pelagic whaling from 1967/68 to 1980/81 summed over year and Area is shown in Table 1. It was explained that there were several reasons why an animal might not be aged:

(i) the plugs are damaged during collection or cannot be or were not collected;
(ii) the plugs are damaged during preparation;
(iii) the prepared plugs are found to be unreadable (e.g. the early layers or germinal layers are damaged).

It was noted that there was a similar trend of increasing readability with length for both sexes. This shows that the age distribution in the aged sample is not representative of the age distribution of the catch. It was pointed out that if the readability was associated with the length of the animal then the bias could be corrected for by using an age-length key. However if it was associated with the age of the animal, then age compositions obtained with the age-length key may be biased. The Committee was unable to determine which of these might be the case. Similar trends in percentage aged with body length were shown in ear plugs collected at Durban (SC/Jn81/MiS4).

Table 1

Percentage of minke whales aged by length, 1967/68–80/81 Japanese pelagic catches

	Males		Females	
Length (ft)	No.	% Aged	No.	% aged
15			1	0
16			4	0
17	2	0	6	0
18	3	0	8	25.0
19	16	12.5	14	14.3
20	36	22.2	53	22.6
21	72	20.8	80	25.0
22	128	21.9	152	23.0
23	235	27.7	278	32.7
24	525	31.2	543	31.9
25	1059	38.2	725	31.2
26	2024	43.5	1086	39.4
27	3094	47.3	1819	48.2
28	2952	51.8	3244	50.5
29	1471	52.4	3451	51.0
30	478	56.1	2844	52.6
31	105	57.1	1358	53.0
(♂>31)(♀32)	3	100	171	57.3
♀>32			27	48.1

Kato reported that tympanic bullae were collected from animals during the 1980/81 season. Age readings from these (see Christensen, *Rep int. Whal. Commn* 31: 245–53) will be compared with those from ear plugs to determine if the examination of bullae is more satisfactory for the age determination of younger animals.

8.5.2 CPØP

Allen presented the results of CPØP (Appendix 10). These results are very variable. Although there was reason to believe that females are recruited at an earlier age than males, an analysis of variance of the mean age of recruitment by Area and sex failed to discriminate any differences. Allen pointed out that the calculated ages at recruitment fell into two groups, those in the range of about 5.5–8.5 years generally associated with r_{II} recruitment rates of about 0.05 to 0.15, and those about 2.0–2.5 years associated with r_{II} rates less than 0.05. The latter most frequently occurred in pairs for both sexes in the same area and season. This, he suggested, arose from a change in catching practice in those years; probably through an increased tendency to select larger animals. He suggested therefore that the best estimate of ages at recruitment would be provided by the first group. This gave mean ages at recruitment of 7.01 for males and 7.71 for females but the difference was not statistically significant.

Ohsumi considered that the female age of recruitment should be less than that of the males and took the average of all values from Appendix 10, but when these numbers were rounded to the nearest integer a value of 6 years was found for each sex.

It was agreed that if possible runs would be undertaken using values of 6 and of 7 years for both sexes, although priority should be given to the latter if time could not be found to use both sets.

9. ESTIMATES OF ABUNDANCE

9.1 Assessment models

9.1.1 Effort

9.1.1.1 Antarctic

Data were available for 1980/81 from the Japanese expedition in the same form as in previous seasons and time budget data were available from the Soviet expedition. Since the Soviet expeditions had taken minke and sperm whales together until recent seasons it was agreed that attention should be focused on the Japanese data. These data would be corrected for factors of month, zone, sex, visibility and windforce (Grenfell and Allen, *Rep. int. Whal. Commn* 31: 115) for the five regions given in Section 7.

SC/Jn81/MiS11 presented a model of CPUE based on catch per CSW. According to this model it was shown that CPUE might underestimate density by up to 25%. Data from two expeditions showed that this might be a real feature if the assumptions of the model were true. However it was considered that particularly assumption (b) of the study might be violated in that it was likely that the expedition would spend relatively more time in areas of high density. It was also pointed out that bias itself is not important but if the bias is dependent upon density, as appeared likely from the model, then this could be significant. It was agreed that an investigation of searching time in relation to density, within Areas, be carried out to investigate assumption (b). It was noted that the index should represent the average density within each Area and that another approach to minimise the modelled bias might be through indices based on average catch per effort rather than average catch per average effort.

With respect to the effect of stop-catch orders, Best believed that there may be a difference between stop-catch when operations ceased for the rest of the day and stop-catch which occurred in the middle of the day. In the latter case searching may continue during 'stop-catch' although searching time is not recorded. Ohsumi reported that during stop-catch the catchers were often ordered to remain within sight of the factory ship.

9.1.1.2 Durban

SC/Jn81/MiS4 presented sightings data obtained from the spotter aircraft at Durban by month for the years 1968–75. From the length distribution of the catch by month it was agreed to use the data from June to September: the time period over which the larger animals are present in the fishery. The data are shown in Table 2.

Table 2

Sightings of minke whales off Durban from the spotter aircraft, June to September inclusive

Season	No. of whales seen	Effort[1]	Sightings per unit effort
1968	40	4.8899	8.18
1969	50	5.5736	8.97
1970	45	5.8235	7.73
1971	107	5.8160	18.40
1972	74	5.6543	13.09
1973	67	4.9850	13.44
1974	28	4.3370	6.46
1975	62	4.5045	13.76

[1] 12×10^3 miles flown, weather-corrected.

9.1.1.3 Brazil

Data from the Brazilian operation are given by da Rocha (*Rep. int. Whal. Commn* 30: 379–84) and in the Brazilian progress report (SC/33/ProgRep Brazil). The Committee agreed that ideally a refined effort series should be obtained from catcher boat log books. However if it was possible to construct a coarse but acceptable series from the available data then this might be used. Appendix 11 provides estimates of CPUE and sightings per unit effort series, while recognising the limitations of the data. Appendix 12 utilises data obtained later in the meeting and presents revised series which incorporated a seasonality correction factor. The Committee agreed to use the time series of sightings per CSW for 1972 to the present. The pre-1972 data were rejected for several reasons as discussed on p. 718.

The Committee agreed to the recommendations for future work to obtain a refined effort series for Brazil given in Appendix 12. These are listed in Section 13.

9.1.2.1 BALEEN runs (excluding Area II)

The Committee initially agreed that runs should be carried out for Areas III, IV, V, VI, A and α with the biological parameter values proposed in Section 8. This was carried out and the results are summarised in Appendix 13. Free reported that for some Areas the fit of observed and expected catches was good for the range of mortality rates. As suggested by Free, the Committee agreed that the model should be run so as to additionally minimise on M with $t_r = 7$. This proved successful for Areas IV ($M = 0.069$) and V ($M = 0.054$). A list of runs undertaken is given in Table 3.

The Committee discussed how it might choose between Areas A and α. The limited biochemical evidence suggested a separation between Areas IV and V (see Section 7). Free reported that the year in which the observed and expected catches for the Area A runs differed most was a year in which the Area V catch was large. As Area A included Areas IV and VW, whereas Area α did not include Area V, only results for Area α were considered.

Harwood suggested that if Area V catches were a problem for Area A then this might be overcome by a run of III + IV. This was undertaken.

A brief summary of the results obtained for those BALEEN runs considered by the Committee is given in Table 4.

The Committee agreed to choose one model run for each Area for comparison with the independent estimates described in sections 9.1 and 9.3.

Area III	The Committee agreed that this value for the only successful run should not be considered as the fit of observed to expected catches was very poor.

Area IV	The Committee agreed to use the value for 1981/82 obtained by minimising on M, i.e. 39,356.
Area V	The Committee agreed to use the value for 1981/82 obtained by minimising on M, i.e. 13,836.
Area VI	The Committee agreed to use the value for 1981/82 for the only successful run, i.e. 57,833.
Area III + IV	The Committee agreed that the success of this run was probably due to the Area IV data and this value was rejected. Ohsumi considered that this run should have been put forward as an alternative.
Area α	The Committee agreed that it was not practical at this stage in the meeting to consider a new assessment area such as this. However it noted the results and recommended that further work regarding this assessment area be carried out before the next meeting.

In order to facilitate comparison with estimates obtained from other techniques, it was agreed that approximate confidence limits could be obtained using the method described in Appendix 14. The results are shown in Table 7.

Table 3

A list of BALEEN runs undertaken

Area	t_r	M	Converged	Index
III	6	0.06	X	sightings
	6	0.09	√	''
	7	0.06	X	''
	7	0.09	√	''
	7	min	X	''
IV	6	0.06	√	CPUE
	6	0.09	√	''
	7	0.06	√	''
	7	0.09	√	''
	7	min	√	''
V	6	0.09	√	''
	7	0.06	√	''
	7	0.09	√	''
	7	min	√	''
VI	6	0.09	√	''
	7	0.06	X	''
	7	0.09	√	''
	7	min	X	''
III + IV	7	0.06	X	''
	7	0.09	√	''
A	6	0.09	√	''
α	6	0.09	√	''
	7	0.06	√	''
	7	0.09	√	''

9.1.2.2 BALEEN run for Area II

The result from the only successful BALEEN run for Area II (M = 0.09) is presented in Appendix 15. This produced an estimate of total exploitable population in 1981/82 of 127,000, but it was noted that the fit was poor.

Table 4

Summary of BALEEN runs

Area	t_r	M	Exp. N_{1982}	q	F_n
III[1]	7	0.09	56,683	0.244E-04	12.40
IV	6	0.06	45,359	0.205E-04	56.93
		0.09	23,676	0.414E-04	57.46
	7	0.06	47,917	0.199E-04	58.24
		0.09	27,260	0.388E-04	64.84
		0.069[2]	39,356	0.248E-04	57.60
V	7	0.06	12,622	0.831E-04	23.00
		0.09	7,920	0.140E-03	23.34
		0.054[2]	13,836	0.753E-04	23.00
VI	7	0.09	57,833	0.170E-04	32.01
III + IV	7	0.09	145,142	0.885E-04	196.33
α	7	0.06	374,537	0.301E-04	182.96
		0.09	108,212	0.112E-04	200.33

The following runs did not converge:

III	CPUE	neither value of M
	sightings	M = 0.06
III + IV	CPUE	M = 0.06
VI	CPUE	M = 0.06

[1] Aircraft sightings from Durban [2] Minimising on M

9.2 Sightings programmes

9.2.1 Areas III, IV and V

A sub-group was established under the chairmanship of Kirkwood to examine sightings theory in relationship to this Agenda Item. The report is given in Appendix 16. It was agreed that the numbers of exploitable minke whales for Areas III, IV and V could be estimated using the following equation:

$$P = t.e.h.s.N'm.$$

(a) t, proportion recruited

Area III—it was agreed to use the same value as used last year (*Rep. int. Whal. Commn* 31: 105), i.e. 0.81.

Area IV—it was agreed to use the value of 0.82 given by Best and Butterworth (*Rep. int. Whal. Commn* 30: 267–84).

Area V—it was agreed to use the value of 0.57 given in SC/Jn81/MiS15. Ohsumi believed that as there is segregation in the distribution of minke whales in the Antarctic, and that, in particular, younger whales are not common near the pack ice, a value of 0.57 for this Area was too low. He considered that an overview of population structure suggests a higher value than 0.7. However, Best explained that the low value was due to the large number of small whales which were found in the Ross Sea by both Soviet and Japanese vessels.

(b) e, model conversion factor

This factor accounts for a change in model form from the untruncated negative exponential model using unsmeared data. Appendix 16 presented and discussed four alternative models: Kelker Strip; Cox-Eberhardt; untruncated negative exponential; generalised exponential. The Committee agreed not to consider the last model which had a very different conversion factor to the rest, and agreed that in the absence of further information a value of e of 1 (corresponding to the negative exponential model) would be used which was within the range of e values for the three models (0.95–1.17, see Appendix 16, Table 7).

(c) h, 1/g(0), the reciprocal of the probability of sighting an animal on the track line.

SC/Jn81/MiS13 described an experiment to determine g(0) which was carried out during the 1980/81 IWC/IDCR Minke whale cruise. It was estimated to be 0.80 although the estimate was not significantly different from 1.0. Independent simulation studies using the Doi technique (SC/Jn81/MiS29) revised by the sub-committee also produced an estimate of g(0) = 0.8, although as discussed in Appendix 16 the estimate was subject to unquantifiable bias both upwards and downwards.

The Committee agreed to use a value of g(0) = 0.83 based on the value obtained for a range of 5.5–7 knots in SC/Jn81/MiS13, as this to some extent eliminated the model dependence in the above two estimates.

(d) s, mean school size

The Committee agreed to use the values suggested in Appendix 16, Table 6, i.e. Area III: 3.02, Area IV: 2.41, Area V: 2.90.

(e) N′, no. of schools in each half of the Areas

The Committee agreed to use the values calculated using the contouring method and assuming an untruncated negative exponential distribution for the perpendicular sightings distances as given in Appendix 16, Table 6.

i.e.	Area III	W: 14,466	E: 10,750
	Area IV	W: 13,969	E: 11,271
	Area V	W: 7,105	E: 34,482

(f) m, correction factor for the random movement of whales

The Committee agreed to use the same value as last year, i.e. 0.96. It also recommended that further work along the lines presented in SC/Jn81/MiS7 be carried out before the next meeting.

(g) Coefficient of variation (CV)

The Committee agreed to calculate CV using the method outlined in Appendix 16, page 736, while recognising that this gives only approximate values.

Sightings estimates were then calculated for these values and are presented in Table 5.

Table 5

Sightings estimates (exploitable populations) for minke whales in the Southern Hemisphere (see text for details)

Area I	
(a) Doi technique 27,687	No confidence limits
(b) Line transect 28,298	No confidence limits
Area III	
West 41,112 (S.D. 9,045) East 30,552 (S.D. 6,721)	71,664 (S.D. 15,766*)
Area IV	
West 32,073 (S.D. 6,415) East 25,878 (S.D. 5,176)	57,951 (S.D. 11,590*)
Area V	
West 13,642 (S.D. 3,274) East 66,205 (S.D. 15,889)	79,847 (S.D. 19,163*)
Area VI 31,069	No confidence limits

* Note the S.D. should not have been calculated as the sum of individual S.D.s.

9.2.2 Area I

Appendix 17 presented a revised estimate of the Area I population as calculated in SC/Jn81/MiS28 using data from a Japanese scouting boat in 1980/81 and employing the Doi sighting model using the correction factors in SC/Jn81/MiS29. The result is given in Table 5.

Appendix 18 presented a revised estimate using the same sightings data but employing a stratification method. Appendix 16 showed that for the Area III sightings data, the estimate produced using stratification was about 20% higher than that using contouring. The Committee therefore agreed to reduce the stratification estimate for Area I by 20%. The result is shown in Table 5.

9.2.3 Area VI

The Committee agreed to use the value obtained last year (*Rep. int. Whal. Commn* 31: 106) but corrected for a g(0) value of 0.83 (see 9.2.1(c)). The result is shown in Table 5.

9.3 Mark and recapture estimates

Tillman examined the available marking data for Areas III, IV and III + IV (Appendix 19). The results are summarised in Table 6.

SC/Jn81/MiS28 presented a mark-recapture estimate for Area 1. The data were reanalysed using revised catch information and the method described by Horwood (*Rep. int. Whal. Commn* 31: 291) for when there are no recoveries (1980/81: 134 whales marked; Japanese catch 450; Soviet catch 318). It was assumed that the marking mortality was 5% and that 81% of the marked whales were in the recruited population. The results are in Table 6.

Table 6

Marking estimates for Southern Hemisphere minke whales

	Result	Source
Area I		
1980/81	P(N < 26,457) = 0.05 P(N < 34,406) = 0.10	This meeting
Area III		
1979/80	P(N < 194,000) = 0.05[1] P(N < 127,000) = 0.01[1]	Horwood, IWC31
Series	257,790 (129,126; 895,926—95% limits)	Appendix 19
1980/81	153,203 ± SD 68,126	Appendix 19
Area IV		
1978/79		
(i)	91,000 ± SD 38,000	Best and Butterworth
(ii)	106,000 ± SD 44,000	IWC 30, p. 257
Series	136,417 (91,920: 230,940—95% limits)	Appendix 19
1980/81	110,518 ± SD 32,892	Appendix 19
Area III + IV		
1980/81	247,985 ± SD 63,437	Appendix 19
Area V		
1980/81	94,109 ± 2 SD 93,774	This meeting

[1] Assumed that 66% of the marked whales were in the recruited population.

10. WEIGHTING PROCEDURES FOR AREAS WITH MORE THAN ONE ESTIMATE OF ABUNDANCE

10.1 Areas I, III–VI

Given independent estimates of stock size it was agreed that these should be weighted by the inverse of their variance. However for the model runs it was not possible to obtain a variance for the current estimates of stock size. It was therefore agreed to weight each estimate by the inverse of the approximate 95% confidence range. The

Area VI point estimate from the sightings, for which no confidence interval was available, was not used. Results are given in Table 7.

Table 7

Agreed independent estimates of exploitable stock size from Section 9

Area I		
Sightings:	28,000 (1980/81)	
Marking:	(>26,457 p = 0.95)	
	(>34,406 p = 0.90)	
Area III		
Sightings:	71,644	4 × S.D. = 63,064 (1979/80)
Marking:	257,790	95% c.l. = 766,800 (1979/80)
Weighted:	85,790	
Area IV		
Sightings:	57,951	4 × S.D. = 46,360 (1978/79)
Marking:	136,417	95% c.l. = 139,020 (1980/81)
Model:	39,860	4 × S.D. = 5,200 (1980/81)
Weighted:	44,767	
Area V		
Sightings:	79,847	4 × S.D. = 76,652 (1980/81)
Marking:	94,109	4 × S.D. = 187,548 (1980/81)
Model:	14,409	4 × S.D. = 60,625 (1980/81)
Weighted:	51,075	
Area VI		
Sightings:	31,069	(rejected) (1979/80)
Model:	52,928	4 × S.D. = 90,848 (1979/80)
Weighted:	52,928	

11. UNBALANCED CATCHES BY SEX

The proportion of females in the Japanese and Soviet catches in the Southern Hemisphere in 1980/81 was 0.528 and 0.606 respectively (weighted average 0.567).

Last year one of the ways the Committee suggested to safeguard against unbalanced catches by sex was to recommend a total catch limit by dividing the female replacement yield by the factor 0.658. The factor 0.658 was the highest proportion of females in the catch in the previous ten years. Such a procedure helps to ensure that the female replacement-yield is not exceeded. It was suggested that taking the highest value over such a long timespan did not take into account the efforts of the industry to reduce the levels of females in the catch. In addition, the foetal sex ratio (53% females; SC/Jn81/MiS32) suggested that there may be a preponderence of females in the population, although there is no estimate of the sex ratio at birth.

SC/Jn81/MiS24 examined the problem of unbalanced catches and showed that in the last three seasons, for those Areas where the Scientific Committee had estimated replacement yields by sex, and for which the Commission had set a total catch limit, in 6 cases the replacement yields by sex had been exceeded and in 22 cases they had not been reached. One consequence of this was that it would increase the imbalance of males to females in the population.

It was noted that this problem varied by Area, and that in Areas I and VI more males than females had been caught in each season since 1978/79 (SC/Jn81/MiS24, Table 1). The Committee agreed to calculate factors for each Area by taking the average of the sex ratio in the catch in each Area for the last 3 years. The procedure followed is then the same as was applied last year, but for each Area separately. In Areas I and VI the total limits would be the sum of the male and female replacement yields. This method would thus take into account the efforts of industry to reduce the proportion of females in the catch. The following values of the factors were calculated:

Area II: 0.69, Area III: 0.64, Area IV: 0.54, Area V: 0.67.

It was agreed to present the estimates of replacement yields by sex and total limits using the above procedure (Table 8, Section 12).

12. REPLACEMENT YIELDS, CATCH LIMITS BASED UPON ALTERNATIVE MANAGEMENT PROCEDURES AND EFFECTS OF VARIOUS CATCHING REGIMES

12.1 Areas I, III–VI

It was agreed that the BALEEN model should be run so as to fit the weighted values given in Table 7. This is described in Appendix 20. The value of M used for all runs was M = 0.0687 as obtained by the minimisation for Area IV. The results are given in Appendix 20.

Replacement yields were then calculated by sex for each Area as follows:

$$RY = (N_{85} - N_{81} + C_{81})/4$$

The results are given in Table 8. If the factors discussed in Section 11 are used then the total catch by Area is given in the final column.

Table 8

Replacement yields, factors and total catch limit obtained if the factor is used, Areas I, III–VI

Area	♀RY	♂RY	Factor	Total catch limit
I	578	601	—	1,179
III	1,782	1,519	0.64	2,784
IV	836	720	0.54	1,548
V	1,008	918	0.67	1,504
VI	829	840	—	1,669

12.2 Area II

The Committee agreed not to consider the estimate obtained from the model run in view of its poor fit and because of the unrefined nature of the effort series.

As in previous years, an index of relative abundance was obtained using an average of Japanese and Soviet CPUE data for comparable periods (from SC/Jn81/MiS25), weighted between years, and an area proportional to the length of the ice edge (Appendix 21). These relative indices are presented below.

Area	CPUE	Ice edge (n.m.)	Relative index
I	0.60	1,587	0.52
II	1.02	2,262	1.27
III	1.26	1,932	1.34
IV	1.00	1,819	1.00
V	0.92	2,221	1.11
VI	—	1,453	—

It was accepted that the Area IV population estimate was probably the best of the model runs and the estimate for Area II was derived from weighted average of Area IV results, giving an exploitable population of 56,358 for 1981/82.

Some members believed that as the large value (127,000) obtained from the BALEEN run was being disregarded, the extrapolation procedure provided a reasonable estimate for the population in Area II. They also noted the lack of any downward trend in the Brazilian CPUE data form. The BALEEN program was run using M = 0.0687 (Appendix 22), and given the replacement yield was calculated using the equation given in 12.1. The result is shown below:

♂RY: 865 ♀RY: 1,099 Total limits: 1,593 (factor 0.69)

Some other members noted the inconsistent results obtained from last year's and this year's attempts to estimate abundance by extrapolating estimates from one Area to another, and concluded that the use of relative abundance indices was an inappropriate procedure for estimating the abundance for Area II. They believed that in the absence of a proper assessment it was not possible to provide scientific advice as to the catch limit for Area II.

The Committee noted that a proposed IDCR cruise to Area II in 1981/82 was likely to provide a better basis for assessment next year.

12.3 Allowances between Areas

Last year the Committee had been unable to agree on a recommendation regarding allowances between Areas (*Rep. int. Whal. Commn* 31: 110). Some members believed that allowances were acceptable because replacement yields by sex had only been exceeded in 6 out of 28 possible occasions in the last three years (SC/Jn81/MiS24) although the allowance system had been operating. Other members believed that in view of the uncertainties in the estimates, there was no scientific basis for a discussion of this subject.

The Committee was unable to make a recommendation.

12.4 Effects of various catching regimes

The Committee was unable to consider in the time available the effects of various catching regimes as recommended in IWC/33/13.

12.5 Comparison with last year's results

This year's results are compared with those of last year in Table 9.

13. RECOMMENDATIONS

13.1 Catch limits

It was agreed that as last year, catch limits would be presented based on replacement yields by sex, and as a total figure which would help to ensure that the replacement yield of females was not exceeded. The Committee agreed that Table 10 was an appropriate basis for setting catch limits for Areas I and III–VI.

Table 10

Recommended catch limits for 1981/82

Area	(i) Catch limits by sex		(ii) Total catch limits ensuring female RY not exceeded
	Male	Female	
I	601	578	1,179
III	1,519	1,782	2,784
IV	720	836	1,548
V	918	1,008	1,504
VI	840	829	1,669

As discussed in Section 12.1, some members believed that it was appropriate to recommend the following as the basis for setting catch limits for Area II:

♂RY: 865, ♀RY: 1,099, Total limits 1,593*

Other members believed that it was not possible to provide scientific advice for Area II.

The Committee noted that a proposed IDCR cruise to Area II in 1981/82 was likely to provide a better basis for assessment next year.

The Committee was unable to make a recommendation regarding the allowance system.

13.2 Other recommendations

The Committee made the following recommendations with respect to obtaining improved data for the Brazilian minke whaling operations:

(i) The catcher log books should be examined from 1966 onwards to determine the number of days and hours worked in each month. The number of hours worked each month could be ascertained as the time that the catcher left port until it returned.

(ii) The identity of the vessels which operated during the early period of minke whaling and their characteristics should be clarified.

Table 9

Summary of estimates and replacement yields from the 1980 and 1981 Scientific Committee meetings, and the catch limits set by the Commission for 1980/81

			Replacement yield					
	Exploitable pop'n		1980/81		1981/82			
Area	1980/81	1981/82	♀	♂	♀	♂	Catch limits[1] 1981/2	Catch limits 1980/81
I	*	28,628	*	*	578	601	1,179	867
II	*	56,358[2]	*	*	1,099	865	1,593	1,120
III	74,837	88,218	775	759	1,782	1,519	2,784	1,178
IV	80,579	44,376	1,495	1,374	836	720	1,548	2,272
V	*	51,804	*	*	1,008	918	1,504	1,190
VI	26,892	54,142	293	297	829	840	1,669	445

[1] Using the factors described in Section 11.

[2] Not agreed by all members of the Committee (see text).

* No agreed estimates were available.

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* These values were altered slightly at the Annual Meeting: see p. 51 and 139–41.

(iii) The locations of the catches for each month for at least some of the years should be determined. This could be in the form of catch per 5′ square.

(iv) It can be seen from the time budget in SC/33/ProgRep Brazil that the time spent travelling to whaling ground varies from month to month and between the 1979 and 1980 seasons. It should be clarified whether this navigation time includes an element of searching, that is, is it the time taken from leaving port to start chasing the first whale? If this is so then it would be more appropriate to record searching time as beginning at the time when the vessel reaches the 100 fathom line since this is the edge of the whaling ground according to Williamson (1975).

(v) There are discrepancies between the BIWS length statistics and the statistics presented in da Rocha (SC/33/ProgRep Brazil) and these should be reconciled if possible (especially the years 1968, 1977 and 1980). (The 1966, 1967, 1969 and 1970 length distributions are not published in the BIWS.)

(vi) Chasing times for sperm whales during the seasons 1979 and 1980 should be determined.

(vii) Basic data such as sea state, visibility, wind and sea turbidity throughout the last few seasons should be compiled to determine whether any corrections for these factors may be required.

It was also recommended that (a) further work on the effect of the random movement of whales on sightings estimates along the lines presented in SC/Jn81/MiS7 be carried out before the next meeting: (b) further work regarding the implementation of new assessment (particularly Area α) and management areas be carried out before the next meeting.

Appendix 1

LIST OF PARTICIPANTS

AUSTRALIA
K. R. Allen
G. P. Kirkwood
W. K. de la Mare

BRAZIL
J. da Rocha

CANADA
M. Bigg

JAPAN
I. Ikeda
F. Kasamatsu
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S. Misaki
S. Ohsumi
Y. Shimadzu
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KOREA
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L. Fleischer

NETHERLANDS
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NEW ZEALAND
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SOUTH AFRICA
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T. Smith
M. Tillman

IWC
G. P. Donovan
C. A. Free
R. C. Harrison

INVITED PARTICIPANTS
P. Hammond (IATTC)

Appendix 2

AGENDA

1. Convenor's opening remarks
2. Appointment of Chairman
3. Appointment of rapporteurs
4. Adoption of Agenda
5. Review of documents and reports
6. Review of computer facilities and available data
7. Definition of management Areas, or combinations thereof
8. Biological parameters
9. Estimates of abundance based upon:
    - 9.1 assessment models
    - 9.2 sightings programmes
    - 9.3 Mark and recapture experiments
10. Weighting procedures for Areas with more than one estimate of abundance (i.e. to find a 'best' estimate)
11. Unbalanced catches by sex
12. Replacement yields, catch limits based upon alternative management procedures (as suggested by the Technical Committee Working Group) and effects of various catching regimes
13. Recommendations

Appendix 3

LIST OF DOCUMENTS

SC/Jn81/MiS1	Singarajah, K. V. Observations on the occurrence and behaviour of minke whales off the coast of Brazil.*
SC/Jn81/MiS2	Mizroch, S. A. and Tsunoda, L. Examination of possible schemes for stratifying the IWC/IDCR minke whale sightings data.
SC/Jn81/MiS3	van Beek, J. A review of the morphological and biochemical research on stock identification of Southern minke whales.
SC/Jn81/MiS4	Best, P. B. Seasonal abundance, feeding, reproduction, age and growth in minke whales off Durban.
SC/Jn81/MiS5	Butterworth, D. S. Some comments on experiments planned for the 1980/81 IWC/IDCR minke whale assessment cruise.
SC/Jn81/MiS6	Joyce, G. Preliminary result on the examination of blow patterns as sightings cues for minke whales in the Antarctic.
SC/Jn81/MiS7	Hiby, A. R. Alternative methods of estimating population sizes from whale sighting surveys.
SC/Jn81/MiS8	Leatherwood, J. S., Awbrey, F. T., Thomas, J. A., Jehl, J. R. and Evans, W. E. Observations on minke whales, *Balaenoptera acutorostrata*, off northwestern Ross Island.*
SC/Jn81/MiS9	Leatherwood, J. S., Awbrey, F. T. and Thomas, J. A. Minke whale response to a survey vessel.
SC/Jn81/MiS10	Brown, S. G. Southern Hemisphere marking of minke whales.
SC/Jn81/MiS11	Zahl, S. Bias of the CPUE using search time as effort measure.
SC/Jn81/MiS12	Kirkwood, G. P. A preliminary look at the effect of concentrating whale sightings in a small arc around the trackline.
SC/Jn81/MiS13	Butterworth, D. S. and Best, P. B. Preliminary analysis of results of experiments to test the effect of vessel speed on sightings carried out during the 1980/81 IWC/IDCR minke whale cruise.
SC/Jn81/MiS14	Butterworth, D. S. Total school size estimates for minke whale surveys using universal kriging.
SC/Jn81/MiS15	Butterworth, D. S. and Best, P. B. An estimate for the minke whale population in Area V from sightings data from the 1980/81 assessment cruise.
SC/Jn81/MiS16	Butterworth, D. S. An alternative estimate for the minke whale population in Area III from sightings data from the 1979/80 assessment cruise.
SC/Jn81/MiS17	Butterworth, D. S. and Basson, M. Preliminary analysis of results of the parallel ship experiment carried out during the 1980/81 IWC/IDCR minke whale cruise.
SC/Jn81/MiS18	Butterworth, D. S. On the choice of a functional form for g(y) for minke whale sightings.
SC/Jn81/MiS19	Best, P. B. Southern Hemisphere IDCR minke whale assessment cruise 1980/81—cruise report.
SC/Jn81/MiS20	Clark, W. G. Early changes in recruitment rates of Antarctic minke whales inferred from recent age distributions.
SC/Jn81/MiS21	Miyashita, T. Estimation of population sizes of minke whales in Areas III and IV in 1980/81 by means of mark recapture method.
SC/Jn81/MiS22	Shimadzu, Y. and Kasamatsu, F. Operating pattern and time budget data for the Antarctic minke whaling by Japanese expedition in 1980/81 season.
SC/Jn81/MiS23	Kato, H. and Miyashita, T. Summary of the experiment on mark recovery efficiency on the Japanese factory ship.
SC/Jn81/MiS24	Shimadzu, Y. Unbalanced sex ratio of minke whale catch and its effect to management.
SC/Jn81/MiS25	Kasamatsu, F. and Ohsumi, S. Yearly change in CPUE of the minke whale stocks by sexes in the Antarctic.*
SC/Jn81/MiS26	Ohsumi, S. and Kasamatsu, F. Whale sightings efficiency of crew on board of ocean research vessels in BIOMASS/FIBEX.*
SC/Jn81/MiS27	Furukawa, F. The Report of the minke whaling in the 1980/81 Antarctic whaling season.*
SC/Jn81/MiS28	Miyashita, T. Estimation of population size of minke whale stock in the Antarctic Area I by means of whale sighting and marking.
SC/Jn81/MiS29	Doi, T., Kasamatsu, F. and Nakano, T. A simulation study on sighting survey of minke whales in the Antarctic.
SC/Jn81/MiS30	Naito, Y. Sighting records of the Antarctic minke whale in the pack ice and adjacent waters off the coast of Enderby land.
SC/Jn81/MiS31	Wada, S. Some information from mark recovery data on the Antarctic minke whale.
SC/Jn81/MiS32	Kato, H. Some biological parameters for the Antarctic minke whale, from 1971/72 to 1979/80 season.
SC/Jn81/MiS33	Ivashin, M. V. Marking of minke whales (*Balaenoptera acutorostrata*) in the waters of the Southern Hemisphere (Soviet programme of tagging).*

All papers except those marked with an asterisk are being published in this volume (some have been combined where appropriate).

Appendix 4

ANALYSIS OF THE BIOCHEMICAL DATA BY G-STATISTICS

Shiro Wada

In SC/Jn81/MiS3, van Beek outlines three morphological and biochemical studies concerning stock identification previously presented to the Scientific Committee meeting (Doroshenko, 1979; Wada and Numachi, 1979; Borisov, 1980) and concludes that no significant difference is found among minke whale populations separated by the current area boundaries. On the contrary, I get a significant result on an areal difference from a new analysis on my biochemical data using G-statistics (Sokal and Rohlf, 1969) based on 10° square allele frequencies.

Table 1

Allele frequencies on the two loci by 10° squares in the Antarctic minke whales

Allele / Square	6-PGD				SDH				
	C	S	N	F	S	N	F	R	E
A1	12	19	66	1	1	88	9	0	0
B1	27	22	147	2	1	163	29	7	0
B12	68	50	284	14	8	339	63	4	4
B13	133	128	709	20	7	814	148	21	2
B14	26	24	127	1	1	142	33	3	1
B17	4	1	17	2	0	20	4	0	0
B18	17	23	66	4	0	92	16	2	0
B19	68	74	313	9	12	386	56	5	1
B20	53	40	236	3	3	266	54	5	2
B21	43	37	239	3	1	256	58	6	1
B22	8	14	62	0	0	73	7	2	0
A28	2	1	7	0	1	6	3	0	0
B29	6	7	20	3	0	30	5	1	0
B30	22	20	99	3	1	105	34	1	3
C30	41	43	208	4	6	230	53	6	1
B31	14	14	64	2	0	77	16	1	0
C31	58	54	252	6	10	297	56	6	1
B32	21	19	81	1	0	101	19	2	0
B33	2	0	13	1	0	15	1	0	0
B34	18	23	83	4	1	102	21	4	2
B35	57	35	302	10	2	316	71	12	1

$GH = 73.31 < \chi^2(60:0.05) = 79.08$ Not significant

$GH = 102.02 > \chi^2(80:0.05) = 101.88$ Significant

Table 1 shows allele frequencies from two loci (6-PGD and SDH) in 10° squares. Heterogeneity G-test was performed to test whether the samples as a whole are homogeneous or not. G-value was given as 79.08 with 60 degree of freedom for 6-PGD locus and 102.02 with 80 degree of freedom for SDH locus. The latter G-value is significant at 5% level of significance showing that these samples are not from a homogeneous population.

Following that the independence G-test should be performed to know where the significant difference occurs in the samples. Table 2 shows 10 possible pair-wise comparisons among 5 sample groups. In this case pair-wise level of significance is set at 0.5% to achieve an experimental-wise level of significance at 5% (*Rep. int. Whal. Commn* 31: 113). G-values for 6-PGD locus and SDH locus separately are not significant in any pair-wise comparisons, however, when the two loci were combined (G = 22.20, d.f. = 7) a significant difference of allele frequencies is detected at 5% level between groups C (Area IV) and D (Area V). These are more reliable results than those I have presented previously (Wada and Numachi, 1979).

Table 2

G-values for test of independence among five sample groups

Group	A	B	C	D
B	2.60 4.78	—	—	—
C	4.66 6.66	5.42 8.82	—	—
D	0.62 4.76	6.82 1.90	12.10 10.44	—
E	2.56 7.94	0.48 3.10	4.02 11.64	6.92 3.92

Upper: 6-PGD, Lower: SDH.
$\chi^2(7:0.005) = 20.28$.

Appendix 5

EXAMINATION OF THE QUESTION WHETHER THE CONCENTRATION OF PELAGIC WHALING OPERATIONS NEAR CERTAIN BOUNDARIES OF MANAGEMENT AREAS IS A RESULT OF THE SETTING OF CATCH LIMITS BY AREAS

Sidney Holt

In *Rep. int. Whal. Commn* 29: 458 I wrote, with respect to Japanese catches, 'There was, in most years (1971/72–1976/77), both before and after the institution of quotas by Areas a strong grouping of catches near the boundary of Areas III and IV'.

In subsequent discussions it has been asserted that the bunched geographical distributions are not relevant to consideration of stock divisions because they arise from operational considerations, specifically the need for expeditions to operate near boundaries to reduce travel in the taking of allocated catch limits in neighbouring Areas. The purpose of this note is to examine this question by comparing catch and effort distributions before and after the decision to sub-divide the Southern Hemisphere minke catch limits by Area. The data used are the annual catches (both sexes combined) by ten-degree square by the Japanese and Soviet expeditions, and the corresponding catchers days work as provided by BIWS. There may be small discrepancies between my figures and those tabulated by Mr Free for this meeting; I have used my own compilation from the BIWS sheets which I made in 1980 for the preparation of paper SC/32/Mi2. This also explains the omission of 1980/81 data from this analysis.

In 1971/72 only Japan reported a significant catch of minke whales. Three thousand were taken, all in Areas III and IV and with a strong concentration towards the eastern side of IV but not adjacent to the boundary of IV with Area V. There was no catch limit and effort data are not available.

In 1972/73 the Japanese catches were all in Area IV and again concentrated at the eastern side, but not near the boundary. Although effort data are available this year of operations provides no basis for comparative analysis as far as the Japanese catch is concerned. In this, the first year of Soviet operations, the Soviet catch was also entirely in Areas IV and V but was strongly clustered around the boundary of those two Areas. In this season the USSR took nearly two-thirds of the total minke catch.

From the 1973/74 season the longitudinal distribution of catches becomes wider and a number of comparisons is possible. The whaling countries agreed between themselves not to take more than 4,000 minke whales each. Japan took 3,713 in Areas III and IV, and a few in the easternmost square (B6) of Area II. The USSR took a total of 4,000 mainly in Areas in III and IV but with a substantial number in Area I.

For the first time the catch limit was allocated geographically in 1974/75—a total of 7,000 as follows:

	Limit	Catch	
Areas I and II	3,300	2,676	
Areas III and IV	4,140	3,590	
Area V and VI	1,060	734	
Sum	8,500	7,000	3,500 by each country.

Total catch not to exceed 7,000.

The Japanese catch was mainly in Areas III and IV, but with a substantial take in the two most westerly squares of Area V. The Soviet catch was distributed widely in Area IV, in the two westerly squares of Area V and in the west of Area I, but no animals were taken in Area III. From the 1975/76 season the catch limits were allocated to the six Areas. The catches, while still concentrated mainly in Areas III and IV, are thereafter distributed more widely. In certain cases there is a tendency for them to be highest near to boundaries. This is true more for the Japanese catches than for the Soviet ones. Thus in 1975/76 and 1976/77 there is a concentration of Japanese catches near to the boundary of Areas VI and I, and in 1977/78 near the boundary of Areas V and VI. As far as the Soviet catches are concerned there is just a slight indication of concentration near to the I–II boundary in 1976/77. But for none of these boundaries is comparison possible with the earlier situation. This analysis is therefore confined to the distributions near the III–IV and IV–V boundaries.

In Table 1 the Japanese catches and the corresponding crude effort data are summarized. They are grouped in pairs of adjacent ten-degree squares chosen such that certain pairs straddle a boundary and others do not. All cases are shown in which whaling occurred in two or more years in boundary pairs and in adjacent non-boundary pairs. Before and after allocation comparisons can be made with respect to the Area III–IV boundary for the season series 1973/74–74/75 and 1975/76–78/79; and for the IV–V boundary for 1972/73–73/74 and 1974/75–75/76. In the latter case however the pre-allocation catches were made in the pair of squares straddling the boundary only on the western (Area IV) side, so the comparison is not very satisfactory.

Looking first at the bottom righthand of the Table we see that the pre-allocation catch was higher in IVE than in IV–V, but this was due to a very high catch in one square in 1972/73, the year in which there was the narrowest ever longitudinal range of operation. Nevertheless the average CPUE was higher in the boundary pair of squares. In the post-allocation period both catch and CPUE were higher in the boundary pair than in the pairs on either side of it. There is an indication that the allocation has resulted in a shift of effort towards the boundary but, all the same it has the highest density of whales in that region to the south of Australia. We now turn to the Area III–IV boundary. In the post-allocation period the catches, efforts and catch per unit efforts are all higher in the boundary pair of squares than on either side of it. But virtually the same situation prevailed in the pre-allocation period. Furthermore, there is no indication of a strong movement towards the boundary after allocation; the relative sizes of catches and efforts in the three pairs of squares are little changed.

It is also interesting to note that in 1974/75 there were about equal degrees of concentration near both boundaries even though one of them was affected by the allocation system that year and the other not.

In all periods the CPUE is lowest in pair IVE.

Table 2 shows the distribution of Soviet catches. Pre- and post-allocation comparisons are possible only with respect to the III–IV boundary. Pre-allocation catches are

Table 1

Japanese pelagic catches of minke whales, and associated effort, grouped by pairs of ten-degree squares
Top line of each set: average catch per season during the period. Second line: average number of CDW per season.
Third line: average catch per catcher days work.

Squares Designation	9–10 IIIW	11–12 IIIE	13–14 III–IV	15–16 IVW	17–18 IVE	19–20 IV–V	21–22 VW
Period:							
Pre-allocation							
1973/74–74/75	192	570	1,423	241			
	22	64	142	57			
	8.9	8.7	9.1	4.4			
1972/73–73/74					1,104	472	
					107	55	
					5.5	7.0	
Intermediate							
1974/75		407	1,232	235	188	349	151
		57	171	51	72	54	24
		7.1	7.2	4.1	2.6	6.5	6.3
Post-allocation							
1975/76–78/79		439	1,258	137			
		51	133	16			
		8.7	9.8	9.6			
1974/75–78/79					204	573	236
					47	68	38
					5.5	8.6	6.0

Table 2

USSR pelagic catches of minke whales, grouped by pairs of ten-degree squares

Designation	IIIW	IIIE	III–IV	IVW	IVE	IV–V	VW
Season:							
1972/73	621	217	1,107	1,705	9		
1973/74	66	99	1,422	1,141			
1974/75			233	1,067	90	144	90
1975/76			713	812	203	201	10
1976/77		892	733	514		112	345
1977/78		113	729	329		182	34
1978/79	325	416	272	293		183	58

highest either in pair III–IV or in IVW. Post-allocation there is a clear preference for II–IV in three of the four years. In the fourth year (1978/79) catches are higher on both sides of the boundary pair.

The USSR rarely seemed to find it worthwhile to operate in IVE, and when it did it took only small catches.

In the post-allocation period a clear preference for the IV–V boundary appears in four of the five years.

These data support the hypothesis that there are naturally high concentrations of minke whales near the boundary of Areas III and IV and, less strongly, near the boundary of IV and V; and that these concentrations attracted attention before allocated catch limits were agreed. Later, the allocations enhanced the attention given to the boundary regions. There is a naturally relatively low density in the eastern half of Area IV.

These density differences tell us nothing about the boundaries of biological populations, but they do suggest that to attempt separate assessments of Areas IV and V is inappropriate. A more appropriate grouping of data would be:

1. Area III, or at least the Indian Ocean Sector of it, with the western part of Area IV (arbitrarily up to and including square 16 or 17).

2. The eastern part of Area IV and all of Area V or perhaps only as far east as square 24.

Appendix 6

JAPANESE MINKE WHALE CATCH AND EFFORT

Table 1

Catch and CSW (south of 50°S) summed over years 1972–81, listed by 10° longitudinal strip

Square No.	Total catch	CSW	Catch/CSW
1	163	663.19	0.25
2	2	82.42	0.02
3	9	165.58	0.05
4	408	126.82	3.22
5	101	67.48	1.50
6	685	475.83	1.44
7	406	196.55	2.07
8	226	175.96	1.28
9	296	200.01	1.48
10	317	266.39	1.19
11	953	544.51	1.75
12	1,596	1,228.77	1.30
13	6,299	3,081.78	2.04
14	2,997	2,743.16	1.09
15	2,121	1,615.57	1.31
16	1,209	1,198.69	1.01
17	1,866	1,482.61	1.26
18	2,386	2,241.56	1.06
19	2,591	2,049.23	1.26
20	2,251	1,798.19	1.25
21	1,032	1,122.86	0.92
22	334	515.30	0.65
23	95	241.01	0.39
24	78	204.82	0.38
25	86	280.47	0.31
26	342	544.96	0.63
27	90	34.44	2.61
28	18	81.26	0.22
29	60	279.65	0.21
30	277	442.79	0.63
31	584	775.99	0.75
32	177	321.51	0.55
33	12	107.85	0.11
34	260	260.26	1.00
35	450	257.83	1.75

Note: there was no information recorded for square zero.

Table 2

Catch and CSW (south of 60°S) summed over years 1972–81, listed by 10° longitudinal strip

Square No.	Total catch	CSW	Catch/CSW
1	110	503.82	0.22
2	2	82.42	0.02
3	9	165.58	0.05
4	408	126.82	3.22
5	101	67.48	1.50
6	685	475.83	1.44
7	406	196.55	2.07
8	226	175.96	1.28
9	296	200.01	1.48
10	317	266.39	1.19
11	953	544.51	1.75
12	1,596	1,228.77	1.30
13	6,299	3,081.78	2.04
14	2,997	2,743.16	1.09
15	2,067	1,434.81	1.44
16	1,209	1,198.69	1.01
17	1,864	1,388.71	1.34
18	2,386	2,241.56	1.06
19	2,591	2,049.23	1.26
20	2,251	1,798.19	1.25
21	1,032	1,122.86	0.92
22	334	515.30	0.65
23	95	241.01	0.39
24	78	204.82	0.38
25	86	280.47	0.31
26	342	544.96	0.63
27	90	34.44	2.61
28	1	6.00	0.17
29	60	279.65	0.21
30	277	442.79	0.63
31	584	775.99	0.75
32	177	321.51	0.55
33	12	107.85	0.11
34	260	260.26	1.00
35	450	257.83	1.75

Appendix 7

CATCH AND CPUE OF MINKE WHALE BY JAPANESE EXPEDITIONS

Compiled by Y. Shimadzu

Square	CSW	Weather corrected CSW[1]	Weather and season corrected CSW[2]	Catch			CPUE		
				M	F	Total	M	F	Total
607	216.33	288.28		121	269	390	0.42	0.93	1.35
608	175.96	232.87		70	156	226	0.30	0.67	0.97
609	200.01	214.45		59	237	296	0.28	1.10	1.38
610	353.51	433.75		99	218	317	0.23	0.50	0.73
611	466.76	661.35		279	463	742	0.42	0.70	1.12
612	600.42	996.89		253	471	724	0.25	0.47	0.73
613	894.28	1,266.70		437	837	1,274	0.34	0.66	1.00
614	1,015.19	1,185.27	1,018.11	465	645	1,110	0.46	0.63	1.09
615	874.22	1,234.04	1,097.74	970	619	1,589	0.88	0.56	1.45
616	547.73	514.36	414.00	546	254	800	1.32	0.61	1.93
617	682.15	838.45	665.35	235	910	1,145	0.35	1.37	1.72
618	436.54	487.40	342.09	214	283	497	0.62	0.83	1.45
619	368.74	468.55	321.27	175	310	485	0.54	0.96	1.51
620	501.04	526.50		197	304	501	0.37	0.58	0.95
621	325.04	499.53		102	213	315	0.20	0.43	0.63
622	93.23	98.71		73	116	189	0.74	1.18	1.91
623+723	55.05	96.23		16	48	64	0.17	0.50	0.66
724	100.32	83.15		10	64	74	0.12	0.77	0.89
725	75.17	67.74		8	44	52	0.12	0.65	0.77
726	89.56	116.83		57	52	109	0.49	0.38	0.93
727	34.44	64.04		43	47	90	0.67	0.81	1.40
728	—	—	—	—	—	—	—	—	—
729+629	47.57	59.99		18	16	34	0.36	0.27	0.57

CSW are summed up for December to February.
Relevant references: *Rep. int. Whal. Commn* 29: 427, *ibid.* 30: 429.
Data are for Area III: 74CY, 75CY, 803N
VI: 72JY, 793N, 803N, 813N
V: 783N, 813N
VI: 813N
In these operations Japanese expedition operated through those Areas. (*Rep. int. Whal. Commn* 30: 349–55; SC/Jn81/MiS22.)

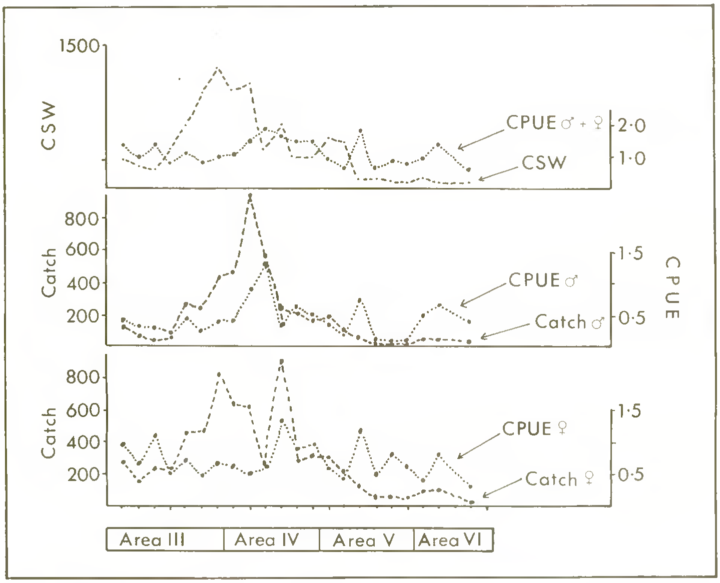

Fig. 1. Minke whale catches and CPUE for Japanese expeditions. Weather corrected CSW (*Rep. int. Whal. Commn* 29: 427), seasonality corrected for Area IV (*ibid.* 30: 429). Fleets: Area III, 74 CY, 75 CY, 80 3N; Area IV, 72 JY, 79 3N, 80 3N, 81 3N; Area V, 78 3N, 81 3N; Area VI, 81 3N.

Appendix 9

FURTHER COMMENTS ON RECENT AGE DISTRIBUTIONS OF ANTARCTIC MINKE WHALES

(AREAS III, IV)

D. G. Chapman

In SC/Jn81/MiS20, Clark points out the problems in the age distribution of catches by Japan of this stock. He notes that the steep slope of recent age distribution can be explained:

(1) by a value of M (adult natural mortality rate) much lower than previously considered and a severalfold increase in recruitment rates between 1930 and 1950 due in part at least to decreases in the juvenile mortality rate;
(2) by declining catchability with age as suggested by Grenfell and Beddington, *Rep. int. Whal. Commn* 31: 233–39 in particular note Fig. 3, p. 237;
(3) by increasing natural mortality with age.

The purpose of this note is to follow up on this third possibility. To assure that we are dealing with fully recruited classes, a second degree equation has been fitted to the estimated number of 20+ females (as calculated by Clark SC/Jn81/MiS20 in his Table 1). The equation fitted is

$$Y_t = \ln n_t - \frac{1}{n_t + 1} = a + bt + ct^2$$

n_t = estimated number at coded age t where coded age t is taken to be actual age minus 20.

The factor $\left\{\frac{1}{n_t} + 1\right\}$

is used to correct for bias (cf. Chapman and Robson; *Biometrics*, 1960).

The resulting equation is

$$Y = 5.421 - 0.100\,t - 0.0030\,t^2.$$

This suggests a mortality rate increasing from 0.100 at age 20 to 0.220 at age 60.

With this mortality rate series the ratio of the proportion of population from 30 to 39 compared to the proportion 40+ is calculated to be 0.217 vs the observed 0.192 (for females)—cf. Clark's Table 2. Thus this model explains the anomaly that is unexplained by Clark's model.

It is necessary to make some assumptions to estimate the mortality rates at ages younger than 20 since it is agreed that these ages are not fully recruited. Two assumptions are considered:

(1) M is constant from ages 15 to 20;
(2) M is given by the same quadratic function in the age range 15–20 as estimated above for older ages.

We start with the age 15 since this is taken as the age of first parturition in the 'unexploited' population, i.e. the population prior to response to exploitation of other baleen whales. Starting with a unit recruitment at age 15 the distributions of the population by age groups for these two assumptions are summarized in Table 1.

Table 1

Age distributions of minke whale population according to two assumptions on mortality rate

Age group	M = 10 15–20	M given by quadratic 15–20
15	1	1
15–19	4.092	4.198
20–29	3.742	3.943
30–39	0.987	1.040
40–60	0.215	0.226
Total 15–60	9.036	9.407

We can then derive from the balance equation the calculated average mortality m^1 over the initial 15 years for various values of p, the pregnancy rate.

Two values of p are considered

$p = 0.50$ (female births per adult female) which is only possible with an annual cycle with no missed conceptions,
$p = 0.43$ the rate most recently used for this population.

The balance equation is

$$1 = \{p\, e^{-15M^1}\} \times \text{Adult Age Group}$$

$$\text{or } M^1 = \frac{\ln\,[p \times \text{Adult Age Group}].}{15}$$

For M = 0.10 constant from ages 10 to 15
$p = 0.50 \Rightarrow M^1 = 0.100$
$p = 0.43 \Rightarrow M^1 = 0.090.$
For M given by quadratic model for ages 10–15
$p = 0.50 \Rightarrow M^1 = 0.103$
$p = 0.43 \Rightarrow M^1 = 0.093.$

For the quadratic model the mortality rates estimated for ages 15 to 20 are as follows:

15	0.085	18	0.094
16	0.088	19	0.097
17	0.091	20	0.100.

If it is assumed that juvenile mortality is M_j from ages 0 to 4 and at the adult rate 0.095 from ages 4 to 15 this means that for the quadratic model, p = 0.43.
$M_j = 0.116$ which is not an unreasonable result.

Appendix 10

MINKE WHALES—ANTARCTIC

R_{II} RECRUITMENT RATES AND MEAN AGES AT RECRUITMENT

K. Radway Allen

The following table is based on data taken from the Japanese minke biological data file. A raw age-length key was constructed from all the aged records in the file; separate keys were made for each sex. Age distributions were calculated, by area, sea and season, by applying the sex-specific key to the corresponding total length distributions. Recruitment rates and ages were then calculated using the CPOP routine, taking T = 1.0.

		Male			Female		
Area	Season	r_{II}	est. T	t_r	r_{II}	est. T	t_r
I	1976	0.057	1.10	9.22*	−0.045†	0.96	0.51*
II	1974	0.083	1.39	4.86	0.128	2.13	8.82
	1975	0.175	1.06	7.07	0.151	2.55	7.47
III	1974	0.075	2.15	8.77	0.159	2.29	7.81
	1975	0.083	1.07	5.49*	0.069	2.12	7.81
	1976	0.023†	1.00	1.76*	−0.003†	2.17	2.26
	1977	0.001†	0.91	7.47*	−0.032†	0.87	2.18*
	1978	0.150	1.73	7.58	0.219	1.21	8.35
	1979	0.069	1.86	8.10	0.027†	2.37	5.86
IV	1974	0.132	1.08	8.02*	0.183	2.29	7.25
	1975	−0.123†	0.69	2.01	−0.292†	0.60	2.09
	1976	0.096	2.13	7.78	0.211	2.26	8.01
	1977	0.086	1.61	6.31	0.015†	0.94	2.60*
	1978	0.162	1.09	7.63*	0.209	2.10	7.21
	1979	0.003†	0.96	2.51*	−0.038†	0.90	2.01*
V	1975	0.048	1.09	6.03*	0.178	1.84	7.19
	1976	0.142	2.31	7.97	0.103	1.21	8.30
	1977	0.091	2.30	6.59	0.052	2.10	6.47
	1978	0.221	1.25	6.99	0.210	1.40	7.17
	1979	−0.054†	0.86	2.38*	−0.051†	0.85	2.08*
VI	1976	0.173	1.06	6.90*	0.030†	3.01	4.81
	1977	0.147	1.44	5.93	0.257	1.53	7.13

The value of T (the ratio for annual survival rate of recruits to that of older animals) computed in the program is also given in the table since an estimate widely different from 1.0 is often an indicator that the particular data sets concerned have substantial irregularities probably due to sampling and that the estimates of r_{II} and t_r are therefore unreliable. Following Ohsumi (1979) the estimates associated with estimates of T outside the range 0.8–1.2 have been marked with an asterisk.

The proportion of the divergent T values is however unusually high and the estimates of t_r associated with them are not more variable than those associated with T values near to 1.0. This suggests that the shape of these minke whale age distributions is such as to make the present method of estimating T inappropriate in this case. It should be noted that the technique by which the estimate of T is obtained from the age distributions is quite independent of the method of estimating r_{II} and t_r. Both techniques utilise the comparative series of age distributions for two successive years, but do so in quite different ways.

The results do however show another important feature. The estimates fall into two separate groups. One group has values of t_r not more than 2.6 and generally between 2.0 and 2.6; these cases generally have values of r_{II} less than 0.05. In the other group t_r is greater than 4.8 and generally between 5.5 and 9.0, and r_{II} is generally greater than 0.05. In most instances the estimates in each year for the two sexes, and these are quite independent, fall in the same group. Using a value of r_{II} of 0.04 as a criterion, the cases in the first group are marked in the table with †. Among the pairs of values for the two sexes in a given year and area, 5 have both sexes in group 1, 12 have both sexes in group 2, 4 have the two sexes in different groups and one contains an anomalous result. This suggests that the low values arise when an upward change in the lower sizes in the catches between successive years causes a reduction in the recruitment rate. If so, the values in the higher group can be taken as representing the normal age at recruitment.

The mean ages at recruitment of the males and females in this 'normal' group are 7.01 and 7.71 years respectively. The value of t for this comparison is 1.21 with 11 degrees of freedom. The difference between the sexes in mean age at recruitment is therefore not significant.

REFERENCE

Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 407–20.

Appendix 11

CATCH PER UNIT EFFORT: AN ESTIMATED SERIES FROM BRAZILIAN MINKE WHALING OPERATIONS

J. G. van Beek, S. J. Holt, W. K. de la Mare, J. M. da Rocha, Y. Shimadzu

From published information on Brazilian coastal whaling operations a CPUE series for minke whales is estimated. Table 1 is reproduced from Table 6 of da Rocha (1980, SC/31/43). This table was inadvertently omitted from the version of the paper published in *Rep. int. Whal. Commn* 30. This table contains the basic information from which a CPUE series can be extracted, when an estimate is made of the catcher chasing hours. The column in Table 1 headed search hours is the total hours spent searching and chasing for the operations on all three species listed in the table. The search time in Table 1 was estimated by da Rocha by assigning a fixed length working day: the vessel starts to operate in the whaling ground at 0600 and stops catching at 1700 unless the vessel returned before this time. The catch was considered as being towed back to the station after 1700. This daily value is summed for the days worked in each season to obtain an estimate of total working hours for the season. From these hours worked per season were subtracted handling time on a budget of 15 minutes for each whale caught. To convert these values to hours spent searching, the time spent chasing for each species must be subtracted. In treating the data in this way it is assumed that searching effort is not directed preferentially towards a given species, that is, the first suitable whale is pursued regardless of species. This assumption is regarded as valid by da Rocha.

Estimates of chasing time for minke whales in 1979 and 1980 by the Brazilian operation can be calculated directly from Table 2 of time budget data reported in da Rocha and Braga (SC/33/ProgRep Brazil). This value is found to be 0.46 hours per whale which is similar to a typical Japanese pelagic value of 0.40 (Ohsumi, 1979). Unfortunately similar time budget data are not available to date for calculating the chasing time for the sei and sperm whales in the Brazilian operations and therefore these will be approximated by chasing time values from other operations on these species. In the Japanese pelagic operations this value ranges from 0.60 to 0.77 hours per whale in the years 1961/62 to 1976/77 respectively (IWC, 1980).

Best (1981) reported a value for the chasing time of sperm whales in the Durban operations of 0.76 hours per whale. For simplicity a value of 0.7 is chosen. The results were recomputed with the sperm whale chasing time set to 1 hour per whale: the results were affected only in the second or third decimal place.

The results of the conversion of research hours to CSW and CPUE values are shown in Table 2. The CPUE series is shown graphically in Fig. 1. The figures for 1979 and 1980 are computed directly from the time budget data in SC/33/ProgRep Brazil. No weather correction is applied because conditions are quite uniform throughout the season (da Rocha, 1980). The whaling operations did not occur over the same length of the season in all years but no satisfactory way could be devised to correct the series for seasonality. On the 8 October 1978 a new catcher boat the *Cabo Branco* commenced trial operations from the Brazilian station. This vessel has the following characteristics: gross tonnage 395.2 t, total length 49.6 m, maximum speed 17.1 knots, power 3,150 hp. The old vessel, the *Seiho Maru 2*, which operated till 1 December 1977, had the following characteristics: gross tonnage 306.4 t, total length 40.0 m, maximum speed 14.5 knots, 1,800 hp. It is possible that a third vessel, the *Daishin Maru I* (47.95 m), may have been used in the first years of the series and this requires clarification. It could not be agreed as to what effect the change in catcher vessel in 1977 may have had on the CPUE series.

Another index of abundance is available. Da Rocha (1980, Table 5) shows annual relative abundance in terms

Table 1

Percentage of whales caught in relation to number sighted and search hours from da Rocha (1980, Table 6) (1965–1978)

Years	Catches			Sighted whales				Caught			Search hours
	Minke	Sperm	Sei	Minke	Sperm	Sei	Others	Minke	Sperm	Sei	
1965		13			67				19.4		
1966	352	24	72	852	72	134	20	41.3	33.3	53.7	1,624
1967	488	20	55	1,148	78	92	15	42.5	25.6	59.8	1,709
1968	456	39	64	1,192	135	100	8	38.3	28.9	64.0	1,716
1969	617	75	62	1,207	232	87	9	51.1	32.3	71.3	1,850
1970	701	76	26	1,277	232	45	5	54.9	32.8	57.8	1,888
1971	900	55	20	1,766	177	34	1	51.0	31.1	58.8	2,369
1972	702	66	5	1,108	330	17	6	63.4	20.0	29.4	1,865
1973	650	75	7	1,041	270	13	5	62.4	27.8	53.8	1,539
1974	765	29	3	1,091	127	12	6	70.1	22.8	25.0	1,810
1975	1,039	54	3	1,562	143	11	2	66.5	37.8	27.3	1,813
1976	776	9	3	1,170	50	14	4	66.3	18.0	21.4	1,742
1977	1,000	25	5	1,627	175	22	9	61.5	14.3	22.7	2,177
1978	690	24	—	1,092	58	5	—	63.2	41.4	—	1,187

Table 2

Catch and effort data for Brazilian minke whale operations

Year	Catch		Search hours (Ri)	CSW_i	CPUE	S_i	N_i
	Minke	Other					
1966	352	96	1,624	1,395	0.253	0.525	0.611
1967	488	75	1,709	1,432	0.341	0.672	0.802
1968	456	103	1,716	1,434	0.318	0.695	0.832
1969	617	135	1,850	1,470	0.420	0.648	0.816
1970	701	102	1,888	1,494	0.469	0.676	0.854
1971	900	75	2,369	1,903	0.473	0.895	1,114
1972	702	71	1,865	1,494	0.470	0.596	0.744
1973	650	82	1,539	1,183	0.549	0.661	0.860
1974	765	32	1,810	1,436	0.533	0.599	0.755
1975	1,039	57	1,813	1,295	0.802	0.864	1.210
1976	776	12	1,742	1,377	0.564	0.781	0.988
1977	1,000	30	2,177	1,696	0.590	0.747	0.959
1978	690	24	1,187	853	0.809	0.745	1.037
1979	738	27	1,123	1,123	0.657	1.000	1.000
1980	902	30	1,368	1,368	0.660	1.000	1.002

of sighted individuals per 'research hour'. Figures for year are then converted into number per CSW as:

$$N_i = S_i \times R_i/CSW_i$$

where: S_i is the number sighted per research hours;
R_i is search hours;
CSW_i is estimated CSW;
N_i is abundance of index for year, i.

These indices are also shown in Table 2 and N_i in Fig. 1.

An upward trend is observed during these 15 years with slightly different pattern from CPUE series.

Since the speed of the vessel in the searching phase has an optimum level the introduction of a new catcher boat in 1977 might not affect the searching efficiency, however, there may be some effect on chasing and travelling time to grounds which may alter CSW which were estimated from the calculated searching hours of Table 1.

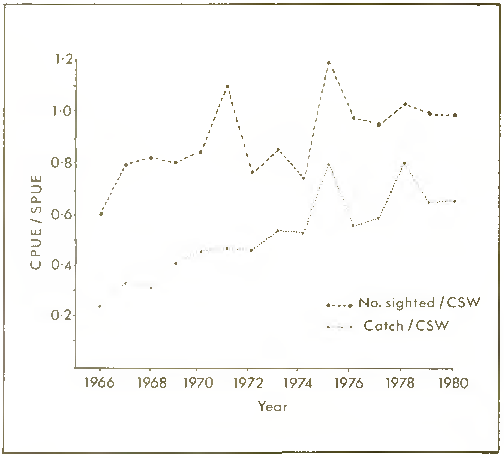

Fig. 1. CPUE and No. sighted/CSW series in Brazilian minke whale stock.

REFERENCES

Best, P. B. 1981. Reconsideration of catch per unit effort as an index of availability for sperm whales off Durban. *Rep. int. Whal. Commn* 31: 769–81.

da Rocha, J. M. 1980. Progress report on Brazilian minke whaling. *Rep. int. Whal. Commn* 30: 379–84.

da Rocha, J. M. and Braga, N. M. A. 1981. Brazil Progress Report on Whale Research. Paper SC/33/ProgRep Brazil (published in this volume).

International Whaling Commission. 1980. Report of the Special Meeting on Southern Hemisphere Sei Whales. *Rep. int. Whal. Commn* 31: 379–84.

Ohsumi, S. 1979. Population assessment of the Antarctic Minke Whale. *Rep. int. Whal. Commn* 29: 407–20.

Appendix 12

A REVIEW OF INFORMATION AVAILABLE FOR THE ASSESSMENT OF MINKE WHALES IN AREA II

S. J. Holt, W. K. de la Mare, J. G. van Beek

INTRODUCTION

In the early 1960s the Brazilian shore station at Costinha operated on a mixed catch of sei and sperm and a small catch of Bryde's whales. The latter species was not always differentiated from sei whales in the catch statistics (Williamson, 1975). In 1966, substantial numbers of minke whales began to be taken. The operations continued on these four species but the catch of sei and Bryde's whales reduced steadily to only a few animals per year by 1972 and ceased altogether in 1978. Since 1966 the number of sperm whales caught per season has ranged between a low of 9 and a peak of 76, with an annual average of 42 whales. The operations fall within Area II.

During the period of minke whaling, two or possibly three catcher vessels have been employed at different times. In 1963, before the start of minke whaling, one or both vessels, *Daishin Maru 1* and *Daishin Maru 2*, were operating (Paiva and Grangeiro, 1965). It is not clear when these vessels were replaced by the *Seiho Maru 2* which was engaged in the operation until 1 December 1977. On 8 October 1977 the *Cabo Branco* (not to be confused with another vessel of the same name which operated in 1961 and possibly other years) commenced trial operations and has been the catcher vessel employed in subsequent seasons. The characteristics of the latter two vessels are given in Table 1.

Table 1

Characteristics of two Brazilian catcher vessels

	Gross tonnage	Total length	Max. speed	Horsepower
Seiho Maru 2	306.4 t	40.0 m	14.48 knots	1,800
Cabo Branco	395.2 t	49.6 m	17.10 knots	3,150

LOCATION OF THE WHALING GROUND

In attempting to establish an unbiased series of indices of abundance suitable for making assessments, it is necessary to examine the location of the whaling grounds with respect to any change over time.

Paiva and Grangeiro (1965) gave maps for the annual distribution of sei/Bryde's whale and sperm whale catches for the years 1960 to 1963. The mean location of the catches for these years has been calculated and is shown in Table 2. The land station is located at 6°57′S, 34°52′W. In this period 17 sperm whales were caught and the mean position of this catch is similar to the mean position of the sei/Bryde's whale catch. Two similar maps are available for minke whales for 1972 (da Rocha, 1980) and 1980 (SC/Jn81/MiS1). The mean positions for catches in both of these years are separated by less than one nautical mile at a position of 7°5′S, 34°10′W. Thus the whaling ground shifted 20 miles to the south east between 1963 and 1972. The distance of the mean position of the sei whaling ground in 1960–63 was 26 miles from the shore station and the distance of the mean position in 1972 of the minke whaling ground is 42 miles from the station. This change will have altered the time budget of operations but the exact nature of this change cannot be determined.

Table 2

Mean location of the sei/Bryde's whale catch in Brazilian waters for the years 1960–1963

1960	6°52′S	34°27′W
1961	6°48′S	34°29′W
1962	6°52′S	34°25′W
1963	7°02′S	34°24′W
All years	6°53′S	34°26′W

CATCH HISTORY OF MINKE WHALES IN AREA II

Apart from the steady rate of catch from the Brazilian shore station there have been a number of catches by pelagic operations in the Antarctic. The total catches are shown in Table 3 by year, sex and operation. Also shown are the mean lengths of each catch.

Japan has taken minke whales in Area II in the three seasons 1973/74 to 1975/76 and length distributions are available from these catches. These catches were taken in the eastern half of the Area in all three years and also a few in the western half in 1975/76.

The USSR catch in Area II has been far larger than the Japanese catch. Length distributions are available for the USSR catches every season from 1973/74 to 1980/81. Very small catches were taken on the western side in 1973/75 and 1978/81. In all other years the catches were taken on the eastern side.

The combined Japanese and USSR catch is less than 70% of the Brazilian catch over the same period. The length distribution of the combined pelagic catches does not seem to be significantly different from that of the Brazilian catch.

BIOLOGICAL PARAMETERS

In the Special Meeting on Southern Hemisphere Minke Whales, Allen and Free obtained estimates for the age of recruitment for all Southern Hemisphere Areas including an estimate for Area II from the pelagic catch data, using the CPOP procedure. The value obtained for Area II was similar to the other Areas and a value of six or seven would seem appropriate. Unfortunately, there are no length at age data available for the Brazilian catch and so no direct estimate of age of recruitment can be made for the Brazilian component of the Area.

However, since the distributions of lengths in the pelagic and coastal catches are similar it would seem appropriate to use the age of recruitment estimated from the pelagic portion of the catch.

There is no evidence to suggest that values for the other biological parameters should be any different from those selected for the other Areas.

Table 3

Catch and mean length by country and sex in Area II from BIWS data, except 1966, 67, 69 and 70, which are given by da Rocha (SC/33/ProgRep Brazil) Length in feet

	Males			Females		
Years	Brazil	Japan	USSR	Brazil	Japan	USSR
1966	120			240		
1967	155			335		
1968	152			304		
1969	204			413		
1970	233			468		
1971	330			570		
1972	233			469		
1973	210			440		
1974	247 (27.8)	25 (27.0)	7 (26.3)	514 (29.1)	138 (28.7)	6 (28.0)
1975	381 (27.5)	74 (26.8)	5 (25.2)	657 (28.8)	726 (28.4)	1 (26.0)
1976	278 (27.8)	159 (26.4)	215 (27.7)	498 (29.3)	246 (27.5)	544 (28.7)
1977	329 (26.9)		236 (28.1)	665 (28.4)		629 (29.4)
1978	225 (27.3)		110 (27.9)	463 (28.7)		252 (29.1)
1979	241 (27.0)		87 (27.9)	497 (28.5)		310 (29.3)
1980[1]	315 (27.2)		31 (27.7)	587 (28.3)		270 (29.7)
1981			115			57
Average length 1974–1980	27.4	26.7	27.3	28.7	28.2	28.6

[1] 1980 means 1979/80 pelagic catch and 1980 land station catch.

INDICES OF ABUNDANCE

Van Beek, Holt, de la Mare, da Rocha and Shimadzu, (Appendix 11, p. 715–6) estimated a catch per unit effort series (CPUE) and sightings per unit effort series (SPUE/N_i), based on estimated catcher searching hours worked (CSW). The sightings and catch per unit effort are shown in Table 4 and Fig. 1.

The purpose of this paper is to provide some background to the series observed in van Beek *et al.* and to discuss some aspects of the series pertinent to their use in the derivation of assessments for Area II.

An examination of Fig. 1 shows a steeply rising trend in the CPUE and SPUE over the first years of the series, and there seem to be several reasons why the changes in the series prior to 1972 will not accurately reflect the relative abundance of minke whales off Brazil.

First, the years prior to 1972 correspond with the period in which the operations were changing from sei/Bryde's whales to minke whales, and it can be supposed that it is over this period that the whaling grounds shifted to the south east into a region of higher abundance for minke whales. The fact that the mean position of catches in 1972 and 1978 are virtually identical suggests that this shift was complete by 1972 but at this stage there are no data to determine whether this transition phase was completed before that year. Further, 1972 was the first year in which the catch of sei and Bryde's whales was sharply reduced and this tends to suggest that the transition was, in fact, not completed until that year.

Second, the CPUE on sperm whales, shown in Fig. 1, also increases in this period and this also is most probably explicable in terms of the change in the location of the whaling ground.

Third, it can be seen from Table 5 that the proportion of minke whales reported as being sighted that were caught increased steadily until 1972, after which it becomes more or less constant. This tendency could arise, either due to increasing efficiency or it could be an effect of a preference for the other species during the early period. If the latter reason is true then the assumption upon which the series were estimated is violated for the early years.

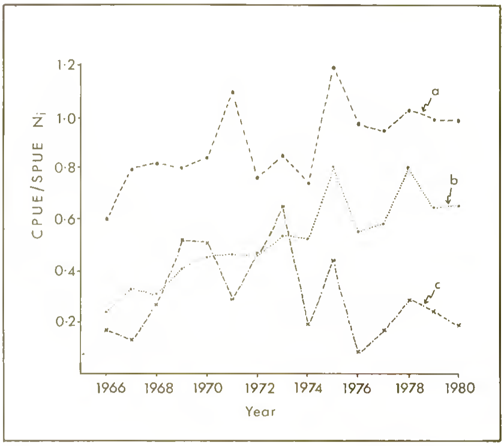

Fig. 1. CPUE and No. sighted/CSW series in Brazilian minke whale stock and CPUE series of Brazilian sperm whale stock.

Fourth, the 1971 season was shorter than the usual season due to the local quota set by Brazil being reached in November (Williamson, 1975).

Fifth, between 1971 and 1972 there is a sharp change in the length composition of the catch. Up to 1970 the proportion of animals, of both sexes, 25 ft long or less is high and variable; from 1972 this proportion is much lower, and less variable.

The five factors identified strongly suggest that the data from the years prior to 1972 should be excluded from both series if they are to be used for an assessment in Area II.

Table 4

Catch and sightings per unit effort in the Brazilian minke stock

Year	CPUE	SPUE/N_i
1966	0.253	0.611
1967	0.341	0.802
1968	0.318	0.832
1969	0.420	0.816
1970	0.469	0.854
1971	0.473	1.114
1972	0.470	0.744
1973	0.549	0.860
1974	0.533	0.755
1975	0.802	1.210
1976	0.564	0.988
1977	0.590	0.959
1978	0.209	1.037
1979	0.657	1.000
1980	0.660	1.002

Table 5

Percentage of minke whales caught in relation to number sighted

	Catch	Sighted	% caught
1966	352	852	41.3
1967	488	1,148	42.5
1968	456	1,192	38.3
1969	617	1,207	51.1
1970	701	1,277	54.9
1971	900	1,766	51.0
1972	702	1,108	63.4
1973	650	1,041	62.4
1974	765	1,091	70.1
1975	1,039	1,562	66.5
1976	776	1,170	66.3
1977	1,000	1,627	61.5
1978	690	1,092	63.2
1979	738	1,123	65.7
1980	902	1,370	65.8

Table 6

Mean date of the Brazilian minke catch

Year	Date
1964	7 October
1965	16 September
1966	3 October
1967	30 October
1968	17 October
1969	3 October
1970	21 September
1971	28 September
1972	11 October
1973	11 October
1974	29 September
1975	30 September
1976	18 September
1977	9 October
1978	13 October
1979	1 October

Table 7

Seasonal distribution of minke sightings and catches (relative to October)

	Sightings per 'research hour'			Catches per month	
	1979	1980	1979–80	1979–80	1972–80
June	—	0.028	0.032	0.008	0.027
July	0.456	0.237	0.301	0.264	0.253
August	0.495	0.326	0.396	0.479	0.650
September	1.100	0.641	0.825	0.746	0.997
October	1.000	1.000	1.000	1.000	1.000
November	0.484	0.575	0.534	0.437	0.825
December	0.135	0.126	0.128	0.095	0.168
Aug.–Nov.	0.770	0.636	0.689	0.666	0.868

SEASONAL CORRECTION

The series derived in van Beek *et al.* do not have any correction for seasonality. An examination of the sightings data in da Rocha (1980), and the BIWS catch data both show that a sharp peak in the abundance of minke whales off Brazil occurs in the months September and October. Table 6 shows the mean date of operation in each season and the observed variations strongly suggest that some seasonality correction should be applied. An inspection of the time budgets for 1979 and 1980 in da Rocha (SC/33/ProgRep Brazil) clearly shows the effect of the changing monthly abundance on the operation. In Table 7 the sightings of minke whales per research hour (searching + chasing) are shown as a proportion of the number sighted per research hour in October which is the usual month of peak abundance.

Operations do not always occur throughout June or December and in some years not at all. Even in July there is not always a full month of operations and in some past years (1964, 1978) there were none.

Van Beek *et al.* did not make the necessary corrections, essentially because the full log book data were not available by month. The highly peaked nature of relative abundance over months makes the potential size of seasonality corrections quite large and it is thus important if the indices of abundance series are to be of any use, that a correction be attempted. Fortunately the basic information necessary for a seasonality correction to the indices of abundance is available in a series of graphs shown in da Rocha (1980, Fig. 9).

Values from these graphs have been read as accurately as possible and compiled as a set of average sightings per research hour for the period of August to November each year. Small corrections have been made for the variation in the duration of the working month indicated in da Rocha (SC/33/ProgRep Brazil). The results are shown in Table 8. In considering indices derived from these data it should be remembered that some bias may still remain. This applies in particular to 1971 when there was a stop catch some time in November. In 1972 there was no catch in December and the November catch was abnormally small and so whaling probably stopped some time before the end of that month. Similarly, in 1978, there was no catch in July and the August catch is low and the season may not have started until part way through that month. It would be possible to restrict the data set still further, omitting November and even August but this leads to a large part of the data being ignored. Minke catch data are available by month in the BIWS publications. The third column of Table 8 shows the annual catches in the period August to November. These can be used in the calculation of chasing and handling times in the same way as in van Beek *et al.*

Correspondingly sei whale catches are not available by month. However, the catch can be approximately distributed through the season from data contained in the literature. Paiva and Grangeiro (1965) gave monthly

Table 8

Calculation of season corrected indices of abundance

Year$_i$	S$_i$'	Catch$_i$'	catch'% / catch	R$_i$'	CSW$_i$'	CPUE$_i$'	N$_i$'	Length of season (days)
1966	0.665	326	93	1,226	1,041	0.313	0.783	158
1967	0.900	448	92	1,200	979	0.458	1.103	168
1968	0.789	365	80	1,214	1,009	0.362	0.949	169
1969	0.837	528	86	1,165	874	0.604	1.115	125
1970	0.824	573	82	1,162	875	0.655	1.094	190
1971	0.854	817	91	1,108	738	1.107	1.282	237 (147)
1972	0.823	614	88	1,160	871	0.705	1.096	187
1973	0.803	610	94	1,158	860	0.709	1.081	157
1974	0.785	634	83	1,165	892	0.710	1.024	183
1975	1.154	874	84	1,098	715	1.222	1.772	190
1976	0.979	684	88	1,157	876	0.781	1.293	176
1977	0.900	953	95	1,025	634	0.691	1.427	221 (168)
1978	0.926	680	99	1,155	866	0.785	1.234	124
1979	0.990	649	88	1,162	886	0.733	1.299	162
1980	1.057	774	86	1,130	802	0.965	1.489	182

catches of sei whales for the period 1960 to 1963 and 28% of the catch is taken in June and July. August had 32% of the catch, September 31% and October only 9%. Since later publications refer to the fact that catches of sei whales tend to be earlier in the season than those of minke whales it was decided to approximate to the August–November sei catch by multiplying the total catch by the ratio of the minke catch in August–October each year to the minke catch from the beginning of the season until the end of October.

Sperm whales tend to be caught somewhat later than sei whales, according to the author cited above. The factors used to adjust the sperm catches were taken as the ratios of minke catches from July to the end of November to the total minke catch from July to the end of the season. Trials were made to determine if the results were sensitive to these assumptions by comparing the results of including all sperm whale catches in the August to November season with the results from including only the proportion of the sperm whale catch equal to the minke whale in the August to November period. These alternatives make differences only in the third significant figure of the results.

The estimated indices of abundance after correcting for seasonality by the technique described are shown in Table 8 and plotted in Fig. 2. It can be seen from these results that there are some anomalously high values in both indices in certain years, particularly 1971, 1975 and 1977. In an effort to identify any reason for such anomalies the length of the whaling season was back-calculated from the last column in Table 1 of van Beek *et al.*, inverting the methods of calculation described in that paper. The results are also shown in Table 8. It can be seen that the lengths of the 1971 and 1977 seasons exceed the maximum lengths of those seasons indicated by the monthly statistics, which suggests that there are some errors in the raw data set. For example the monthly catch statistics show that the 1971 season started in late June and ended in November and thus there could not have been 2,369 research hours. The error could in fact be a misprint in the search time for that year because if 2,369 from the Table 1 of van Beek *et al.* is replaced with 1,369 the length of the season calculated agrees with the length suggested by catch statistics. The season in 1977 began in late June and finished in early December, and thus could not have exceeded 160 days in length. However the difference between this length and the 221 days estimated in Table 8 is accounted for by simultaneous operation of the new and the old vessel. This means that the number of operating days in the period August to November must be taken as 144 rather than 121 as in other years. The abundance indices in Table 8 have been adjusted accordingly.

RECOMMENDATIONS

There is a considerable need for improvements in the data describing the Brazilian minke whaling operation, and the following suggestions are made as to how some improvements could be achieved.

(i) The catcher log books should be examined from 1966 onwards to determine the number of days and hours worked in each month. The number of hours worked each month could be ascertained as from the time that the catcher left port until it returned.

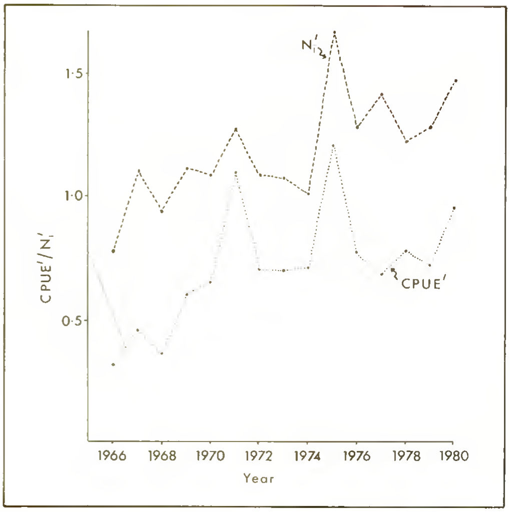

Fig. 2. CPUE and SPUE series corrected for seasonality in Brazilian minke whale stock.

(ii) The identity of the vessels which operated during the early period of minke whaling and their characteristics should be clarified.

(iii) The locations of the catches for each month for at least some of the years should be determined. This could be in the form of catch per 5′ square.

(iv) It can be seen from the time budget in da Rocha (SC/33/ProgRep Brazil) that the time spent travelling to the whaling ground varies from month to month and between the 1979 and 1980 seasons. It should be clarified whether this navigation time includes an element of searching, that is, is it the time taken from leaving port to start chasing the first whale? If this is so then it would be more appropriate to record searching time as beginning at the time when the vessel reaches the 100 fathom line since this is the edge of the whaling ground according to Williamson (1975).

(v) There are some discrepancies between the BIWS length statistics and the statistics presented in da Rocha (SC/33/ProgRep Brazil) and these should be reconciled if possible (especially the years 1968, 1977 and 1980). (The 1966, 1967, 1969 and 1970 length distributions are not published in the BIWS.)

(vi) Chasing times for sperm whales during the seasons 1979 and 1980 should be determined.

(vii) Basic data such as sea state, visibility, wind and sea turbidity throughout the last few seasons should be compiled to determine whether any corrections for these factors may be required.

REFERENCES

van Beek, J. G., Holt, S. J., de la Mare, W. K., da Rocha, J. M. and Shimadzu, Y. 1982. Report of the special workshop on Southern Hemisphere minke whales. Appendix 11, this volume, p. 715–6.

Paiva, M. P. and Grangeiro, B. F. 1965. Biological investigations on the whaling season 1960/63 off north eastern coast of Brazil. *Arq. Est. Biol. Mar. Univ. Ceara*, 5(1): 29–64.

Williamson, G. R. 1975. Minke whales off Brazil. *Sci. Rep. Whales Res. Inst., Tokyo* 27: 37–59.

da Rocha, J. M. 1980. Brazil Progress Report on Cetacean Research. *Rep. int. Whal. Commn* 30: 379–84.

Singarajah, K. V. 1981. Observations on the occurrence and behavior of minke whales off the coast of Brazil. Paper SC/Jn81/MiS1 presented to the IWC Scientific Committee, June 1981.

da Rocha, J. M. 1982. Brazil Progress Report on Cetacean Research (published in this volume).

Appendix 13

Table 1

Area IV minke run—Shimadzu catch and effort data. Table of catch and effort data

YEAR	------------ CATCH		------------		----- KNOWN EFFORT -----			CATCH PER KNOWN EFFORT		
	TOTAL		KNOWN EFFORT							
	MALE	FEMALE	MALE	FEMALE	ACTUAL	MODIFIER	MODIFIED	MALE	FEMALE	TOTAL
1930	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1960	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1961	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1962	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1963	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1964	44.	50.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1965	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1966	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1967	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1968	267.	330.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1969	16.	25.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1970	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1971	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1972	919.	1726.	2645.	0.	2645.	1.0	2645.0	1.000	0.0	1.000
1973	2410.	2146.	2091.	0.	1904.	1.0	1904.0	1.098	0.0	1.098
1974	1761.	2808.	2043.	0.	2453.	1.0	2453.0	0.833	0.0	0.833
1975	907.	1323.	841.	0.	1124.	1.0	1124.0	0.748	0.0	0.748
1976	429.	452.	435.	0.	425.	1.0	425.0	1.024	0.0	1.024
1977	917.	683.	950.	0.	1040.	1.0	1040.0	0.913	0.0	0.913
1978	251.	712.	481.	0.	405.	1.0	405.0	1.188	0.0	1.188
1979	512.	858.	960.	0.	722.	1.0	722.0	1.330	0.0	1.330
1980	1177.	684.	1530.	0.	1801.	1.0	1801.0	0.850	0.0	0.850
1981	881.	1505.	1193.	0.	1319.	1.0	1319.0	0.904	0.0	0.904
1982	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1983	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1984	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0
1985	0.	0.	0.	0.	0.	1.0	0.0	0.0	0.0	0.0

Table 2

Area IV minke run—Shimadzu catch and effort data. Table of time varying parameters

YEAR	MEAN AGE AT RECRUITMENT				MEAN AGE FIRST PARTURITION		PREGNANCY
	TOTAL CATCH		KNOWN EFFORT				
	FEM.	MALE	FEM.	MALE	FEM.	MALE	RATE
1930	7.0	7.0	7.0	7.0	15.0	14.0	0.86
1955	7.0	7.0	7.0	7.0	15.0	14.0	0.86
1956	7.0	7.0	7.0	7.0	15.0	14.0	0.86
1957	7.0	7.0	7.0	7.0	15.0	14.0	0.86
1958	7.0	7.0	7.0	7.0	14.0	13.0	0.86
1959	7.0	7.0	7.0	7.0	14.0	13.0	0.86
1960	7.0	7.0	7.0	7.0	13.0	12.0	0.86
1961	7.0	7.0	7.0	7.0	13.0	12.0	0.86
1962	7.0	7.0	7.0	7.0	12.0	11.0	0.86
1963	7.0	7.0	7.0	7.0	12.0	11.0	0.86
1964	7.0	7.0	7.0	7.0	11.0	10.0	0.86
1965	7.0	7.0	7.0	7.0	11.0	10.0	0.86
1966	7.0	7.0	7.0	7.0	10.0	9.0	0.86
1967	7.0	7.0	7.0	7.0	9.0	8.0	0.86
1968	7.0	7.0	7.0	7.0	9.0	8.0	0.86
1969	7.0	7.0	7.0	7.0	8.0	7.0	0.86
1970	7.0	7.0	7.0	7.0	8.0	7.0	0.86
1971	7.0	7.0	7.0	7.0	8.0	7.0	0.86
1972	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1973	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1974	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1975	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1976	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1977	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1978	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1979	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1980	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1981	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1982	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1983	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1984	7.0	7.0	7.0	7.0	7.0	6.0	0.86
1985	7.0	7.0	7.0	7.0	7.0	6.0	0.86

Table 3

Area IV minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 11,850.6

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4870
MALE   JUVENILE MORTALITY RATE =  0.4870
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687
```

YEAR	-----FEMALE	POPULATION------		------MALE	POPULATION-------		TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1930	16651	11851	20539	16651	12694	20539	41077	0	0
1955	16651	11851	20539	16651	12694	20539	41077	0	0
1956	16651	11851	20539	16651	12694	20539	41077	0	0
1957	16651	11851	20539	16651	12694	20539	41077	0	0
1958	16651	12694	20539	16651	13597	20539	41077	0	0
1959	17014	12694	20539	17014	13597	20539	41077	0	0
1960	17236	13597	20539	17236	14565	20539	41077	0	0
1961	17762	13597	20539	17762	14565	20539	41077	0	0
1962	18128	14565	20539	18128	15601	20539	41077	0	0
1963	18810	14565	20539	18810	15601	20539	41077	0	0
1964	19314	15601	20539	19314	16711	20539	41077	44	50
1965	20149	15563	20492	20149	16675	20497	40989	0	0
1966	20672	16671	20592	20672	17862	20597	41189	0	0
1967	21555	17860	20686	21555	19229	20690	41376	0	0
1968	22638	17947	20877	22638	19316	20881	41758	267	330
1969	23429	19182	20747	23429	20811	20811	41558	16	25
1970	24476	19346	21023	24476	21090	21090	42113	0	0
1971	25347	19626	21303	25347	21366	21366	42669	0	0
1972	26034	21684	21684	24115	23662	21743	43427	919	1726
1973	27513	20424	20424	25457	23288	21232	41656	2410	2146
1974	27918	18983	18983	25715	21694	19491	38474	1761	2808
1975	27539	17157	17157	25326	20822	18609	35765	907	1323
1976	26694	16848	16848	24329	20958	18592	35440	429	452
1977	26002	17516	17516	23617	21551	19165	36680	917	683
1978	25821	17942	17942	23401	21683	19263	37205	251	712
1979	25737	18345	18345	23063	22683	20009	38353	512	858
1980	25480	18822	18822	22962	23217	20698	39520	1177	684
1981	25500	19284	19284	23159	22917	20576	39860	881	1505
1982	25783	18784	18784	23667	22688	20572	39356	0	0
1983	25939	19511	19511	23861	23258	21181	40692	0	0
1984	26463	20155	20155	24302	23873	21713	41868	0	0
1985	27094	20833	20833	24881	24500	22287	43120	0	0

Table 4

Area IV minke run—Shimadzu catch and effort data. Table of observed and expected catches corresponding to best fit

YEAR	OBSERVED	EXPECTED
1972	2645.	2761.1
1973	2091.	1858.9
1974	2043.	2201.0
1975	841.	965.6
1976	435.	368.8
1977	950.	925.2
1978	481.	368.7
1979	960.	674.3
1980	1530.	1723.1
1981	1193.	1264.5

Table 5

Summary of results from BALEEN runs

AREA	t_r	M	q	F_n	$N_{0,♂♀}$	$N_{82,♂}$	$N_{82,♀}$	Total
III	6	0.09	0.304E-04	12.31	16526	23568	19835	43403
	7	0.09	0.244E-04	12.40	21026	30208	26475	56683
IV	6	0.06	0.205E-04	56.93	24481	23624	21736	45359
	6	0.09	0.414E-04	57.46	12098	12624	11052	23676
	7	0.06	0.199E-04	58.24	25549	24903	23015	47917
	7	0.09	0.388E-04	64.84	13038	14416	12844	27260
	7	0.069	0.248E-04	57.60	20539	20572	18784	39356
V	6	0.09	0.143E-03	23.15	3637	4514	3197	7711
	7	0.06	0.831E-04	23.00	7031	7025	5597	12622
	7	0.09	0.140E-03	23.34	3864	4619	3302	7920
	7	0.054	0.753E-04	23.00	7866	7643	6193	13836
VI	6	0.09	0.183E-04	31.72	15902	26916	27074	53990
	7	0.09	0.170E-04	32.01	17778	28837	28996	57833
III+IV	7	0.09	0.885E-05	196.33	52541	75223	69919	145142
A	6	0.09	0.149E-04	137.62	32189	42086	36446	78532
∝	6	0.09	0.127E-04	196.78	36743	49830	43073	92903
	7	0.06	0.301E-05	182.96	159624	191177	183360	374537
	7	0.09	0.112E-04	200.33	42066	57485	50727	108212

Table 6

Observed and expected catches from BALEEN runs

Area	Year	Observed catch	Expected Catches.					
			$t_r = 6$	6	7	7	7	7
			M = 0·06	0·09	0·06	0·09	0·069	0·054
III sightings	1968	40.	51.3		51.6			
	1969	50.	59.6		59.5			
	1970	45.	63.3		63.4			
	1971	107.	64.6		64.3			
	1972	74.	63.9		63.8			
	1973	67.	56.9		56.6			
	1974	28.	49.6		49.4			
	1975	62.	51.6		51.9			
IV	1972	2645.	2734.2	2832.4	2733.7	2810.7	2761.1	
	1973	2091.	1866.0	1845.0	1862.8	1828.3	1858.9	
	1974	2043.	2246.3	2090.5	2239.6	2070.7	2201.0	
	1975	841.	988.5	893.4	988.6	894.9	965.6	
	1976	435.	376.8	351.9	375.6	349.1	368.8	
	1977	950.	935.5	905.6	934.0	902.8	925.2	
	1978	481.	369.5	370.0	369.3	369.7	368.7	
	1979	960.	674.6	709.0	669.8	694.1	674.3	
	1980	1530.	1694.0	1812.8	1696.5	1827.7	1723.1	
	1981	1193.	1226.7	1300.9	1240.9	1356.1	1264.5	

Table 6 (*continued*)

Area	Year	Observed catch	Expected Catches.					
			$t_r = 6$	6	7	7	7	7
			$M = 0{\cdot}06$	0·09	0·06	0·09	0·069	0·054
V	1975	500.		527.2	521.3	528.4		520.5
	1976	420.		512.7	506.3	509.4		505.8
	1977	1010.		795.8	802.4	796.1		803.1
	1978	634.		718.2	739.4	722.7		741.4
	1979	173.		134.8	134.4	133.5		134.5
	1980	496.		489.0	481.7	486.8		480.9
	1981	625.		657.2	649.5	657.8		648.4
VI	1974	13.		12.8		12.9		
	1975	0.		0.0		0.0		
	1976	159.		174.9		174.4		
	1977	149.		116.8		116.9		
	1978	233.		258.3		259.4		
	1979	0.		0.0		0.0		
	1980	0.		0.0		0.0		
	1981	233.		220.3		219.7		
III+IV	1972	2999.				3052.3		
	1973	2091.				1915.4		
	1974	3537.				4009.0		
	1975	2200.				2475.0		
	1976	1456.				1053.0		
	1977	2335.				1759.8		
	1978	1493.				1069.2		
	1979	2560.				2187.9		
	1980	2783.				3269.7		
	1981	1812.				2278.5		
A	1972	2998.		3198.1				
	1973	2090.		1742.9				
	1974	2954.		3334.9				
	1975	2610.		2946.8				
	1976	1876.		1610.0				
	1977	3345.		2556.0				
	1978	2082.		1837.5				
	1979	2732.		2606.4				
	1980	2700.		3044.0				
	1981	2247.		2619.9				
∝	1972	2998.		3099.3	3016.3	3086.1		
	1973	2090.		1767.6	1751.3	1755.9		
	1974	3700.		4316.6	4383.1	4284.6		
	1975	2999.		3212.4	3324.5	3218.7		
	1976	1687.		1262.1	1294.4	1255.4		
	1977	2335.		1667.8	1710.6	1671.8		
	1978	1493.		1080.2	1100.1	1088.1		
	1979	2559.		2447.6	2415.6	2428.5		
	1980	2783.		3208.1	3137.9	3225.6		
	1981	1812.		2197.5	2139.3	2241.0		

Appendix 14

CONFIDENCE LIMITS ON POPULATION ESTIMATES FOR SOUTHERN HEMISPHERE MINKE WHALES

C. A. Free

Table 1 shows confidence intervals obtained from running the BALEEN assessment program on data for minke whales in Antarctic Areas IV, V and VI.

The procedure followed is to calculate the limits on N_0, the initial mature female population size, as

N_0 (lower) = $N_0 - 2\cdot$ (standard error of N_0)
and N_0 (upper) = $N_0 + 2\cdot$ (standard error of N_0).

These limits are inserted into BALEEN, which is then used purely as a simulation program and does not perform any minimisation. The resulting population trajectories are tabulated for recent years.

The bounds on the Area VI estimate are of dubious validity: the standard error is sufficiently large compared with the mean as to imply an asymmetrical, non-ellipoidal region.

The confidence intervals for Area IV are obtained by re-running BALEEN with the adult mortality rate fixed at the value previously obtained by minimisation.

To use the results from the variance–covariance matrix produced by the minimisation run would ignore the high correlation between N_0 and m in the minimisation process.

Table 1

Confidence intervals for Southern Hemisphere minke whale assessments: BALEEN runs

	m	N_0 (best estimate)	Standard error	N_0 (lower)	Total 1981 population	N_0 (upper)	Total 1981 population
IV	0.0687	11,851	299	11,253	84,537	12,449	97,189
V	0.0542	5,103	1,887	1,329	not feasible	8,877	60,625
VI	0.06	no convergence	—	—	—	—	—
VI	0.09	8,653	3,481	1,671	28,522	15,635	270,555

$t_r = 7$ throughout.

Table 2

Area V minke run—*Shimadzu* catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 8,877.0

```
NO. OF AGE CLASSES IN MODEL =    30
FEMALE JUVENILE MORTALITY RATE =   0.6962
MALE   JUVENILE MORTALITY RATE =   0.6962
FEMALE ADULT MORTALITY RATE =  0.0542
MALE   ADULT MORTALITY RATE =  0.0542

YEAR    -----FEMALE POPULATION------    ------MALE POPULATION-------    TOTAL      ---CATCH---
        IMM-UNEX    MATURE    EXPL.     IMM-UNEX    MATURE    EXPL.     EXPL. POP     M      F

1968     12876      12327     13857      12876      13050     13857     27713         0      0
1969     13199      13125     13931      13199      13931     13931     27862         0      0
1970     13735      13196     14047      13735      14047     14047     28093         0      0
1971     14114      13305     14156      14114      14156     14156     28312         0      0
1972     14384      14307     14307      13435      15256     14307     28614         0      0
1973     15041      14450     14450      14040      15452     14450     28901         0      0
1974     15472      14636     14636      14415      15693     14636     29272         0      0
1975     15783      14865     14865      14723      15925     14865     29729       258    476
1976     16124      14633     14633      14995      15969     14840     29473       317    314
1977     16219      14633     14633      15085      15960     14825     29458       597    870
1978     16327      14111     14111      15183      15697     14552     28664       352    516
1979     16218      13961     13961      14987      15765     14535     28496       142    272
1980     16069      14132     14132      14827      16041     14798     28931       544    800
1981     16070      13806     13806      14811      15938     14679     28485       295    953
1982     15896      13367     13367      14617      16096     14817     28184         0      0
1983     15570      13872     13872      14311      16505     15246     29118         0      0
1984     15614      14332     14332      14355      16892     15633     29965         0      0
1985     15798      14767     14767      14584      17214     16000     30768         0      0
```

Table 3

Area VI minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 1,671.0

NO. OF AGE CLASSES IN MODEL = 30
FEMALE JUVENILE MORTALITY RATE = 0.2193
MALE JUVENILE MORTALITY RATE = 0.2193
FEMALE ADULT MORTALITY RATE = 0.0900
MALE ADULT MORTALITY RATE = 0.0900

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	4767	2891	3540	4767	3186	3540	7080	0	0
1969	5009	3235	3589	5009	3589	3589	7178	0	0
1970	5334	3280	3667	5334	3667	3667	7334	0	0
1971	5633	3352	3739	5633	3739	3739	7477	0	0
1972	5886	3840	3840	5423	4304	3840	7681	0	0
1973	6322	3933	3933	5815	4440	3933	7867	0	0
1974	6694	4058	4058	6139	4613	4058	8116	10	3
1975	7022	4213	4213	6462	4766	4207	8420	0	0
1976	7374	4362	4362	6748	4982	4356	8717	92	67
1977	7686	4497	4497	7052	5104	4469	8966	51	98
1978	8009	4600	4600	7361	5266	4618	9218	321	200
1979	8324	4614	4614	7581	5262	4519	9134	79	56
1980	8521	4845	4845	7760	5498	4737	9582	0	0
1981	8780	5124	5124	7995	5810	5025	10149	252	177
1982	9102	5238	5238	8287	5895	5080	10318	0	0
1983	9396	5532	5532	8552	6231	5388	10920	0	0
1984	9749	5828	5828	8879	6565	5695	11523	0	0
1985	10157	6121	6121	9267	6890	6000	12121	0	0

Table 4

Area VI minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 15,635.0

NO. OF AGE CLASSES IN MODEL = 30
FEMALE JUVENILE MORTALITY RATE = 0.2193
MALE JUVENILE MORTALITY RATE = 0.2193
FEMALE ADULT MORTALITY RATE = 0.0900
MALE ADULT MORTALITY RATE = 0.0900

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	44600	27047	33122	44600	29812	33122	66243	0	0
1969	46864	30271	33581	46864	33581	33581	67162	0	0
1970	49909	30691	34312	49909	34312	34312	68624	0	0
1971	52710	31359	34980	52710	34980	34980	69961	0	0
1972	55073	35932	35932	50737	40268	35932	71865	0	0
1973	59151	36802	36802	54407	41546	36802	73605	0	0
1974	62636	37971	37971	57445	43161	37971	75941	10	3
1975	65698	39444	39444	60465	44670	39437	78881	0	0
1976	69003	40832	40832	63146	46682	40826	81657	92	67
1977	71935	42609	42609	65997	48518	42580	85189	51	98
1978	75182	44279	44279	69115	50363	44296	88574	321	200
1979	78611	45830	45830	71659	52687	45735	91565	79	56
1980	81456	48188	48188	74336	55200	48080	96268	0	0
1981	84779	50548	50548	77432	57796	50449	100997	252	177
1982	88452	52749	52749	80820	60222	52591	105340	0	0
1983	92292	55184	55184	84392	62939	55039	110223	0	0
1984	96408	57654	57654	88164	65765	57522	115176	0	0
1985	100717	60226	60226	92150	68672	60105	120331	0	0

Table 5

Area IV minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 11,253.0

NO. OF AGE CLASSES IN MODEL = 30
FEMALE JUVENILE MORTALITY RATE = 0.4870
MALE JUVENILE MORTALITY RATE = 0.4870
FEMALE ADULT MORTALITY RATE = 0.0687
MALE ADULT MORTALITY RATE = 0.0687

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	21494	17040	19822	21494	18340	19827	39649	267	330
1969	22246	18197	19684	22246	19747	19747	39431	16	25
1970	23233	18353	19945	23233	20012	20012	39958	0	0
1971	24055	18620	20213	24055	20275	20275	40488	0	0
1972	24706	20575	20575	22883	22456	20634	41209	919	1726
1973	26108	19298	19298	24156	22059	20107	39405	2410	2146
1974	26457	17835	17835	24366	20435	18343	36179	1761	2808
1975	26033	15981	15981	23932	19534	17433	33414	907	1323
1976	25140	15646	15646	22895	19634	17390	33036	429	452
1977	24406	16280	16280	22142	20193	17929	34210	917	683
1978	24178	16674	16674	21881	20292	17995	34669	251	712
1979	24044	17045	17045	21507	21247	18709	35755	512	858
1980	23747	17481	17481	21367	21737	19357	36838	1177	684
1981	23720	17903	17903	21520	21394	19194	37097	881	1505
1982	23953	17362	17362	21982	21121	19150	36512	0	0
1983	24057	18049	18049	22128	21648	19718	37767	0	0
1984	24527	18651	18651	22519	22217	20210	38861	0	0
1985	25103	19286	19286	23047	22798	20741	40028	0	0

Table 6

Area IV minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 12,449.0

NO. OF AGE CLASSES IN MODEL = 30
FEMALE JUVENILE MORTALITY RATE = 0.4870
MALE JUVENILE MORTALITY RATE = 0.4870
FEMALE ADULT MORTALITY RATE = 0.0687
MALE ADULT MORTALITY RATE = 0.0687

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	23782	18855	21933	23782	20293	21938	43870	267	330
1969	24614	20168	21812	24614	21875	21875	43688	16	25
1970	25721	20340	22102	25721	22169	22169	44270	0	0
1971	26640	20633	22395	26640	22458	22458	44853	0	0
1972	27364	22794	22794	25348	24869	22853	45647	919	1726
1973	28919	21551	21551	26759	24519	22359	43910	2410	2146
1974	29381	20132	20132	27067	22954	20640	40773	1761	2808
1975	29047	18334	18334	26722	22111	19786	38119	907	1323
1976	28251	18052	18052	25763	22282	19795	37847	429	452
1977	27601	18752	18752	25093	22910	20402	39154	917	683
1978	27466	19211	19211	24922	23077	20532	39743	251	712
1979	27432	19646	19646	24621	24120	21309	40955	512	858
1980	27216	20164	20164	24558	24698	22040	42204	1177	684
1981	27282	20667	20667	24799	24441	21958	42625	881	1505
1982	27615	20207	20207	25354	24256	21995	42202	0	0
1983	27823	20975	20975	25597	24871	22645	43620	0	0
1984	28400	21660	21660	26088	25531	23219	44879	0	0
1985	29087	22380	22380	26718	26205	23835	46216	0	0

Appendix 15

ANTARCTIC AREA II MINKE WHALE ASSESSMENT

The BALEEN estimation program was run on the sightings and sighting effort series given in Appendix 12.

Minimising jointly on m and N_0 gave a point estimate of $N_0 = 6.423$, $m = 0.107$, where N_0 is the initial mature female stock size and m is the adult mortality rate. Minimising with m set to 0.06 failed to produce convergence.

The assessment for the joint estimation can be ignored, since it produces a juvenile mortality rate close to zero. Only the m = 0.09 run remains from those attempted. Unfortunately, the fit was very poor ($N_0 \pm 2$ S.E.:20,406 ± 17,270). No confidence limits were therefore calculated for the 1981 stock.

A plot of observed and expected catches for m = 0.09 is given in Fig. 1 together with a listing of the end of the time series.

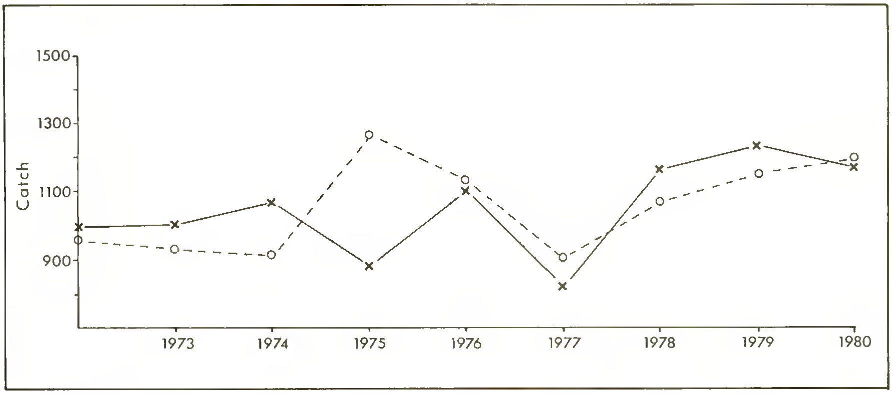

Fig. 1. Observed (○) and expected (×) catches, Area II.

Table 1

Area II minke run—Brazilian sightings series. Time series of simulated baleen whale population components with initial mature female population of 20,406.5

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.2193
MALE   JUVENILE MORTALITY RATE =  0.2193
FEMALE ADULT MORTALITY RATE =  0.0900
MALE   ADULT MORTALITY RATE =  0.0900

YEAR    -----FEMALE POPULATION------    ------MALE POPULATION-------    TOTAL      ---CATCH---
        IMM-UNEX   MATURE      EXPL.    IMM-UNEX    MATURE      EXPL.   EXPL. POP      M      F

1968     58075     34814      42717      58075      38597      42917     85634      152    304
1969     60846     38763      43083      60846      43404      43404     86486      217    404
1970     64560     39005      43732      64560      44196      44196     87928      301    400
1971     67868     39602      44329      67868      44844      44844     89173      330    570
1972     70541     45165      45165      64886      51509      45854     91019      233    469
1973     75341     46017      46017      69161      53043      46863     92880      210    440
1974     79326     47302      47302      72600      55012      48286     95588      279    662
1975     82769     48773      48773      76033      56758      50022     98796      460   1385
1976     86445     49466      49466      78945      58952      51452    100918      652   1287
1977     89284     50886      50886      81738      60829      53282    104168      565   1300
1978     92358     52215      52215      84696      62739      55077    107292      335    717
1979     95540     54068      54068      86801      65771      57033    111101      328    808
1980     98143     56662      56662      89240      68714      59811    116473      272    767
1981    101347     59221      59221      92195      71703      62551    121772      430    644
1982    104954     61900      61900      95518      74575      65138    127038        0      0
1983    108921     65196      65196      99351      77727      68156    133353        0      0
1984    113616     68332      68332     103771      80882      71037    139368        0      0
1985    118744     71448      71448     108642      84023      73920    145369        0      0
```

Appendix 16

REPORT OF SIGHTINGS SUBGROUP

Members: Kirkwood (Chairman); Buckland, Butterworth, Hammond, Harwood, Hiby, Leatherwood, Kasamatsu, Misaki, Mizroch, Yamamura.

Three IWC/IDCR Minke whale sightings cruises have been completed since 1978/79. The 1978/79 cruise was carried out in Area IV, and the cruise report and initial analysis of the data are described in *Rep. int. Whal. Commn* 30: 257–84. These data were subsequently reanalysed in *Rep. int. Whal. Commn* 30: 101–2. The 1979/80 cruise carried out in Area III and analysis of the data are described in *Rep. int. Whal. Commn* 31: 287–314. A reanalysis of the data is given in SC/Jn81/MiS16. In 1980/81, the sightings cruise was carried out in Area V, as reported in SC/Jn81/MiS19. Analyses of the sightings data from this cruise and the several additional experiments undertaken are found in SC/Jn81/MiS25 13, 14, 15, 17 and 29. Estimates of population sizes based on Japanese sightings records in Area VI were described in *Rep. int. Whal. Commn* 31: 323–6, with these data being reanalysed in *Rep. int. Whal. Commn* 31: 116. Estimates for Area I based on Japanese sightings records are given in SC/Jn81/MiS28.

A commonly used method for estimation of population sizes using data from whale sightings cruises, as described in *Rep. int. Whal. Commn* 30: 257–84, employs the equation

$$P = tsN,$$

where t is the proportion of sighted animals that are exploitable, s is the mean school size, and N is the adjusted estimate of number of schools. The number of schools is estimated as

$$N = emh\,N',$$

where N′ is the estimated number of schools calculated from density estimates using untruncated negative exponential model for the density of perpendicular sighting distances employing the contouring method described in *Rep. int. Whal. Commn* 30: 275. The factors e, m and h are conversion factors accounting respectively for a change in model from untruncated to truncated negative exponential, random movement of whales, and the probability of sighting a whale on the trackline possibly not being 1.0. In assessments to date h has been taken as 1.0, reflecting the (untested) assumption that all whales on the trackline are seen.

Table 1 outlines the values of each of the terms in the above equation used in previous assessments and contained in papers to this meeting.

The subgroup agreed that in principle the method was appropriate for use in estimation of population sizes during the meeting. However it noted that there were uncertainties in both the data and the method, a number of which had already been identified in *Rep. int. Whal. Commn* 30: 276–8 and in SC/33/Rep 2. The uncertainties identified were:

(i) Perpendicular sightings distances were estimated using the angle of sighting and either the estimated radial distance or calculated radial distance obtained from knowledge of the speed of the vessel and the time to close. Recorded measurements of both angle of sighting and time to close included rounding errors, which could have a significant effect near zero angle or times. This problem was discussed in SC/Jn81/MiS18. The relative merits of use of estimated or calculated distances are also unclear.

(ii) Although to date the perpendicular distance distribution has been modelled by a truncated or untruncated negative exponential, the fit of these distributions to the data remains somewhat unsatisfactory. Extensive discussions reported in SC/33/Rep 2 indicate a number of alternative models that warrant consideration. Another potentially useful model is described in SC/Jn81/MiS18.

(iii) An experiment specifically designed to estimate the probability of sighting an animal on the trackline, previously assumed to be 1.0, was carried out during the 1980/81 sightings cruise. The results of this experiment are described in SC/Jn81/MiS13. This probably was also independently estimated using Doi's sighting model (SC/Jn81/MiS29), and there are further data pertaining to this problem in SC/33/O 11.

(iv) Although random whale movement with respect to the vessel can affect estimates of density (see (v) below), a serious bias can be caused if there is systematic movement of whales either towards or away from the vessel, i.e. ship seeking or avoidance. An experiment designed in part to determine whether this occurred was carried out on the 1980/81 cruise (SC/Jn81/MiS17), and additional data on direction of movement at first sightings were also recorded (SC/Jn81/MiS19). SC/Jn81/MiS19 provides similar data.

Table 1

Past estimates of factors in equation for the population estimate

$P = t.e.m.h.s.N'$

Area	Reported in	Model*	P	s	e	h	m	t	Remarks
III	IWC[1] 31: 287–314	TNE	(33,150)	3.26	(1)	1	1	0.66	(e incorporated in P) Stratified
	SC/Jn81/MiS6	NE	25,216	3.02	2.17	1	0.96	0.66	Contoured (revised)
IV	IWC[1] 30: 257–84	NE/TNE	25,240	2.41	1.64	1	0.96	0.82	Contoured
	: 101–2	TNE	37,400	3.93	1	1	1	0.48–0.58	Stratified
V	SC/Jn81/MiS13	—	—	—	—	1.25	—	—	Varying velocity expt.
	14	—	41,587	—	—	—	—	—	Kriging estimate
	15	TNE	44,527	2.29	1.56	1	0.96	0.57	Contoured
	29	—	—	—	—	1.25	—	—	Doi model (revised)

* TNE = Truncated Negative Exponential, NE = Negative Exponential. [1] IWC = *Rep. int. Whal. Commn*

(v) The effect on line transect density estimates of random whale movement had previously been thought to be minor (*Rep. int. Whal. Commn* 30: 278, 281). However SC/Jn81/MiS7 presents an alternative analysis of this phenomenon that suggests that the biasing effect may be larger than previously thought.

(vi) It is clear that the density of whales over the entire area surveyed is not uniform. Two methods have been used to allow for this heterogeneity; one based on contouring (*Rep. int. Whal. Commn* 30: 275) and the other on stratification (*Rep. int. Whal. Commn* 30: 100–1). An experiment to determine the density gradient near the ice edge was carried out in 1980/81 (SC/Jn81/MiS19). Possible stratification schemes are discussed in SC/Jn81/MiS2. An additional problem area is in the method of estimation of mean school size and the possible need for stratification.

In view of these identified problem areas, and the availability of new data throwing light on them, the subgroup decided to attempt a reanalysis of the sightings data obtained on each of the three IDCR cruises.

CALCULATION OF PERPENDICULAR SIGHTINGS DISTANCES

Several aspects of the sighting distance, r, and sighting angle θ were re-examined for all three surveys. There were two methods of obtaining r, the radial sighting distance. One was the distance estimated by the observer at the time of first sighting, r_{est}, and the other was the product of the speed of the boat, v, and the time to close with the whale, t. Comparisons of the estimated distance r_{est}, and the calculated distance $t_{cal} = vt$ were made for the 1979/80 data. The appropriate data were not available at the meeting for the other years' surveys, but similar comparisons should be made for each year. Comparisons indicate similarities between r_{est} and t_{cal} within the first two miles, and differences beyond. The calculated distance tends to be larger than the estimated distance at distances exceeding 2 miles (Fig. 1a and 1b).

The estimated distance data resulted from estimates made by observers with extensive whaling experience, and are likely to be more accurate than the calculated ones at close distances. Members with field experience thought that for distances of less than 0.5 nm, the error would be of the order of 0.1 nm or less. At distances greater than 0.5 nm, the error might increase. Most distances greater than 1.0 nm were recorded to the nearest 0.5 nm.

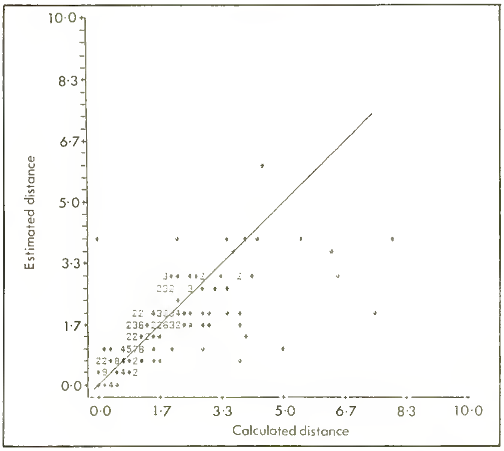

Fig. 1a. Comparison of calculated versus estimated radial distances recorded on the *Kyo Maru No. 27*, 1979/80.

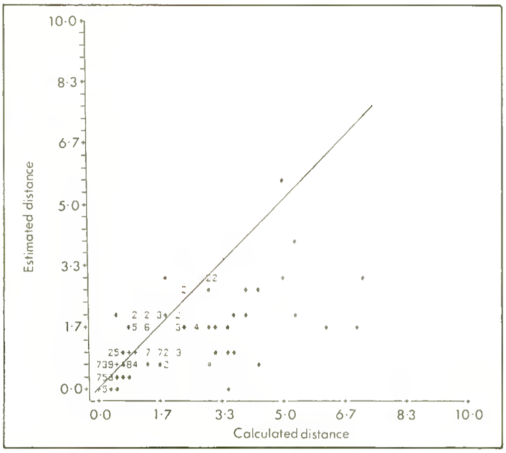

Fig. 1b. Comparison of calculated versus estimated radial distances recorded on the *Toshi Maru No. 11*, 1979/80.

Distances based on the product vt have several sources of uncertainty, including accuracy of vessel speed, the time taken to change direction to approach the whale, and the span of time and distance where the vessel is slowed to half speed at some point near the whale. Also, vt is the distance at which the whale is found after approaching, which may be different from the position at which the whale was first sighted. The time to approach, t, was recorded to the nearest minute in the first two surveys, which means that all $t \leqslant \frac{1}{2}$ minute were recorded as zero, resulting in $vt = 0$. At $v = 15$ nm/hr (0.25 nm/minute) these zero entries could represent distances up to 0.12 nm, and $t = 1$ minute could represent distances from 0.12 to 0.37 nm, these differences being due only to rounding.

These uncertainties in time measurement will have a decreasing relative contribution to errors in vt as distance increases, but uncertainties in boat speed and amount of whale movement will have an increasing relative contribution with distance.

The group could not determine which of r_{cal} or r_{est} were to be preferred, and therefore separate estimates for the 1979/80 data sets were computed for each type of distance estimate.

Data such as r_{est}, r_{cal}, and the angle of observation θ, were recognized as being grouped data, in that certain distance bands or angular groups tended to be assigned one central value. In 1980/81 the estimated distances r_{est}, are grouped to the nearest 0.1 nm within 1 nm, and to the nearest 0.5 nm beyond 1 nm. Times to close with the whale were recorded to the nearest minute in 1978/79 and 1979/80, and to the nearest second in 1980/81. Inspection of the data reveals a tendency to record θ to the nearest 10°, with a few values at intermediate points. The data are dominated by a large number of angles recorded as 0° which could represent some angle greater than 0°, and, in the first two years, by a large number of times recorded as zero that are some number between 0 and ½ minute.

Frequency distributions of perpendicular sightings distance using both estimated and calculated radial distances are shown in Fig. 2 for the 1979/80 pooled data. Lack of a major difference between the two histograms suggests that the use of either estimated or calculated sighting distances will not make an appreciable difference.

It was recognised that, due to the grouping in recording the angle of sighting, and the estimated radial distance or speed and time to close, in general the data allow assignment of an observation of perpendicular sighting distance only to an interval. If the radial distance is believed to be accurate to $\pm\rho$, and the sighting angle to $\pm\delta$, the minimum and maximum values that may bound each calculated right angle distance are

$$Y_{min} = (r - 0) \sin (\theta - \delta) \text{ or zero if appropriate,}$$

and $Y_{max} = (r + \rho) \sin (\theta + \delta)$.

The potential error ρ is either that associated with estimated sighting distance, or the combined error resulting from errors in recording of vessel speed and time to close.

The groups agreed with conclusions reached in SC/33/Rep 2 and SC/Jn81/MiS18 that at least a partial explanation of the high peak at zero perpendicular distance was the fact that any perpendicular distance with either angle less than 5° or time to close less than ½ minute is calculated to be zero. In SC/Jn81/MiS18, a technique described as 'smearing' was used in an attempt to rectify this artefact of rounding. This technique involved random selection of angles and times under the assumption that they were uniformly distributed over the range recorded value ± rounding error.

The group preferred an alternative approach in which, instead of assuming uniform errors in angle and time, it was assumed that the perpendicular sighting distance was distributed uniformly between Y_{min} and Y_{max}. In order to display these values in a frequency distribution, a value from each interval (Y_{min}, Y_{max}) was assigned randomly according to a uniform distribution. It was noted that, as the interval width of the histogram increased, more intervals fell wholly within a histogram interval, and so the importance of the uniform distribution assumption decreases. In particular, as the average estimated radial distance of sightings on the trackline is of the order of 1 nm, a histogram interval of width sin (δ) would allow most of the zero angle observations to be assigned to a histogram interval, independent of the uniform distribution assumption.

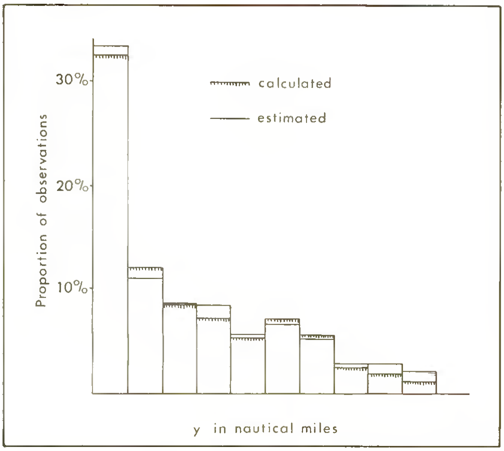

Fig. 2. Comparison of the frequency distribution of right-angle distances calculated with estimated radial distances and with calculated radial distances for 1979/80.

In SC/Jn81/MiS18, the level of accuracy of recorded angles, speeds and times was taken, as discussed in SC/33/Rep 2, to be equivalent to the rounding error of recording. Initially the group adopted these assumptions and generated the 'smeared' histograms of perpendicular sighting distances shown in Fig. 3. Also shown in Fig. 3 for comparison are the raw observed data. While this 'smearing' has lowered the peak at zero from that in the raw data, the group felt considerable unease about the steep fall-off from zero perpendicular sighting distance.

Table 2

Distribution of sightings around the trackline—1979/80 cruise

Distance along trackline	Distance from trackline		
	0–0.1 nm	0.1–0.2 nm	0.2–0.3 nm
1.0–1.5 nm	12.3	5.8	4.2
0.5–1.0 nm	23.9	7.5	6.7
0–0.5 nm	61.4	25.0	18.3

Discussions revolving around the observations of members with field experience, the group felt that at least for some interval of perpendicular sighting distance from zero, the probability of sighting a whale should remain relatively constant. Such a feature was not present even in the 'smeared' data, unless this effect only occurs over a distance of less than 0.1 nm from the trackline. The group was disturbed further with the large decrease in numbers sighted within 0.1 to 0.2 nm of the trackline to those within 0.1 nm of the trackline.

Hiby presented the results of calculation of the position of each sighting along the trackline for those observations made in the 1979/80 cruises which were close to the trackline. The results (Table 1) indicated that at 1–1.5 nm from the ship less than half as many whales were seen 0.1–0.2 nm from the trackline as were seen within 0.1 nm of it. As 0.1 nm corresponds to only a 6–7° divergence from the trackline at this radial distance and since the field of view of the binoculars used was 7°, the group felt that this was most unlikely.

Re-examining the assumptions that had been made, Yamamura and Kasamatsu reported that in their opinion the level of accuracy of sighting angle (as opposed to rounding error of recording) may well be ±10 degrees (δ = 10). The yaw of the bow alone is up to 5° either side, to which must be added the inherent inaccuracy of estimation of the angle by the observers. Following further calculations, Hiby reported that with this assumption, the effect shown in Table 1 virtually disappears (see Table 2). The resulting 'smeared' histograms of perpendicular sighting distance are shown in Fig. 4.

To investigate the sensitivity of the distribution of right angle distances to changes in the assumption of level of accuracy in the radial sighting distance calculated from speed by time to close, Hiby assumed the error in time to close was ±1 min. The results of using this assumption to generate 'smeared' histograms, along with δ = 10, are shown in Table 2 and Fig. 5. Inspection of Figs 4 and 5 indicates that changing the assumed error in time to close

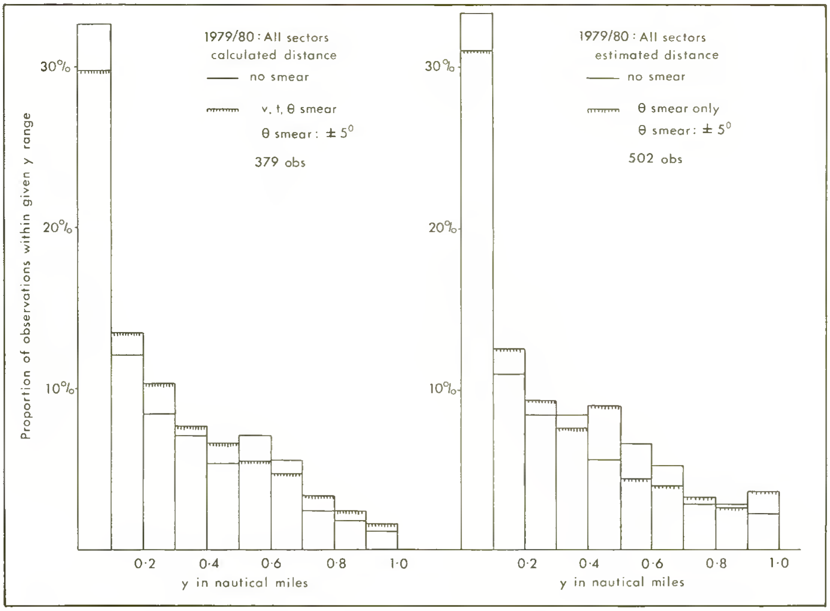

Fig. 3. Histograms of raw and smeared perpendicular distance data, for both calculated and estimated distances (θ accurate to ±5°).

from ±½ min to ±1 min results in a changed shape of the histograms near zero perpendicular sighting distance.

PROBABILITY OF SIGHTING WHALES ON THE TRACKLINE

In the absence of specific data to suggest otherwise, a conservative approach of assuming that the probability of sighting a whale on the trackline had been adopted in past analyses of minke whale sightings data. An experiment designed to estimate this probability was carried out on the 1980/81 cruise, based on varying the speed of the sighting vessel. The analysis of the results of this experiment is described in SC/Jn81/MiS13, and the probability was estimated to be 0.80 with one standard deviation, limits 0.5 to 1.0. The estimate was not significantly different from 1.0, however the recondite statistical properties of the estimator precluded reliable estimation of a lower confidence limit for the estimate. The group noted the further opinion expressed in SC/Jn81/MiS13 that it was unlikely that more than 50% of whales on the trackline were missed. Also it was agreed that the effect of random whale movement outlined in SC/Jn81/MiS7 may indicate a small upward bias in the estimated probability.

Independently, simulation studies employing the Doi sighting model reported in SC/Jn81/MiS29 resulted in an estimated probability of sighting a whale on the line of 0.782. Kasamatsu reported that this analysis had excluded the presence of additional spotters to those in the flying bridge, and that a revised estimate taking this into account was 0.80. In discussion of the methods used, two possible sources of bias were identified. On the one hand, the sighting conditions assumed in the simulations were ideal, and certainly better than the average conditions experienced in the field, even for primary sightings. This would suggest that the estimate was biased upwards. On the other hand, the model assumes equal concentration of sightings effort on angles 0–90°. The observed higher concentrations of effort on small angles would result in the estimate being biased downwards. The group was unable to determine the relative sizes of these possible biases.

Discussion of the above and on data on minke whale dive and blow times (e.g. SC/Jn81/MiS8, SC/33/O 11) suggested that on the available evidence it is unlikely that all the whales on the trackline are seen at the speed at which surveys were conducted.

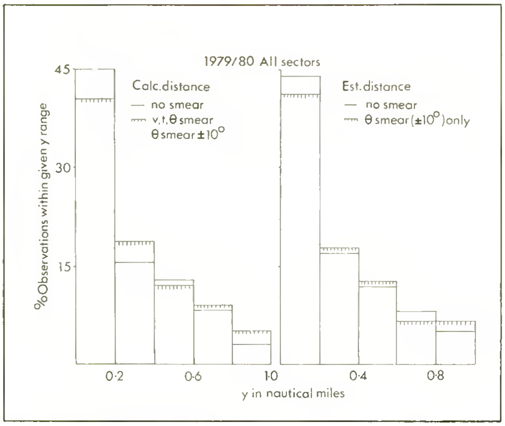

Fig. 4. Histograms of raw and smeared perpendicular distance data, for both calculated and estimated distances (θ accurate to ± 10°).

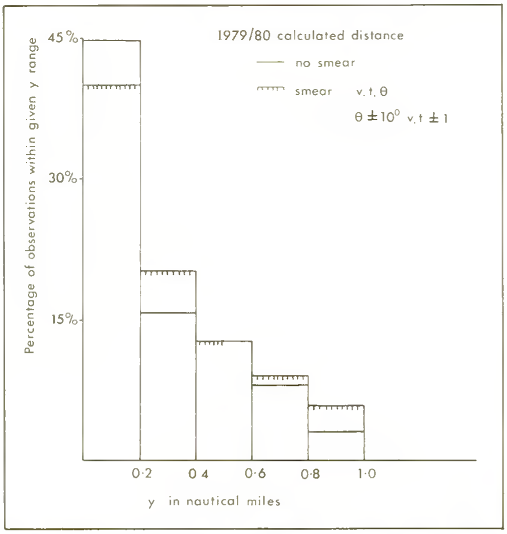

Fig. 5. Histograms as for Fig. 4 except that assumed error in time to close is ± 1 minute not ± ½ minute.

SELECTION OF MODELS

Estimates of density of schools of whales can be obtained from the distribution of right angle distances (Figs 4, 5), in conjunction with the number of track miles searched, using line transect methods.

In all previous assessments of these data sets the negative exponential model for the distribution of right angle distances has been used in either truncated or untruncated form. Several deficiencies in this model have been noted elsewhere, and were discussed briefly. The group agreed that other models of the sighting process should be considered.

In discussing the likely functional forms for a model of the distribution of right angle distances, the group reiterated its earlier concension that it was to be expected that near zero perpendicular distance the probability of sighting a whale should not decrease markedly. However the scale of this 'shoulder' phenomenon could not be determined on physical grounds alone. It noted the conclusions of SC/Jn81/MiS7 and 12 that increased concentration of sighting effort on small sighting angles will reduce the width of the shoulder. The frequency distribution of angles crossed by binoculars of observers (SC/Jn81/MiS29) shows a marked tendency for forward angles to be searched, with approximately 60% of the searching at angles less than 30° to either side of the trackline.

Table 3

Distribution of right-angle distances from trackline—effects of degree of 'smearing'

	Distance from trackline (nm)				
	0–0.1	0.1–0.2	0.2–0.3	0.3–0.4	0.4–0.5
±½ knot, ±½ minute, ±5°	104	50	38	28	24
±½ knot, ±½ minute, ±10°	96	54	39	30	24
±1 knot, ±1 minute, ±10°	81	61	40	32	26

In view of the uncertainty in the estimated perpendicular distance, and the lack of an observed shoulder in the frequency distributions (Figs 4, 5) when adjusted for this uncertainty, the group agreed that any shoulder does not extend beyond 0.2 nm. The group agreed that it was not reasonable to attempt to fit a model which requires a shoulder whose width (and even existence) was not defined by the data.

On these grounds, the Fourier series approach of Burnham *et al.* (*Wildlife Monographs* 72, 1980) could not be adopted, as the 'shape criterion' was violated.

The group agreed that the following models/methods of estimation should be considered, in addition to the previously used truncated and untruncated negative exponential: Kelker strip, Cox-Eberhardt, and generalised negative exponential (SC/Jn81/MiS18). The appropriate strip width for the Kelker strip method was thought to be the width of the first bin in the perpendicular sighting distance histograms (Figs 4, 5).

Ship-seeking or ship-avoidance

On the question of whether southern minke whales show a response to survey vessels, the results from three analyses were studied. Firstly, SC/Jn81/MiS17 reported on the results of the parallel ship experiment to investigate ship-seeking or ship-avoidance behaviour, conducted during the 1980/81 IDCR/IWC minke whale cruises. They concluded that the data were insufficient to draw firm (i.e. statistically significant) conclusions whether either behaviour existed, but nonetheless the available data gave no positive indication of ship-seeking. Secondly, experiments conducted to investigate the response of minke whales to survey vessels, described in SC/Jn81/MiS9, showed that whales encountered whilst the vessel was moving did not exhibit either ship seeking or avoidance. Whilst the vessel was stationary, however, it was frequently approached by minke whales.

Thirdly, an analysis of the recorded heading of sighted whales relative to the survey vessel using data collected on the 1979/80 IDCR/IWC minke whale cruises has been done, (Table 4). The significant result for the vessel K27 is due to apparent ship-avoidance behaviour in the northern leg.

In conclusion, it seems clear that there is no evidence of ship-seeking behaviour, but that there may be some evidence of ship-avoidance behaviour by southern minke whales.

Effect of random movement

The group discussed the analysis and the model presented in SC/Jn81/MiS7 at length. Hiby reported that the combination of the hazard rate function he had used, and the observed angular concentrations of effort given in SC/Jn81/MiS29 could not reproduce a density g(y) of perpendicular sightings distances with a similar peak to that in the observed data. Consequently, the degrees of bias in neglecting random whale movement described in SC/Jn81/MiS7 may not be applicable, and if the observed high peak in g(y) is a real phenomenon, the true bias will be smaller than that in SC/Jn81/MiS7. The group decided that further investigation of this phenomenon was needed. For the purposes of estimating population sizes during this meeting, it was agreed that the previous estimated bias of

Table 4

Summarised results of an analysis of the direction of minke whale travel relative to the survey vessel. Data are from initial sightings made on the 1979/80 IWC/IDCR minke whale cruises

Vessel	T11		K27	
Leg	Southern	Northern	Southern	Northern
Number of sightings				
Towards vessel	68	30	46	6
Away from vessel	70	35	44	29
Test of the null hypothesis that neither ship-seeking nor ship-avoidance occurs	$\chi^2 = 0.07[<\chi^2_{p=0.05} = 3.84]$		$\chi^2 = 10.6[>\chi^2_{p=0.05} = 3.84]$	

4% (*Rep. int. Whal. Commn* 30: 281) should be used to calculate population sizes. Lacking the further analyses, the group was unable to determine whether the true bias was less or greater than 4%.

Stratification

Smith outlined to the group the two basic methods used to convert local estimates of density of schools to an overall estimate of the number of schools in a large area. These approaches were the contouring method of *Rep. int. Whal. Commn* 30: 275, and a method involving dividing the area into a small number of strata, normally two by latitude and two by school size (*Rep. int. Whal. Commn* 30: 100–1). The group discussed the relationship between estimates obtained using both methods. For Area IV, the two estimates of number of schools were 25,240 by contouring (*Rep. int. Whal. Commn* 30: 257–84) and 37,400 by stratification (*Rep. int. Whal. Comm.* 30:100–1). For Area III, the two estimates for the western segment of Area III (contouring 14,470, SC/Jn81/MiS17; stratification 17,300, *Rep. int. Whal. Commn* 31: 287–314) were similar, but the two estimates for the eastern segment differed (contouring, 10,750; stratification, 15,850). This difference was in the opposite direction to that possibly expected, in view of the apparently conservative stratification of Horwood (*Rep. int. Whal. Commn* 31: 287–314).

Discussing first the differences between the stratified and contouring estimates for Area III, the group noted that the stratified estimate in the eastern sector includes a correction for truncating the negative exponential form for g(y), the perpendicular sighting distance distribution, whereas the contouring estimate quoted does not include such a correction. Taking this into account yields a revised comparison: contouring 10,750; stratification 12,610. This is a now similar difference to that observed in the western sector. The direction of the difference found is still surprising, given the strata chosen by Horwood. The rest of the difference appears to result from the fact that Horwood stratified on school size. For small school sizes, he found the mean perpendicular sighting distance $\bar{y}$ of 0.33 nm compared to $\bar{y}$ of 0.51 nm for all schools used in the contouring. Thus the smaller school sizes, which dominate in numbers, are accorded a 50% greater density in Horwood's estimate, accounting for the overall difference in estimates of numbers of schools.

For Area IV, the contouring and stratification estimates are more widely disparate. Again the stratification on school size as well as on a latitudinal basis renders the comparison difficult, however the larger value for the stratified estimate is probably accounted for by two factors:

(i) the smaller value for $\bar{y}$ for small school sizes than that used for the contour estimates. This leads particularly to a large estimate of the number of small schools in the northern stratum

(ii) a less conservative (c.f. Horwood) demarcation of the boundary between the high (south) and low (north) density strata; 23% of the area was included in the high density stratum in Area IV, compared to 14% in Area III discussed above.

Table 5

Estimates of mean density of schools by distance from ice edge extracted from daily density and contouring data in SC/Jn81/MiS15 and 16. Distances from ice edge were split into three categories: near ice edge (inner), medium distance from ice edge (middle) and large distance from ice edge (outer).

	Area III West	Area III East	Area V West	Area V East
Inner	0.14	0.06	0.15[1]	0.08
Middle	0.05	0.04	0.08[2]	0.04
Outer	0.02	0.02	0.01[3]	0.01

[1] Ross Sea, exhibiting much higher density than remaining areas near ice edge.

[2] Other near ice edge data.

[3] Remaining areas.

In discussing the relative merits of the two methods, the group reiterated a conclusion it had reached in earlier discussions that it preferred the contouring method. The stratification method requires that schools are distributed randomly in space throughout each stratum. However, the contours clearly indicated high variability in local density of schools, and there was also evidence of a density gradient away from the ice edge (see Table 5 extracted from the daily density data). On these grounds, and the inability to satisfactorily select appropriate stratum boundaries independently from the data, the group agreed that stratification by latitude was inappropriate.

Insufficient time was available to discuss stratification by school size.

The group agreed to proceed with the method described in *Rep. int. Whal. Commn* 30: 257–84. This involves regressing school size against perpendicular sighting distance from the trackline for all schools spotted within one mile of the trackline, and estimating 'trackline school size' by the zero intercept, provided the regression had a positive slope. In a change to the previously reported technique, the group agreed that if the slope was zero or negative, the mean school size within one mile was to be adopted as an estimate.

The group noted that the experiment carried out on the 1980/81 cruise to estimate the proportion of whales on the trackline not sighted, had involved transects perpendicular to the ice edge some 30 nm in length. These data could yield information on the density gradient near the ice edge. However, insufficient time was available to carry out analysis of these data.

CALCULATION OF POPULATION ESTIMATES

(a) Methodology

Estimates of the number of takeable minke whales in the eastern and western sectors of Areas III, IV and V were calculated using the equation on the first page of this report,

$$P = t.e.h.s.N'$$

N' = estimated number of schools in an Area Sector calculated using the contouring method and assuming an untruncated negative exponential distribution for the perpendicular sightings distances,
t = percentage of takeable animals in the sighted population,
s = mean school size calculated using the method described in *Rep. int. Whal. Commn* 30: 279–81 (modified as above where necessary).
m = correction factor accounting for random movement of whales,
h = $1/g(O)$, the reciprocal of the probability of sighting an animal on the trackline,
e = correction factor accounting for a change in model from the untruncated negative exponential model for the perpendicular sighting distance distribution.

It is also highly desirable that estimates of the likely accuracy of the population estimates obtained as described above should be obtained. In the above formula for P,s and the product eN′ are values of observed random variables. Looking first at e.N′, estimates of the coefficients of variation of a line transect population estimates are available (e.g. Burnham *et al.*, *Wildlife Monographs* 72, 1980) for each method of estimation/model described earlier, on the assumption that the whales are randomly distributed. It is likely, however, that this assumption is violated, and in these circumstances Burnham *et al.* suggest that, as a compromise to allow for this, the coefficient of variation should be doubled.

Further, the coefficients of variation (CV) of the estimates of school sizes are readily calculated. Thus, if the estimated CV of s is C_1, and that of e.N′ is C_2, the CV of their product is given approximately by

$$C^2 = C^2_1 + C^2_2.$$

Although the remaining multiplicative conversion factors t, m and h are not known precisely, no means of estimating their likely variance is available. As a first approximation, if they are taken as constants, then the CV of the final estimated population size for each Area sector is given by C. It was recognised that this will lead to an underestimate of the true coefficient of variation.

(b) Results

From *Rep. int. Whal. Commn* 30: 267–84, SC/Jn81/MiS15 and 16 we have the estimates of the number of schools by Area sector (N′), mean school size (s) and percentage takeable (t) from the 1978/79, 1979/80 and 1980/81 IWC/IDCR minke whale sightings cruises shown in Table 6 below.

Table 6

Estimates of N′, s and t

	N′	s	t
Area III	14,466 (W) 10,750 (E)	3.02[1]	0.66
Area IV	13,969 (W) 11,271 (E)	2.41	0.82
Area V	7,105 (W)	2.90[2]	0.57

[1] Adjusted to account for inclusion of 'outliers' in regression of mean school size against perpendicular distance.

[2] Adjusted from reported procedure according to revised procedure for estimation of school size described above.

Estimates of the correction factor and for each model and for each year are shown in Table 7, using the 'smeared' data illustrated in Fig. 3. The level of smearing used for θ was ±10°, 1½ knots for V and ±½ minute for t when using calculated radial distances; and ±10 for θ alone when using estimated radial distances.

In SC/Jn81/MiS18, the generalised exponential model $[\exp(-\lambda y^p)]$ was fitted to the 'smeared' data shown in Fig. 4, and the best fit was obtained with parameter $p = 0.6$. Shortness of time precluded the group from attempting to fit this model with alternative values of p to the data shown in Fig. 4 (θ 'smeared' to ±10°). Instead, the values shown in Table 6 above record the estimates of e based on using the generalised exponential with $p = 0.6$. With the change in the data to which the model is applied, this particular form of the generalised exponential may no longer yield the best fit. One basis for preferring the generalised exponential with $p < 1$ (though not necessarily $p = 0.6$) to the negative exponential is that it provides a better fit to the peak in perpendicular sightings distances near zero. However, Table 3 indicates that the height of this peak is dependent on the degree of 'smearing' applied to the data, and consequently so is the estimate of e.

The Kelker Strip method produces results that are biased downwards if the true frequency distribution of perpendicular sightings distances does not have a shoulder on the same scale as the strip width. In addition, with a strip width of 0.2 nm, the estimates were relatively insensitive to the degree of 'smearing'. The group agreed that estimates made using this method are likely to be biased downwards. This conclusion is supported by the fact that the number of schools seen by both vessels to those seen by only one vessel in the parallel ship experiment (SC/Jn81/MiS17) on the 1980/81 cruise is lower than that implied by the Kelker strip estimate (though such a conclusion assumes no ship avoidance behaviour).

Similarly, the group agreed that the estimates obtained using the untruncated negative exponential distribution on the 'smeared' data in Fig. 4 would be biased downwards, because the number of sightings at large perpendicular distances is greater than that predicted by the model. One technique that has previously been adopted in an attempt to overcome this bias is that of truncation. Unfortunately, again time was not available to allow examination of this effect of truncation on either the negative or generalised exponential models for these data. Butterworth reported

Table 7

Multiplicative conversion factors, e, allowing for the use of the listed models on 'smeared' data instead of use of the untruncated negative exponential model on 'unsmeared' data, for both estimated or calculated sighting distances

Area	Year	Radial distance	Kelker Strip (width = 0.2 nm)	Cox-Eberhardt	Untruncated neg. exp.	Gen. exp.
III	1979/80	Calc.	1.05	1.17	0.94	1.92
		Est.	1.00	1.13	0.95	1.90
IV	1978/79	Calc.	0.95	1.09	0.95	1.90
V	1980/81	Est. (K27)	1.10	1.09	0.98	1.88
		Est. (T11)	1.01	0.86	1.00	1.87

that a very rough estimate of the effect of truncating the negative exponential in this case would be an increase of some 20% in e, however specific calculations would be necessary for an accurate estimate.

The Cox-Eberhardt method is known to produce similar estimates to those based on a negative exponential, but it is not affected by sightings at large distances, and therefore avoids some of the biases associated with the lack of fit of the negative exponential in this area.

The group agreed that producing best estimates of some of the factors in the calculation of population estimates is problematic, and agreed to defer their selection for consideration by the main Committee, in view of the uncertainties noted above. Following choice of agreed values for each of the factors, population estimates are easily calculated, as is illustrated by the following example.

Using the data in Table 5, the Kelker Strip estimate for Area IV West in Table 7, and correction factors m = 0.96 and h = 1.25,

$$\hat{P} = 0.82 \times 0.95 \times 0.96 \times 1.25 \times 2.41 \times 13{,}969 = 31{,}470.$$

Butterworth reported that for each of the models in Table 7 the estimate of the coefficient of variation is of the order of 10% if whales are assumed to be randomly distributed. Following the approach outlined above, this suggests that the coefficient of variation should be estimated as approximately 20% due to likely failure of the random distribution assumption. This estimate is similar to the estimate obtained in SC/Jn81/MiS14 from Kriging of 16% for Area V excluding the Ross Sea.

Further research

In view of the uncertainties as to the actual accuracy of measurements of radial sighting distances and angles of sightings, the group recommended that further research be carried out to estimate objectively the accuracy of these measurements.

Appendix 17

RE-ANALYSIS OF AREA I SIGHTING DATA BY MEANS OF REVISED DOI MODEL

Michael F. Tillman

The basic Doi Model is as follows:

$$Y = \frac{A}{2X_1L} \cdot \frac{ns}{p}$$

where Y = estimated numbers of whales
A = size of area
X_1 = sighting width
L = distance searched
n = number of schools sighted
s = average school size
P = real rate of sighting.

The real rate of sighting is obtained as

$$P = \bar{P}K_w$$

where $\bar{P}$ = a modified average rate of sightings
K_w = a correction factor for proportion of whales missed

Paper SC/Jn81/MiS29 provided new results concerning the correction factor, K_w. From Table 9 of that paper I obtained the following values:

Number of topmen	K_w
2	0.782
4	0.967

These values have been used to recalculate the estimates presented in paper SC/Jn81/MiS28.

Four strata were utilized (small schools and large schools, both near pack ice and off shore). An estimate was obtained for each stratum. The data used are as follows:

	Near pack ice		Offshore	
Parameter	Small school	Large school	Small school	Large school
A	69,172	69,172	289,848	289,848
X_1	3.3	4.5	3.8	3.1
L	2,212	2,212	1,055	1,055
n	104	27	34	9
s	1.6	9.5	1.52	6.56
$\bar{P}$	0.3739	0.2284	0.1805	0.2289
P	0.292[1]	0.179	0.141	0.179
	0.362[2]	0.221	0.175	0.221

[1] For 2 topmen.
[2] For 4 topmen.

The resulting estimates of total population are as follows:

Number of topmen	N
2	35,545
4	28,725

Paper SC/Jn81/MiS28 reported that the mean number of topmen is 2.3 if one accounts for sighting effort on the bridge as well as in the barrel. Interpolating linearly between the above estimates gives an estimated total population of 34,522 minke whales in Area I South of 60°S in 1980/81. Following SC/33/MiS28 and assuming 80.2% of the total is exploitable, the estimated exploitable population is thus 27,687 minke whales.

Appendix 18

REVISED ESTIMATES OF ABUNDANCE OF MINKE WHALES IN AREA I BY STRATIFIED ANALYSIS OF SIGHTING DATA

Y. Shimadzu

SC/Jn81/MiS28 shows two estimations of minke whale abundance in Area I. One of them, which was estimated based on Doi's Model, was re-analysed by Tillman. The other estimates, based on stratification, were revised as follows:

Employing a basic equation,

$$P = \frac{nA}{2LY} \cdot s \cdot \frac{1}{g(0)} \cdot t \cdot M$$

where Y = mean sighting distance
L = length of transect
A = area of stratum
n = number of schools seen
S = average school size
*g(0) = probability of sighting on a track line
t = takeable, 80.2% (SC/Jn81/MiS28)
M = correction of bias for target moving (*Rep. int. Whal. Commn* 30: 281)

Table 1

Data used and revised estimates for minke whale abundance in Area I

Stratum**	Mean sighting distance (Y)	Length of transect (L)	Area of stratum (Anm)	Number of schools seen (n)	Average school size (s)	Average school size variance	Total population size	Exploitable population size
Small North	0.47	1,055	289,848	34	1.52	0.508	17,400	
Large North	0.66	1,055	289,848	9	6.56	10.528	14,156	
Small South	0.53	2,212	69,172	104	1.60	0.607	5,655	
Large South	0.67	2,212	69,172	27	9.50	42.900	6,895	
							44,106	35,373

* SC/Jn81/MiS29 resulted in an estimated probability of sighting on a track line (K_w) as 0.782 in the case of two observers in barrel. Taking several additional observers into account, this probability is revised to be 0.80.

** Northern stratum: 30 miles from ice edge to 65°S (120W–70W)
to 60°S (70W–60W)
Southern stratum: pack ice edge to 30 miles offshore.

As a conclusion, the estimated exploitable population in Area I by stratified analysis is 35,373 whales.

Appendix 19

MARK–RECAPTURE ESTIMATES OF ABUNDANCE FOR MINKE WHALES IN SOUTHERN HEMISPHERE AREAS III AND IV

Michael F. Tillman

Papers SC/Jn81/MiS10 and 31 provided recapture data resulting from IDCR marking experiments conducted during the 1978/79 season in Southern Hemisphere Area IV and during 1979/80 in Southern Hemisphere Area III. Paper SC/Jn81/MiS21 analyzed these data to obtain estimates of abundance but did not take advantage of the entire series of recapture data available for each experiment: 3 years of recaptures in Area IV, 2 years in Area III.

According to Chapman (1952), an appropriate estimator for a series of mark-recapture data is as follows:

$$\hat{N} = \frac{\varepsilon M_i C_i}{(\varepsilon R_i) + 1}$$

where M_i = number of available marks in season *i*
C_i = catch during season *i*
R_i = recaptured marks from season *i*.

Available marks during a season are calculated as the number marked just prior to the start of the season plus those marked whales, less recoveries, surviving from previous seasons:

$$M_i = M'_i + (M_{i-1} - R_{i-1})e{-}M$$

where M'_i = number marked just before season begins
M = instantaneous rate of natural mortality.

According to Seber (1973) an approximate 95% confidence interval for $\hat{N}$ is given by

$$\frac{4d}{(1.96 + \sqrt{4L - 1})^2} < \hat{N} < \frac{4d}{(-1.96 + \sqrt{4L - 1})^2}$$

where $d = \varepsilon M_i C_i$
$L = (\varepsilon R_i) + 1$.

Only recoveries resulting from the IDCR marking experiments have been used in this analysis. Table 1 shows that 4 such recoveries occurred in Area III, while 16 occurred in Area IV. As reported by Brown and Best (1981), 703 minke whales were scored as hits in Area III while 732 were so scored in Area IV.

Following Best and Butterworth (1980), I have assumed that marking mortality would result in an immediate 5% loss. The instantaneous rate of natural mortality, M, was taken as 0.09, as agreed by the working group.

Although all sizes of minke whales were marked during these experiments, not all were taken by pelagic whaling operations. Thus not all marks were available for recapture. Best and Butterworth (1980) reported that the proportion of recruited marks was 0.816, while the minke whale sub-committee adopted 0.809 as the appropriate value (*Rep. int. Whal. Commn* 31: 111). In this report I have used 0.81 to determine the number of marks available for recapture at the start of experiments.

At the start of each experiment, whales were marked after the Soviet fleet had taken its allocated catch and

Table 1

Recoveries of marked minke whales from IDCR Southern Hemisphere marking experiments

Experiment Area	Mark No.	Season marked	Season recovered	Area marked	Area recovered	Country recovering
III	34.559	78/79	79/80	IV	III	J
	35,170	79/80	80/81	III	III	J
	35,722	79/80	80/81	III	III	S
	34,102	78/79	80/81	IV	III	J
IV	34,130	78/79	78/79	IV	IV	J
	37,007	78/79	78/79	IV	IV	J
	37,008	78/79	78/79	IV	IV	J
	37,010	78/79	78/79	IV	IV	J
	33,896[1]	78/79	78/79	IV	IV	J
	37,169	78/79	79/80	IV	IV	J
	34,390	78/79	79/80	IV	IV	J
	26,260 27,968	78/79	79/80	IV	IV	J
	34,576	78/79	79/80	IV	IV	J
	31,461	78/79	80/81	IV	IV	J
	31,466	78/79	80/81	IV	IV	J
	33,975	78/79	80/81	IV	IV	S
	34,266	78/79	80/81	IV	IV	S
	34,216	78/79	80/81	IV	IV	S
	38.820	79/80	80/81	III	IV	S
	38,822	79/80	80/81	III	IV	S

[1] Marked just over boundary in Area V but judged to be part of Area IV experiment.

departed. Thus, in the first season the Japanese catch constituted the only effective recovery effort, and the Soviet catch was excluded.

Table 2 shows the recoveries obtained by each country. Soviet recoveries were actually the result of a joint Soviet-Japanese operation. Mark recovery efficiency experiments indicated 100% recovery rates during Japanese processing of minke whales (paper SC/Jn81/MiS23). Best reported to the working group that similar experiments revealed a 70% recovery rate for joint Soviet-Japanese processing of minke whales. Soviet recoveries were thus adjusted to reflect this difference in recovery efficiency.

Table 2

Recoveries of marked minke whales in each Southern Hemisphere Area according to country recovering and in total

	Recoveries in Area III			Recoveries in Area IV		
Season	Japan	USSR	Total	Japan	USSR	Total
1978/79	—	—	—	5	0	5
1979/80	1	0	1	4	0	4
1980/81	2	1	3	2	5	7

Recoveries in Area III of whales marked in Area IV, and vice versa (Table 3), indicate that some mixing occurred between these two Areas. I have assumed that migration between the two is equivalent, and thus have included all recoveries within an area, irrespective of their source. Table 4 gives the effective mark, effective catch, and adjusted recovery data used by the Chapman estimator.

Table 3

Recoveries of marked minke whales in each Southern Hemisphere Area according to source (where marked) and in total

	Recoveries in Area III			Recoveries in Area IV		
Season	Within III	From IV	Total	Within IV	From III	Total
1978/79	–	–	–	5	0	5
1979/80	0	1	1	4	0	4
1980/81	2	1	3	5	2	7

Table 4

Effective catch, effective mark and adjusted recovery data for Southern Hemisphere minke whales in two Areas

Season	C_i	M_i	R_i
Area III:	available marks = 703 × 0.95 × 0.81		
1979/80	1,253	541	1
1980/81	1,237	494	3
		Total	4
Area IV:	available marks = 732 × 0.95 × 0.81		
1978/79	960	563	5
1979/80	1,861	510	4
1980/81	2,386	462	9
		Total	18

I also estimated abundance for the two Areas combined. However, the Chapman estimator could not be used in this regard since I could not assume that random mixing of marks had occurred throughout the two Areas until the start of the 1980/81 season. I thus estimated abundance for that season alone using the methods of paper SC/Jn81/MiS21:

$$\hat{N} = \frac{(M + 1)(C + 1)}{R + 1}$$

$$\mathrm{Var}(\hat{N}) = \frac{(M + 1)(C + 1)(M - R)(C - R)}{(R + 1)^2(R + 2)}$$

Table 5 gives the mark and recovery data used for the combined estimate.

Table 5

Total marks available and recoveries during the 1980/81 season in Areas III and IV combined

Season	New marks	Area implanted	Total marks	Recoveries
1978/79	563	IV	563	5
1979/80	541	III	1,051	5
1980/81	0	—	957	13 (4 + 6/0.7)

Table 6 summarizes all abundance estimates obtained. For purposes of comparison I also calculated the 1980/81 estimate for each Area using the methods of paper SC/Jn81/MiS21 shown above.

Table 6

Mark-recapture estimates of abundance for minke whales in Southern Hemisphere Areas III and IV

Area	Basis of estimate	$\hat{N}$	Measure of error
III	Series	257,790	(129,126, 895,926)[1]
	1980/81	153,203	+68,126[2]
IV	Series	136,417	(91,920, 230,940)[1]
	1980/81	110,518	±32,892[2]
III and IV	1980/81	247,985	±63,437[2]

[1] 95% confidence interval.

[1] Standard deviation.

REFERENCES

Chapman, D. G. 1952. Inverse, multiple and sequential sample censuses. *Biometrics* 8(4): 286–306.

Best, P. B., and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Brown, S. G., and Best, P. B. 1981. Recoveries of whale marks from minke whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 357–58.

International Whaling Commission. 1981. Annex E, Report of the Minke Whale Sub-Committee. *Rep. int. Whal. Commn* 31: 103–13.

Seber, G. A. F. 1973. *The Estimation of Animal Abundance and Related Parameters*. Hafner Press, New York. 506pp.

Appendix 20

POPULATION TRAJECTORIES FOR AGREED ESTIMATES OF FINAL (1981) EXPLOITABLE POPULATION SIZES OF ANTARCTIC MINKE WHALES

C. A. Free

The tables show population trajectories by Area derived from the BALEEN program by iterating manually on initial conditions until the trajectory passed through or close to the agreed estimate of the 1981 exploitable population size.

The earlier suggestion of varying the mortality rate m so as to stay within a given part of the confidence region produced by the joint minimisation of m and N_0 (initial mature female population size) proved not to be feasible. Essentially, the confidence region defines a set of trajectories with very little variation in the 1981 population size. It is therefore not possible to retain a particular level of fit to the effort series and simultaneously increase the 1981 stock size. Accordingly, the procedure adopted in 1980 was repeated for the tabulated estimates. That is, the mortality rate was held fixed (at the value of 0.0687 obtained by joint minimisation) and N_0 was manipulated until an acceptable trajectory resulted.

Table 1

Area I minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 7,235.0

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4875
MALE   JUVENILE MORTALITY RATE =  0.4875
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687
```

```
YEAR   -----FEMALE POPULATION------   ------MALE POPULATION-------    TOTAL      ---CATCH---
       IMM-UNEX   MATURE     EXPL.   IMM-UNEX   MATURE     EXPL.   EXPL. POP        M     F

1968     13831    10977     12764     13831     11810     12764     25529         0     0
1969     14317    11917     12872     14317     12872     12872     25744         0     0
1970     15038    12017     13040     15038     13040     13040     26080         0     0
1971     15621    12174     13197     15621     13197     13197     26394         0     0
1972     16067    13416     13416     14894     14590     13416     26832         0     0
1973     16988    13621     13621     15731     14878     13621     27242         0     0
1974     17673    13890     13890     16327     15236     13890     27780       764   492
1975     18213    13765     13765     16860     14864     13511     27276       929   939
1976     18603    13237     13237     17134     14478     13010     26247       569   476
1977     18626    13285     13285     17145     14466     12985     26270       345   747
1978     18740    13088     13088     17240     14684     13184     26271       147   316
1979     18781    13324     13324     17128     15224     13571     26896       364   289
1980     18802    13713     13713     17123     15552     13874     27587       576   368
1981     18949    14026     14026     17237     15693     13982     28008       556   211
1982     19116    14495     14495     17420     15828     14132     28628         0     0
1983     19413    15116     15116     17782     16408     14777     29894         0     0
1984     19927    15636     15636     18290     16956     15319     30954         0     0
1985     20499    16126     16126     18887     17443     15830     31956         0     0
1986     21143    16560     16560     19502     17926     16284     32845         0     0
```

Table 2

Area III minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 21,510.0

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4875
MALE   JUVENILE MORTALITY RATE =  0.4875
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687

YEAR   -----FEMALE POPULATION------   ------MALE POPULATION-------    TOTAL      ---CATCH---
       IMM-UNEX   MATURE     EXPL.   IMM-UNEX   MATURE     EXPL.   EXPL. POP       M      F

1968    41119     32630     37943     41119     35096     37935     75878        71     26
1969    42561     35400     38239     42561     38189     38189     76427        71     41
1970    44694     35661     38702     44694     38627     38627     77329        97     74
1971    46404     36063     39104     46404     39013     39013     78117       138     70
1972    47688     39699     39699     44200     43039     39551     79250       247    242
1973    50373     40094     40094     46637     43687     39951     80045       615    745
1974    52285     40225     40225     48283     44215     40213     80438       528   1353
1975    53517     40028     40028     49496     44806     40786     80814       637    852
1976    54514     40328     40328     50152     45599     41237     81565       793   1361
1977    55271     40452     40452     50877     46225     41831     82283       759   2117
1978    55976     39892     39892     51533     46890     42447     82339       531   1270
1979    56306     40206     40206     51414     48173     43281     83487       857   1639
1980    56397     40573     40573     51456     49114     44174     84747       828   1880
1981    56598     40736     40736     51642     50037     45081     85817       602    635
1982    56764     42066     42066     51832     51084     46153     88218         0      0
1983    57460     43877     43877     52491     52662     47693     91570         0      0
1984    58658     45603     45603     53674     54149     49165     94768         0      0
1985    60143     47229     47229     55228     55469     50554     97783         0      0
1986    61903     48682     48682     56949     56740     51786    100468         0      0
```

Table 3

Area IV minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 12,915.0

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4875
MALE   JUVENILE MORTALITY RATE =  0.4875
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687

YEAR   -----FEMALE POPULATION------   ------MALE POPULATION-------    TOTAL      ---CATCH---
       IMM-UNEX   MATURE     EXPL.   IMM-UNEX   MATURE     EXPL.   EXPL. POP       M      F

1968    24655     19558     22748     24655     21048     22752     45500       267    330
1969    25517     20929     22634     25517     22697     22697     45330        16     25
1970    26668     21108     22933     26668     23000     23000     45934         0      0
1971    27623     21411     23236     27623     23299     23299     46535         0      0
1972    28375     23649     23649     26285     25797     23708     47357       919   1726
1973    29987     22419     22419     27748     25465     23227     45645      2410   2146
1974    30491     21016     21016     28093     23922     21524     42541      1761   2808
1975    30190     19238     19238     27780     23100     20690     39928       907   1323
1976    29430     18976     18976     26851     23298     20719     39695       429    452
1977    28812     19701     19701     26211     23951     21351     41052       917    683
1978    28713     20184     20184     26075     24143     21505     41689       251    712
1979    28715     20642     20642     25801     25220     22306     42947       512    858
1980    28529     21190     21190     25767     25829     23067     44258      1177    684
1981    28630     21724     21724     26040     25605     23016     44739       881   1505
1982    29000     21294     21294     26630     25453     23083     44376         0      0
1983    29246     22093     22093     26908     26101     23763     45856         0      0
1984    29864     22809     22809     27436     26795     24368     47177         0      0
1985    30591     23561     23561     28104     27503     25016     48577         0      0
1986    31372     24318     24318     28829     28220     25677     49996         0      0
```

Table 4

Area V minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 12,000.0

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4875
MALE   JUVENILE MORTALITY RATE =  0.4875
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687
```

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	22940	18207	21171	22940	19588	21171	42342	0	0
1969	23746	19766	21349	23746	21349	21349	42699	0	0
1970	24942	19932	21628	24942	21628	21628	43256	0	0
1971	25909	20192	21888	25909	21888	21888	43777	0	0
1972	26649	22252	22252	24703	24198	22252	44504	0	0
1973	28176	22592	22592	26091	24676	22592	45183	0	0
1974	29313	23038	23038	27080	25271	23038	46076	0	0
1975	30208	23593	23593	27964	25836	23593	47186	258	476
1976	31182	23676	23676	28747	26315	23880	47556	317	314
1977	31834	24085	24085	29378	26728	24272	48357	597	870
1978	32541	23966	23966	30054	26884	24396	48362	352	516
1979	33058	24216	24216	30316	27512	24770	48987	142	272
1980	33392	24914	24914	30608	28336	25553	50467	544	800
1981	33941	25112	25112	31102	28786	25947	51059	295	953
1982	34370	25205	25205	31463	29506	26599	51804	0	0
1983	34660	26245	26245	31743	30464	27547	53792	0	0
1984	35340	27226	27226	32372	31409	28442	55668	0	0
1985	36199	28189	28189	33246	32277	29324	57513	0	0
1986	37205	29075	29075	34222	33117	30134	59208	0	0

Table 5

Area VI minke run—Shimadzu catch and effort data. Time series of simulated baleen whale population components with initial mature female population of 11,625.0

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4875
MALE   JUVENILE MORTALITY RATE =  0.4875
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687
```

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	22223	17638	20510	22223	18975	20510	41019	0	0
1969	23004	19148	20682	23004	20682	20682	41364	0	0
1970	24163	19309	20952	24163	20952	20952	41905	0	0
1971	25100	19561	21204	25100	21204	21204	42409	0	0
1972	25816	21557	21557	23931	23442	21557	43114	0	0
1973	27295	21886	21886	25276	23905	21886	43771	0	0
1974	28397	22318	22318	26234	24481	22318	44636	10	3
1975	29264	22853	22853	27091	25019	22846	45699	0	0
1976	30206	23364	23364	27847	25718	23358	46723	92	67
1977	31023	23953	23953	28644	26303	23924	47877	51	98
1978	31904	24493	24493	29494	26919	24509	49002	321	200
1979	32806	24930	24930	30150	27489	24832	49762	79	56
1980	33482	25702	25702	30786	28286	25590	51292	0	0
1981	34303	26513	26513	31553	29158	26408	52921	252	177
1982	35225	27155	27155	32409	29803	26987	54142	0	0
1983	36123	27981	27981	33244	30703	27824	55805	0	0
1984	37102	28811	28811	34150	31615	28664	57475	0	0
1985	38137	29653	29653	35119	32534	29516	59170	0	0
1986	39220	30502	30502	36148	33446	30374	60876	0	0

Appendix 21

LENGTH OF THE ICE EDGE IN STATISTICAL AREAS

The following figures have been calculated from the average latitude of minimum sea ice in each 5° sector as given by Holt in IWC SC/32/Mi2. It has been assumed for purposes of calculation that the ice edge ran through each section on an east–west line at the mean latitude and that if a change in latitude occurred between sectors the ice edge followed a north–south line at the boundary between the sectors. If a sector boundary where a change occurred also fell on a boundary between statistical areas half the length of the north–south part of the ice edge was allotted to each sector. It was also assumed that the earth is a perfect sphere with radius such that the length of a 1° arc on the earth's surface at the equator is 60 nautical miles.

	Nautical Miles
Area I	1,587
Area II	2,262
Area III	1,932
Area IV	1,819
Area V	2,221
Area VI	1,453
	11,274
Area A	4,153
Area α	4,549

Appendix 22

Table 1

Area II minke run—Brazilian sightings series. Time series of simulated baleen whale population components with initial mature female population of 14,425.0 (RY ♂ = 864; RY ♀ = 1,099)

```
NO. OF AGE CLASSES IN MODEL =   30
FEMALE JUVENILE MORTALITY RATE =  0.4875
MALE   JUVENILE MORTALITY RATE =  0.4875
FEMALE ADULT MORTALITY RATE =  0.0687
MALE   ADULT MORTALITY RATE =  0.0687
```

YEAR	-----FEMALE POPULATION------			------MALE POPULATION-------			TOTAL	---CATCH---	
	IMM-UNEX	MATURE	EXPL.	IMM-UNEX	MATURE	EXPL.	EXPL. POP	M	F
1968	27441	21375	24919	27441	23222	25126	50045	152	304
1969	28240	22980	24884	28240	25219	25219	50103	217	404
1970	29456	22855	24894	29456	25381	25381	50275	301	400
1971	30329	22868	24907	30329	25454	25454	50361	330	570
1972	30886	24905	24905	28549	27977	25640	50545	233	469
1973	32293	24995	24995	29795	28400	25902	50896	210	440
1974	33214	25257	25257	30563	28969	26318	51574	279	662
1975	33859	25437	25437	31226	29419	26785	52222	460	1385
1976	34512	24914	24914	31681	29868	27036	51950	652	1287
1977	34665	24702	24702	31849	30092	27276	51978	565	1300
1978	34788	24477	24477	31970	30384	27567	52043	335	717
1979	34877	24813	24813	31809	31123	28054	52867	328	808
1980	34920	25276	25276	31840	31830	28750	54026	272	767
1981	35121	25757	25757	32010	32574	29462	55219	430	644
1982	35394	26351	26351	32260	33144	30010	56361	0	0
1983	35778	27527	27527	32709	34013	30944	58471	0	0
1984	36581	28565	28565	33537	34799	31755	60320	0	0
1985	37589	29510	29510	34573	35504	32488	61998	0	0
1986	38721	30367	30367	35664	36204	33147	63513	0	0
1987	39890	31205	31205	36775	36915	33800	65005	0	0

SC/Jn81/MiS2

Examination of Possible Schemes for Stratifying the IWC/IDCR Minke Whale Sightings Data

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Beginning in 1978, three minke whale assessment cruises have been conducted under the sponsorship of the International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR). The 1978/79 cruise was conducted in IWC Area IV (see Best and Butterworth (1980) for the full report), the 1979/80 cruise in Area III (Horwood, 1981), and the 1980/81 cruise in Area V (Butterworth and Best, 1982). Minke whale populations were assessed using both marking and sighting techniques. The 1979/80 sightings data collected in Area III are analyzed in this paper.

The sightings data (radial distances in nautical miles (nm) and angles in degrees) were collected by observers at four locations: (1) the barrel or crow's nest, (2) above the sonar (ASDIC) room, (3) the flying bridge, and (4) the wheelhouse. Sightings from the barrel predominated (333 of 510 total primary sightings), followed by sightings from the flying bridge (162/510), with minor additions from the other locations (15/510). Sightings were conducted during varying wind, weather, visibility and ice conditions, and these factors, along with location of observer, may affect the distribution of sightings and consequently the shape of the density function used in abundance estimation.

Two Japanese scouting vessels, the *Toshi Maru* 11 (T11) and the *Kyo Maru* 27 (K27) served as sighting platforms, each conducting a series of near-ice and off-ice transects. While T11 steamed the north (off-ice) transect during 27 December 1979–16 January 1980, K27 progressed along the south (near-ice) leg off the pack ice. The roles were switched at mid-cruise with T11 cruising the south (near-ice) leg and K27 the north (off-ice) transect during 20 January—16 February 1980.

METHODS

For analysis, the data were stratified into six subsets

(1) T11 south and north legs (T11)
(2) K27 south and north legs (K27)
(3) T11 south leg (T11S)
(4) K27 south leg (K27S)
(5) T11 north leg (T11N)
(6) K27 north leg (K27N)

and then the effects of the environmental factors on the distribution of right angle distance were studied for each subset. In some cases, small sample sizes precluded some statistical analyses for the north legs. The right angle distances ($r\sin\theta$, r = radial distance, θ = angle of sighting) were compared because most sightings models base the computation of an abundance estimator on the shape of the distribution of right angle distances.

The following factors were investigated to determine their effects on the distribution of right angle distances:

(1) location of observer (barrel versus flying bridge)
(2) sighting cue (blow, splash, animal, ring)
(3) number of people on watch in the barrel (one versus two)
(4) weather (codes 1–12) and visibility (in nautical miles)
(5) ice condition from 0 to 10/10, coverage in 10ths
(6) school size

Rather than compare the different distributions of right angle distances from the transect line out to the farthest sighting, a comparison of frequencies in the range 0–0.5 nm was chosen for this study. This cut-off point was selected arbitrarily, based on the dwindling sample sizes for distances greater than 0.5 nm. Also, since the near line sightings make up the bulk of the data, they are the most important part of the distribution for estimating the shape of the sightings density function. Sightings in the tail contribute little to the density function, and as long as the near line distributions are homogeneous, the far line data may be pooled. Pooling will increase sample size as well as have little to no effect on the shape of the curve near the transect line (Quinn, pers. comm.). Consequently, the following analyses are comparisons of the frequency distributions of sightings between 0 and 0.5 nm in 0.1 nm segments.

RESULTS

Comparison of sightings by location of observer

Most initial sightings were logged by the observers in the barrel, and secondly by observers on the flying bridge. The data from the other sites of observation are insufficient to quantify their distributions and could either be eliminated, or pooled, in hopes that if they do not fit in they will not affect the estimator adversely.

To determine how the barrel and flying bridge data were distributed, plots were produced which showed the distribution of angles and radial distances for each subset of the data (T11, K27, T11S, K27S, T11N, K27N; Figs 1–6). The sightings distributions by vessel looked quite different, especially the radically different distributions as shown in Figs 3 and 4, T11S versus K27S. Since this is the most dramatic of the plot comparisons, it is worth studying in further detail.

For the south leg data, plots of sightings from the flying bridge and sightings from the barrel (Figs 7–10) show that barrel observers on the T11S apparently scanned distances closer to the vessel and over a larger range of angles than the K27S. The difference in angle scanned was compared using the following χ^2 test:

	Barrel sightings	
Angle group	T11S	K27S
0°	18 (19%)	40 (28%)
1–44	35 (36%)	40 (28%)
45–90	14 (15%)	8 (6%)
270–314	14 (15%)	15 (11%)
315–359	15 (16%)	39 (27%)

$\chi^2_4 = 12.59$ p = 0.0134

Note that the K27S data show proportionally fewer sightings in the 45–90 and 270–314 group.

Although the distribution of angles appears to be different between the vessels, there are two questions that need to be addressed before any conclusions can be made: (1) what would make these distributions so different, and more importantly (2) what effect does this difference have on the distribution of the right angle distances, a product of both angle and radial distance?

Weather, visibility and ice condition may affect the distribution of angles and are discussed in more detail in a later section. However, these factors seem to have little effect on the near transect distribution of sightings, as the following comparisons have shown no significant statistical differences:

(a) Distribution of right angle distances on the K27S versus the distribution on the T11S.

(b) Comparison of the distribution of sightings from the barrel versus sightings from the flying bridge on each vessel.

(c) Comparison of T11 and T11S sightings from the barrel versus K27 and K27S barrel sightings.

(d) Comparison of sightings from the flying bridge for each subset of the data.

The data, χ^2 values and significance levels are shown in Tables 1 and 2.

Table 1

Distribution of sightings by right angle distance increments by vessel

Sightings by vessel by distance increment

	Data subset		
Distance increment (nm)	T11	K27	
0–0.1	84	93	
0–0.2	26	27	$\chi^2 = 1.46$
0–0.3	23	20	p = 0.833
0–0.4	21	19	
0–0.5	9	16	
	T11S	K27S	
0–0.1	64	67	
0–0.2	20	18	$\chi^2 = 0.77$
0–0.3	19	16	p = 0.942
0–0.4	16	13	
0–0.5	18	15	
	T11N	T11S	
0–0.1	20	26	
0–0.2	6	9	$\chi^2 = 0.36$
0–0.3	4	4	p = 0.948
0–0.4	5	6	

Table 2

Distribution of sightings by location of observer

Sightings by location of observer by distance increment
Barrel versus flying bridge

Subset[1]	χ^2	df	p
T11	0.368	4	0.985
K27	2.953	4	0.566
T11S	2.418	4	0.659
K27S	1.539	4	0.820

Barrel versus barrel

Subset[1]	χ^2	df	p
T11 vs K27	1.28	4	0.865
T11S vs K27S	1.70	4	0.791

Flying bridge versus flying bridge

Subset[1]	χ^2	df	p
T11 vs K27	2.61	4	0.625
T11S vs K27S	2.24	4	0.692

[1] North subset sample sizes were too small for these comparisons.

Sighting cues and location of observer

The cues 'blow' and 'animal' predominated, and comparison of right angle distances by cue showed no significant differences on the distribution of sightings by cue for any subset except for K27 (Table 3). A comparison of cue by location of observer for the K27 shows that flying bridge observers saw approximately 50% blows and 50% animals, while barrel observers saw approximately 75% blows and 25% animals. The flying bridge observations on the K27 exhibit a slight tendency to cluster near the track line, but this effect was not apparent when the data were pooled.

Table 3

Results of χ^2 tests comparing frequency distributions of right angle distances (0–0.5 nm) by sighting cue and comparing frequency distributions of cue by observer

Blow versus animal by distance increment

Subset[1]	χ^2	df	p
T11	0.16	4	0.997
K27	11.49	3	0.009*
T11S	1.54	4	0.820
K27S	6.55	3	0.088

Barrel versus flying bridge by blow versus animal

Subset[1]	χ^2	df	p
T11	0.116	1	0.734
K27	9.630	1	0.002*
T11S	0.008	1	0.928
K27S	4.890	1	0.026*
T11N	0.006	1	0.938
K27N	5.830	1	0.016*

[1] North subset sample sizes were too small for this comparison.
* Significant at the 0.05 level.

One versus two observers in the barrel

A χ^2 comparison of the distribution of sightings by right angle distances when only one observer was in the barrel versus sightings made with two observers in the barrel showed no significant differences in any subset. However, the 'one observer' cell sample sizes were small in most cases, which stretches the limits of the χ^2 test, so the data were pooled over vessels and again there were no significant differences.

Right angle distance (nm)	T11 + K27 One observer Number	%	T11 + K27 Two observers Number	%
0–0.1	26	60	80	48
0.1–0.2	5	12	29	17
0.2–0.3	7	16	19	11
0.3–0.4	2	5	22	13
0.4–0.5	3	7	16	10
	43		166	

$\chi^2_4 = 4.84$ p = 0.304

Although the χ^2 test showed no differences, the above data and all subsets had an important feature in common. The proportion of sightings in the 0–0.1 nm cell was always substantially higher for the 'one observer' sightings than the 'two observer' sightings, and the 'one observer' frequency distribution always dropped off more sharply. This peak at small distances, if pooled with other data, may adversely affect the estimation of the density function. Also one should consider the increased likelihood that, in cases of reduced coverage, (e.g. only one observer in the barrel), more animals on the track line may be missed. Until we can settle the problem of how to treat the possibility that even with full coverage, animals on the track line may be missed, it seems futile to attempt to quantify the effect of reduced coverage. It is suggested that these data (representing 12% or 62/510) be omitted, because of their peaked nature and the unknown quantity of animals missed due to reduced coverage.

Effects of visibility and weather

Visibility estimation is subjective and was found to be highly correlated with weather (T11, $r = -0.88$, $p < 0.001$, $n = 243$; K27, $r = 0.80$, $p < 0.001$, $n = 267$), and consequently need not be considered separately from weather. Mean estimated visibility (in nm) by weather condition was compared, and there were apparent similarities in visibility for weather conditions 1–4, (blue, blue-cloudy, cloudy, and overcast), with codes 6 (mist), 7 (fog), and 10 (snow) in a totally different visibility range. As shown in Fig. 11, the 95% confidence intervals indicate that blue and blue-cloudy may be pooled, as well as cloudy and overcast. Mist, fog and snow were ignored at this point, since they account for only a few sightings (25/510). Analysis of the distribution of right angle distances by weather conditions (blue and blue-cloudy pooled versus cloudy and overcast pooled) showed neither significant differences (Table 4), nor a tendency to cluster near the trackline.

Sightings during snow conditions made up 4% (21/510) of the sample and these sightings did show a sharp drop off away from the trackline. It is possible therefore to pool weather conditions 1 through 4 while omitting sightings during conditions 6, 7 and 10 because they may add to the 'peakedness' of the data.

Table 4

Comparison of the distribution of right angle distances (0–0.05 nm) by weather code

Blue and blue-cloudy versus cloudy and overcast by distance increment

Subset[1]	χ^2	df	p
T11	2.25	4	0.690
K27	3.63	4	0.458
T11S	2.91	4	0.573
K27S	4.44	4	0.350

[1] North subset sample sizes were too small for this comparison.

Effects of ice conditions

A possible explanation for the asymmetry of sightings as shown in Figs 3 and 4 may be the differences in mean ice condition on the south legs of each vessel. The T11 spent more time in, and consequently sighted more animals in, heavier ice conditions. (T11S, mean ice condition = 2.8 ± 0.32; K27S, mean ice condition = 2.0 ± 0.20.) This could have a marked effect on the distribution of the long range sightings, since it is likely that ice would obscure minke whales from view, even if weather conditions or visibility were favorable.

The effect of the different ice conditions on the distribution of the right angle distances appears to be minimal, however, since the previous statistical tests have shown no significant differences in most comparisons of right angle distance distributions.

School size and clustering

As noted by Best and Butterworth (1980), there is a positive correlation between school size and right angle distance from the track line. In this case, we examined the correlation between school size and radial distance, and for all subsets, a significant positive correlation was found.

Subset	r	p	n
T11	0.36	0.00000	243
T11N	0.49	0.00010	67
T11S	0.42	0.00000	176
K27	0.21	0.00022	267
K27N	0.42	0.00036	62
K27S	0.19	0.00302	204

We agree that this seems to be due to an increased probability of sighting a larger school as distance from the track line increases. Quinn (1981) discusses this situation in detail, and presents two methods of analyzing these data, pooling and post-stratifying. The appropriate method of analysis is based on the nature of the estimator chosen.

The increasing probability of sighting as a function of group size is a real occurrence, but once accounted for, should not present theoretical problems. Selection of an appropriate estimator is a much more important problem.

To see if clustering or schooling behaviour changes during a day (due to grouping while feeding, etc.), the correlation between time of day and school size was examined. There was no significant correlation between these two factors for any subset of the data.

Subset	r	p	n
T11	0.07	0.14	243
T11N	−0.02	0.46	67
T11S	0.09	0.12	176
K27	−0.06	0.18	267
K27N	0.09	0.25	62
K27S	−0.06	0.18	204

CONCLUSIONS

The distribution of right angle distances seems quite homogeneous under most conditions. Most of the data may be pooled, with the possible exception of weather codes other than 1–4 and instances where only one observer watched from the barrel. Fig. 12 shows the frequency distribution of sightings for each vessel, both legs pooled. As expected, the distributions are remarkably similar out to 0.5 nm, and even beyond.

It is recommended that once an estimator is chosen, the goodness-of-fit be tested using all the data, and then re-tested after eliminating the potentially confounding weather and observer data. Whichever gives the best fit should then be used for the density estimate. Note, though, that eliminating weather codes 6, 7 and 10, and all 'one observer' barrel sightings will have little effect in reducing the large peak of sightings in the 0–0.1 nm increment, which as Butterworth noted in the Report of the Workshop on Sightings Surveys (IWC, 1982) is due to the large number of sightings recorded at 0° angle (see the earlier section on the distribution of angles by vessel). The factors considered here appear to have only a minor effect on the distribution of right angle distances when compared to the effect of large numbers of sightings recorded at 0°.

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REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–84.

Butterworth, D. S. and Best, P. B. 1982. Report of the Southern Hemisphere minke whale assessment cruise 1980/81 Paper SC/Jn81/MiS14+15+19 (published in this volume).

Horwood, J. W. 1981. Results from the IWC/IDCR minke whale marking and sighting cruise 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

International Whaling Commission. 1982. Report of the Workshop on the Design of Sightings Surveys, Annex D, Addendum 3 (published in this volume).

Quinn, T. J. II. 1981. The effect of group size on line transect estimators of abundance. *Avian Biol.* 6: 502–8.

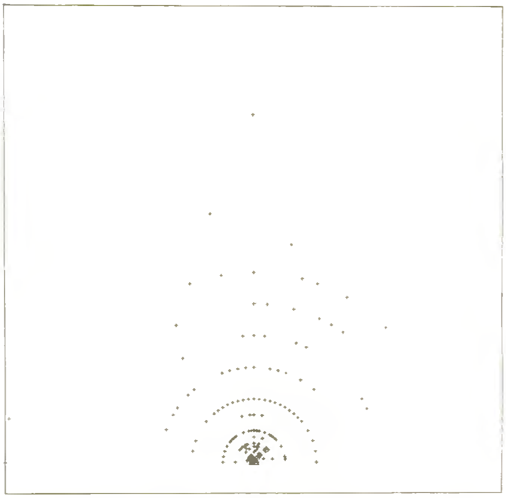

Fig. 1. Distribution of primary sightings made by all observers on the *Toshi Maru* No. 11, both north and south legs (27 Dec. 1979–16 Feb. 1980).

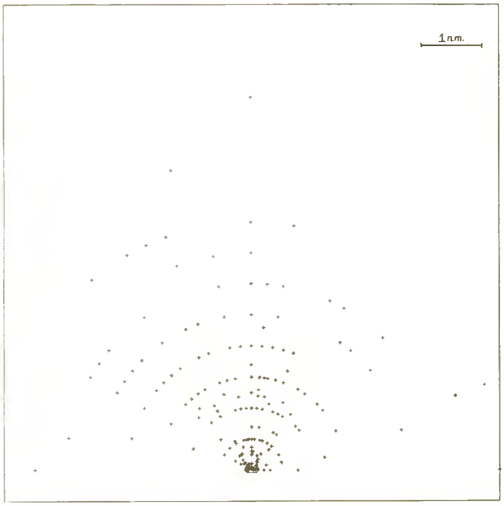

Fig. 2. Distribution of primary sightings made by all observers on the *Kyo Maru* No. 27, both north and south legs (27 Dec. 1979–16 Feb. 1980).

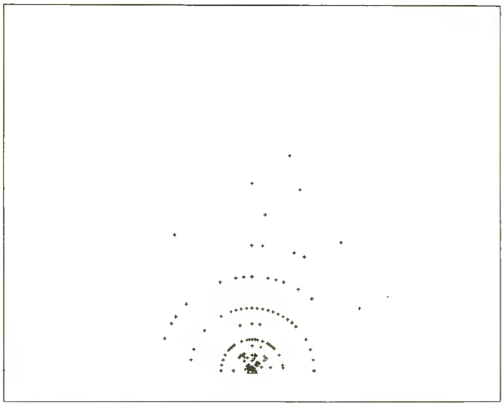

Fig. 3. Distribution of primary sightings made by all observers on the *Toshi Maru* No. 11, south leg only (25 Jan. 1979–16 Feb. 1980).

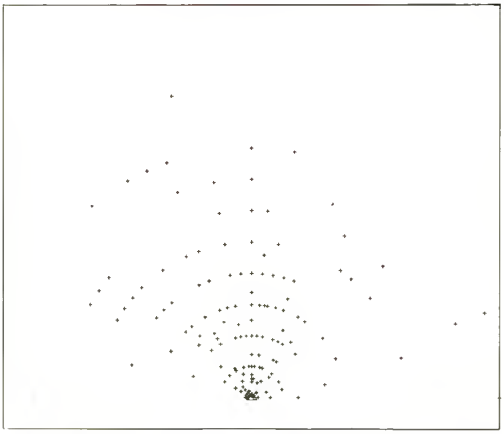

Fig. 4. Distribution of primary sightings made by all observers on the *Kyo Maru* No. 27, south leg only (27 Dec. 1979–16 Jan. 1980).

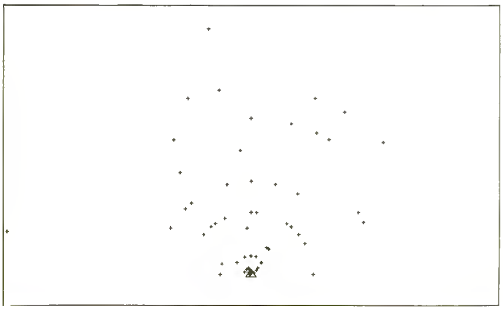

Fig. 5. Distribution of primary sightings made by all observers on the *Toshi Maru* No. 11, north leg only (27 Dec. 1979–16 Jan. 1980).

Fig. 6. Distribution of primary sightings made by all observers on the *Kyo Maru* No. 27, north leg only (27 Jan. 1979–16 Feb. 1980).

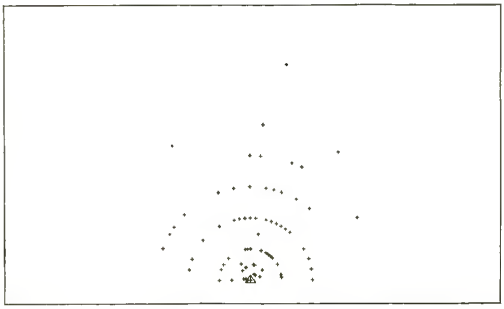

Fig. 7. Distribution of primary sightings made by barrel observers on the *Toshi Maru* No. 11, south leg only (25 Jan. 1979–16 Feb. 1980).

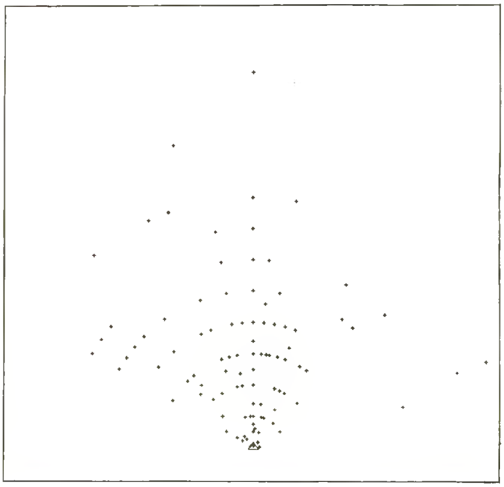

Fig. 8. Distribution of primary sightings made by barrel observers on the *Kyo Maru* No. 27, south leg only (27 Dec. 1979–16 Jan. 1980).

Fig. 9. Distribution of primary sightings made by flying bridge observers on the *Toshi Maru* No. 11, south leg only (25 Jan. 1979–16 Feb. 1980).

Fig. 10. Distribution of primary sightings made by flying bridge observers on the *Kyo Maru* No. 27, south leg only (27 Dec. 1979–16 Jan. 1980).

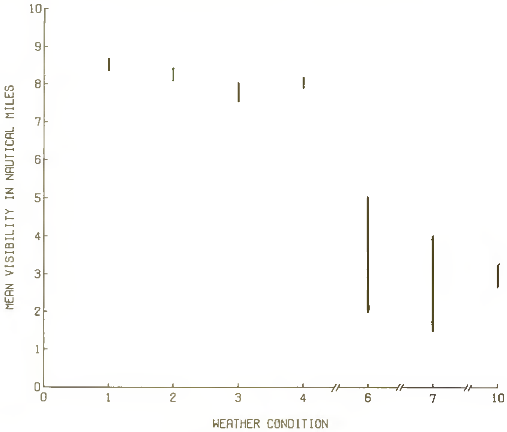

Fig. 11. Mean visibility and 95% confidence interval (in nautical miles) for weather codes (1) blue, (2) blue-cloudy, (3) cloudy, (4) overcast, (6) mist, (7) fog, and (10) snow.

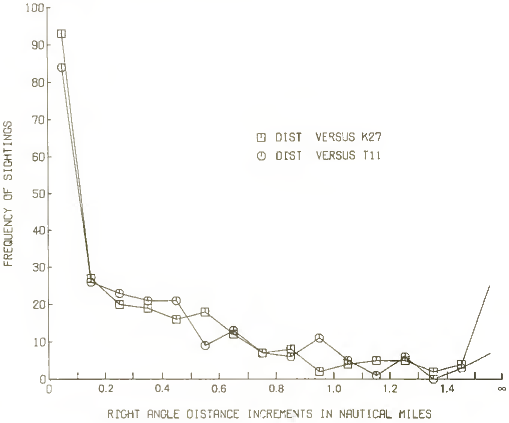

Fig. 12. Distribution of sightings by right angle distances by vessel, *Toshi Maru* No. 11 versus *Kyo Maru* No. 27.

SC/Jn81/MiS3

A Review of the Morphological and Biochemical Research on Population Identification of Southern Minke Whales

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ABSTRACT

This paper examines the available evidence on stock divisions of minke whales in the Southern Hemisphere and in particular critically examines the studies which purport to support the use of the stock boundaries which have been traditionally used in the IWC for other baleen whales. A new method of testing the Hardy-Weinberg equilibrium using a maximum likelihood technique is introduced. It is concluded that current information does not support the present stock boundaries for minke whales.

INTRODUCTION

In general, whales have a grouped distribution: in some parts of the oceans many can be found while in other parts much fewer or even no animals at all are found. Two types of group can be distinguished: populations and stocks. A population in this context is a group of animals breeding freely with each other but never (or hardly ever) with animals of another group. Owing to the processes of random genetic drift or selection, biochemical and morphological differences can appear among populations. If selection and drift do not occur, populations remain genetically identical in spite of their isolation. Groups of animals breeding freely with animals of the same and of other groups are defined as stocks. Normally populations are divided into several stocks. Although no genetic differences in body properties may appear among stocks, differences caused by specific environmental factors in the area (e.g. the quantity of available food) can be recognised, for example in dynamic parameters of the stocks such as the natural mortality rate.

Minke whales in the Southern Hemisphere are mainly caught along the edge of the Antarctic pack-ice during the southern summer. In 1973 the Scientific Committee (IWC, 1974) first recommended that catch limits for minke whales in the Antarctic should be allocated by area to avoid over-exploitation in any particular area. The boundaries were, due to lack of relevant information, made identical to those of the larger baleen whales such as the fin whale (IWC, 1976). Results of some subsequent biochemical and morphological research seemed to confirm these Areas (Doroshenko, 1979; Wada and Numachi, 1979). Recently some doubt has been expressed about the validity of the current minke stock divisions on the grounds that (a) the accumulated catch distribution does not correspond with the present boundaries, and (b) the analysis of the biochemical data used to confirm the boundaries was done incorrectly (IWC, 1981, pp. 114–5).

For the rational exploitation of whale resources it is very important to correctly identify stock and/or populations in order to apply the appropriate parameter values and catch and effort data. The first step is to identify the stocks: this may be done using the accumulated catch and catch per unit effort (CPUE) and sightings per unit of effort (SPUE) data, correlated with the geographic position. Migration between groups can be shown by mark-recovery experiments. Having obtained the stock distribution and defined the boundaries the next stage, in the case of limited or no migration, is to determine whether some or all of the stocks are also genetically isolated (i.e. are populations) by examining differences in biochemical and morphological characters taking into account any influence of the environment. Isoenzymes are usually used as biochemical characters. If the heredity of the isoenzymes can be reasonably determined, then the allele frequencies can be calculated. The advantage in using allele frequencies is that small but real differences can be detected. This is much more difficult to do using genotype frequencies because of the greater variation due to sampling and random deviation around the Hardy-Weinberg equilibrium. In the absence of suitable data for southern minke whales the Scientific Committee did not follow the sequence of analysis just described but used the same stocks and boundaries as used for other baleen whales, as a means of sub-dividing the catches and subsequently analysed various results with this *a priori* division. We were also unable to follow the correct sequence, because the catch and CPUE data were not available to us. Therefore we have only reanalysed data which were presented as supporting the current stock divisions (Doroshenko, 1979; Wada and Numachi, 1979; and Borisov, 1981). Marking results are also examined.

EVALUATION

During the special Scientific Committee meeting on southern minke whales in Seattle 1978, the results on stock division research by Doroshenko (1979) and Wada and Numachi (1979) were presented and discussed.

Doroshenko's results

Doroshenko first described some qualitative, morphological differences between minke whales from four locations using results of earlier research (published in Russian). He then described the results obtained for minke whales taken by the *Sovietskaya Rossiya* during the 1975/76 season in two locations of the Antarctic—the Indian Ocean (IO) and the New Zealand (NZ) areas which were examined for eight morphological characters. Whales from two other locations were examined for only one character. He concluded that marked differences between the populations could be seen for four of the characters: shape of fluke notch; colour of flippers; number of baleen

Table 1

Frequency of occurrence of morphological characters in various minke whale samples (from Doroshenko, 1979): n = sample size

		Samples			
Character	Type	Brazilian	Indian	New Zealand	Chilean–Peruvian
Shape of fluke notch	n		519	202	
	1		149	68	
	2		278	112	
	3		92	22	
Colour of flippers	n	230	562	204	185
	1	170	250	51	95
	2	60	312	153	90
Number of baleen plates	n		42	30	
			242	274	
Number of phalanges by digit	n		16	10	
	1st		5	4	
	4th		5	4	

plates; and number of phalanges on the 1st and 4th digits. Little difference was observed for the remaining characters.

These differences however, were not statistically tested for random effects. Three variations in the shape of fluke notches were described (see Fig. 2 in Doroshenko's paper). The absolute frequencies of the types from the IO and NZ samples are calculated and given in Table 1 using the percentages of Doroshenko. A maximum likelihood test of independence—G statistic—(Sokal and Rohlf, 1969) did not show a significant result: $G = 5.89$, $df = 2$, $0.05 < P < 0.10$. Two flipper types based on colour were described. The frequencies of these types for four locations are given in Table 1 (calculated as before). The G-test gave a highly significant result: $G = 113.15$, $df = 3$, $P \ll 0.01$. Doroshenko also reported marked differences in the number of baleen plates on one side of the head between the IO and NZ samples. However, only the average values are given (see Table 1 and Doroshenko's Table 1) with no standard deviations, so that these values cannot be tested. The fourth character presented by Doroshenko was the number of phalanges on the 1st and 4th digits of the flipper. He stated that the 'Indian population sample usually had five phalanges on the first and fourth digits while the New Zealand sample had four phalanges on these digits'. Again the raw data were not presented so the values cannot be tested. However, Doroshenko himself stressed that the sample size (26) was very small for this character and that further work was necessary.

Thus an examination of Doroshenko's results reveals that a significant difference between groups is only demonstrated for flipper colouration. However, the two types described by Doroshenko for this character are not the only types which can be found among minke whales. Wada and Numachi (1979) describe four flipper pigmentation types in southern minke whales including the two described by Doroshenko. Best (1979) also noted a type in the Durban catch which Doroshenko did not mention. So if flipper colouration is to be used to divide the whole Southern Hemisphere then Doroshenko's two-type division is insufficient.

Wada and Numachi's results

Wada and Numachi (1979) describe three morphological and three biochemical characters which they used in their research on population identity of southern minke whales. The results in the research with morphological characters could not be used because of the great variation which was probably due to the different interpretation of the classification criteria used by the collectors on board the factory ships.

The minke whales used for the biochemical analysis were caught in the 1975/76 and 1976/77 season in a large number of 10° squares spread over most of the Antarctic. The three polymorphic enzymes demonstrated by electrophoresis were: 6-PGD, SDH and GOT. In order to analyse the results a number of the 10° square samples were combined into five large samples, whose boundaries more or less corresponded to the present Area boundaries. The analysis of each enzyme was composed of (a) a goodness of fit test of the observed and expected genotype frequencies according to the Hardy-Weinberg theorem in each sample and (b) a pair-wise comparison of the samples with every allele frequency. Wada and Numachi concluded that there were at least four minke whale populations in the Southern Hemisphere.

These analyses were criticised by Van Beek and De la Mare (IWC, 1981, pp. 114–5). The criticism was twofold: (a) the pair-wise comparisons of samples were not independent for the different alleles at one locus: if a certain allele frequency differs significantly between two samples it is highly probable that these samples also show a significant difference in the frequency of another allele at the same locus; (b) the chance of one or more type I errors was very great with the large number of comparisons: in the 6-PGD example with 40 comparisons this was calculated to be 0.87.

The allele frequencies for the two enzymes (6-PGD and SDH) for which Wada and Numachi found significant differences were tested for independence between the samples by Van Beek and De la Mare who concluded that the five groups are homogeneous.

A similar criticism had already been given by scientists of the UK Fisheries Laboratories at Lowestoft (UK) (Horwood, 1980). The English scientists also reanalysed the allele frequencies using several coefficients of genetic distance. They concluded that the genetic distances were very small and well within the range of genetic distances of several animal races (see also Ayala, 1975). One of the coefficients, Rogers' genetic distance, can be statistically analysed for random effects (Smith, Francis and Paul, 1978). The English scientists carried out this test and concluded that only the samples from the eastern Indian Ocean and the western Pacific were significantly different. Wada agreed with this analysis and disputed the independence test used by Van Beek and De la Mare (IWC, 1981, pp. 114–5). Using as an example samples from snapper groups (Smith *et al.*, 1978) Wada illustrated his opinion that independence tests often produce a non-significant result which does not necessarily mean that the samples are homogeneous. An independence test with the enzyme GPi-1 (bi-allelic) on all the snapper samples gave a χ^2 of 13.95 which is not significant with 11 df. In spite of this, Wada stated that the snapper samples A and F were different from each other because an independence test on these two samples gave a χ^2 of 6.54 which with 1 df is significant (critical $\chi^2 = 3.84$ by $P = 0.05$ and 1 df).

However, in our opinion Wada's snapper analysis is an unpermitted *a posteriori* method. The standard procedures for *a posteriori* tests are: (a) to test all possible pair-wise comparisons, with a critical χ^2 corresponding to the total number of degrees of freedom (Simultaneous Test Produce), (b) to set the pair-wise error rate such that the experiment-wise error rate does not exceed the fixed overall level of significance. In both cases further analysis should not be undertaken if the test on all groups is not significant (Sokal and Rohlf, 1969). Thus for the snapper samples Wada should have used either the critical χ^2 corresponding to 11 df or a significant level of < 0.001 (66 pairwise comparisons; IWC, 1981). If this is done samples A and F are also of course independent. If *a priori* reasons exist for comparing certain groups from a greater number of groups, the number of df is derived from the compared groups. Some conditions for *a priori* tests also exist.

The English scientists do not stipulate whether in their examination of Rogers' distance they have taken into account that only two alleles per locus are permitted by this test, whilst the loci concerned had more than two alleles. Loci with multiple alleles can be used by collecting the least frequent alleles together. Table 2 shows the relative allele frequencies of the enzymes after doing so and Table 3 shows the Rogers' distances. A comparison of the values in Table 3 and the appropriate matrix of Horwood (1981) reveals only small differences between them. According to Smith *et al.*, (1978) a test on random effects on Rogers' distances in biallelic cases is possible if the mean and variance of this variable is known or can be estimated from a sample. They estimated from a particular sample the mean and variance of Rogers' distance and subsequently tested the Rogers' distance from the same sample for random effect with these parameters. We believe this to be a dubious procedure. Moreover, even if we accept this test procedure, the *a posteriori* tests with a pair-wise error rate of 0.005 (10 comparisons; IWC, 1981) showed no significant results, although the Rogers' distance for samples C and D (0.034) was close to the critical value of 0.035. The English scientists used a pair-wise error rate of 0.05, so did not adjust it for the *a posteriori* procedure.

Wada and Numachi grouped their original 10° square samples from two years into five large samples as otherwise the sample error increased to the extent that no significant differences between samples could be detected. They found support for their clustering because a χ^2 goodness of fit test on the Hardy-Weinberg equilibrium for the five samples did not show a significant deviation (Tables 2, 3 and 4 in Wada and Numachi, 1979). However the χ^2 test is not very suitable in this case because the expectation of the numbers in many classes is less than five. A more proper test is the maximum likelihood test as described in Appendix 1. Employing this test on the 6-PGD and SDH genotypes in the five samples did not give a significant result. Table 4 shows the G values and the χ^2 values of Wada and Numachi for comparison with the appropriate degrees of freedom. The GOT genotypes were not used because this enzyme can hardly be termed polymorphic and because the interpretation of the zymogram presented difficulties to Wada and Numachi.

Table 3

Rogers' genetic distances calculated with the values from Table 2

	A	B	C	D	E
A	χ				
A	χ				
B	0.017	χ			
C	0.025	0.028	χ		
D	0.014	0.010	0.034	χ	
E	0.026	0.015	0.029	0.019	χ

If populations in one area are found with differences in allele frequencies and if each population is in Hardy-Weinberg equilibrium, a deviation from the Hardy-Weinberg equilibrium in the added genotype frequencies can be expected, i.e. a surplus of homozygotes and a shortage of heterozygotes: the Wahlund effect (Solbrig and Solbrig, 1979).

It different allele frequencies are present within the samples, the Wahlund effect should appear in the added genotype frequencies. Table 5 shows the observed and expected added genotype frequencies, and the results of the maximum likelihood test. A significant deviation only occurred in the SDH-genotypes. The direction of the deviation was in 40 and 45% of the comparisons (total 10, 11) for 6-PGD and SDH respectively; not in agreement

Table 2

The relative allele frequencies of three enzymes in five samples of southern minke whales (from Wada and Numachi, 1979)

Enzyme		6-PGD		SDH		GOT	
Allele		n	c + s + f	n	s + f + r + e	n	s + f + r + c
Sample	A	0.720	0.280	0.842	0.158	0.953	0.047
	B	0.707	0.293	0.814	0.186	0.944	0.056
	C	0.662	0.338	0.835	0.165	0.962	0.038
	D	0.728	0.272	0.811	0.189	0.951	0.049
	E	0.697	0.303	0.790	0.210	0.956	0.044

Table 4

The G-value, degrees of freedom and significance of the maximum likelihood test on the Hardy-Weinberg equilibrium for two enzymes in five minke samples. The χ^2 plus df from Wada and Numachi (1979) is given for comparison

	6-PGD					SDH				
	G	df	Significance	χ^2	df	G	df	Significance	χ^2	df
A	2.22	6	—	2.11	6	3.05	6	—	1.77	10
B	4.89	6	—	4.31	6	15.61	10	—	11.48	10
C	4.74	6	—	5.41	6	5.16	10	—	9.32	10
D	7.53	6	—	7.58	6	9.30	10	—	11.03	10
E	4.29	6	—	3.62	6	15.75	10	—	17.4	10

Note: $6/\chi^2$ equals 12.59 and 10.31 by 6 and 10 df and $P = 0.05$.

Table 5

The added frequencies of 6-PGD and SDH genotypes from Wada and Numachi (1979) and the expected frequencies according to the Hardy-Weinberg theorem. Also the Wahlund expectation and deviation from it are given

	6-PGD genotypes										
	CC	CS	CN	CF	SS	SN	SF	NN	NF	FF	
Observed	54	101	473	18	49	443	6	1,205	69	0	2,418
H-W expected	51	94	491	13	43	455	12	1,191	65	1	$G = 10.14, df = 6$
Wahlund expected	+	–	–	–	+	–	–	+	–	+	$0.10 < P < 0.50$
Observed	+	+	–	+	+	–	–	+	+	–	

	SDH genotypes											
	SN	SF	SR	NN	NF	NR	NE	FF	FR	FE	RR	
Observed	46	7	2	1,584	608	76	18	71	3	1	2	2,418
H-W expected	45	9	1	1,586	616	69	15	60	13	3	1	$G = 21.24, df = 10$
Wahlund expected	–	–	–	–	–	–	–	–	–	–	–	$0.01 < P < 0.05$
Observed	–	–	–	–	–	–	–	–	–	–	–	

with the Wahlund expectations. The deviation in the SDH genotypes could have been caused by the Wahlund effect (and so different allele frequencies between samples) but it is more likely that other factors influenced the results. One indication of this is the difference from Hardy-Weinberg equilibrium for genotypes with an F allele in samples B, D and E (Table 3, Wada and Numachi, 1979).

The use of this approach in identifying populations is not really necessary as a better method is available in which random deviations around the Hardy-Weinberg equilibrium can be avoided: the independence test on allele frequencies used by Van Beek and De la Mare (IWC, 1981, pp. 114–5).

We therefore conclude that the Wada and Numachi results in their current format, do not contain significant indications for different minke whale populations in the southern waters. A slight indication of the existence of populations was found by using Rogers' genetic distance. However, the other equally valid genetic coefficients did not reveal any indications (Horwood, 1981).

Borisov's results

Ivashin (1981) referred to Soviet studies on the morphology of minke whales which indicated the existence of an Indian Ocean and a New Zealand population, but this did not included the original data and so they could not be examined.

Borisov (1981) presented the results of Russian biochemical research on the population identity of southern minke whales. He demonstrated in four samples a haptoglobin (a blood protein involved in haemoglobin turnover) polymorphism regulated by two codominant alleles.

Of the four minke whale samples collected in 1974, two (14 and 20 animals) were taken from the centre of Area IV, one (20 animals) was taken 5° to the west of this and the other (26 animals) was from Area V, close to the boundary with Area IV. The exact geographic location of the samples was not reported. Using a χ^2 test he found no deviations from the Hardy-Weinberg equilibrium, or using a t-test on the separate genotype frequencies after arcsin transformation. However, neither test was particularly suitable because: (a) each of the four samples was smaller than 50 animals and the expected number of animals in two of the three genotype classes was generally much smaller than five; thus the conditions for a χ^2 test were not satisfactorily fulfilled, (b) the three t-tests (there were three genotypes) within a sample were not independent. Using the maximum likelihood test a significant deviation of the Hardy-Weinberg equilibrium was found in the second group (= third sample): $G = 4.28$, $df = 1$, $0.01 < P < 0.05$.

Borisov analysed his results further for sample differences. He compared the three genotype frequencies in two samples and calculated the corresponding χ^2 value. The critical χ^2 he used was χ^2 with 2 df and $P = 0.05$ (3 columns and 2 rows). He also applied a t-test to the differences in genotype frequencies, per two samples and per genotype class. Borisov concluded on the results of his statistical analysis that the first group (samples 1 and 2) and the second group (sample 3) differed significantly. Again the t-test is not suitable. The χ^2 test is also incorrectly used because no adjustment to the *a posteriori* test method was applied.

Considering the significant deviation from the Hardy-Weinberg equilibrium it is better to test the samples with the allele frequencies. Table 6 shows the allele frequencies in the four samples; these are calculated with the data from Borisov's Table 1. The maximum likelihood test of independence did not give a significant result: $G = 3.47$, $df = 3$, $0.010 < P < 0.50$. We therefore conclude that the Russian biochemical results did not provide evidence for different populations of minke whales in the Southern Hemisphere.

Table 6

Haptoglobin allele frequencies in four samples of southern minke whales (from Borisov, 1981)

Allele	A	B	Total
Sample			
1	24	4	28
2	34	6	40
3	29	11	40
4	45	7	52
	132	28	160

Mark-recovery results

Brown and Best (1981) gave a summary of the marking and mark-recoveries. An extensive programme of minke whale marking in the Southern Hemisphere has been carried out since 1978: during the 1978/79 and 1979/80 seasons 1,620 animals have been marked whereas before 1978 only 159 animals were marked. Eleven animals (12 marks) marked under the International Scheme had been captured at the end of the 1979/80 season. The marked and captured animals are schematically divided over the Areas as follows:

	Area III	IV	V
Marked in 1976/77 season	1		
Captured in 1976/77	1		
Marked in 1978/79		9	1
Captured in			
1978/79		5↙	
1979/80	1↙	4	
Marked in 1979/80 season	0		
Captured in 1979/80	0		

Under the Soviet marking scheme one animal marked in 1978/79 in Area III was captured in the next season in the same Area. One animal marked in 1979/80 in Area III was captured the same season in Area II. Of the thirteen captured animals six were captured one season later and of those six, one animal had crossed a boundary. Of the seven animals which were taken in the same season two had crossed a boundary. When attempting to discover differences between populations, the possible causes of these differences must be kept in mind. Two of the most important are selection and random genetic drift. It seems plausible to accept as a working hypothesis that in the southern oceans no selection differences between populations exist. Random drift can occur if a population goes or has gone through a 'bottleneck' in terms of number. Differences between populations created by these factors can only be maintained if migration is negligible. Kimura and Ohta (1971) have shown in a theoretical study that if $Nm > 4$ no differentiation through drift can take place, where N is the total effective population size of minke whales in the Southern Hemisphere and m is the migration rate by generation. It seems almost certain that Nm for the southern minke whales with the present. Area-boundaries is greater than four considering the estimated population size of more than 200,000 animals in Areas III, IV and VI (IWC, 1981) and using a migration rate of the order implied by the mark recovery experiments.

CONCLUSION

An extensive statistical analysis of the morphological and biochemical results of three independent investigations on the population identity of the southern minke whale did not reveal significant differences between minke whale groups separated by the current Area boundaries. As a consequence of these results no valid arguments remain for the current Area divisions, which are only based on the divisions for other baleen whales. We believe that new stock divisions based on CPUE and the accumulated catch data should be devised during the next IWC meeting. In terms of management it is not that important to know whether genetic differentiation between populations has taken place. However, it is crucial that the stocks, which have their own dynamics caused by specific environmental factors, are clearly defined so that appropriate biological parameter values, catch and effort data can be applied to the stocks and correct assessments can be carried out. Perhaps with new boundaries and further research (including an examination of Wada and Numachi's results by 10° square) the question as to whether different minke whale populations exist in the Southern Hemisphere can be answered adequately. It is however also possible that small but real differences between populations cannot be demonstrated using current analytical methods.

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REFERENCES

Ayala, F. I. 1975. Genetic differentiation during the speciation process. pp. 1–75. *In:* Dobzhansky *et al., Evolutionary Biology*. Plenum Press, New York. 389 pp.

Best, P. B. 1978. External characters of minke whales landed at Durban. Paper S1 presented to the special meeting of the IWC Scientific Committee, Seattle, May 1978.

Borisov, V. I. 1980. Haptoglobin polymorphism of minke whales and sei whales. Paper SC/32/O 13 presented to the IWC Scientific Committee, June 1980.

Brown, S. G. and Best, P. B. 1981. Recoveries of marks from minke whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 357–8.

Doroshenko, N. V. 1979. Populations of minke whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 29: 361–5.

Horwood, J. W. 1980. An analysis of Wada's data. Paper SC/32/Mi26 presented to the IWC Scientific Committee, June 1980.

International Whaling Commission. 1974. Report of the Scientific Committee. *Rep. int. Whal. Commn* 24: 39–54.

International Whaling Commission. 1976. Report of the Scientific Committee. *Rep. int. Whal. Commn* 26: 1–17.

International Whaling Commission. 1981. Report of the sub-committee on minke whales. *Rep. int. Whal. Commn* 31: 103–22.
Ivashin, M. V. 1981. USSR Progress report on cetacean research. *Rep. int. Whal. Commn* 31: 221–6.
Kimura, M. and Ohta, T. 1971. Protein polymorphism as a phase of molecular evolution. *Nature* 229: 467–9.
Smith, P. J., Francis, R.I.C.C. and Paul, L. J. 1978. Genetic variation and population structure in the New Zealand snapper. *NZ J. Mar. Freshwater Res.* 12(4): 343–50.
Sokal, P. R. and Rohlf, F. I. 1969. *Biometry. The Principles and Practice of Statistics in Biological Research.* Freeman and Co., San Francisco. 776 pp.
Solbrig, O. T. and Solbrig, D. I. 1979. *Introduction to Population Biology and Evolution.* Addison-Wesley Co., 468 pp.
Wada, S. and Numachi, K. 1979. External and biochemical characters as an approach to stock identification for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 421–32.

Appendix 1

DERIVATION MAXIMUM LIKELIHOOD TEST OF HARDY-WEINBERG EQUILIBRIUM

Null hypothesis, Ho

Likelihood Hardy-Weinberg equilibrium L =

$$\underbrace{\frac{N!}{\prod_{i=1}^{n}.\prod_{j=1}^{i}(m_{ij}!)}}_{C} . \prod_{i=1}^{n} . p_i^{2m_{ii}} . \prod_{i=2}^{n} . \prod_{j=1}^{i-1} . (2p_ip_j)^{m_{ij}}$$

m_{ii} = number of homozygotes of allele i
m_{ij} = number of homozygotes of allele i and j
p_i = chance on allele i
p_j =chance on allele j
n = number of alleles
N total samples size.

$$\ln L = \ln C + 2.\sum_{i=1}^{n} m_{ii} \ln p_i + \sum_{i=2}^{n}\sum_{j=1}^{i-1} m_{ij} \ln (2p_ip_j)$$

$$\ln L = \ln C + \sum_{i=1}^{n} ((m_{ii} + \sum_{j=1}^{n} m_{ij}) . \ln p_i)$$

$$+ (N - \sum_{i=1}^{n} m_{ii}). \ln 2 \quad m_{ij} = m_{ji} \text{ for all i and j}$$

$$\left.\begin{array}{l} \dfrac{d\ln L}{dp_i} = \dfrac{m_{ii} + \sum_{j=1}^{n} m_{ij}}{p_i} \\ \sum_{i=1}^{n} p_i = 1 \end{array}\right\} \quad \hat{p}_i = \frac{m_{ii} + \sum_{j=1}^{n} m_{ij}}{2N} \text{ for all i}$$

$$\ln \hat{L} = \ln C + \sum_{i=1}^{n}\left\{(m_{ii} + \sum_{j=1}^{n} m_{ij}).\ln (m_{ii} + \sum_{j=1}^{n} m_{ij})\right\}$$

$$- \sum_{i=1}^{n}\left\{(m_{ii} + \sum_{j=1}^{n} m_{ij}) \ln 2N\right\} + (N - \sum_{i=1}^{n} m_{ii}) \ln 2$$

$$\ln \hat{L} = \ln C + \sum_{i=1}^{n}\left\{(m_{ii} + \sum_{j=1}^{n} m_{ij}.\ln (m_{ii} + \sum_{j=1}^{n} m_{ij})\right\}$$

$$- 2N.\ln N - (N + \sum_{i=1}^{n} m_{ii}).\ln 2$$

Alternative hypothesis (general model), H_1

$$\text{Likelihood} = C. \prod_{i=1}^{n}\prod_{j=1}^{i} q_{ij}^{m_{ij}}$$

q_{ij} = chance on animal heterozygote for alleles i and j
q_{ii} = chance on animal heterozygote for allele i

$$\ln \hat{L} = \ln C + \sum_{i=1}^{n}\sum_{j=1}^{i} (m_{ij}.\ln q_{ij})$$

$$\left.\begin{array}{l} \dfrac{d\ln L}{d\,q_{ij}} = \dfrac{m_{ij}}{q_{ij}} \text{ for all i and j} \\ \sum_{i=1}^{n}\sum_{j=1}^{i} q_{ij} = 1 \end{array}\right\} \hat{q}_{ij} = \frac{m_{ij}}{N} \text{ for all i and j}$$

$$\ln \hat{L} = \ln C + \sum_{i=1}^{n}\sum_{j=1}^{i} m_{ij}.\ln m_{ij} - N.\ln N$$

Test statistic $G = 2(\ln \hat{L}_{H1} - \ln \hat{L}_{H0})$

$$G = 2\left[\sum_{i=1}^{n}\sum_{j=1}^{i} m_{ij}.\ln m_{ij} - \sum_{i=1}^{n}\left\{(m_{ii} + \sum_{j=1}^{n} m_{ij}).\ln(m_{ii} + \sum_{j=1}^{n} m_{ij})\right\} + N.\ln N + (N + \sum_{i=1}^{n} m_{ii}).\ln 2\right[$$

This test statistic follows approximately a Chi-square distribution with ½n(n − 1) degrees of freedom.

SC/Jn81/MiS4

Seasonal Abundance, Feeding, Reproduction, Age and Growth in Minke Whales off Durban (with incidental observations from the Antarctic)[1]

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ABSTRACT

Although minke whales were present in temperate waters of the southwestern Indian Ocean throughout the year, their abundance off Durban rose to a peak from June to September, when the catch was predominantly of sexually mature animals in which males outnumbered females 2:1. The composition of schools in August and September suggested that pairing took place at this time. Feeding off Durban was at a very low level, and consisted almost entirely of euphausiids. Scarring on the bodies (especially flippers) of some minke whales in the Antarctic suggested unsuccessful killer whale attacks. Males examined at Durban reached sexual maturity at 24.9 feet and females at 26.6 feet. Mature males at Durban had heavier testes than those from the Antarctic. Most (63.3%) of the mature females examined had recently ovulated, but very few (0.9%) were obviously pregnant. The majority (77.1%) of animals were still lactating when ovulation occurred, and from the size of three accompanying calves it is estimated that ovulation occurred about 4 months after parturition. Lactation is estimated to last 6 months, and the minimum calving interval to be about 14 months. From the proportion of resting females in the catch the 'true' pregnancy rate is calculated to be 78.4% (or an average calving interval of 15.3 months).

In females with 7 to 20 growth layers in the ear plug, 0.811 ± 0.144 ovarian corpora accumulated per growth layer, which, when compared with the 'true' pregnancy rate, suggested that one growth layer was deposited per year. Sexual maturity was attained at an age of 5–8 years in males and 7–9 years in females. An analysis of the transition phase in the ear plug (correlated with the attainment of sexual maturity) showed that the age of animals reaching maturity declined from 10.5 years in 1945 to 7.7 years in 1973. The readability of plugs increased with body length. Growth ceased at 28.2 feet in males and 29.3 feet in females, at about 18 years of age.

INTRODUCTION

The whaling station at Durban (29°53′S 31°03′E) commenced taking minke whales in significant numbers in 1968, largely to compensate for the reduced abundance of the larger baleen whales, particularly sei whales (Best and Gambell, 1968). As the station ceased whaling at the end of the 1975 season, the exploitation phase for minke whales was comparatively brief, and a total of 1,113 animals was taken in eight seasons. The data gathered from this catch, however, are of considerable interest because they cover a period of the year and a latitudinal zone complementary to the whaling season in the Antarctic. The only comparable data available for southern minke whales come from the catches made off Brazil (Williamson, 1975; da Rocha, 1980).

This paper presents information on the seasonal abundance, migration, group composition, feeding, age and reproduction of minke whales off Durban: data on their external characteristics will be presented elsewhere. Incidental observations made on the Japanese factory ship *Nisshin Maru no. 3* during the 1978/79 Antarctic season are also included where relevant.

MATERIAL AND METHODS

Even though they featured regularly in catches from 1968 onwards, minke whales were never a species of choice for the Durban gunners. This was principally because of their low value relative to sperm, fin or sei whales (Best and Surmon, 1974), but there were also other factors involved. Leaving minke whales in flag, for instance, was soon found to be impossible because sharks rapidly damaged the carcase so much that it sank, so minke whales always had to be taken alongside as soon as they were killed. Gunners were therefore unwilling to take a minke whale early in the day if there was a possibility that other, more valuable species might be encountered later, for a minke whale towed alongside slowed the catcher down while it was chasing, and was liable to lose value due to damage and decomposition in the process. Because of this lack of interest it is difficult to identify the catching effort specifically devoted to this species. For the purposes of this paper the total catching effort has been adopted as an approximation, and this has been expressed on a fleet basis as the number of productive boat-days per month (i.e. those days on which a catcher was at sea) multiplied by the mean tonnage of the fleet (= catcher-ton-days). No correction for asdic has been made because this equipment was rarely used in chasing minke whales: these animals fled as soon as transmissions started, so leading to a prolonged chase.

A spotter aircraft (Cessna 310) operated in conjunction with the whaling fleet throughout the period of minke whale exploitation. The *modus operandi* of this aircraft has been described by Bannister and Gambell (1965). As most (if not all) whales of commercial interest seen were recorded, irrespective of species, the spotting records should not suffer from the same drawbacks as the catching effort. Sightings of minke whales were not systematically recorded prior to 1968 so that available data only cover the period 1968–75. Estimates of the searching effort have been derived principally from the total flight time each

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[1] Revised since the June 1981 meeting.

month. Because spotting ability was obviously limited by weather conditions, the total number of hours flown each month was converted into 'equivalent-good-hours' by using a weather-correction factor. Each day's flight was characterised by the pilot as either a full patrol or a short patrol, and the weather conditions as fine, fair or poor. The latter classification was made as follows (K. J. Pinkerton, letter dated 27.6.1968).

Fine—days of good visibility with light winds and sunny skies. On such days lines of search were opened up slightly and an increased area of coverage was obtained.

Fair—days of moderate winds (10 knots and above but below 20 knots), with moderate to good visibility and partly cloudy conditions. Lines of search were narrowed slightly and the area covered was about the norm as stated. In these conditions whales on the surface or blowing would not be missed.

Poor—days with winds above 20 knots when sea state made sighting far more difficult and cloud cover further reduced the chances. There were also some days with moderate conditions but very bad visibilities due to haze and these were also classed as poor. Generally a poor day was one when the distance at which a blow could be seen was less than 1½ miles.

The weather-correction factor was calculated as:

$$\frac{\text{No. of good patrols} + \tfrac{1}{2}\,(\text{no. of bad patrols} + \tfrac{1}{2}\ \text{no. of short patrols})}{\text{No. of good} + \text{bad} + \tfrac{1}{2}\ \text{no. of short patrols},}$$

where good patrols were those on which the weather was classified as fine or fair, and bad patrols were those on which the weather was poor. This formula was developed originally by Bannister and Gambell but not fully described in their 1965 paper.

The number of equivalent-good-hours was then converted into the distance flown by multiplying by the average cruising speed of 135 knots. That this does not necessarily correspond to the area searched (due to circling, etc.) is acknowledged by Gambell (1972), and a better indication would be to measure the actual distances covered on the flight chart for each day. Unfortunately it has so far proved impossible to trace such charts prior to 1972.

The company operating the spotter aircraft provided two sources of data on the number of whales seen. Daily diary sheets were filled in by the aircrew, giving for each sighting the date, time, position, species and number of individuals seen. For most sightings the prevailing weather conditions and direction of movement of the whales were also given, and in some instances observations of behaviour were included. In addition the company provided a monthly summary giving (*inter alia*) the number of whales seen and number of sightings made for each species. These data were available for all seasons from 1968 to 1975. On occasions a comparison of the daily diary sheets and monthly summary produced inconsistencies in the number of whales seen or sightings made. There was no consistent bias and either the diary sheets or monthly summary could produce a higher figure. Because there was reason to believe that some fraction of minke whale sightings might not have been recorded (due to their generally low commercial importance), the higher figure for the number of whales seen per month has been adopted in this paper irrespective of whether it came from the monthly summaries or the diary sheets. In total the aircraft data provided 283 sightings of 588 minke whales.

A further source of data on minke whale group sizes came from whale-marking cruises on the Durban whaling grounds in February 1968, 1971, 1972 and 1973, August 1969 and January 1975, and an extended cruise in the Southwest Indian Ocean from November 1973 to February 1974 (Gambell, Best and Rice, 1975). Apart from the latter cruise, which was supported by funds from Australia, South Africa, United Kingdom and the United States of America, the marking cruises were all financed jointly by the Institute of Oceanographic Sciences, UK, and the Department of Industries, South Africa. In addition, I made observations of minke whale group size and composition at sea from whale-catchers in March 1971, March and April 1973 and August and September 1971.

All minke whales landed at the whaling station were measured and sexed by either the whaling inspector or the platform foreman, measurements of total length being taken according to the Schedule of the International Whaling Commission. At my request, however, such measurements were recorded to the nearest inch rather than the nearest foot.

Although whaling inspectors at Durban were instructed to make systematic observations of minke whale stomach contents (and in fact they collected several samples from stomachs) their routine recording of the presence or absence of food is not considered reliable enough to be used here. This is mainly because of individual variation in interpretation and the fact that the extremely small quantities of food usually present could easily be missed (especially during flensing at night) unless the stomach was examined very carefully. Consequently only data collected by personnel belonging to the marine mammal section of the Sea Fisheries Institute have been used for this purpose.

The methods of examining minke whale stomachs were as described previously for other baleen whales (Best, 1967a). Any fluid present in the stomach was subsampled using a plastic tea-strainer and any food thus found preserved in 10% formalin.

Instructions were issued to the whaling inspectors to collect certain reproductive material and data from minke whales landed at Durban each season from 1968 until 1975 (when the station closed down). The mammary glands of each female were to be inspected for the presence of milk, the maximum thickness (= depth) of the gland measured and a sample collected. Both ovaries were to be collected from each female. The diameters of both cornua of the uterus were to be measured across their widest part, when the uterus was lying flat on the deck. If either ovary bore a corpus luteum, the uterus was then to be opened and searched for the presence of a foetus. Any foetus found was to be measured (total length) and sexed. Finally a sample of the wall of the uterus was to be collected. All samples were labelled with the year and platform number of the whale and preserved in 10% formolsaline.

Unfortunately the collection of material in this manner did not prove entirely satisfactory, due mainly to neglect on the part of some inspectors and unsatisfactory methodology on the part of others. During the 1970 season, and in the months of August and September 1971, a technician from the Sea Fisheries Institute collected data and material from minke whales at the station, and the latter data only have frequently been used in this paper when the inspectors' data were considered to have been biassed.

Accurate mammary gland measurements proved difficult to take, particularly in sexually immature animals, because the gland was either partly or completely stripped off when the blubber was removed. Eventually measurements of the gland's thickness were made before the belly blubber was removed, by making transverse incisions through the body wall as far as the muscle, removing a section of the blubber with mammary gland attached, and then measuring the width of the gland as it lay flat.

From the total of 367 females landed, 184 pairs of ovaries and 13 single ovaries were collected. These were subsequently weighed, sectioned and examined in the laboratory, exactly as described for sperm whales (Best, 1967b), though in this instance sections were cut at an average thickness of 3 or 4 mm rather than 5 mm. To date, histological examination of the mammary gland and uterine mucosa samples has not been possible.

Because it was reported that a large proportion of the minke whale population off Durban in late winter and early spring (August, September) consisted of adults accompanied by calves, it was decided to investigate the reproductive condition of these females more closely through an experimental catch. Consequently, under provision of Article VIII of the International Convention for the Regulation of Whaling, 1946, the South African Department of Industries issued two special scientific permits for the taking of lactating minke whales and their calves at Durban. The first of these was for 25 mother-calf pairs and was valid for the whole 1970 season. Only 12 females and 2 calves were taken. A second permit for 12 mother-calf pairs was issued for August and September, 1971. I was present on a catcher throughout this period to supervise the taking of the animals. Only 9 females and 1 calf were taken. Failure to take the numbers of animals permitted was not due to a scarcity of suitable animals but rather to ethical objections and superstitions of the gunners concerning the taking of mothers and calves. The small proportion of calves taken was due primarily to the fact that the gunners preferred to take the mother first because of its greater commercial value, hoping that the calf would stand by the dead female. However this rarely happened, and by the time the female had been killed and secured alongside, the calf had usually disappeared.

Both testes were removed from male minke whales landed at Durban, trimmed and weighed to the nearest 20 g on a spring balance and a sample taken from the larger. The sample was usually an entire cross-section of the testis at its midlength, about 1.5 cm thick. This was fixed in a 1:3 formalin:seawater solution and later examined in the laboratory, where a subsample was taken (usually from just beneath the tunica albuginea). Histological sections 3μ thick were prepared and stained in Haematoxylin and Eosin. From the total of 743 males landed, testes weights are available for 379 and histological samples from 345 animals.

Either one or (preferably) both ear plugs were collected from 604 minke whales (54.3% of the catch). The method of collection and fixation was exactly as described for Bryde's whales (Best, 1977). Fifty-one of these could not be sectioned, usually because they were too crumbly or too greasy. The remainder were sectioned on a freezing microtome at a thickness of about 50μ. A median, sagittal section was transferred to 70% alcohol for 5 mins, stained in Sudan Black for 5 to 10 mins, washed in 70% alcohol until excess stain disappeared, counterstained in Alcoholic Eosin for 1 min, rinsed in 70% alcohol, taken up on a clean slide and mounted in glycerol jelly. The edges of the coverslip were sealed with nail varnish. Examination of the sections took place under a low-power binocular dissecting microscope.

From 20 January to 17 February 1979 I examined 161 minke whales while on board the Japanese factory ship *Nisshin Maru no. 3* as part of the first IWC southern minke whale assessment cruise (Best and Ohsumi, 1980). At the time the factory was operating along the ice edge between the longitudes of 62° and 107°E. The procedures followed were almost identical to those listed or described above, except that no preserved material was examined as it was destined for the Japanese Fishery Agency.

SEASONAL ABUNDANCE

Two indices of minke whale abundance have been used, one derived from the catch (the catch per 10^5 catcher-ton-days) and the other from the aircraft sightings (the number seen per 12×10^3 miles flown, weather-corrected). Although the second index should be independent of the first, the reverse situation is not true (as pointed out by Smith and Perrin, 1976) because the success of catching operations was to some extent dependent on whales spotted from the aircraft. As there are also serious difficulties associated with the measurement of catching effort for minke whales (see above), the aircraft sightings must be considered as the better indicator of minke whale abundance off Durban (Table 1).

In Fig. 1 both CPUE and sightings data have been expressed on a monthly basis as the mean value for eight (or fewer) seasons, plus or minus one standard error of the mean. Because of restrictions of season, the catch data cover only the period April to September, while aircraft sightings are available from February to September. In general minke whales were rarely seen off Durban in February and March but increased in abundance in April and May. Their abundance then remained at about the same level until the last month of the whaling season (September), when it increased further to a maximum value for the eight months covered.

This pattern most closely resembles that of the sei whale off Durban, in that the peak period of abundance is in September, but there is no indication of a secondary, earlier peak of abundance in autumn, as described for that species by Bannister and Gambell (1965). It is therefore difficult to associate particular 'waves' of abundance in the area with possible northerly or southerly movements out of and into the Antarctic.

Within the Antarctic minke whale density increases from November to a peak in January and then declines in February (Shimadzu, 1980), although there are differences in timing between the sexes (Kasamatsu and Ohsumi, 1981). Observations of minke whales between the latitudes of 20° and 40°S in summer (November to February) suggested that although the species was widely distributed its general density was low relative to observations made in higher latitudes of the Antarctic. There appeared to be a higher density north of 30°S than south of it, and the majority of animals seen were judged to be immature from their size (Gambell *et al.*, 1975). Consequently the majority of at least the mature population of minke whales appears to be south of 40°S in summer.

According to Williamson (1975), the first minke whales arrive off Brazil (in a latitude of 7°S) each year in late June and July, rise to their maximum numbers from September to November, and the last individuals leave in December. He makes the point that the simultaneous occurrence of

Table 1

Abundance of minke whales off Durban from aircraft sightings

	Season								
	1968	1969	1970	1971	1972	1973	1974	1975	
Month	Number of whales seen per month (Number seen per 12 × 10^3 miles flown[1])								Mean
February	—	—	—	—	—	—	0 ((0))	0 ((0))	((0))
March	—	1 (0.5)	7 (4.1)	0 (0)	1 (0.6)	3 (1.9)	3 (1.7)	2 (1.4)	(1.5)
April	2 (1.4)	11 (7.1)	5 (4.2)	18 (12.3)	11 (7.0)	8 (5.2)	4 (2.3)	2 (1.2)	(5.1)
May	16 (9.0)	41 (26.9)	34 (21.1)	28 (19.4)	6 (3.7)	7 (5.0)	1 (0.7)	3 (2.0)	(11.0)
June	6 (4.6)	18 (11.3)	7 (5.2)	31 (18.7)	27 (14.1)	14 (7.6)	4 (3.5)	15 (11.8)	(9.6)
July	20 (13.0)	13 (8.5)	12 (8.0)	21 (12.5)	24 (18.4)	24 (19.7)	9 (5.9)	5 (4.2)	(11.3)
August	3 (2.4)	9 (8.8)	14 (9.6)	36 (25.1)	10 (7.5)	14 (14.1)	7 (7.6)	12 (10.1)	(10.7)
September	11 (13.8)	10 (7.0)	12[2] (7.9)	19 (18.2)	13[2] (11.8)	15 (16.1)	8 (10.7)	30 (35.1)	(15.1)
Total	58	103	91	153	92	85	36	69	

[1] Weather-corrected. [2] Including 3 patrols in October 1970 and 1 patrol in October 1972.

large numbers of minke whales off Brazil and in the Antarctic in November–December would suggest either that there are separate stocks or that there is great variation in the timing of migration between different individuals.

The data from Durban are in general agreement with the trend described by Williamson (1975), although minke whales appear to arrive somewhat earlier off Durban in autumn (April/May) than off Brazil: the limited time-span of the Durban data does not permit a comparison with the timing of the departure of minke whales off Brazil.

These data therefore suggest that the minke whale population tends to shift northwards into lower latitudes in winter. However, minke whales (estimated from 8 to 11 m in length) have been reported from the Antarctic trapped in sea-ice from May to October (Taylor, 1957), so some mature animals may overwinter in higher latitudes.

Incidence of diatoms

When I accompanied whale-catchers at sea off Durban I noted that several of the minke whales taken bore patches of diatom film on their skin. Such patches were not easily detected during examination of whales on the flensing platform for several reasons. Firstly, the warm water and relatively long towing-times for minke whales (see Material and Methods) meant that the epidermis had frequently sloughed or been rubbed off before the whales were brought to shore. Secondly, members of the public often stripped the skin from large areas of the body for fish bait when the whales were lying on the slipway before being brought to the whaling station. Finally, many minke whales were flensed at night under poor artificial illumination, when the contrast in coloration between the diatom film and the surrounding skin became far harder to detect than in daylight.

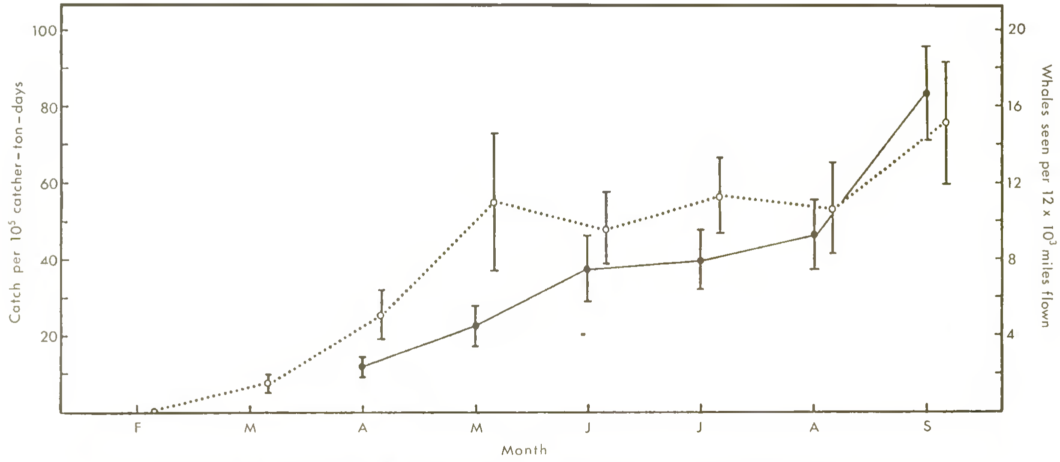

Fig. 1. Seasonal abundance of minke whales off Durban from CPUE (solid line) and aircraft sightings (dotted line), 1968–75.

In the live or freshly-dead animal, however, the diatom films were quite obvious. All those that I saw were orange-brown or yellowish in colour, and were located as irregular patches along the lateral and ventral sides of the body, particularly round and on the flipper, on the ventral grooves and on the side of the caudal peduncle, although they were also recorded round the eye, on the side of the mandible, round the genital aperture and on the tail. (Diatom patches on the darkly pigmented areas of the body were probably harder to see.) Samples were collected from 18 whales, and all proved to be the cold water species *Cocconeis ceticola* (Nemoto, Best, Ishimaru and Takano, 1980). Taylor (1957) recorded minke whales trapped in pools in Antarctic sea-ice as having "dark 'copper-coloured' flanks, presumably due to a layer of diatoms". Williamson (1959) mentioned one of three minke whales examined in the Antarctic as having diatom patches present and one as having none, while Ohsumi, Masaki and Kawamura (1970) reported the presence of yellowish-brown films of *Cocconeis ceticola* on six minke whales from the Antarctic. The presence of diatom films on minke whales in subtropical waters may therefore indicate that such animals have recently arrived from the Antarctic (Hart, 1935).

The incidence of patches of diatom film on freshly-killed minke whales off Durban was recorded in August and September 1971 while I was onboard a whale-catcher, and during the 1973 whaling season by G. Smith, the boatswain of a whale-catcher (Table 2). During both seasons samples of suspected diatom film were collected from whales shortly after death as they lay alongside the catcher, and preserved in formalin (in the absence of a visible film no systematic collections were made to inspect for the presence of spores). Although the total numbers examined were small, the proportion of minke whales carrying diatoms was high throughout the period June to September, and there was no sign of a decline in incidence as the season progressed: this contrasts with the situation in sperm whales (Best, 1969b). This would suggest that there is a continual arrival of minke whales from the Antarctic during the months June to September.

The overall incidence of diatoms on this species was surprisingly high (35.7%). Lockyer (in press) has reviewed the infestation of southern blue and fin whales. Within the Antarctic rates of infestation of both species varied with month, more carrying diatoms later in the season than earlier, with maximum rates varying from 30 to 100%. The incidence of diatom film on sei whales at South Georgia in summer was much lower, from 2.8 to 26.7% (Gambell, 1968). During the winter, blue and fin whales taken off South Africa rarely carried films: none of the few mature whales examined was infested, and a maximum of 45% of immature whales in any one month carried diatoms: this normally occurred in August or September (Lockyer, in press). It is not clear whether the high degree of infestation found for minke whales in this paper is due to their being examined while still freshly-killed, or whether there is a naturally high rate of diatom infestation in this species due to differences in migratory behaviour from other balaenopterids.

In 160 minke whales examined on the *Nisshin Maru no. 3* between 20 January and 17 February 1979, diatoms were present in 108 (or 67.5%). The majority of animals had patches on the mandible, around the eye and flipper insertion, spreading to the flanks and ventral grooves in heavier infestations.

Table 2

Presence of diatoms on minke whales off Durban

Incidence of diatoms	May	June	July	August	September	Total
Personal obs.						
No. examined	0	0	0	10	6	16
% with diatoms	—	—	—	40.0	50.0	43.8
G. Smith's obs.						
No. examined	1	16	6	2	1	26
% with diatoms	0	31.3	33.3	0	100	30.8
Combined obs.						
No. examined	1	16	6	12	7	42
% with diatoms	0	31.3	33.3	33.3	57.1	35.7

Direction of movement

The direction of movement of minke whales was recorded from the spotter aircraft before the catchers arrived, and so presumably referred to animals in a relatively undisturbed state. The directions were recorded to the nearest 10° interval and tended to coincide with particular compass points (N, NE, E, etc.), probably reflecting rough approximations made in the field. For the purposes of analysis, therefore, all the sightings have been grouped around a particular compass point, e.g. all records of whales moving in a direction between 340° and 20° have been entered as moving N, and all those moving in a direction between 30° and 60° as moving NE (Table 3). At the same time the pilot also recorded many animals not moving in a particular direction, i.e. they were either 'jumping', 'playing' or 'circling'. These have been combined under the generalised heading 'idling' animals (Table 3).

The majority of non-idling animals in the season as a whole were either moving N and NE (52.8%) or S and SW (31.0%). As the coastline in the region of Durban runs approximately in a NE–SW direction, most animals were therefore moving up or down the coast. The overall predominance of northerly moving animals resembles the situation off Durban described for fin whales by Bannister and Gambell (1965) and for sperm whales by Gambell (1967). Best (1969b) has suggested that, for sperm whales at least, such a pattern might arise in response to the prevailing southwesterly movement of the Agulhas Current.

A consideration of monthly changes in the pattern of movement produces no clear-cut trend (Fig. 2). Apart from July, the proportion of northward-moving animals (expressed either as number of whales or number of sightings) fluctuated widely (from 45 to 85%) but showed no clear trend. In July, however, the proportion moving in a northerly direction fell to 30 to 35%. The significance of this drop is not known, but overall there is no suggestion of a reversal in the direction of movement as the season progresses. In both fin and sei whales off Durban, the tendency for a northward movement was less at the end than at the beginning of the season, and in sei whales there was a reversal of movement so that in September the majority of animals were moving in a southerly direction (Bannister and Gambell, 1965). If a general southerly movement of minke whales does occur off Durban then presumably it must take place after September.

The proportion of idling animals amongst minke whales seen from the spotter aircraft was high in March, April and May but low thereafter (Fig. 2). This infers that those animals seen early in the season (before the main influx of

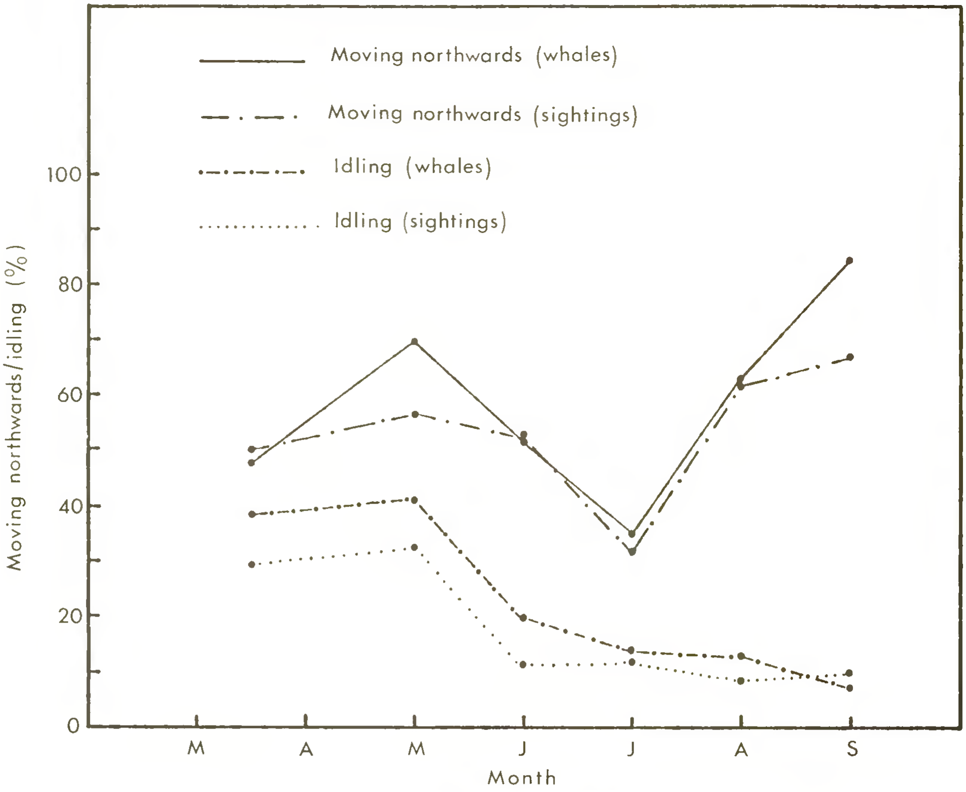

Fig. 2. Proportions of northward-moving and idling minke whales off Durban, 1968–75.

Table 3

Direction of movement of minke whales off Durban (from aircraft sightings only), 1968–75

Direction of movement	March	April	May	June	July	August	September	Total
	Number of animals seen per month (Number of sightings per month)							
NW	1 (1)		2 (2)	5 (2)			3 (1)	11 (6)
N			18 (6)	7 (6)	14 (7)	7 (5)	12 (4)	58 (28)
NE	6 (3)	3 (2)	19 (5)	23 (12)	12 (7)	22 (8)	17 (7)	102 (44)
E			1 (1)	2 (1)	8 (4)	3 (1)	1 (1)	15 (8)
SE			4 (3)	2 (2)	8 (5)			14 (10)
S		8 (4)	7 (4)	19 (10)	17 (15)	3 (2)	3 (3)	57 (38)
SW			4 (1)	7 (3)	15 (6)	9 (3)	2 (2)	37 (15)
W	1 (1)	2 (1)	1 (1)	3 (2)		2 (2)		9 (7)
Idling	1 (1)	12 (4)	39 (11)	17 (5)	12 (6)	7 (2)	3 (2)	91 (31)
Total	9 (6)	25 (11)	95 (34)	85 (43)	86 (50)	53 (23)	41 (20)	394 (187)

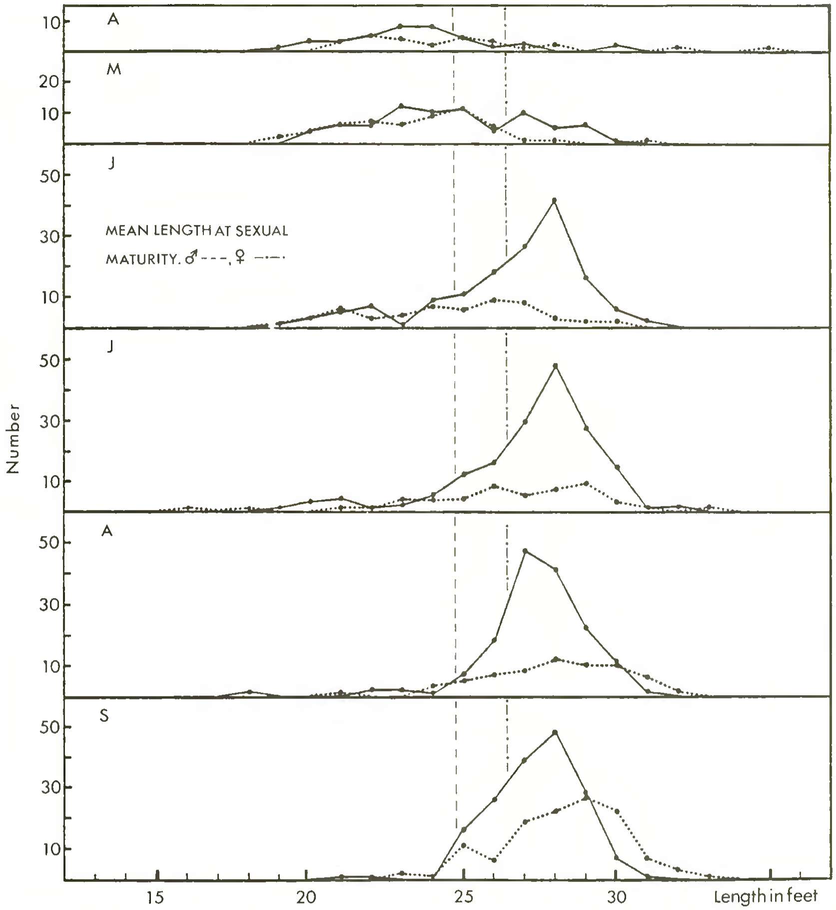

Fig. 3. Monthly length distribution of minke whale catch at Durban, 1968–75.

minke whales took place) were not moving so actively through the whaling grounds as the later arrivals. It will be shown below that minke whales killed during April and May contained a higher proportion of small and immature animals than in subsequent months.

Seasonal size and sex composition of catch

As there was no legal minimum length for minke whales in force at the time, there were theoretically no constraints on the size of minke whale that the Durban whalers could take. As there was also no quota in force in any of the seasons it might be assumed that the catch was a random one and that any minke whale seen was taken. In practice, however, the Durban gunners did exercise some selection in the whales they took. Because the vessels were equipped with 90 mm cannons, for instance, it was clearly not desirable to attempt to take very small minke whales because of the damage that could be caused to the animal (even by a cold grenade). Such targets were also small and difficult to hit, and were therefore avoided: the catch-leader informed me (T. Haakestadt, pers. comm. 20.9.1971) that early in the 1971 season (April/May) he had seen plenty of small minke whales, 15 to 17 feet long, unaccompanied by adults, but that these had been 'too small to take'. It was also clearly uneconomical for a catcher of this size (average gross tonnage 539 to 593 tons) to tow only one or two small minke whales back to the whaling station. Consequently some size selection must have taken place, and the composition of the catch probably does not adequately represent the proportion of smaller animals in the population.

The lengths at which 50% of minke whales off Durban are sexually mature have been estimated below as 24.9 feet for males and 26.6 feet for females. These lengths can be used to provide estimates of the proportions of immature and mature whales in the catch.

In April and May the catch was composed of a large proportion of sexually immature animals, with males slightly predominating (Fig. 3). In June (and subsequent months), however, a large proportion of the catch consisted of mature males, while the proportion of immature males rapidly declined. Although mature females also began to form a larger proportion of the catch in June (but more noticeably from July onwards), males outnumbered females in the total catch by more than 2 to 1 in June, July and August, and it was only in September that the proportions of the sexes more closely approached parity (1.38 males to 1 female). The overall ratio in the catch was 2.02 males to 1 female.

Off Brazil the situation is similar but reversed, i.e. whales taken at the beginning of the whaling season are smaller than later in the season and include a higher proportion of sexually immature animals but in this case in nearly every month females outnumber males, the overall proportion in the catch being 2 females to 1 male (Williamson, 1975).

Some of the preponderance of males off Durban might be attributed to selection, as many of the mature females were lactating. However this obviously cannot account for the reverse situation off Brazil. The northern minke whale is well known as showing marked segregation of the sexes and different size-groups at some times of the year (Jonsgård, 1951), and Kasamatsu and Ohsumi (1981) have described segregation by sexes for the southern minke whale in the Antarctic. In general, males reach the Antarctic before the females, but females occur closer to the ice edge than males. The imbalance in the sexes off both Durban and Brazil may therefore reflect segregation of the sexes during their winter migration.

Williamson (1975) also stated that minke whales of progressively larger sizes enter the whaling area off Brazil each month, and that they depart in the same sequence. The relative abundance of immature minke whales off Durban in April and May, and their subsequent decline as a proportion of the catch, have already been mentioned. In addition to this, however, there are indications that the larger mature females arrive later in the season than the smaller ones. There was in fact a significant correlation from June to September between the sizes of mature females and the month ($r = 0.2922$, $p < 0.005$). Over the same period, however, there was no significant increase in the sizes of mature males ($r = 0.0300$, $p > 0.4$). Inspection of Fig. 4 in Williamson (1975) suggests that similar patterns may apply to the two sexes off Brazil. This suggests that not only is there segregation by sexes during the winter migration but that, for mature females at least, there may also be segregation by size (and presumably age). Ohsumi *et al.* (1970) have proposed that there may be segregation by age in minke whales during the summer in the Antarctic, particularly in males.

Group size

Aerial counts should provide one of the most reliable methods of assessing whale group size. Entries made in the daily diary sheets for minke whales seen from the spotter aircraft have therefore been analysed for group size, omitting those records where it was specifically stated that a group was scattered over a wide area, as these probably referred to accumulations of several units. Single animals were the most commonly encountered unit in nearly every month, with pairs the next most frequent grouping seen (Table 4). Groups of more than 5 whales were rarely found (comprising 3.5% of the total number of groups seen) and the maximum number was 15. No seasonal trends in group size could be detected from the data: there was no significant difference between the incidence of single whales and groups of 2 or more whales in the months April to September (chi-square test, $p > 0.05$, 5 df). The mean group size was 2.08 ± 0.10 (s.e.) whales.

Table 4
Group sizes of minke whales off Durban (from aircraft sightings), 1968–75

No. in group	Number of sightings in each month							
	March	April	May	June	July	Aug.	Sept.	Total
1	5	7	18	28	40	14	18	130
2	2	9	18	23	16	13	7	88
3	1	3	3	5	8	6	8	34
4		3	1	3	5	2	1	15
5		1	1	1	1	1	1	6
6		1				1	1	3
7			1					1
8				1		1		2
9								
10			1					1
11								
12			2					2
13								
14								
15			1					1
Total	8	24	46	61	70	38	36	283

While at sea on whale-catchers on marking cruises or during whaling operations I made observations of minke whale group size (Table 5). These data also include information given directly to me over the radio by the captains of other whale-catchers in response to my queries. The incidence of groups containing calves was also recorded separately. These data cover a somewhat wider time span than the aircraft data, and fall into two periods, August and September and November to April. The incidence of single animals, pairs and groups of 3 or more was significantly different in these two time periods (chi-square test, $p < 0.02$, 2 df). Southern minke whales in subtropical waters therefore seem to be found more often as singles during summer and autumn than in spring, when they tend to form pairs or larger groupings.

Williamson (1975) described the grouping of minke whales off Brazil as 'Many small groups and a few single whales. Most groups are of 4–5 whales'. He also commented that single minke whales appeared early in the whaling season (late June and July) and groups (of 4 to 5 whales) later. Towards the end of the season (November) groups were no longer seen, only pairs and single whales. This description suggests that minke whales off Brazil tended to form larger groups than off Durban in spring, but that the seasonal trend to have smaller groupings in summer and autumn was probably similar to that seen at Durban.

The size of minke whale groups in the Antarctic in summer has been discussed by Ohsumi *et al.* (1970). Between 40° and 50° single whales greatly predominated (66.7% of all schools seen), while between 50° and 60°S pairs predominated and the incidence of single whales fell to 26.4% of schools seen. Ohsumi *et al.* mentioned that there was a tendency for schools to be larger when minke whale density was high, and they suggested that minke whales might associate together more often in high latitudinal feeding areas. They had no data on the maximum number in a school, though between 40° and 60°S no school larger than six individuals was seen among 560 schools encountered.

Best and Butterworth (1980) demonstrated that a bias existed in shipboard estimates of minke whale school size, due to the fact that larger schools were seen at greater distances than smaller schools. After correction for this effect they calculated the mean school size for minke whales in Area IV south of 60°S as 2.41, with single animals as the commonest grouping and a maximum school size of 60. Horwood (1981) found a similar bias in data for Area III, but stratified the data into large schools and small schools rather than attempting to obtain an overall corrected value for mean school size.

Table 5

Group sizes of minke whales in SW Indian Ocean (from personal observations), 1968–75

	Number of sightings in each month								
No. in group	Aug.	Sept.	Nov.	Dec.	Jan.	Feb.	March	April	Total
1	6	6	4	7	5	3	2	2	35
1 + calf	1	3		1	2	2			9
2	6	4	1	1			2	1	15
2 + calf	4	3			1				8
3		1						2	3
3 + calf	1	1							2
4	1								1
4 + calf	1								1
5								1	1
Total	20	18	5	9	8	5	4	6	75

Best and Butterworth (1980) attempted to investigate Ohsumi *et al.*'s (1970) contention that school size increased with density by testing for a significant increase in school size with latitude (without success). Horwood (1981) however tested for a correlation between the average school size in a day and the total number of whales seen per day and found a positive and significant correlation in a subset of the data, lending some support for the hypothesis of Ohsumi *et al.* (1970).

Group composition

While I was at sea off Durban on whale-catchers during August and September 1971 I was able to make observations on the composition of some of the minke whale groupings from which the catchers killed individuals. These were supplemented by observations from other catchers reported to me over the radio at the time the whales were killed. Of particular interest were the groupings where a calf was present (Table 6). Of 14 such groups, 10 had more than one adult present. Of these 10 groups, six had animals killed from them, and all six included at least one mature male. The commonest such grouping encountered at this time of year was in fact one mature male and a female with calf. In addition, five pairs of whales and one trio unaccompanied by a calf were taken in their entirety. Of the pairs, four consisted of a mature male and female together and one of two mature males. The trio consisted of two mature males and a female. Clearly at this time of year (spring) both sexes of minke whales off Durban were in close association.

Table 6

Composition of minke whale groups containing a calf

	August–September		
No. of adults present	No. seen	No. sampled	No. containing mature male
1	4	—	—
2	7	4	4
3	2	1	1
4	1	1	1
Total	14	6	6

By contrast, observations of minke whale groups containing a calf during summer (December–February) in the Southwestern Indian Ocean between 20° and 40°S indicated that only a small proportion was composed of more than the cow and its calf (Table 5). No such groups could be sampled, but it appears that after September the association of mature males with mother–calf pairs must break down rapidly.

According to Budylenko and Pervushin (1972), minke whales encountered in November and December around 30°S (apparently in the Atlantic and Indian Oceans) were alone or in groups of 2–4 animals, usually accompanied by calves.

Off Brazil Williamson (1975) has described the usual composition of minke whale groups as '4 or 5 individuals, which are sometimes of one sex, sometimes mixed sexes. Less frequent pairs of whales are usually one male with one female'. He also stated that about 12 mothers with calf are seen each year, estimated in a table as 3% of mature females. The situation off Durban is different in that groups are smaller and the incidence of mother–calf pairs apparently much higher.

Kasamatsu and Ohsumi (1981) have given details of nine schools of minke whales in the Antarctic from which all members were killed. While males predominated overall (27 out of 40 animals), all but one school contained at least one animal of each sex. Consequently although substantial segregation of the sexes may occur in higher latitudes, it seems that social segregation within individual schools is not complete.

There appears to be a complete absence of lactating minke whales from high latitudes of the Antarctic (Ohsumi and Masaki, 1975). Minke whales accompanied by calves have only been seen twice on the three IDCR cruises in Areas III, IV and V. On 26 December 1980 a calf (estimated at 15 to 16 feet long) was seen in a group of 7 whales, and on 16 January 1981 a calf (estimated at 6 m in length) was seen in a group of 6 whales. As the sightings were fairly close together (at 64°04′S, 155°10′E and 63°43′S, 161°10′E respectively) they could conceivably have been of the same animal. Females may either wean their calves before arriving on the feeding grounds, or remain in lower latitudes during summer. Records of mother–calf pairs in the Southwestern Indian Ocean from December to February (Table 5) suggest that at least some geographical segregation may take place.

Summary and conclusions

Minke whales seem to be present in temperate waters of the Southwestern Indian Ocean throughout the year. During summer and autumn, however a large proportion of this population consists of small, sexually immature animals, and the observed densities north of 40°S are obviously substantially lower than those recorded for the Antarctic. In April and May the abundance of minke whales off Durban began to increase, and it remained at a high level in June, July, August and particularly September. Unlike other baleen whale species off Durban, it was not possible to identify separate northward and southward 'waves' of abundance, or to observe a reversal with time of their direction of movement as recorded from the spotter aircraft. Furthermore the incidence of films of the diatom *Cocconeis ceticola* was high throughout the period June to September and showed no sign of decreasing with time. The catch during the period of highest abundance (June to September) was overwhelmingly composed of mature males, usually outnumbering mature females by more than 2 to 1. There therefore appeared to be segregation by sex during the winter migration, as well as segregation by size (and presumably age) in mature females, as the larger animals arrived off Durban later than the smaller ones. The available evidence thus suggests that the minke whale migration to warmer waters of the Southwestern Indian Ocean in winter is more protracted and less well-defined than the equivalent migrations of fin or sei whales.

Observations of group size and composition in temperate waters indicate that during winter minke whales form larger groupings than they do in summer. In addition, mother–calf pairs in August and September are usually accompanied by at least one mature male, and groups of adults only usually contain animals of both sexes. There is a strong likelihood therefore that pairing takes place during this period. By December, January and February, most mother–calf pairs in temperate waters are unaccompanied by other adults, so it would appear that the pairing season does not continue on into summer. This is supported by the substantial segregation of the sexes seen on the feeding grounds in higher latitudes.

FEEDING

Information on the feeding of southern minke whales outside the Antarctic Ocean is confined to the remarks of Williamson (1975) that off the coast of Brazil 'The stomachs of nearly all the whales are empty. A little krill is found in the stomachs of about 3% of the whales'. In a later table the same author lists data for five minke whales taken in the Southwestern Atlantic, of which four had empty stomachs and one 'some krill'. A single minke whale examined at Donkergat on the west coast of South Africa also had an empty stomach (Best, 1967a).

Extent of feeding

The majority of minke whales examined at Durban had empty stomachs (Table 7). Data for 299 fin, 208 sei and 25 humpback whales examined at Durban (Bannister and Baker, 1967) have been compared with those for the 66 minke whales with undamaged stomachs examined in the present study, and the proportions containing food are not significantly different (chi-square test, $p > 0.3$, 3 df). All four baleen whale species therefore appear to be feeding very little in these waters.

Table 7

Classification of stomach contents of minke whales at Durban, 1971

Month	No. examined	No. damaged[1]	Crustaceans present	Empty[2]	% feeding
August	48	14	4	30	11.8
September	37	5	6	26	18.8
Total	85	19	10	56	15.2

[1] Either cut open or containing blood.
[2] Mostly containing water or mucus.

This is confirmed by the small quantities of food found in stomachs. Although the volume or weight of food in minke whale stomachs was not measured, no single case was found where the stomach could conceivably be termed 'full'. In most cases (as described by Bannister and Baker for other baleen whales species at Durban) any food present was only found in small amounts and often in watery fluid, so that quantitative measurement was impossible without straining the entire contents of the stomach. This was not practicable in the time available on the flensing platform. In retrospect, however, it is estimated that most stomachs containing food could probably have been placed in the class 'few' as used at Donkergat, where such stomachs were assessed as containing on average 4.5 litres of euphausiids (Best, 1967a).

Composition of food

The composition of the minke whale's food in these waters is overwhelmingly euphausiid, these crustaceans being found in all 22 stomachs sampled (Table 8). The principal species were *Thysanoessa gregaria* (7 stomachs) and *Euphausia recurva* (6 stomachs) while other euphausiid species (*E. lucens*, *E. diomedeae*) were only found occasionally (though sometimes in relatively large numbers). No copepods were found, and fish remains were confined to a single larva from one stomach.

The composition of fin and sei whale food at Durban (as determined by Bannister and Baker, 1967) was similar to that of minke whales: the food was almost always crustacean, and the crustaceans sampled were virtually all small euphausiids of which *E. recurva* was by far the commonest species with *T. gregaria* the next most common. *E. diomedeae* and *E. spinifera* were only found once, while *E. lucens* was not recorded at all.

Because of the small numbers of whales found with food in their stomach it is difficult to make statistically meaningful comparisons between the species composition of the food eaten by minke, fin and sei whales off Durban. All that can be compared is the relative incidence of *E. recurva* (including the 'recurva' group of Bannister and Baker) and *T. gregaria* in minke and fin whales. There is no significant difference between the incidence of these two euphausiid species in the two whales (chi-square test, $p > 0.25$, df 1).

Data are now available from a further 14 fin and 4 sei whales landed at Durban between 1968 and 1973. Apart from the stomachs of 3 fin whales and 1 sei whale that contained unidentifiable crustacean remains, the remaining stomachs only contained euphausiids (Table 9). The number of animals examined is too small to make any meaningful comparison with minke whale data, but the

Table 8

Identification of samples of stomach contents from minke whales landed at Durban, 1968–73

Platform no.	Date killed	Length (ft, in)	Sex	Identification of food sample	No. identified	No. present
U 68/911	2 July	21′ 8″	F	*T. gregaria*	(mainly)	—
				E. diomedeae	(many)	—
U 68/953	9 July	27′ 10″	M	*E. recurva*	4	12
U 68/1002	15 July	28′ 4″	M	*E. recurva*	2	19
U 68/1236	25 Aug.	26′ 11″	F	*T. gregaria*	38	±200
				E. recurva	16	
U 68/1354	13 Sept.	29′ 10″	F	*E. recurva*	16	—
U 68/1386	17 Sept.	27′ 2″	M	Crustacean remains	—	—
				Euphausia sp.	1	1
U 68/1393	17 Sept.	27′ 0″	M	*E. lucens*	26	±1,500
U 69/671	27 April	22′ 2″	F	*T. gregaria*	16	±2,000
U 69/926	21 May	27′ 5″	M	Euphausiid remains	—	—
U 69/1131	1 June	25′ 2″	M	Euphausiid remains	—	—
U 69/1135	2 June	21′ 6″	M	Euphausiid remains	—	—
U 71/2081	13 Aug.	26′ 8″	F	*Euphausia* sp. remains	—	—
U 71/2203	29 Aug.	25′ 0″	F	Euphausiid remains	—	—
U 71/2205	30 Aug.	26′ 0″	M	*E. lucens*	1	1
				Euphausia sp. remains	—	—
U 71/2232	31 Aug.	27′ 0″	M	*T. gregaria*	3	3
				E. recurva	2	2
U 71/2246	5 Sept.	23′ 5″	F	Euphausiid remains	—	—
U 71/2253	9 Sept.	25′ 9″	M	*T. gregaria*	2	18
U 71/2307	16 Sept.	29′ 0″	M	*Euphausia ? lucens*	1	1
U 71/2313	16 Sept.	27′ 0″	F	*T. gregaria*	3	3
				Euphausia sp.	1	1
				+ euphausiid remains		
U 71/2316	20 Sept.	30′ 11″	F	Crustacean remains (incl. euphausiids)	—	—
U 71/2317	20 Sept.	30′ 2″	F	*T. gregaria*	2	24
U 73/1824	20 Sept.	29′ 7″	F	*E. recurva*	126	126
				+ many *Euphausia* sp.		
				+ 1 larva of *Etrumeus teres*		

presence of *E. lucens* in fin, sei and minke stomachs is interesting, as this species was not found by Bannister and Baker (1967) in any of the stomachs they examined in 1962 and 1963.

Conclusions

The southern minke whale feeds predominantly on euphausiids both on its summer feeding grounds (Ohsumi *et al.*, 1970) and during its winter breeding migrations. There is no substantial fish component to the diet, in contrast to northern minke whales. As might be expected, the extent of feeding in summer is considerably greater than in winter. The incidence of food in minke whale stomachs in high latitudes of the Antarctic Ocean is about 55% compared to about 15% off Durban, and stomachs clearly contain more food in the Antarctic (Ohsumi *et al.*, 1970).

The question of whether interspecific competition for food occurs between minke and other whales in the Antarctic is not considered here. The species composition of minke, sei and fin whale food off Durban is similar, and although the amounts consumed are small, the significance of any competition for food in these latitudes could be considerable. In a poor summer feeding season, for instance, feeding in lower latitudes might be critical for survival on low energy reserves, especially for lactating females and their young (Lockyer, *in litt.* 18 December 1981).

It is interesting to note that, unlike other baleen whales, female minke whales apparently do not wean their calves on the Antarctic feeding grounds (see above), so that presumably *E. superba* does not play an important part in the diet of the weaned calf. Jonsgård (1951) recorded copepods from seven minke whales 15 to 18 feet long in the North Atlantic, and Ohsumi *et al.* (1970) described *Calanus tonsus* from the stomachs of five minke whales at latitudes 59°33′S and 61°27′S. By being left in lower latitudes it is therefore possible that the newly-weaned calf has to survive on a diet of copepods, small euphausiids or fish. The distribution of calves of this age in the southern hemisphere is not known: in the North Atlantic they are known to be present in large numbers off the west coast of Norway (between about 63° and 69°N) in summer (Jonsgård, 1951). Gambell *et al.* (1975) observed many immature minke whales north of 40°S (and particularly north of 30°S) in the Southwestern Indian Ocean in summer.

Table 9

Stomach contents of fin and sei whales landed at Durban, 1968–73
(figures refer to number of stomachs)

Species	Fin	Sei
E. recurva	1	–
E. lucens	3	1
T. gregaria	1	–
E. recurva + *T. gregaria*	–	1
Euphausia sp. + *T. gregaria*	–	1
Euphausia sp.	6	–

very close to the spot where the minke went down, and an object resembling a dead squid was seen. At 0815 we left the area after trying to harpoon the big male. No blood was seen in the water, though there was a slight oily "slick".'

Jonsgård (1968) has referred to verbal accounts by Norwegian 'small-type' whalers that both minke and bottlenose whales had been caught, the flippers of which had been bitten off by killer whales. While on the *Nisshin Maru No. 3* in 1979, eight instances of flipper damage to minke whales were recorded (Table 10), in all of which the tips of the flippers were missing and the scarring present suggested an attack by killer whales (Fig. 4). In the 161 whales systematically examined, such damage occurred to one or both flippers of 5 whales, or 3.1% of the catch.

Further parallel scarring on the body surface that might be attributable to killer whales was recorded in another six minke whales (Table 10).

Shevchenko (1975) describes similar scarring from sperm, minke, sei and fin whales in the Antarctic, mainly on the flippers and tail flukes, with an incidence for minke whales of 6.4%.

These data suggest that killer whales do occasionally attack minke whales, and may attempt to grasp the flippers as being a convenient means of slowing the fleeing animal. The frequency of success of such attacks is unknown: Mikhalev, Ivashin, Savusin and Zelenaya (1981) list the minke whale as a common food item in the stomachs of killer whales from the southern hemisphere, but it is not clear to what extent their sample may have been affected by scavenging from minke whales taken commercially. Shevchenko (1975) infers from the low percentage of scarred minke whales compared to the other, larger species that practically all the minke whales that are attacked fall victim to the predators.

PARASITES

Apart from diatoms, minke whales landed on the *Nisshin Maru No. 3* were examined for the presence of other ectoparasites. In 160 whales specifically examined, 32 (or 20%) carried cyamids (those from one whale identified as *Cyamus balaenopterae*). Counts made on one side of the animal ranged from 1 to 405, with a mean of 55 ± 18 (s.e.). Most cyamids were found at the extreme posterior end of the ventral grooves or around the umbilicus. Ohsumi *et al.* (1970) found from 5 to 50 *C. balaenopterae* on the ventral grooves of seven Antarctic minke whales, but the incidence of their occurrence was not given.

One *Penella* sp. was found on a 8.0 m female killed 24 January 1979 in 67°04′S 62°02′E. No other ectoparasites were recorded.

A specific search for endoparasites was not undertaken, but the presence of numerous adult cestodes in the intestine appeared to be very common. One example was identified as *Tetrabothrius affinis*.

REPRODUCTION

Williamson (1975) has summarized the evidence for either a one-year or a two-year reproductive cycle for female minke whales. Observations in the Antarctic in summer have revealed a very high pregnancy rate amongst mature females (89.5%) but a complete absence of lactating females: the ovulation rate (assuming that one ear plug growth layer is laid down per year) has been estimated as 0.866 per year (Ohsumi and Masaki, 1975). Observations off Brazil in winter, however, have apparently indicated a complete absence of pregnant females and a very low proportion (3%) of lactating females (Williamson, 1975). Clearly the segregation of sexes and size-groups characteristic of this species (Jonsgård, 1951; Ohsumi and Masaki, 1975) may be affecting the composition of the catch, but as Williamson (1975) has pointed out, detailed examinations of the reproductive condition of mature females in warmer waters during winter might provide the data needed to clarify the controversy surrounding the reproductive cycle of the species.

Table 10

Possible killer whale scarring on minke whales, *Nisshin Maru No. 3*, 20.1–17.2.79

Platform no.	Length (m)	Sex	Remarks
			Flipper damage
1640	8.1	F	Right flipper tip bitten off and healed. Two sets of three parallel scars with spacing 3.5–4 cm.
1896	8.9	F	Left flipper tip missing. Wound healed long time and 'tooth' scars may be defaced. Spacing 3–5.5 cm.
1968	8.8	F	Right flipper abbreviated and carrying scars almost identical to no. 1896.
1984	9.0	F	Right flipper abbreviated and with similar scars (healed) to nos 1640, 1896 and 1968. Left flipper not abbreviated.
2187	9.0	F	Right flipper abbreviated, 'tooth' marks only obvious at tip.
2192	8.9	F	Right flipper abbreviated. 'Tooth' spacing 3–4 cm. Other flipper also damaged.
2262	8.4	M	'Tooth' marks on right flipper. Maximum spacing 3.5 cm. Left flipper also abbreviated. Maximum 'tooth' spacing 4.5 cm.
2285	7.9	M	Damaged left flipper tip. Other flipper undamaged.
			Other damage
1529	7.6	F	4 parallel scars on left side anterior to dorsal fin *c.* 3.5 cm apart.
1545	9.1	F	2 parallel scars on right flank, spacing 4.5 cm.
1562	7.8	M	Possible killer whale tooth marks by blowhole; 4 parallel scars 1.9 cm apart.
1979	7.9	F	Old scars on left flank, possibly from killer whale. Roughly parallel, average 2.5 cm spacing.
2070	9.0	F	Left flank scarred with long parallel lines, maximum spacing (just below dorsal fin) of 10 cm.
2265	8.7	M	Possible killer whale scars on left peduncle, maximum spacing 4 cm.

Size at sexual maturity

Females were classified as sexually mature if they possessed a corpus luteum or one or more corpora albicantia in the ovaries, or (if the ovaries had not been collected) they were recorded as lactating. Animals from which only one ovary had been collected were classified as mature if it contained at least one corpus luteum or albicans, but were omitted from consideration if that ovary bore no corpora. Data are available for a total of 220 females.

Three whales were sexually mature at exceptionally small sizes. One at 21 feet had two ovarian corpora, and two at 24 feet had three ovarian corpora. Of these animals two (one at 21 feet and the other at 24 feet) were individuals with atypical flipper coloration, and the third was also atypically pigmented in that it carried an unusually high proportion (68%) of white baleen plates on the left side of the head and a black outer border to one of its longest baleen plates that comprised less than 10% (7%) of the width of the plate. These colour forms of the southern minke whale will be described in a separate paper, but the above evidence suggests that they reach puberty at a smaller size than typical southern minke whales. The three females mentioned have consequently been omitted from subsequent analysis.

For the remaining 217 females the length at which 50% of animals were sexually mature and 50% immature can be interpolated on Fig. 4 as 26.6 feet. This is very close to the values of 26.2 feet, 26.5 feet and 26.2–26.6 feet (8.0–8.1 m) given by Ohsumi and Masaki (1975), da Rocha (1980) and Doroshenko, Kuzmin, Nikolsky and Patsenko (1974) respectively.

Because only a very small proportion of the landed catch consisted of pregnant females, it proved impossible to identify any primigravid females. The length at first parturition cannot therefore be determined from these data.

Males were classified as sexually mature if spermatozoa were present in one or more of the seminiferous tubules examined histologically. Individuals in which the sample of testis examined contained both immature and mature tubules were classified as mature. Data are available for a total of 345 males.

In 91 minke whales landed during 1968 and 1969, samples were taken from both the dead-centre and periphery of the testis (positions *a* and c_2 in Best, 1969a). The histological appearance of these samples was classified as either immature, immature (maturing), mature (maturing) or mature (Table 11). Those classified as immature (maturing) had no tubules containing spermatozoa but some with an expanded lumen and signs of early spermatogenesis. Those classified as mature (maturing) had at least one tubule containing spermatozoa but also possessed tubules in an immature condition. In 84.6% of cases there was no difference between the classification of the testis at the centre or the periphery, while in 9.9% of cases the centre and in 5.5% of cases the periphery was classified as more advanced in development. Thus the minke whale does not seem to show the gradient of maturation from the centre of the testis described for the sperm whale (Best 1969a).

Table 11

Comparison of maturation status of the centre and periphery of minke whale testes, Durban, 1968–9

		Centre			
		Immature	Immature (maturing)	Mature (maturing)	Mature
Periphery	Immature	12	5		
	Immature (maturing)				
	Mature (maturing)			2	4
	Mature			5	63
Total		12	5	7	67

Four whales were sexually mature at exceptionally small sizes. All were between 22 feet and 22 feet 5 inches long and had combined testes weights of 1,220 to 1,980 g (mean 1,595 g). Three of these had similar atypical flipper coloration to that described above for females, while the fourth had an unusually narrow black stripe to the largest baleen plate of its left series (measuring 6% of the basal width of the plate). It is assumed that all four animals belonged to the same diminutive colour form described above for females, and so they have been omitted from subsequent analysis.

For the remaining 341 males the length at which 50% were sexually mature can be interpolated on Fig. 5 as 24.9 feet. This apparently corresponded to a combined testes weight of 1–1.25 kg (Table 12).

Table 12

Weight and maturity of testes in 205 minke whales landed at Durban

Combined testes weight[1] (g)	Number examined	Per cent mature
0–240	3	0
250–490	9	0
500–740	1	0
750–990	4	0
1,000–1,240	6	66.7
1,250–1,490	7	100
1,500–1,740	7	85.7
1,750–1,990	13	84.6
2,000–2,240	17	88.2
2,250–2,490	13	100
2,500–2,740	15	93.3
2,750–2,990	13	100
3,000–3,240	21	100
3,250–3,490	14	100
3,500–3,740	5	100
3,750–3,990	7	100
4,000–4,240	14	100
4,250–4,490	13	100
4,500–4,740	8	100
4,750–4,990	5	100
5,000+	10	100

[1] For four immature and six mature animals weight of single testis available was doubled.

The length at sexual maturity for male minke whales in the Antarctic has been given as 23.6 feet (Ohsumi and Masaki, 1975), but this was based on the frequency distribution of testis weights and not histological criteria. A larger testis weighing 0.4 kg was taken as indicating a mature animal, presumably equivalent to a combined testes weight of slightly less than 0.8 kg. In a similar analysis to Ohsumi and Masaki's, da Rocha (1980) found a transition weight of 600 g for the larger testis, and a body length at maturity of 25 feet.

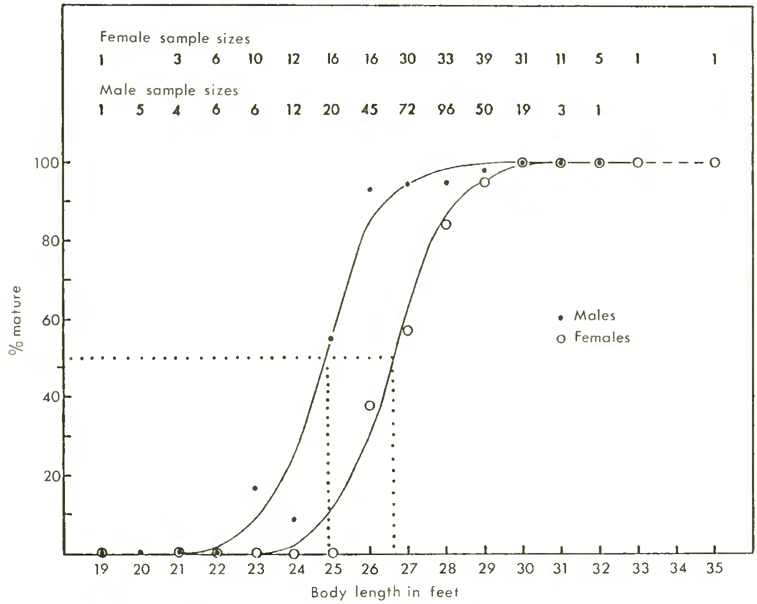

Fig. 5. Body length and proportion of mature minke whales at Durban, 1968–75.

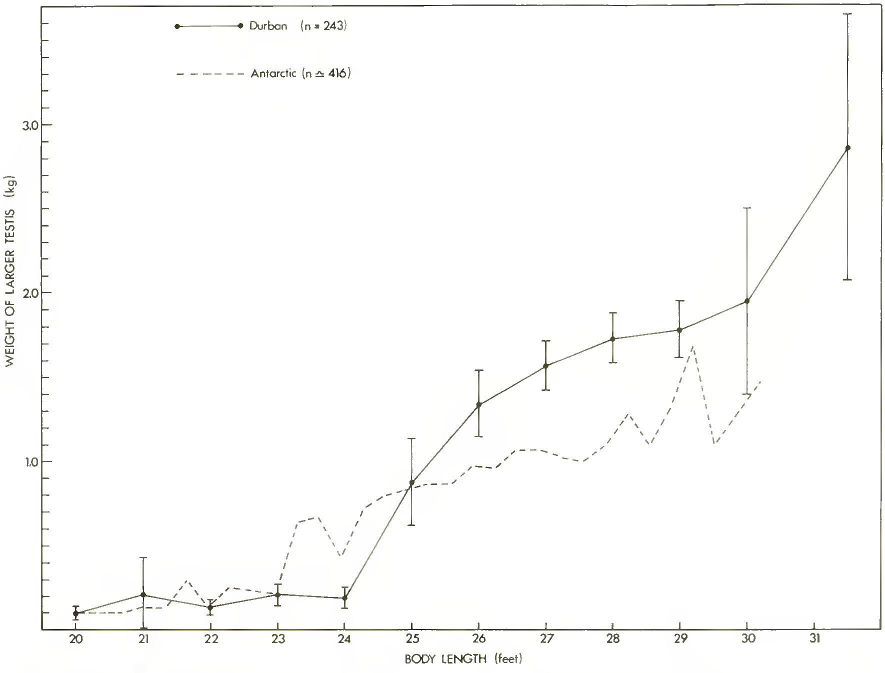

Fig. 6. Testis weights in minke whales at Durban and in the Antarctic (vertical bars indicate ± 2 s.e. of the mean).

In Fig. 6 the mean weights of the larger testis are plotted against body length for minke whales in the Antarctic (from Ohsumi *et al.*, 1970) and at Durban. For mature males (i.e. over 25 feet in length) the mean testis weight at each body length was higher at Durban than in the Antarctic, by an average of about 40%. This suggestion of seasonal activity in the testis needs histological confirmation.

Occurrence of different reproductive classes in the population

Mature females examined were classed as pregnant (presence of foetus in uterus), lactating (presence of milk in mammary gland), recently ovulated (presence of small corpus luteum with loosely-packed luteal tissue in ovaries, no foetus) or resting (no foetus, no milk in mammary glands and no corpus luteum). Strictly speaking, some of the whales classed as recently ovulated may have been in very early stages of pregnancy (e.g. with unimplanted blastocysts), as it is practically impossible to detect these macroscopically under field conditions. From an inspection of the data it seemed that there was serious under-representation of lactating animals in the data collected by the inspectors compared to those collected in 1970 and August and September 1971 by technicians. This might have resulted in part from the special scientific permits for lactating females in force at the time that the technicians made their collections (see below). However as the effect of these permits was probably to produce a catch that was a somewhat less biassed sample of the population at large, the data collected by the technicians are considered to be the best available approximation of the reproductive composition of the population.

Nevertheless, in order to make the most efficient use of the data, two separate analyses of the catch have been carried out. In the first the incidence of females that had recently ovulated was calculated using ovarian data only (Table 13). Because this analysis avoided having to make decisions regarding the state of the mammary glands, material collected by the inspectors could be included. The most striking feature of this table was the very low incidence of pregnant females. Apart from the individual whose ovaries were collected, only one other pregnant animal was recorded amongst the 367 females landed. Both animals carried large foetuses (6 ft 6 ins male and 8 ft 5 ins female), were not lactating, and were killed in June. Clearly the majority of pregnant females with detectable foetuses did not enter the range of the Durban catchers during the whaling season.

Table 13

Reproductive condition of mature females, based on ovary examinations only

Reproductive condition	Number examined in each month (per cent examined in each month)						
	April	May	June	July	Aug.	Sept.	Total
Pregnant	0	0	1 (20.0)	0	0	0	1 (0.9)
Recently ovulated	1 (100)	0	2 (40.0)	7 (38.9)	26 (74.3)	33 (67.3)	69 (63.3)
Non-preg., non-ov.	0	1 (100)	2 (40.0)	11 (61.1)	9 (25.7)	16 (32.7)	39 (35.8)
Total	1	1	5	18	35	49	109

Females that had recently ovulated were recorded in every month from April to September except May, with an overall proportion of 63.3% (Table 13). The highest incidence was in August, when nearly three quarters of the mature females examined had recently ovulated. It should be stated here that it is not clear whether these females were still fertile or whether they had already conceived or failed to be fertilised. Consequently although the incidence of such females during the Durban season seemed to be at its highest in spring (August/September), the timing of the actual peak of the pairing season might be somewhat earlier than this. However the frequency with which adult males were found accompanying mother–calf pairs at this time of year (see above) suggests that actual pairing was still in progress during August and September.

Ohsumi *et al.* (1970) did not mention the timing of the breeding season for southern minke whales but inferred that there was six months difference between the northern and southern hemispheres. As pairing takes place in the northern minke whale from January to May (Jonsgård, 1951), the southern minke whale pairing season may extend from June to November.

Doroshenko *et al.* (1974) believed that mating in southern minke whales was protracted over several months but reached a peak from late October to early December, apparently based on an increase in testis weight at that time. Their conclusion, however, does not agree well with the pattern of foetal growth illustrated by Ivashin and Mikhalev (1978), who estimated that the peak of the mating season occurred at the end of August. The Durban data tend to support the latter estimate.

Table 14

Incidence of reproductive classes amongst mature females examined at Durban in 1970 and August and September 1971

Reproductive class	Number examined in each month (Per cent examined in each month)						
	April	May	June	July	Aug.	Sept.	Total
Pregnant	—	—	—	—	—	—	0 (0)
Recently ovulated	—	—	—	1[1] (33.3)	5[1] (22.7)	2 (7.4)	8 (15.1)
Recently ovulated and lactating	1 (100)	—	—	—	13 (59.1)	13 (48.2)	27 (50.9)
Lactating	—	—	—	2 (66.7)	1 (4.6)	10 (37.0)	13 (24.5)
Resting	—	—	—	—	3 (13.6)	2 (7.4)	5 (9.4)
Total	1	—	—	3	22	27	53

[1] Of which one animal had ovulated for the first time.

The second analysis of the reproductive composition of the catch depends on an accurate assessment of whether the mammary glands contained milk or not, so only the technicians' observations could be used (Table 14). This analysis shows that besides a high proportion of recently ovulated animals in the catch (66% overall), the majority of animals were also lactating. Excluding those females known to have ovulated for the first time (i.e. with only a corpus luteum in the ovaries), the proportion of lactating animals overall was 78.4%. This figure may well underestimate the true proportion of the mature female population off Durban that was lactating at this time of year because, despite the existence of special scientific permits for the taking of lactating females, the gunners still had personal objections to taking such animals (see Material and Methods).

Table 15

Lactating minke whales killed under special permit, Durban, 1970, 1971

Whale no.	Date killed	Length (feet and inches)	Depth mammary gland (cm)	Milk present	Diameter corpus luteum (cm)	Diameter largest corpus albicans (cm)	Diameter largest Graafian follicle (cm)	Corpora count	Diameter uterine cornua (cm)	Foetus present	Ear plug growth layers	Calf, length and sex (feet and inches)
1638	12.8.70	29′ 4″	—	No	—[1]	—[1]	—[1]	—[1]	6: 7	No	26?	Escaped
1676	18.8.70	29′ 8″	2.5[2]	Yes	None	2.35	2.60	19	20:22	No	28	Est. 6–7′
1677	18.8.70	28′ 5″	7.0	Yes	4.00	3.35	1.75	13	13:14	No	—	13′ 4″ ♀
1679	18.8.70	31′ 0″	9.0	Yes	—[1]	—[1]	—[1]	—[1]	18:22	No	18	Est. 9–10′
1736	24.8.70	27′ 1″	13.0	Yes	4.70	4.50	1.65	17	15:18	No	—	14′ 0″ ♀
1911	17.9.70	28′ 7″	12.0	Yes	—[1]	—[1]	—[1]	—[1]	11:13	No	12+	Est. 7′
1912	17.9.70	30′ 6″	8.0	Yes	—[1]	—[1]	—[1]	—[1]	13:15	No	15+	Est. 8′
1915	17.9.70	28′ 2″	10.0	Yes	—[1]	—[1]	—[1]	—[1]	15:20	No	23	Est. 7′
1962	22.9.70	29′ 0″	8.0	Yes	3.17	4.95	1.95	11	17:19	No	—	Est. 9–10′
1966	22.9.70	30′ 3″	8.0	Yes	4.05	3.80	1.55	11	16:18	No	—	Est. 6–7′
1986	23.9.70	29′ 7″	—	Yes	3.83	4.80	1.00	4	—	No	26	Est. 12–14′
1987	23.9.70	28′ 2″	—	Yes	2.80	4.15	1.70	5	—	No	17?	Est. 7–8′
1952	7.8.71	28′ 2″	6.5	Yes	3.13	3.50	1.25	9	11:11	No	14	Est. 8′
1969	8.8.71	29′ 0″	8.5	Yes	5.77	3.00	2.20	11	13:15	No	12?	Est. 10–11′
2073	12.8.71	30′ 0″	12.0	Yes	3.17	3.10	1.60	9	12:17	No	7+?	Est. 8–10′
2095	14.8.71	29′ 2″	12.0	Yes	3.13	3.73	1.85	19	13:16	No	24	Est. 6′
2143	24.8.71	27′ 5″	8.5	Yes	2.47	4.10	1.05	4	19.5:19.5	No	16?	12′ 1″ ♂
2199	28.8.71	31′ 1″	10.0	Yes	2.60	3.10	1.70	18	16:18	No	31	Est. 11–12′
2247	5.9.71	28′ 0″	8.0	Yes	None	3.70	1.40	5	14:14	No	18	Est. 6–7′
2316	20.9.71	30′ 11″	12.0	Yes	3.60	2.80	1.80	5	13:13	No	14	Est. 15–16′
2327	22.9.71	28′ 1″	10.0	Yes	2.57	3.13	1.50	19	16.5:16.5	No	26	Est. 10′

[1] Ovaries lost.

[2] Incomplete gland.

Most of the females that had recently ovulated were also lactating. Excluding females that had ovulated for the first time, 81.8% were also lactating.

Finally, the proportion of resting females in the catch was extremely low (9.4% overall).

To summarize, the virtual absence of pregnant females from the catch indicates that segregation of this class must take place. Secondly, it is clear that ovulations can occur during the autumn and winter but are most frequent in spring. The majority of animals are still lactating when ovulation takes place. This factor, plus the very low incidence of resting animals, seems to favour the suggestion that southern minke whales normally reproduce annually. However the timing of ovulation in relation to the stage of lactation is obviously crucial in deciding on the rate of reproduction, i.e. does ovulation take place at the end of an extended lactation period (inferring that the reproductive cycle must occupy substantially more than one year), or near the beginning of a shorter period (inferring that the female may be able to calve annually)?

Timing of ovulations during lactation

It was mainly to answer the above question that the South African Department of Industries issued special scientific permits for the taking of lactating females and their calves in 1970 and 1971 (see Material and Methods). A total of 21 such females and three of their calves were taken (Table 15). Relevant information was also available from lactating females accidentally taken at Durban from the 1968 season onwards.

The largest corpus albicans in a lactating female must represent the regressing corpus luteum of the previous pregnancy (provided that there have been no post-partum ovulations). Consequently the size of the largest corpus albicans in a lactating female provides a measure of the degree of regression of the corpus luteum of pregnancy and hence of the relative stage of lactation.

I have been unable to trace any published figure for the mean size of the corpus luteum of pregnancy in minke whales. The only pregnant minke whale at Durban whose ovaries were collected had a corpus luteum 5.8 cm in diameter (after fixation). Corpora lutea measured fresh on the *Nisshin Maru no. 3* in 1978/79 averaged 6.64 ± 0.10 (s.e.) cm in 84 pregnant females examined. Lockyer (*in litt.* 18 December 1981) has measured the mean size of 38 corpora lutea from formalin-fixed minke ovaries from the Antarctic as 6.55 ± 0.12 (s.e.) cm.

The diameter of the largest corpus albicans in 26 lactating minke whales that were also ovulating ranged from 2.05 to 4.67 cm with a mean of 3.44 ± 0.12 (s.e.) cm. This represents a regression to 52.5% of the mean size of a fixed corpus luteum of pregnancy. The mean size of the largest corpus albicans in late lactation was estimated as 41% of the mean size of the sei whale corpus luteum of pregnancy in late pregnancy (Gambell, 1968), and 40% of the corpus luteum of pregnancy in inshore Bryde's whales (Best, 1977). Although regression of the corpus luteum of pregnancy is rapid immediately after parturition but much slower later in lactation (Gambell, 1968), the comparatively small size of the largest corpus albicans in minke whales that had recently ovulated and were simultaneously lactating indicates that ovulation occurred later in lactation rather than earlier.

According to Masaki (1976), the depth of the mammary gland forms the best indicator of the stage of lactation. A comparison of the depth of the mammary gland in lactating, resting, pregnant and immature females is given in Table 16. This represents a combination of Antarctic data (for all pregnant and most immature animals) and Durban data (for all lactating and most resting/ovulating

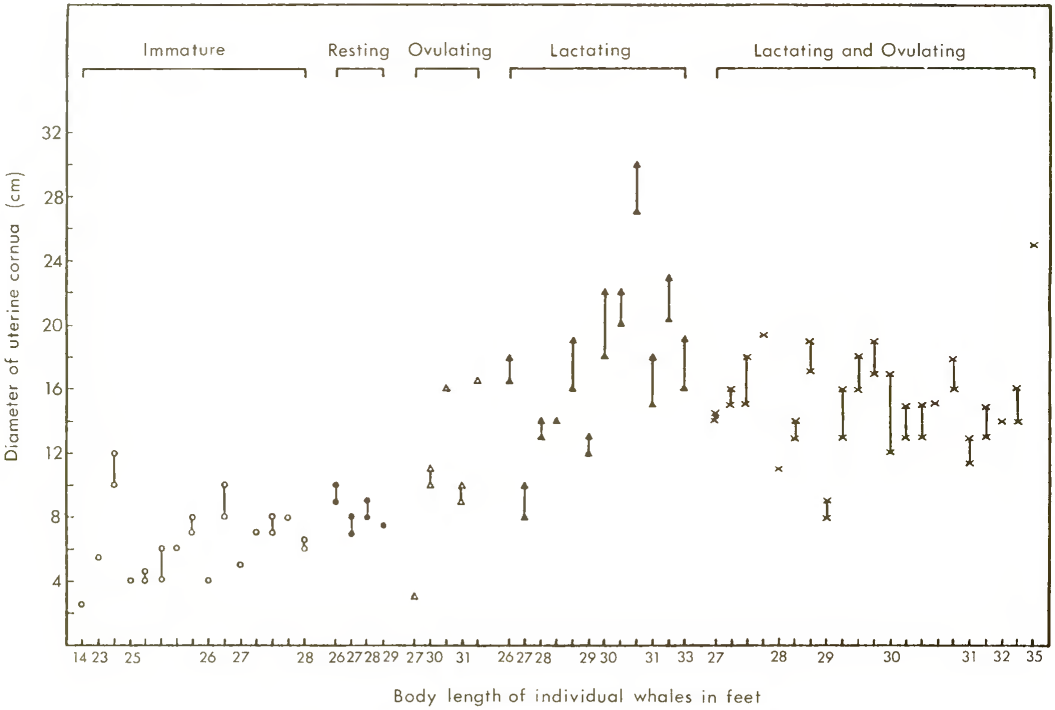

Fig. 7. Diameter of uterine cornua in minke whales at Durban.

Table 16

Depths of mammary gland in minke whales, Durban and Antarctic data combined

Mammary gland depth (cm)	Immature	Primi-gravid	Multi-gravid	Ovulating/resting	Lactating
0.6–0.7	1				
0.8–0.9	1				
1.0–1.1	10				
1.2–1.3	6				
1.4–1.5	5	5	1		
1.6–1.7	1	2	5		
1.8–1.9	2	1	11		
2.0–2.1	2	2	14	1	
2.2–2.3			11		
2.4–2.5	1		10	2	
2.6–2.7			7	1	
2.8–2.9			6		
3.0–3.1			7	3	
3.2–3.3			2		
3.4–3.5			1		
4.0					1
5.0					
6.0					3
7.0					3
8.0					8
9.0					4
10.0					5
11.0					6
12.0					5
13.0					4
14.0					1
16.0					1
Total	29	10	75	7	41

females). Lactation seems to finish when the gland is 3.5 to 4 cm deep. The depth of the gland in 23 lactating and ovulating females ranged from 4 to 13 cm with a mean of 9.5 cm. As this covers almost the entire range of depths observed for lactating females, and with a similar mean (9.5 cf. 9.8 cm), it is not clear from these data at what stage of lactation ovulation occurs.

Samples of milk were collected for analysis from 33 lactating female minke whales at Durban in 1970 or 1971 (Table 17). Total solids ranged from 23.1–75.3% (mean 45.9 ± 2.1%), fat from 4.8–61.7% (mean 24.4 ± 2.1%), protein from 5.3–17.1% (mean 13.6 ± 0.5%) and ash from 0.7–2.3% (mean 1.6 ± 0.1%). The milk of 17 ovulating females had a significantly lower fat content than that of 9 non-ovulating females (21.5 ± 2.5% vs 33.4 ± 4.6%, $t = 2.48$, $p < 0.025$), and a significantly higher ash content (1.8 ± 0.1% vs 1.4 ± 0.2%, $t = 2.62$, $p < 0.02$). The nature of changes in the composition of milk during lactation are unknown for whales, so that the significance of these differences cannot be established at present.

That ovulation did not occur immediately post-partum is indicated by the diameter of the uterus (Fig. 7). In 21 females that had recently ovulated and were also lactating, the maximum difference in size between the two cornua was a larger horn 1.42 times the diameter of the smaller: the average difference was a larger horn 1.11 times the diameter of the smaller. Clearly the asymmetry would have been much greater if ovulation had occurred shortly after the birth of the calf: in two post-partum gray whales the cornu that had contained the foetus was just over twice the diameter of the other (Rice and Wolman, 1971).

Table 17

Composition of milk from lactating minke whales landed at Durban

Platform no.	Length	Date killed	MG depth (cm)	% total solids	% fat	% protein	% ash
1317	26′ 4″	9.7.70	—	41.9	28.1	11.7	0.8
1676	29′ 8″	18.8.70	—	27.7	8.2	17.1	0.8
1677	28′ 5″	18.8.70	7	50.1	28.9	13.0	2.0
1679	31′ 0″	18.8.70	9	58.3	38.0	14.7	2.0
1696	30′ 5″	19.8.70	11	24.0	8.1	12.7	1.9
1736	27′ 1″	24.8.70	13	40.3	19.7	16.3	2.0
1743	27′ 0″	27.8.70	13	31.9	11.3	16.9	2.2
1856	30	10.9.70	8	52.1	32.5	15.0	1.8
1857	31	10.9.70	10	50.4	30.1	15.6	1.9
1866	28′ 3″	15.9.70	16	53.5	35.3	13.9	1.7
1911	28′ 7″	17.9.70	12	31.1	10.5	14.0	1.9
1912	30′ 6″	17.9.70	8	23.1	16.2	5.3	0.8
1915	28′ 2″	17.9.70	10	46.8	23.1	16.2	2.0
1916	29′ 0″	18.9.70	13	38.7	18.4	14.8	1.9
1918	28′ 0″	18.9.70	14	31.4	13.2	15.6	2.3
1923	28′ 11″	19.9.70	11	47.5	28.2	14.5	1.8
1962	29′ 0″	22.9.70	8	55.7	36.3	15.4	1.9
1966	30′ 3″	22.9.70	8	63.5	43.2	15.7	2.1
1987	28′ 2″	23.9.70	—	48.3	29.8	14.6	1.7
2000	28′ 9″	26.9.70	9	49.7	36.3	10.2	0.8
2001	26′ 10″	26.9.70	11	52.1	39.1	9.9	1.3
2017	32′ 11″	28.9.70	6	75.3	61.7	10.9	1.3
2028	28′ 2″	28.9.70	11	50.2	28.9	15.3	1.8
1969	29′ 0″	8.8.71	8.5	51.4	20.0	15.7	1.1
2095	29′ 2″	13.8.71	12	44.1	12.8	9.7	1.3
2138	26′ 3″	24.8.71	6.5	37.2	20.0	8.1	0.7
2143	27′ 5″	24.8.71	8.5	37.4	17.2	15.7	2.0
2196	29′ 8″	28.8.71	8	58.0	30.0	12.1	1.9
2231	31′ 6″	31.8.71	11	58.1	22.8	14.2	1.7
2308	30′ 9″	16.9.71	4	28.8	4.8	12.5	1.0
2313	27′ 0″	16.9.71	10	53.6	12.0	14.8	1.7
2316	30′11″	20.9.71	12	55.1	22.4	11.9	1.9
2327	28′ 1″	22.9.71	10	46.7	17.2	14.4	1.9

Ovulations usually alternated between ovaries. In 26 females that had recently ovulated and were simultaneously lactating, 18 had the corpus luteum of ovulation in the opposite ovary to the largest corpus albicans. This proportion differed significantly from parity (chi-square test, $p < 0.05$, 1 df). Nevertheless the failure to maintain a consistent alternation between ovaries must mean that a period of recuperation for the uterus after parturition is essential if maximum fertility is to be obtained from subsequent ovulations. Consequently one would not expect ovulation to follow rapidly upon parturition.

It is thus difficult to estimate accurately the interval between parturition and ovulation. Perhaps the best index of the length of this period is the size of the calves accompanying females simultaneously ovulating and lactating.

Only three such calves were taken at Durban under special permit. These were a 13 feet 4 inches female killed on 18 August, a 12 feet 1 inch male and a 14 feet female killed on 24 August (Table 15). The mean length of these three animals was 13 feet 2 inches (4.01 m).

There is still uncertainty regarding the size of the southern minke whale at birth, due mainly to the scarcity of published records of minke whale calves. In Table 18 four published records of small minke whales are combined with 11 unpublished records, all but one from South Africa. Of those animals known to be newborn (i.e. with an unhealed umbilicus), sizes range from 1.92 to 3.01 m: the smallest of these however was a calf with the atypical colour pattern mentioned above, and these animals are believed to be significantly smaller than the normal southern minke whales. Davies and Guiler (1958) considered it likely that their newborn calf 2.16 m long was a premature birth, but other animals of a similar size have been found stranded. It is impossible from these data to determine the mean size at birth. Certainly the dates on which small minke whale calves have been recorded vary widely, from May through October, indicating a quite protracted calving season.

Ohsumi and Masaki (1975) estimated the length at birth of southern minke whales from analogy with northern minke whales as 2.7 to 2.9 m. Ivashin and Mikhalev (1978) calculated the length at birth as 2.80 m, assuming that birth occurs at 90% of the length of the largest foetus. A further estimate can be obtained using a regression equation between body length at sexual maturity in the female and body length at birth for several *Balaenoptera* species given by Ohsumi (1966). Assuming a length at sexual maturity of 8 m, the length at birth can be calculated as 2.73 m.

If the length of 2.73 m is accepted as the size at birth, it is clear from the size of the calves accompanying recently-ovulated females that ovulation must have occurred some considerable time after birth.

Growth rates of suckling calves are available for four species of baleen whales (Table 19). In the case of the humpback whale the size of the calf at weaning has been estimated from the size of two 'yearling' calves 28 feet 9 inches and 29 feet 3 inches in length killed in June: Chittleborough (1958) states that most young humpback

Table 18

Southern minke whale calves

Date	Length (m)	Sex	Colour phase[1]	Umbilicus	State	Locality/Source
6.8.1900	3.05	F	N	—	—	Benham (1901)
20.9.1907	2.10	—	—	—	—	Lahille (1908)
7.6.1957	2.16	F	N	Unhealed	—	Davies and Guiler (1958)
19.5.1958	2.29	M	—	—	—	Gaskin (1968)
1.7.1969	2.16	F	A?	—	—	Hapukea River mouth, NZ (L. Bowring, pers. comm.)
15.5.1972	1.92	M	A	Unhealed	Alive	Kommetjie, Cape Peninsula
17.10.1973	3.01	F	N	Unhealed	Alive	Kasouga River mouth, E. Cape
12.10.1975	3.77	F	N	Healed	Pres. alive	St Helena Bay, Cape
12.10.1976	3.53[2]	M	N	Healed?	Alive	7 km E of Arniston, Cape
18.9.1976	3.43	F	N	Healed?	Alive	Blue Horizon Bay, Van Staden's River, E. Cape
17.7.1978	3.53	M	N	Healed	Alive	Table Bay harbour, Cape Town
20.12.1979	3.49	M	—	—	Pres. alive	Durban shark nets, Natal
21.7.1980	2.54	M	A	Healed	Alive	Gordons Bay, False Bay, Cape
22.9.1980	3.41	M	N	Partly healed	Pres. alive	Salt Rock shark nets, Natal
20.9.1981	3.45	F	N	Partly healed	Pres. alive	Olifantsbar, Cape Point Nature Reserve

[1] N = normal, A = atypical.

[2] Approximate length—animal cut up.

calves are weaned towards the end of June or the beginning of July. The growth rates given in Table 19 are averages assuming that growth in length throughout the suckling period is uniform. Evidence from a gray whale calf kept in captivity from about 2½ months to 14 months of age is in reasonable agreement with this assumption (Wahrenbrock, Maruschak, Elsner and Kenney, 1974). There is a good correlation between the growth rates for the four species and the lengths of the female at sexual maturity ($r = 0.9644$), and a regression has been fitted to the data by the method of least squares, giving the estimating equation

$$y = 0.1516 + 0.1433x$$

where x = length of the female at sexual maturity (m) and y = growth rate of the calf (cm/day). If this regression is extrapolated to the size of the minke whale at sexual maturity (8 m) the growth rate of the calf can be estimated as 0.995 cm/day.

If the minke whale calf grows on average 1 cm a day while it is suckling, the mean age of the three calves killed under special permit can be calculated as

$$\frac{4.01 - 2.73}{0.01} \text{ or 128 days.}$$

Table 19

Growth rates of baleen whale calves during lactation

Species	Growth rate	Source
Blue	3.45 cm/day	Lockyer (in press)
Fin	2.4 cm/day	Lockyer (in press)
Gray	Length at birth 4.9 m	Rice & Wolman (1971)
	Length at weaning 8.5 m	Rice & Wolman (1971)
	Length of lactation 7 months	Rice & Wolman (1971)
	∴ Growth rate 1.71 cm/day	
Humpback	Length at birth 4.27 m (14 ft)	Chittleborough (1958)
	Length at weaning 8.84 m (29 ft)	(see text)
	Length of lactation 10½ months	Chittleborough (1958)
	∴ Growth rate 1.45 cm/day	

On this basis, ovulation must have occurred about 4 months after the birth of the calves, and the mean date of parturition for these three animals would have been in the latter half of April. Ivashin and Mikhalev (1978) estimated (using 2.8 m as the size at birth) that the peak of the calving season in southern minke whales was in early June.

It remains to establish whether the three females whose calves were taken were typical of the recently ovulated animals that were simultaneously lactating. (It should be noted here that although most of the calves accompanying lactating females taken under special permit were estimated by the catcher crew to be smaller than the three taken (Table 15), such estimates of the size of calves were in my experience very unreliable.) The mean size of the largest corpus albicans in the three recently ovulated females whose calves were killed (3.95 ± 0.21 (s.e.) cm) was not significantly different from the mean size of the largest corpus albicans in lactating and recently ovulated females whose calves were not taken (3.37 ± 0.13 (s.e.) cm) (t-test, $p > 0.1$, 24 df). Furthermore, the depth of the mammary gland in these three females averaged 9.5 cm, which (as has been shown above) was identical to the mean for all lactating and ovulating females. Consequently it can be assumed that the conclusions on the timing of the post-partum ovulation reached from an examination of the three mother–calf pairs can be considered as applicable to the group of simultaneously lactating and ovulating females as a whole.

Conclusions and discussion on the reproductive cycle of the female

Ivashin and Mikhalev (1978) have described the foetal growth of Antarctic minke whales over a period of about 3½ months by fitting a power function to the modes of smoothed frequency distributions of foetal lengths. If, as the authors suggested, a birth length of 2.8 m is adopted, this function provides a calculated gestation period of 288 days, or about 9½ months. Ivashin and Mikhalev, however, have claimed that the real calving date will be somewhat later than the calculated one, because (from analogy with other mammals) the rate of foetal growth may decrease shortly before birth. They therefore propose a duration of pregnancy of 9½ to 10 months, with the peak of calving occurring in early June. No allowance has been made for an initial period of very slow growth (cf Huggett and Widdas, 1951), and the authors admit that they were not able to fix the date of the mating peak with great accuracy because of uncertainties regarding the duration of the pre-implantation period. The present data on the incidence of recently-ovulated females, however, do suggest that August and September may represent the peak of the pairing season. Consequently the available evidence supports a gestation period of about 10 months, similar to that recorded for the northern minke whale (Sergeant, 1963).

Evidence given above indicates that the majority of females ovulate about four months after giving birth, while still lactating. The length of lactation for the southern minke whale is not known. As mentioned previously, by the time the recently-impregnated females arrive in the higher latitudes of the Antarctic (from November onwards) they have apparently weaned their calves. However it is possible that lactating females may only migrate to higher latitudes once the calf is weaned, so that the sample being examined in the Antarctic is a biassed one: such a phenomenon seems to occur in the North Atlantic, where lactating females occur off Lofoten but are not found farther north in the Arctic at the same time of year (Jonsgård, 1951). However the scarcity of mother–calf pairs in waters north of 40°S from late November onwards (Gambell *et al.*, 1975) suggests that it would be reasonable to assume that lactation usually ceases by that date. The calf will therefore be suckled for about six months on average. Adopting the growth rate of 1 cm a day calculated above, the calf will grow to about 4.6 m (15 feet 1 inch) before weaning. There is thus no essential disagreement with the published information for northern minke whales that lactation lasts 4 to 5 months and that the calf is weaned at a length of 14 to 15 feet (Jonsgård, 1951).

If a pregnancy of 10 months duration is followed by an ovulation 4 months later the calving interval becomes about 14 months, and it is obvious that the individual female cannot maintain a regular cycle for long. Without some adaptation of part of the cycle a female will eventually give birth too late in the season to ovulate (or to ovulate when males are readily accessible), and will pass into a resting condition once lactation has ended. This 'slip' in the system would result in a prolonged pairing season, typified by the very wide range of foetal lengths seen at any one time (Ivashin and Mikhalev, 1978; Jonsgård, 1951), and confirmed by the fact that females that had recently ovulated were found in five of the six months in which minke whales were taken off Durban. Furthermore, a few females with calves or lactating females have been encountered off Durban in December, January, February (Table 5) and April (Table 14), whereas on average calves are born in June and weaned by December.

In order to be able to estimate the average reproductive rate of the species it is necessary to establish how frequently females fail to ovulate or conceive in a breeding season. If a calving interval of 14 months could be maintained indefinitely it would result in 6 births in 7 years, or an annual calving rate of 85.7%. This is therefore likely to be the upper estimate of the reproductive rate. Although a pregnancy rate of 89.5% has been recorded for the higher latitudes of the Antarctic (Ohsumi and Masaki, 1975), this figure may be affected by reproductive segregation: as pointed out by Ohsumi and Masaki, it is higher than their ovulation rate of 0.866.

In the data from Durban a number of resting females and females that were ovulating but not lactating was reported (Table 14). The largest corpus albicans in these individuals overlapped in size range with the largest corpus albicans of lactating females (both ovulating and non-ovulating), but the distribution of corpora sizes in the non-lactating females was unimodal and the corpora were clearly smaller than those for the lactating females (Fig. 8). The mean size of the largest corpus albicans in non-lactating animals was 2.42 ± 0.08 (s.e.) cm compared to 3.38 ± 0.09 (s.e.) cm for lactating animals. This evidence indicates that the majority (if not all) of the non-lactating animals had given birth some considerable time before, and had certainly not given birth at the most recent calving season and subsequently lost their calf. Consequently they can all be considered as having missed one pairing season.

The best available evidence of the proportion of the population that fails to conceive each year during the breeding season must therefore come from the proportion of the Durban catch that was non-lactating (excluding animals ovulating for the first time). The most appropriate body of data from which this can be calculated is that collected by technicians, as it is less likely to be affected by incorrect classification of the lactation status of the animals. However the sample size then becomes small, and if the data collected by inspectors could be included it would greatly increase the reliability of the conclusions. The size distribution of the largest corpora albicantia in mature females examined by inspectors is therefore also shown in Fig. 8. The distribution is clearly bimodal, with one group of corpora from 1.25 to 2.75 cm and a second from 3.00 to 4.25 cm. The range of the smaller group corresponds well with the range for non-lactating females from the technicians' data, while the second group is also included in the range for lactating females from the technicians' data. In the inspectors' data, however, there seems to be a larger proportion of the smaller corpora. If the frequencies of corpora above 3 cm and below 2.75 cm in size are compared between the two groups of data there is a significant difference (chi-square test, $p < 0.02$, df 1). Assuming that these two size-groups correspond roughly to lactating and non-lactating females, it can be concluded that the inspectors must have examined more non-lactating animals than the technicians. The logical explanation for this is that the gunners normally exercised considerable selection against lactating females, but that this had been relaxed to some extent during the periods in which special scientific permits for the taking of lactating females had been in force. Consequently the technicians' data are clearly more representative of the real situation than the inspectors', and so must be used to calculate the incidence of non-lactating animals in the population. This can be calculated as 21.6%, and the 'true' reproductive rate is therefore 78.4%.

The accuracy of this figure is limited by the assumption that there was no selection practised by the gunners against lactating females, even during the periods when special scientific permits were in force, an assumption which is perhaps not fully justified (see Material and Methods). It is also based on a rather small sample (51 animals). A detailed analysis of similar material from the Brazilian land station might provide a more accurate answer, though

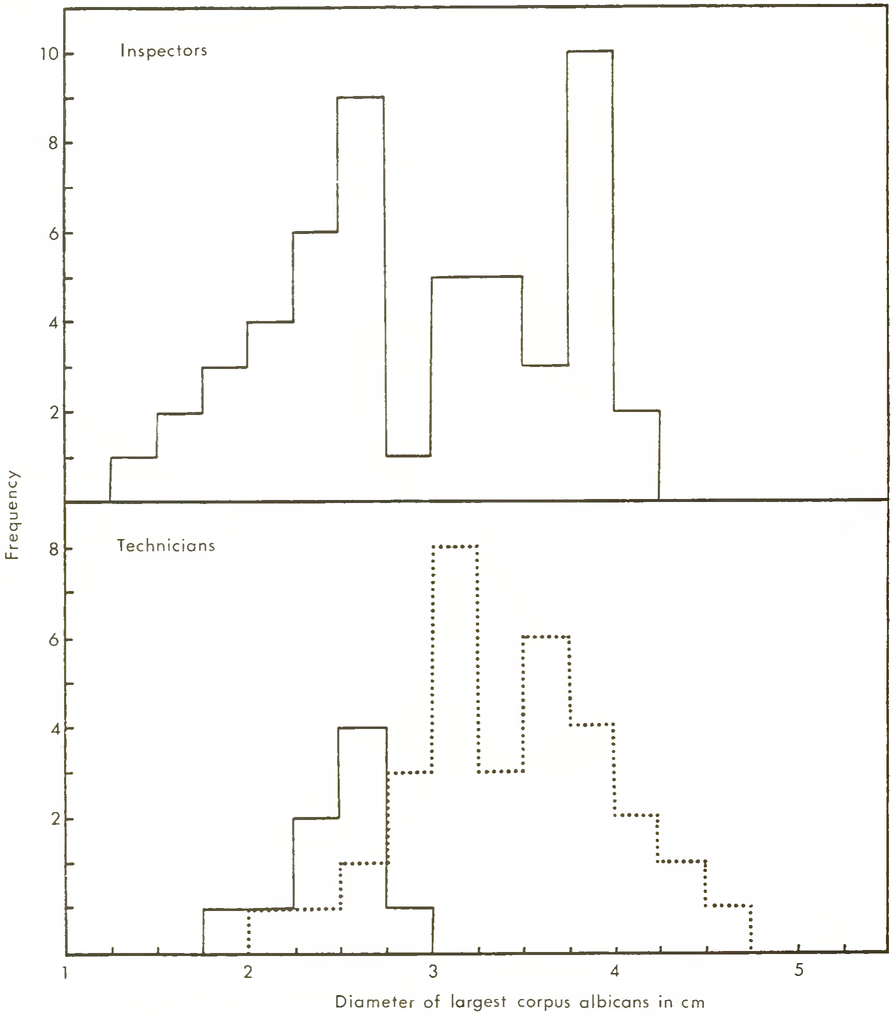

Fig. 8. Size distribution of largest corpus albicans in lactating and non-lactating minke whales at Durban.

present understanding of the catch composition at that station is that very few (3%) of the females are lactating and none is pregnant (Williamson, 1975). However such a concentration of apparently resting females would be most unusual for the species (Jonsgård, 1951), and would suggest that a significant proportion of the population must feed outside the higher latitudes of the Antarctic each summer, or the apparent pregnancy rate of the minke whale in the Antarctic would be much lower. It is considered that a closer examination of the Brazilian catch might reveal a significantly higher proportion of lactating females than is presently reported.

AGE AND GROWTH

The ear plug of the minke whale is considerably smaller than that of any other baleen whale species so far studied, the core length averaging 15.6 ± 0.8 (s.e.) mm in animals with 20 or more growth layers. This small size makes both collection and subsequent examination difficult.

As indicated above, ear plugs were collected from 604 animals, or 54.3% of the catch. Because of the physical nature of the plugs, 51 (or 8.4%) of those collected could not be sectioned. After sectioning and examination, the readability of the remaining plugs was assessed as follows.

(1) Unreadable—unable to obtain even an estimate of the number of growth layers, usually because the pattern of layering was unrecognisable or extremely irregular (11.6% of plugs).

(2) Difficult—only an estimate of the number of growth layers could be made, the pattern of layering being regular but faint or obscured by 'flaws' in the plugs (23.7%).

(3) Incomplete—a portion of the core of the plug was judged to be missing (usually at the base) or unreadable (13.2% of plugs).

(4) Readable—the pattern of layering was regular and the number of growth layers could be counted with some confidence (51.5% of plugs). However this did not automatically mean that the transition phase (see below) could be recognised in such plugs.

Only readable plugs have been used to estimate age in this paper.

The accumulation rate of growth layers in the minke whale ear plug is unknown. In the fin and sei whale (Roe, 1967; Lockyer, 1974) one growth layer is believed to be deposited per year, and as the minke whale is also a balaenopterid with similar seasonal migrations between warmer waters and high latitudes, it seems reasonable to assume that one growth layer is also deposited annually in this species. The only independent evidence available of the accumulation rate comes from an examination of the frequency of ovulation.

Ovulation rate

For several species of large cetacea it has been shown that corpora lutea persist in the ovaries as recognisable corpora albicantia for the remainder of the life of the animal, due apparently to the initial large size of the corpora (Best, 1967b; Gambell, 1968; Laws, 1961). Corpora lutea of ovulation and pregnancy in minke whales are smaller than in any of the previously investigated species, averaging 4.00 ± 0.15 cm ($n = 66$) and 6.55 ± 0.12 cm ($n = 38$) respectively. The equivalent mean weight of the corpora lutea of ovulation is 41.67 ± 4.67 g ($n = 64$). Because of their smaller size, there is a greater likelihood of minke whale corpora being completely resorbed, so the assumption of persistence throughout life needs examination.

During sectioning of the ovaries, corpora albicantia were classified on their morphological appearance as young, medium or old. The criteria adopted were the same as those used for sperm whales (Best, 1967b). The size distribution of 'old' corpora was symmetrical with a mean diameter of 1.03 ± 0.02 cm ($n = 203$), representing shrinkage to 15.7% of the diameter of the original corpus luteum. 'Old' corpora albicantia in fin whale ovaries shrink to 17.6% of the diameter of the corpus luteum of pregnancy (Laws, 1961), in sei whale ovaries to 14.2% (Gambell, 1968) and in sperm whale ovaries to 18.0% (Best, 1967b) or 14.2% (Gambell, 1972). The shrinkage observed in minke whale ovaries is thus as great as observed for other large cetacea, and this, taken in conjunction with the symmetrical distribution and the fact that ovarian sections were cut at a mean thickness of 3 or 4 mm, suggests that it was unlikely that either corpora albicantia were completely resorbed or that significant numbers were missed during sectioning. Consequently it seems reasonable to assume that corpora albicantia persist throughout life in minke whale ovaries and are readily counted.

Data on corpora counts (i.e. the total number of corpora lutea and albicantia in both ovaries combined) and the number of growth layers in the ear plug are available for 66 females, 53 of which were sexually mature. Omitting all immature animals, the linear regression of corpora counts against growth layers produces an estimating equation of

$$y = -2.8819 + 0.6469x$$

where y = number of corpora
and x = number of growth layers.

As each corpus represents an ovulation, the ovulation rate per growth layer is estimated as 0.647 ± 0.064. The two oldest animals (with 39 and 43 growth layers), however, have relatively low corpora counts (both 17), and if they are omitted the regression coefficient (over the age range 7 to 33 growth layers) becomes 0.761 ± 0.069. As Masaki (1979) found some evidence that the ovulation rate is less in females with more than 20 growth layers, a separate regression has been calculated for females carrying 7 to 20 growth layers, giving a regression coefficient of 0.811 ± 0.144. This is somewhat less than the regression coefficients calculated for Antarctic Areas I to VI for the same age range, which vary from 0.835 to 1.401 (Masaki, 1979). Nevertheless, if the true pregnancy rate is about 78% as estimated above, the ovulation rate seems more likely to be in the vicinity of 0.81 per year than 1.62 per year, for the latter implies over 2 ovulations per conception, a failure rate which has not been observed in any other baleen whale to date, apart possibly from the inshore population of Bryde's whales off the west coast of South Africa (Best, 1977). Under these circumstances it seems more likely that one rather than two growth layers accumulates in the minke whale ear plug per year, and this assumption has subsequently been adopted in this paper.

Age at sexual maturity

Because of the small number of minke whales for which information on both age and ovarian or testis maturation was available, it is difficult from a direct comparison to establish the age at sexual maturity in either sex accurately (Table 20). All that can be deduced is that maturity is probably reached between ages 5 and 8 in males and 7 and 9 in females.

An alternative approach is to examine the age at which the transition phase appears in the ear plug. It has been shown for fin and sei whales (Lockyer, 1972; 1974) that the pattern of layer formation in the ear plug changes abruptly at sexual maturity, the width of subsequent layers being considerably less. Using this phenomenon it is possible to estimate the age at which an animal became sexually mature several years prior to death, simply by counting the number of growth layers distal to the transition phase (Fig. 9).

Table 20

Age and sexual maturity in minke whales at Durban

Age (= growth layers)	Males		Females	
	No. examined	% mature	No. examined	% mature[1]
3	2	0	2	0
4	2	0	1	0
5	3	100	2	0
6	3	66.7	1	0
7	3	33.3	4	25.0
8	6	83.3	3	100
9	6	100	3	66.7
10	4	100	1	100
11	2	100	2	50
12	4	100	2	100
13	4	75.0	3	100
14	4	100	5	100
15	6	100	3	66.7
16	6	100	3	100
17	5	100	1	100
18	7	100	5	100
19	5	100		
20	3	100	2	50
21+	29	100	31	100
Total	104		74	

[1] Including lactating females for which no ovarian data was available.

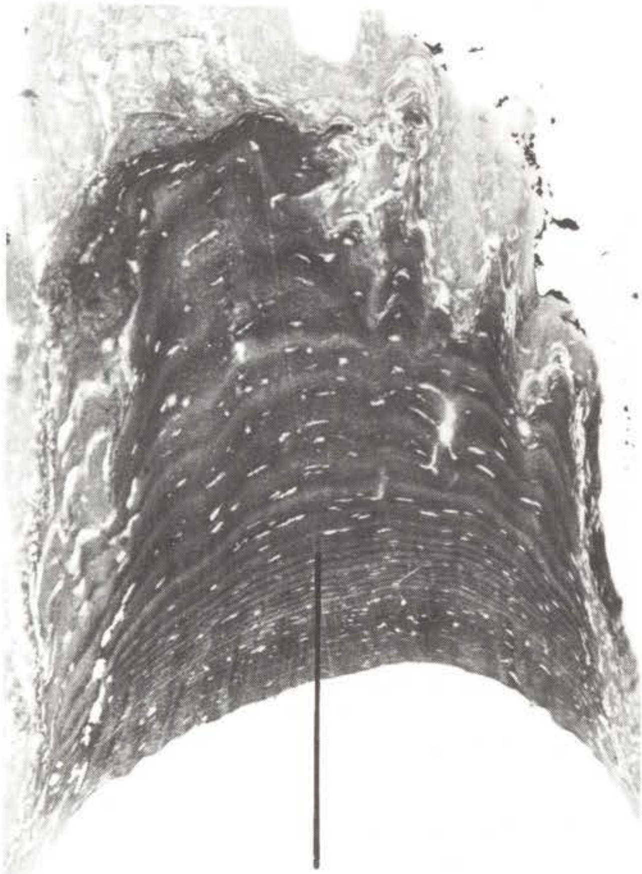

Fig. 9. Stained section of minke whale ear plug. Line indicates transition phase.

There seems a correlation between maturity and the presence of a transition phase in minke whales at Durban, although there is insufficient material to test for each sex separately (Table 21). The assumption has therefore been made that the transition phase also represents the attainment of sexual maturity in minke whales.

Table 21

Presence of a transition phase in the ear plug of minke whales from Durban

Sexual maturity classification	Number examined	% showing transition phase
Immature	21	4.8
Pubertal[1]	12	16.7
Mature	94	83.0

[1] One to two corpora in ovaries or both mature and immature tubules in testes.

The particular value of the transition phase is that it is possible to investigate not only the current age at sexual maturity but also historical trends in this parameter (Lockyer, 1979; Masaki, 1976, 1979). However most previous such analyses have plotted the age at which the transition phase appears against the year of birth of the whale. This approach leads to a bias (which has been recognised by most authors) in that in more recent years there is under-representation of late-maturing whales, leading to under-estimation of the mean age at sexual maturity in those year classes (Free and Beddington, 1980; Horwood, 1980).

In this paper the data for 112 animals have been plotted two ways, firstly against the year of birth and secondly against the year in which the whale became sexually mature (Fig. 10).

Because of the small amount of material available, data for both sexes have had to be combined, but as male and female minke whales mature at very similar ages (Masaki, 1979) the results should be applicable to either sex.

Both data sets indicate a decline in the age at sexual maturity (= transition phase) over time. Ignoring the two oldest animals (whose inclusion might unduly weight the results), linear regressions have been fitted to the remaining data, producing the following estimating equations:

$$y = 11.58 - 0.0986x \text{ (year of maturation)}$$
$$y = 13.21 - 0.1535x \text{ (year of birth)},$$

where y = age at sexual maturity
x = year of maturation or birth (1935 = 1 and 1925 = 1, respectively)

The slopes of both regressions are significantly different from zero ($t = 3.38$, $p. < 0.005$; $t = 6.85$, $p < 0.001$, respectively), though that for the year of birth seems to be somewhat greater than that for the year of maturation. However (as noted above), the fact that late-maturing animals in the more recent age classes have not yet matured means that the coefficient of slope for year of birth may be overestimated. This bias probably came into effect from the 1957 year class, as animals born in that year and maturing at age 12 would only reach maturity in 1969 (or after the sampling started). A linear regression fitted to the data prior to 1957 yields an estimating equation of

$$y = 12.04 - 0.0999x,$$

which is very close to that for the year of maturation. Hence Fig. 10 may be free of the bias inherent in plots of age at maturity against year of birth. From that regression the age at maturity of animals reaching maturity is estimated to have declined from 10.5 in 1945 to 7.7 in 1973 (s.e. ± 1.9 years).

The latter estimate is within the ranges predicted from direct biological observations for both sexes off Durban during the period 1970–75 (in which most of the material was collected). However the two sets of results are not directly comparable, as they concern different segments of the population.

A decline in the age at sexual maturity for both sexes of southern minke whales has also been described by Masaki (1979), although the decline was much greater, from an average of 13.8 years prior to the 1944 year class to 6.2 years after the 1965 year class. Some of this discrepancy may be due to the different methods of analysis used.

This decline commences well before concerted pelagic exploitation of southern minke whales began (1971/72), and may reflect a faster growth rate due presumably to more food being available as a result of depletion of other baleen whale species feeding on *Euphausia superba* (IWC, 1979).

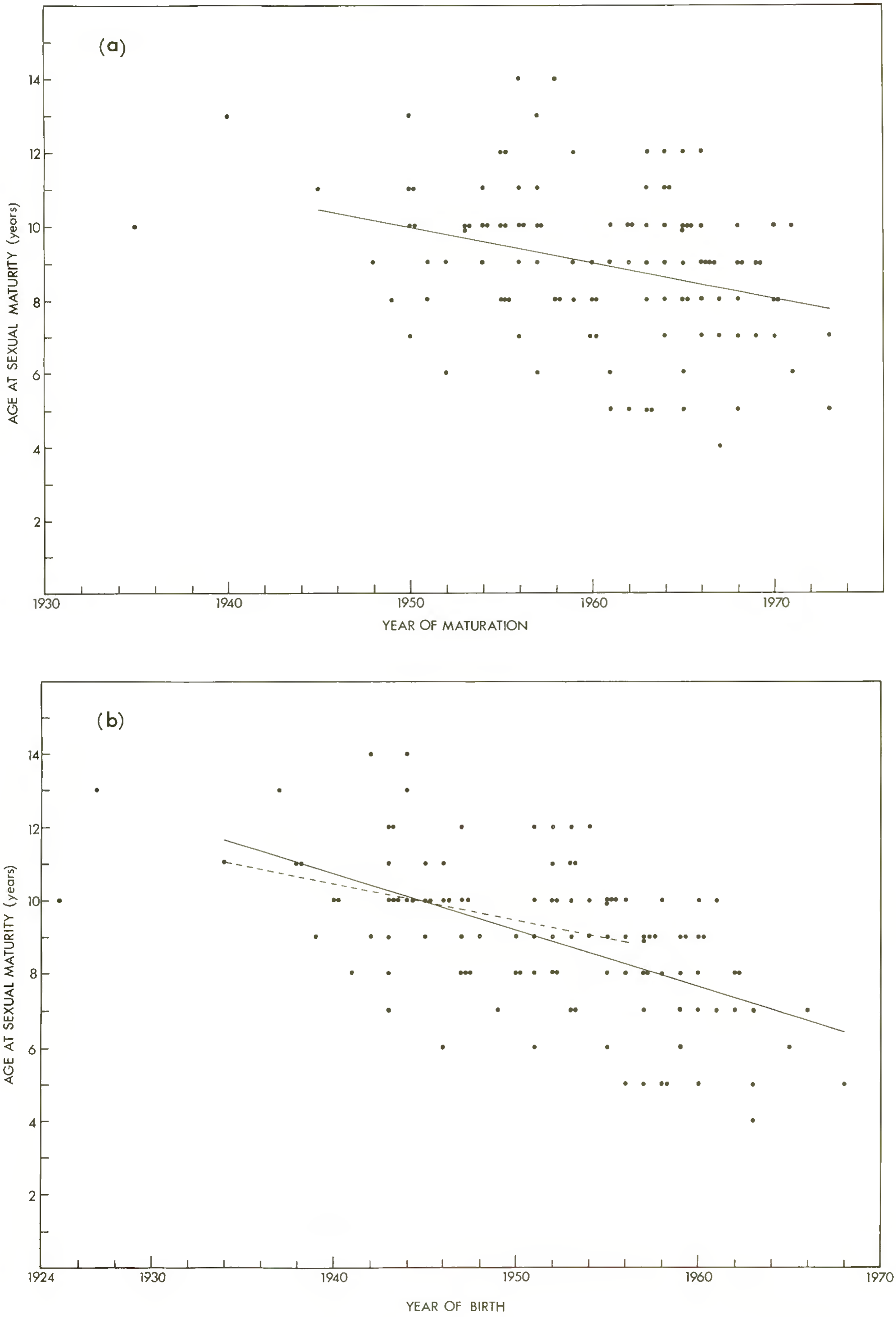

Fig. 10. Age at sexual maturity (= transition phase) in minke whales off Durban plotted against (a) year of maturation and (b) year of birth. Dotted line indicates regression over period 1934 to 1956.

Growth

In order to depict growth or mortality accurately it is essential to have an unbiassed estimate of age. Thus while the age of individual animals can be established through counts of growth layers in the ear plug, an accurate representation of the age composition of the population requires that all components can be aged with equal facility.

A comparison of the length composition of the catch and the aged component, however, shows that the smaller minke whales of either sex at Durban are under-represented in the aged sample compared to the larger animals (Table 22). This probably arises from the difficulty in collecting plugs from small minke whales and in handling them for examination. As a consequence, there will be a bias against smaller animals at a particular age, and possibly a bias in favour of older animals (with larger plugs) at a particular length. These effects, together with the small proportion of the catch that was aged, prevent accurate construction of an age composition.

The mean lengths of minke whales (plus or minus 2 standard errors) at each age are shown for either sex in Figs 11 and 12. A growth curve has been fitted by eye to these points, being constrained to go through the lengths at birth (age 0) of 9 ft (2.73 m), at weaning (age 0.5) of 15 ft and at sexual maturity (age 7.7) of 24.9 ft for males and 26.6 ft for females. These curves illustrate clearly (particularly for males) the under-representation of small animals at the youngest ages.

Table 22

Comparison of size composition of Durban minke whale catch (1970–75) and of aged sample (mostly 1970–75)

Length (feet)	Males		Females	
	Catch	% aged	Catch	% aged
16			1	0
17			—	—
18	1	0	1	0
19	1	0	3	0
20	8	0	5	0
21	15	13.3	17	11.8
22	20	0	12	25.0
23	19	26.3	18	5.6
24	29	13.8	23	13.0
25	48	16.7	42	11.9
26	62	32.3	43	16.3
27	121	32.2	48	18.8
28	156	37.2	56	42.9
29	82	28.0	42	40.5
30	33	24.2	38	31.6
31	4	25.0	14	50.0
32	1	100	3	66.7
33			2	50.0
34			—	—
35			1	100
Total	600	28.2	369	25.5

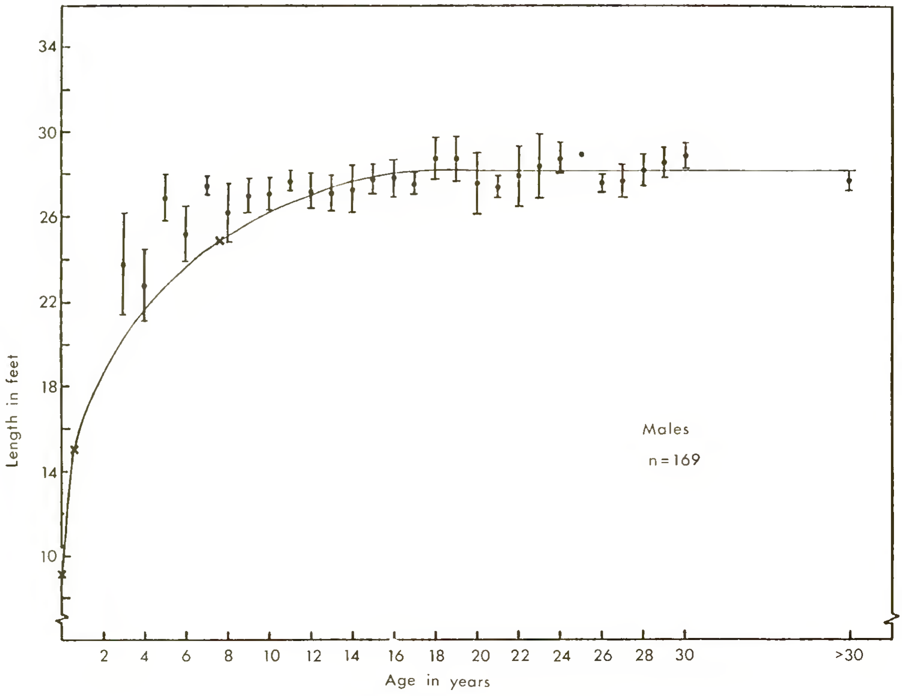

Fig. 11. Growth curve of male minke whales at Durban.

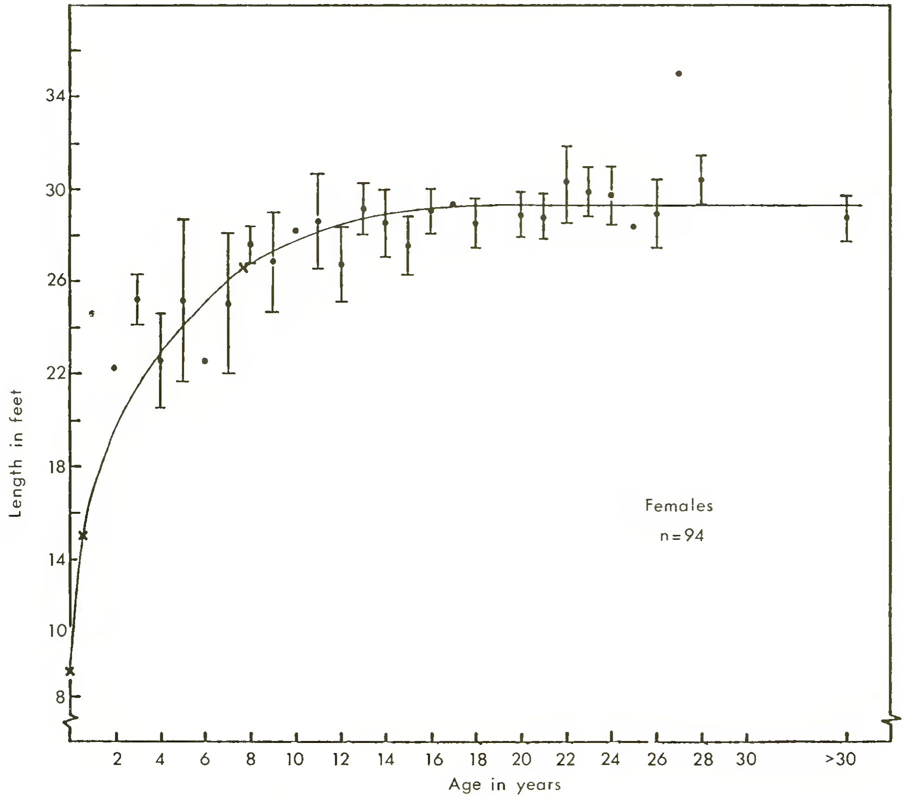

Fig. 12. Growth curve of female minke whales at Durban.

Growth on average appears to cease at lengths of about 28.2 ft in males and 29.3 ft in females, equivalent in both sexes to ages of about 18 years. These figures are in reasonable agreement with those of Ohsumi and Masaki (1975), who found from a much larger sample of animals that maximum size was attained at 27.9 ft in males and 29.5 ft in females, at ages of 18–20 and 20–22 years respectively.

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REFERENCES

Bannister, J. L. and Baker, A. de C. 1967. Observations on food and feeding of baleen whales at Durban. *Norsk Hvalfangsttid.* 56(4): 78–82.

Bannister, J. L. and Gambell, R. 1965. The succession and abundance of fin, sei and other whales off Durban. *Norsk Hvalfangsttid.* 54(3): 45–60.

Benham, W. B. 1901. An account of the external anatomy of a baby rorqual (*Balaenoptera rostrata*). *Trans. Proc. N. Z. Inst.* 34: 151–155.

Best, P. B. 1967a. Distribution and feeding habits of baleen whales off the Cape Province. *Investl Rep. Div. Sea Fish. S. Afr.* 57: 1–44.

Best, P. B. 1967b. The sperm whale (*Physeter catodon*) off the west coast of South Africa 1. Ovarian changes and their significance. *Investl Rep. Div. Sea Fish. S. Afr.* 61: 1–27.

Best, P. B. 1969a. The sperm whale (*Physeter catodon*) off the west coast of South Africa 3. Reproduction in the male. *Investl Rep. Div. Sea Fish. S. Afr.* 72: 1–20.

Best, P. B. 1969b. The sperm whale (*Physeter catodon*) off the west coast of South Africa. 4. Distribution and movements. *Investl Rep. Div. Sea Fish. S. Afr.* 78: 1–12.

Best, P. B. 1977. Two allopatric forms of Bryde's whale off South Africa. *Rep. int. Whal. Commn* (special issue 1): 10–38.

Best, P. B. and Butterworth, D. S. 1980. Report of the southern hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Best, P. B. and Gambell, R. 1968. The abundance of sei whales off South Africa. *Norsk Hvalfangsttid.* 57(6): 168–74.

Best, P. B. and Ohsumi, S. 1980. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR). Southern minke whale assessment cruise, 1978–79. *Polar Rec.* 20(124): 52–57.

Best, P. B. and Surmon, L. C. 1974. Conservation and utilisation of whales off the Natal coast. *J. S. Afr. Wildl. Mgmt Ass.* 4(3): 149–56.

Budylenko, G. and Pervushin, A. S. 1972. Distribution and fishing of minke whale in the Antarctic. *Ryb. khoz.* (12): 24–5.

Chittleborough, R. G. 1958. The breeding cycle of the female humpback whale, *Megaptera nodosa* (Bonnaterre). *Aust. J. Mar. Freshwat. Res.* 9: 1–18.

Da Rocha, J. M. 1980. Progress report on Brazilian minke whaling. *Rep. int. Whal. Commn* 30: 379–84.

Davies, J. L. and Guiler, E. R. 1958. A newborn piked whale in Tasmania. *J. Mammal.* 39(4): 593–4.

Doroshenko, N. V., Kuzmin, A. A., Nikolsky, O. P. and Patsenko, N. M. 1974. A study of the reproduction of the minke whale. In: *Issledovanya po biologii ryb i promyslovojokeanografii* (Ed. S. M. Konovalov) 5: 145–52. TINRO, Vladivostok.

Free, C. A. and Beddington, J. R. 1980. A technique for estimating mean and variance of the age at sexual maturity for data obtained from the transition phase of ear plug laminae. *Rep. int. Whal. Commn* 30: 375–7.

Gambell, R. 1967. Seasonal movements of sperm whales. *Symp. Zool. Soc. Lond.* 19: 237–54.

Gambell, R. 1968. Seasonal cycles and reproduction in sei whales of the southern hemisphere. *'Discovery' Rep.* 35: 31–134.

Gambell, R. 1972. Sperm whales off Durban. *'Discovery' Rep.* 35: 199–358.

Gambell, R., Best, P. B. and Rice, D. W. 1975. Report on the International Indian Ocean whale marking cruise 24 November 1973–3 February 1974. *Rep. int. Whal. Commn* 25: 240–52.

Gaskin, D. E. 1968. The New Zealand Cetacea. *Fish. Res. Bull.* 1(n.s.): 1–92.

Hancock, D. 1965. Killer whales kill and eat a minke whale. *J. Mammal.* 46(2): 341–2.

Hart, T. J. 1935. On the diatoms of the skin film of whales, and their possible bearing on problems of whale movements. *'Discovery' Rep.* 10: 247–82.

Horwood, J. 1980. Population biology and stock assessment of southern hemisphere sei whales. *Rep. int. Whal. Commn* 30: 519–30.

Horwood, J. 1981. Results from the IWC/IDCR minke marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Huggett, A. St. G. and Widdas, W. F. 1951. The relationship between mammalian foetal weight and conception age. *J. Physiol.* 114: 306–17.

International Whaling Commission 1979. Report of the special meeting on southern hemisphere minke whales, Seattle, May 1978. *Rep. int. Whal. Commn* 29: 349–58.

Ivashin, M. V. and Mikhalev, Yu. A. 1978. To the problem of the prenatal growth of minke whales *Balaenoptera acutorostrata* of the southern hemisphere and of the biology of their reproduction. *Rep. int. Whal. Commn* 28: 201–205.

Jonsgård, Å. 1951. Studies on the little piked whale or minke whale (*Balaenoptera acuto-rostrata* Lacépède). Report on Norwegian investigations carried out in the years 1943–50. *Norsk Hvalfangsttid.* 40(5): 209–32.

Jonsgård, Å. 1968. Another note on the attacking behaviour of killer whale (*Orcinus orca*). *Norsk Hvalfangsttid.* 57(6): 175–6.

Kasamatsu, F. and Ohsumi, S. 1981. Distribution pattern of minke whales in the Antarctic with special reference to the sex ratio in the catch. *Rep. int. Whal. Commn* 31: 345–8.

Lahille, F. 1908. Notas sobre un ballenoto de 2.10 metros de largo. *Anal. Mus. Nac. de Buenos-Aires,* 16 ser. 3, t. 9: 375–401.

Laws, R. M. 1961. Reproduction, growth and age of southern fin whales. *'Discovery' Rep.* 31: 327–486.

Lockyer, C. 1972. The age at sexual maturity of the southern fin whale (*Balaenoptera physalus*) using annual layer counts in the ear plug. *J. Cons. int. Explor. Mer* 34: 276–94.

Lockyer, C. 1974. Investigation of the ear plug of the southern sei whale, *Balaenoptera borealis*, as a valid means of determining age. *J. Cons. int. Explor. Mer* 36(1): 71–81.

Lockyer, C. 1979. Changes in a growth parameter associated with exploitation of southern fin and sei whales. *Rep. int. Whal. Commn* 29: 191–6.

Lockyer, C. In press. Growth and energy budgets of large baleen whales from the southern hemisphere. In: *Mammals in the Sea. FAO Fisheries Series* n. 5, vol. 3.

Masaki, Y. 1976. Biological studies on the North Pacific sei whale. *Bull. Far Seas Fish. Res. Lab.* 14: 1–104.

Masaki, Y. 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 375–95.

Mikhalev, Yu. A., Ivashin, M. V., Savusin, V. P. and Zelenaya, F. E. 1981. The distribution and biology of killer whales in the southern hemisphere. *Rep. int. Whal. Commn* 31: 551–66.

Nemoto, T., Best, P. B., Ishimaru, K. and Takano, H. 1980. Diatom films on whales in South African waters. *Sci. Rep. Whales Res. Inst., Tokyo* 32: 97–103.

Ohsumi, S. 1966. Allomorphosis between body length at sexual maturity and body length at birth in the cetacea. *J. Mammal Soc. Japan* 3(1): 3–7.

Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish. Res. Bd Can.* 32: 995–1,004.

Ohsumi, S., Masaki, Y. and Kawamura, A. 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 22: 75–125.

Rice, D. W. and Wolman, A. A. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). *Am. Soc. Mammal. Spec. Publ.* 3: 1–142.

Roe, H. S. J. 1967. Seasonal formation of laminae in the ear plug of the fin whale. *'Discovery' Rep.* 35: 1–30.

Sergeant, D. E. 1963. Minke whales, *Balaenoptera acutorostrata* Lacépède, of the Western North Atlantic. *J. Fish. Res. Bd Can.* 20(6): 1,489–1,504.

Shevchenko, V. I. 1975. The nature of the interrelationships between killer whales and other cetaceans. *Morsk. Mlekopitayushchie Chast'* 2: 173–4. Translation by Canadian Fisheries and Marine Service No. 3839, 1976.

Shimadzu, Y. 1980. Basis of fishing effort for minke whaling in the Antarctic. *Rep. int. Whal. Commn* 30: 425–33.

Smith, T. D. and Perrin, W. F. 1976. [A review of] Schevill, W. (editor). The Whale Problem. A Status Report. Harvard Univ. Press, Cambridge, Massachusetts, 419 pp., 1974. Price, $12.50. *J. Mammal.* 57(2): 421–7.

Taylor, R. J. F. 1957. An unusual record of three species of whale being restricted to pools in Antarctic sea-ice. *Proc. Zool. Soc. Lond.* 129: 325–31.

Wahrenbrock, E. A., Maruschak, G. F., Elsner, R. and Kenney, D. W. 1974. Respiration and metabolism in two baleen whale calves. *Marine Fisheries Review* 36(4): 3–9.

Williamson, G. R. 1959. Three unusual rorqual whales from the Antarctic. *Proc. Zool. Soc. Lond.* 133: 135–44.

Williamson, G. R. 1975. Minke whales off Brazil. *Sci. Rep. Whales Res. Inst., Tokyo* 27: 37–59.

SC/Jn81/MiS6

Blow Patterns as Sighting Cues for Censusing Minke Whales in Antarctic Waters

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ABSTRACT

Minke whales (*Balaenoptera acutorostrata*) in Antarctic waters have been censused each year since 1978 under the International Whaling Commission's International Decade for Cetacean Research (IWC/IDCR). The major sighting cue for spotting minke whales is their blow. The dynamics of this cue were studied during the 1980–81 IWC/IDCR Minke Whale Assessment Cruise to determine how blow patterns influence sighting reliability. The distribution of blows was observed for 15 groups of minke whales; the group size varied from 1 to 50 individuals. The duration individual blows were visible was timed for three groups. Results indicate that the distribution of blows was irregular. The time of day did not appear to affect the frequency of blows. The maximum duration between blows was 7.73 minutes. The duration individual blows were visible ranged from 1.4–16.1 seconds (mean: 6.2 seconds; Standard Deviation: 4.4 seconds). From the results, I believe that some small groups (five or less individuals) could be missed by observers in a survey vessel traveling at 12 knots. These results are preliminary and further study is needed. Data are also needed to relate the results to environmental conditions and to the behavior of the whales.

INTRODUCTION

In the austral summer of 1980–81 (17 December–12 February), through its International Decade of Cetacean Research (IDCR), the International Whaling Commission (IWC) sponsored a research program to evaluate the status of the stock of minke whales (*Balaenoptera acutorostrata*) in Area V of the Antarctic, through sighting and marking studies. Experiments were conducted to gather data on population levels and distributional trends and to investigate the reliability of the survey methodology. One major area of concern, which has existed as long as line transects have been conducted, is the number of animals present but which are undetected. The major sighting cue for minke whales in the Antarctic has been the blow: the visible mist generated by exhalation. There is one respiration (exhalation and inhalation) for each blow, although not all respirations produce a visible blow. Therefore, the number of blows may be less than the number of expirations.

Little is known about minke whale respiration patterns and the frequency of visible blows. Kimura and Nemoto (1956) studied a North Pacific minke whale taken into captivity at Mito Aquarium in Japan. The respiration of the single animal was somewhat rhythmic, the intervals between respirations were longer after short dives and shorter after long dives, with inter-respiratory intervals ranging from 40 seconds to 6 minutes. They also noted that the respiration rate gradually decreased through the afternoon, increased after midnight, and peaked at 0100 hours. Mitchell (1978) stated that the respiration of the minke whale was not as regular as the sei (*B. borealis*) or fin (*B. physalus*) whales. Tomilin (1957), in observations of minke whales in the Bering Strait, stated that a minke whale had an inter-blow rate of 2–3 minutes, but that this rate was variable depending on environmental conditions and the animal's activity. Doi (1974) found that the average duration of dives for the minke whale in the Antarctic was 1.30 minutes and the average surface breathing rate was 3.23 seconds.

This paper reports on the study to assess the reliability of utilizing blows to detect the presence of minke whales in the Antarctic study area. Since the major purpose of the IDCR/IWC research program was to conduct sightings and marking surveys, this experiment was conducted on an opportunistic basis, structured to cause minimal interference with the other studies.

METHODS

Observations were conducted from all three dedicated vessels: The *Kyo Maru 27*, the *Toshi Maru 11*, both of Japanese origin, and the *Vdumchivyi 34*, from the Soviet Union. The vessels, operating at 12 knots, conducted straightline transects. When a group of minke whales was sighted, the animals were approached to within 0.25–0.50 nm. Environmental conditions dictated the maximum distance at which all blows could be reliably seen. The survey was terminated if the minimum distance elicited an avoidance reaction from the animals.

The survey was not conducted if the blows were not consistently visible throughout the period of observation. Once the vessel assumed position it would drift, utilizing the engine only to stay within range of the animal, avoid ice, or move out of sun glare.

Onboard two vessels, the *Kyo Maru 27* and the *Vdumchivyi 34*, the experiments were tape-recorded. These tapes were later transcribed, and blow incidents differentiated to the nearest second. On the other vessel, the *Toshi Maru 11*, the blow intervals were timed by hand and were immediately recorded onto data sheets. While blow intervals were being recorded, data were also collected on the length individual blows were visible. Once the study period was concluded, the vessel approached the group and the number of animals verified.

To assess the differences in the blowing patterns of small, moderate and large groups, three size groups were initially chosen: 1, 2–5 and 6–20 individuals per group. To determine the effect of the time of day, three time periods were selected; morning (0400–0900 hours), midday (0900–1300 hours) and afternoon (1300–2000 hours). Studies were conducted for a period of approximately 15 minutes each, unless behavioral responses or environmental factors curtailed the survey. The runs were limited to 15 minutes to minimize the time lost to the survey studies, but sufficient to observe occurrences of both long and short dives.

RESULTS

A total of 15 valid runs of this experiment was conducted (Table 1). These runs contained four size groups: 1 animal (Group I), 2–5 (Group II), 6–20 (Group III), and over 20 animals (Group IV). A total of 1,208 blows and 761 blow intervals was recorded during the 200.49 minutes of observation (Fig 1).

The mean blow interval per group ranged from 1.50 minutes for Group I to 0.14 minutes for Group IV. The maximum interval between blows was 7.73 minutes (Table 2). The shortest maximum blow interval for any run was 0.83 minutes (run k8). The shortest duration between any two blows for a single animal was 0.23 minutes.

The duration individual blows were visible was timed for 30 blows, over three different runs (Table 3). These three runs were distributed across the three time intervals. The maximum duration a blow was visible was 16.10 seconds and the minimum duration was 1.40 seconds.

DISCUSSION

The mean blow interval ranged from 1.50 minutes for one animal to 0.14 minutes for 50 animals. This was not representative of the frequency of sighting cues. The large standard deviations for these values indicate that the blows are not uniformly distributed throughout the study period (Table 2).

Table 2

Intervals between blows by size groups

Size Group	No. of blow intervals	Average blow interval (min)	Standard deviation (min)	Maximum blow interval (min)
I	27	1.50	1.56	6.15
II	215	0.43	0.88	7.73
III	236	0.15	0.25	1.67
IV	283	0.11	0.22	2.18

Table 3

Duration of visibility for minke whale blows

Run	No. of blows	Average blow duration (sec)	Standard deviation (sec)
K2	8	2.08	0.40
K9	7	12.57	4.33
T2	15	5.37	1.35
Total	30	6.17	4.43

The longest observed blow interval was 7.73 minutes. Since the experiment measured the interval between any two blows, and did not distinguish individual animals, the inter-respiratory period of an individual could be greater. However, in over 40 minutes of observations on single animals, the maximum interval, and therefore the inter-respiratory period, did not exceed 6.15 minutes. In relation to the relative movement of a survey vessel, a blow interval of 7.73 minutes would allow the vessel, travelling at 12 knots, to move 1.55 nm between sighting cues. This would mean that an undetected animal at 1.5 nm ahead of the vessel could remain on the transect line and still not be seen, since with a dive of 7.73 minutes, it could surface behind the moving vessel. If the

Table 1

Experimental runs utilized in the analysis

Size group	Experimental run[1]	No. of animals	Time of day[2]	Length of observations	No. of blows	No. of blow intervals
I	K7	1	Morn	15.41	11	10
	K4	1	Mid	17.63	11	10
	K11	1	Aft	7.05	8	7
II	T2	2	Mid	17.18	47	46
	K2	2	Aft	14.63	14	13
	K5	3	Morn	7.93	18	17
	K1	3	Mid	10.98	17	15
	K10	3	Mid	15.05	15	14
	V4	4	Morn	12.63	41	38
	V1	4	Mid	14.65	86	72
III	K8	13	Aft	10.87	77	58
	V3	15	Aft	15.48	127	109
	K9	20	Morn	9.60	132	69
IV	V2	21	Aft	15.20	255	166
	K6	50	Mid	16.20	349	117

[1] k—Kyo Maru; number—run number.

[2] Morn—morning, Mid—midday, Aft—afternoon.

vessel were transecting at a reduced speed, the distance covered between sighting cues would be less. For a vessel travelling at 10 knots, a distance of 1.29 nm would be covered, and 0.90 nm would be covered at 7 knots. The types of movement for the whales varied, ranging from milling to transiting and even fleeing. It is possible that these movements could increase the distance over which an animal is undetected.

Many initial sightings occurred at distances of 1.5 nm or more. When environmental conditions were less than ideal (eg., scattered snow squalls, fog, or rough seas reduced visibility, the wind rapidly dissipated the blows, or lighting conditions did not highlight the blows), the reliability of seeing the animals at such distances was questionable. Even for a group as large as 50, the vessel would have travelled 0.44 nm during the maximum blow interval. However, with numerous blows both before and after this interval (Fig. 1), it would appear that only the most severe environmental conditions would have allowed these animals to pass the vessel undetected.

When time of day is correlated to the mean blow interval, no trend is apparent (Table 4). However, environmental conditions and the behavior of the animals were not incorporated into the analysis. More data incorporating these factors are needed to detect the presence of any daily pattern.

Table 4

Relationship of time of day to interval between blows (number of blows per whale/minute)

Size group	Morning	Midday	Afternoon
I	0.71	0.62	1.13
II	0.79	0.96	0.48
III	0.69	—	0.55
IV	—	0.28	0.17
Total	0.72	0.53	0.66

The large standard deviation for the duration blows were visible is most likely an effect of the small sample size. However, the apparent grouping of the blow duration by run suggests that there may be non-random factors affecting blow duration. These factors were probably a combination of environmental conditions, including wind speed, cloud cover and the angle between the sun, the whales, and the observers. A slight alteration of environmental conditions resulted in a large change in blow duration. On one occasion a blow of over 16 seconds was immediately followed by a series of surfacings where no blows were visible. However, the animal was still respiring, as indicated by the movement of the blowholes. The change from the extended visible blow to the nonvisible respirations occurred as the angle between the vessel, the animal, and the sun altered slightly while the other environmental conditions remained constant. This change from the visible blow to nonvisible respirations, and the reverse, may explain why some animals were being lost from view when approached and others suddenly appearing near the vessel, without previously being seen. This has occurred even in apparently favourable sighting conditions.

CONCLUSIONS

Minke whales can dive for periods of at least 7.73 minutes, and a group as large as 50 animals may be out of sight for over two minutes. Blows were not equally distributed over the period of observation, and the duration of these blows was variable, ranging from zero to at least 16 seconds. As expected, the dive profile was affected by the size of the group, and it is possible that some small groups of animals could be missed during their long dives. Decreased vessel speed would reduce this possibility.

Future studies are needed to provide a larger data base. Correlations should be made between dive profiles and whale activities, as well as between blow duration and environmental conditions. Additionally, to determine the availiability of the blow as a sighting cue, data should be gathered when the animals are present but the blows cannot be seen.

ACKNOWLEDGEMENTS

My participation in this research was made possible by a grant from Office of Marine Mammals and Endangered Species, National Marine Fisheries Service, R. Rowe Acting Director, and by the extensive efforts of T. McIntyre from that office. Additional funds were provided by the International Whaling Commission. I thank the participating members of the 1980–81 IDCR/IWC Antarctic minke whale assessment cruise, who helped design and conduct this experiment: P. Best, D. Hembree, P. Ensor, L. Tsunoda, F. Kasamatsu, H. Kato, N. Miyazaki, A. Rovnin and R. Rowlett. Additionally, the cruise and this experiment could not have been successful if it had not been for the complete cooperation and extensive knowledge of the animals and the environment provided by Captains K. Yamashita, I. Uchiike and G. Garmanov, as well as the crews of the vessels. I also thank M. Tillman and the staff of the National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, Washington, for providing technical support in the production of this paper. The typing was done by L. Hietala and J. Waychoff and the graphics by C. Hastings of NMFS Graphics Service. This paper was reviewed by H. Braham and M. Tillman.

REFERENCES

Doi. T. 1974. Further development of whale sighting theory, pp. 359–68. *In:* W. E. Schevill (ed.), *The Whale Problem: A Status Report.* Harvard University Press, Cambridge, Mass.

Kimura, S. and Nemoto, T. 1956. A note on a minke whale kept alive in aquarium. *Sci. Rep. Whales Res. Inst., Tokyo* 11: 181–9.

Mitchell, E. 1978. Finner Whales, p. 39. *In:* D. Haley (ed.), *Marine Mammals of Eastern North Pacific and Arctic Waters.* Pacific Search Press, Seattle, 256 pp.

Tomilin, A. G. 1957. *Kitoobraznye* (Cetacea). Vol. IX of *Zveri SSR i prilezhashchikh stran* (Mammals of the USSR and adjacent countries). Izd. Akad. Nauk SSSR, Moskva, 756 pp. (In Russian.) Transl. by Israel Program Sci. Transl., 1967, 717 pp, avail. Natl. Tech. Inf. Serv., Springfield, Va.

SC/Jn81/MiS7[1]

The Effect of Random Whale Movement on Density Estimates Obtained from Whale Sighting Surveys

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ABSTRACT

Random whale movement causes an upward bias in estimates of density from strip or line transects. The bias can be quite large if the whales move at a similar speed to the observation platform, sighting effort is concentrated along the trackline, and the probability of sighting a whale is not highly correlated with the length of time it spends within 'range' of the platform. These theoretical conclusions are confirmed by using computer simulations.

INTRODUCTION

Most whale sighting surveys have used strip or line transect methods to estimate the mean density of a particular population within a given area. Those methods were originally developed to estimate the abundance of terrestrial plants and animals which do not move before being sighted, and the assumption that targets do not move before being sighted is used in the derivation of the density estimate. As targets in a sighting survey whales obviously violate this assumption and this leads to an increase in sighting rate and an upward bias in the resulting estimate of mean density. The following analysis attempts to identify the conditions under which this bias may become large (more than a few percent).

THEORETICAL CONSIDERATIONS

The size of the bias resulting from random whale movement depends upon three factors: the speeds at which the whales are moving relative to the speed of the platform; the pattern of searching effort; and a function relating the probability of missing a whale to the time which it spends within 'range' of the platform.

Consider first a situation where any whale entering an 'encounter region' around the sighting platform is certain to be seen. Skellam (1958) gives a formula relating the encounter rate to the shape of the region and the joint probability density for the velocity and angle of motion of the targets relative to the platform. A particularly simple formula is obtained if the encounter region is circular and the whales move in random directions. It is tempting to use that formula to give a rough idea of the bias due to random whale movement in any given situation. However, the encounter rate is very sensitive to the shape of the encounter region, in particular to its length along the trackline compared to its width across the trackline.

To illustrate the point, consider a whale moving with speed ω at angle θ to the trackline, so that for a whale moving towards the platform along the trackline, $\theta = 0$. The platform moves along the trackline with speed v. A particularly simple result is obtained by assuming that ω is less than v, so that assumption is used below.

The vector $\underline{\tau}$ describes the movement of the whale relative to the platform:

$$\underline{\tau} = \underline{v} + \underline{\omega}$$

where the components v and ω are due to the movement of the platform and whale respectively. The vector $\underline{\tau}$ has magnitude τ and is at angle α to the trackline, as shown in Fig. 1. Let $H(\alpha)$ be the length of the boundary of the encounter region normal to $\underline{\tau}$. If all the whales were moving with the same speed ω in the same direction θ, the encounter rate would be

$$DH(\alpha)\tau \qquad (1)$$

where D is the whale population mean density. For a rectangular encounter region with length y and width x (Fig. 1).

$$H(\alpha) = y \sin \alpha + x \cos \alpha \qquad (2)$$

From Fig. 1,

$$\sin \alpha = \frac{\omega \sin \theta}{\tau}$$

and

$$\cos \alpha = \frac{v + \omega \cos \theta}{\tau}$$

so from equations (1) and (2) the expected encounter rate would be

$$D(xv + \omega(x \cos \theta + y \sin \theta)) \qquad (3)$$

If all the whales move with speed ω but in random directions, then θ is uniformly distributed in the range 0 to π and the expected encounter rate is

$$\int_0^{\pi} D(xv + \omega\,(x \cos \theta + y \sin \theta)) \cdot \frac{1}{\pi}\, d\theta$$

$$= D(xv + \omega y \frac{2}{\pi}) \qquad (4)$$

For stationary whales the expected encounter rate is Dxv so if, for example, whale velocity is half platform velocity, we have the following increases in encounter rate due to random whale movements:

y = x/2	+16%
y = x	+32%
y = 2x	+64%

---

[1] This is a much shortened and revised version of the paper presented to the IWC Scientific Committee, June 1981.

An increase in encounter rate leads to an equivalent increase in the estimate of mean density only if any whale entering the encounter region is certain to be seen. However, as Butterworth (1980) pointed out, the probability of seeing a whale may depend not only on its path relative to the platform but also on the time it spends 'within range' of the platform.

To take the extreme case, suppose the probability of seeing a whale which enters the encounter region is proportional to the time it spends within the encounter region. This would be the case if the minimum dive duration exceeds the maximum time a whale can remain within the region. Then it is easy to see that, whatever the shape of the encounter region, the number of whales sighted is independent of any whale movement which is itself unaffected by the presence of the platform. As before, the encounter rate for whales travelling with velocity τ at angle α relative to the platform is $D\tau H(\alpha)$. The mean time spent within the encounter region is $A/H(\alpha)\tau$ where A is the area of the region, so the probability that a whale is sighted is $xA/H(\alpha)\tau$ for some constant x. Thus the sighting rate is DAx which is independent of τ and α.

In summary, arguments based on the concept of an encounter region suggest that random whale movement may seriously bias the estimate of mean density if the speed of the whales approaches that of the platform, if the encounter region is long rather than wide, and if the probability of sighting a whale is not strongly dependent on the time it spends within the region.

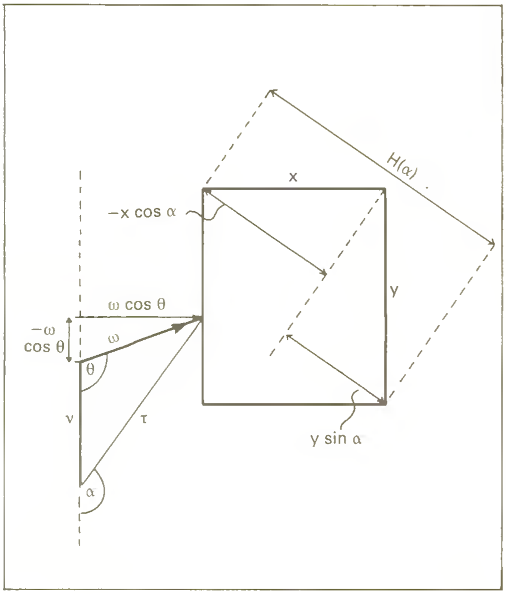

Fig. 1. The vector $\underline{\tau}$ represents the speed and direction of movement of a whale relative to a platform which is itself moving along the trackline. $\underline{\tau}$ is the sum of component vectors $\underline{\omega}$ and $\underline{v}$. $\underline{\omega}$ is due to whale movement at speed ω in direction θ to the trackline. $\underline{v}$ is due to platform movement at speed v along the trackline towards the top of the page. The resultant $\underline{\tau}$ is at angle α to the trackline. The whale can enter the rectangular encounter region around the platform at any point along a boundary with width $H(\alpha)$ normal to $\underline{\tau}$. The area of the region from which the whale can enter during a unit time interval is therefore $H(\alpha)\tau$.

COMPUTER SIMULATIONS

To assess the significance of the above conclusion for line transect surveys, in which the probability of sighting a whale falls off continuously with its distance from the trackline, the following simulation model was used:

The sighting platform is situated at the centre of a ten kilometre square. Fifty whales move across the square with constant speed ω but in random directions. Each whale has an additional velocity v along the trackline to simulate the movement of the platform. As soon as any whale leaves the square another whale enters to maintain a constant density of 0.5 km^{-2}. In order to maintain the random pattern of whales within the square, the direction of movement θ for any new whale is chosen at random from a probability density defined as $h(\theta,\omega,v)/.\int_0^\pi h(\theta,\omega,v)d\theta$. $h(\theta,\omega,v)$ is the total area bordering the square from which a whale moving in direction θ can enter the square in a fixed time increment, Δt. A similar procedure is used to choose at which point on the boundary of the square the new whale enters.

In the simulation model each whale blows at regular intervals and the whale is sighted if any blow is seen from the platform before the whale leaves the square. The probability that a blow is seen depends on its distance from the platform and angle from the trackline according to a specified function.

From the preceding discussion we would expect random whale movement to increase the number of sightings if whale velocity approaches platform velocity, sighting effort is concentrated along the trackline, and the blow rate is high. The results (Table 1) confirm that expectation. Platform velocity was set at 10 km hr^{-1} for each run of the simulation, whale velocity and blow rate being varied as shown in the table. The probability of seeing a blow declined with radial distance τ from the platform following a 'half normal' form. In order to concentrate sighting effort forward along the trackline the probability of seeing a blow also declined with angle from the trackline γ, thus:

$$P(\text{blow seen}) = e^{\frac{-\tau^2}{2\sigma_1^2}} \cdot e^{\frac{-\gamma^2}{2\sigma_2^2}}$$

σ_1, and σ_2 were set at 1 km and 20° respectively.

The increase in sighting rate due to random whale movement can be judged by comparing the runs using whale velocity set at 10 km hr^{-1} and 0 km hr^{-1}. The increase in sighting rate is insignificant when blow rate is low. When the simulation was repeated with equal effort at all angles γ between 0° and 60°, increase in sighting rate with whale velocity was insignificant even at high blow rate.

Table 1

Results of a simulation to assess bias due to random whale movement on line transect sighting rates and density estimates. $D = 0.5\ km^{-2}$

Platform vel. km hr^{-1}	Whale vel. km hr^{-1}	Blow rate hr^{-1}	Sighting rate km^{-1}	$\hat{D}$ km^{-2}	S.E. ($\hat{D}$) km^{-2}
10	0	100	1.072	0.499	0.041
10	10	100	1.240	0.763	0.028
10	0	3	0.134	0.161	0.029
10	10	3	0.139	0.167	0.031

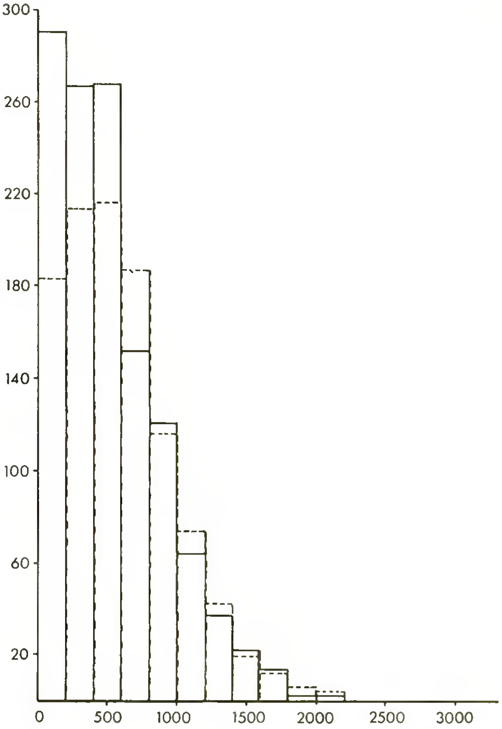

Fig. 2. Results of a simulation to assess bias due to random whale movement on line transect density estimates. The dotted line gives the frequency histogram for perpendicular distance from the trackline to 'sightings' for stationary targets. The frequency histogram given by the continuous line was obtained by setting target velocity equal to platform velocity. Perpendicular distances are shown in metres on the horizontal axis, the vertical axis gives the number of whales 'sighted' within each distance interval along a tracklength of 1,000 km. D = 0.5 whales km^{-2} so the expected number of whales sighted in the 0 → 200 metres interval is 200.

The last two columns in Table 1 show the effect of random whale movement on the estimate of mean density obtained using the Fourier series estimator described by Burnham *et al.* (1980). It is important to note that the increase in $\hat{D}$ is not proportional to the increase in sighting rate. This is because random whale movement affects the shape of the distribution of perpendicular distances from the trackline to the sightings as well as the number of sightings (Fig. 2).

From Fig. 2 it would appear that the bias induced in other estimators by random whale movement will depend on the sensitivity of those estimators to the proportion of sightings occurring near the trackline. In particular, an estimate derived from a narrow strip around the trackline would have a relatively large bias (about 45%, upward bias in the example illustrated by Fig. 2, using a strip width of 0.1 km).

The conditions under which random whale movement can lead to serious bias can occur in shipboard surveys, where platform and whale velocity may be of the same order. Best and Butterworth (1980) interpreted the shape of the distribution of sighting angles from the 1978/79 IDCR minke whale cruise as probably a result of concentrating sighting effort forward along the trackline. The need to detect all whales on the trackline in line transect sampling would tend to reinforce this effect. When the survey is for whales such as minkes, in which blows or other cues occur at a relatively high rate, bias due to random whale movement can be considerable.

REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere Minke Whale Assessment Cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 72, 202 pp.

Butterworth, D. S. 1980. A possible basis for choosing a functional form for the distribution of sightings with right angle distance. Paper SS/7 (published in this volume).

Skellam, J. G. 1958. The mathematical foundations underlying the use of line transects in animals ecology. *Biometrics* 14(3): 385–400.

SC/Jn81/MiS9

Minke Whale Response to a Transiting Survey Vessel

Stephen Leatherwood,[1] Frank T. Awbrey,[2] and Jeanette A. Thomas[1]

ABSTRACT

Ross Sea minke whales were observed from a helicopter within a 5.5 nm radius of an icebreaker transiting at 12 knots. The whales' swimming directions were uniform at all relative bearings from the ship and all distances tested ($P < 0.05$), suggesting that they were not responding to the vessel's presence. Corroborative results were obtained from observers aboard the transiting ship ($P < 0.05$). However, a significant proportion of whales observed did approach the icebreaker when it was 'laying to' or making headway at less than about 1 knot.

INTRODUCTION

Minke whales, *Balaenoptera acutorostrata*, are currently the principal targets of the whaling industry. A major share of recent worldwide harvest quotas (8,102 of 12,006 [1979–80] and 7,072 of 10,987 [1980–81]) has been assigned to the Southern Hemisphere. Almost all those whales are actually taken in Antarctic waters (IWC, 1979; 1980). Southern Hemisphere quotas have been based on estimates of population size obtained from sightings made during vessel surveys (Best and Butterworth, 1980; Horwood, 1981). Such estimates are generally calculated using transect models which are sensitive to the distribution of sighting distances (Burnham, Anderson and Laake, 1980).

Minke whales in both hemispheres are reportedly curious about at least stationary, idling vessels and often approach them (Gambell, Best and Rice, 1975; Leatherwood, Caldwell and Winn, 1976; Leatherwood, Reeves, Perrin and Evans, in press; Mitchell, 1978). There is concern that such curiosity, if manifested in minke whales' approaching survey vessels, might result in inflated estimates of density and therefore in excessive estimates of population total (IWC, 1982). This paper reports on an attempt to quantify response of southern minke whales to a transiting survey vessel.

MATERIALS AND METHODS

Field methods

Searches for minke whales were made from aboard USCGC *Polar Star* as it operated in Ross Sea, Antarctica between 27 January and 2 February 1981. Along seven segments of the cruise track (Fig. 1), concurrent operations were conducted with the ship, steaming at 12 knots, and a ship-based HH-52A helicopter. Segments for such operations were selected where minke whales were being observed from the vessel and weather conditions were suitable for safe helicopter operation. Safety restrictions on helicopter take-off and landing from shipboard—roll and pitch less than five degrees, winds less than 15 knots—worked to the advantage of the project since they assured that surveys were flown only under conditions optimum for sighting whales.

For these operations, the semicircular area forward of the ship's beam was divided into five concentric zones, each 1 nm wide. Each zone was graduated further at 0.25 nm intervals (Fig. 2). For each scheduled flight a starting point of 0.0, 0.25, 0.50 or 0.75 nm was selected at random. The helicopter, alternating between zones I and V as starting points, flew at the selected intervals in each zone, maintaining a constant radial distance from the ship by reference to the helicopter's on-board distance measuring equipment (DME) and covering the area from beam to beam. Because it was too close to the ship to permit adequate coverage in the short time required to complete it, the 0.25 nm interval in zone I was not flown. Whenever 0.25 nm was drawn, we substituted 0.50 nm in zone I, but flew the 0.25 nm transect in the other 4 zones.

Surveys were conducted at an altitude of 750 feet and a speed of 60 knots. One to three observers plus pilots and crew searched for whales along the transect route. When whales were detected, the helicopter diverted from the transect, flew directly over the animals and recorded: whales' swimming direction in degrees magnetic (this was recorded first to avoid bias from whales' possible response to the helicopter); ship's heading in degrees magnetic; magnetic bearing and distance of whales from the ship at the time they were initially seen (determined from the helicopter DME); number of individuals in the group; and relevant details of whales' behavior. The helicopter then returned to the appropriate distance and bearing from ship and resumed the transect.

During all seven segments, from one to three shipboard observers (non-scientific ship's crew), stationed on the flying bridge such that eye level was about 21 m, searched for minke whales. For each sighting, the observer(s) noted local time; estimated radial bearing (determined with a sighting alidade) and distance (subjectively estimated); number of individuals in the group; and estimated swimming direction in degrees magnetic.

Observations of whales were also made when the vessel was 'laying-to' or making slow headway (less than about 1.0 knot). Such observations were more opportunistic than those during the seven study segments described above. Observers noted swim direction of all whales seen but devoted special attention to whales in open water whose swim directions could accurately be estimated.

Data analysis

Helicopter data

Programs written for a *Hewlett Packard* Model 9810 calculator, with plotter, set ship's bearing to 0° and then

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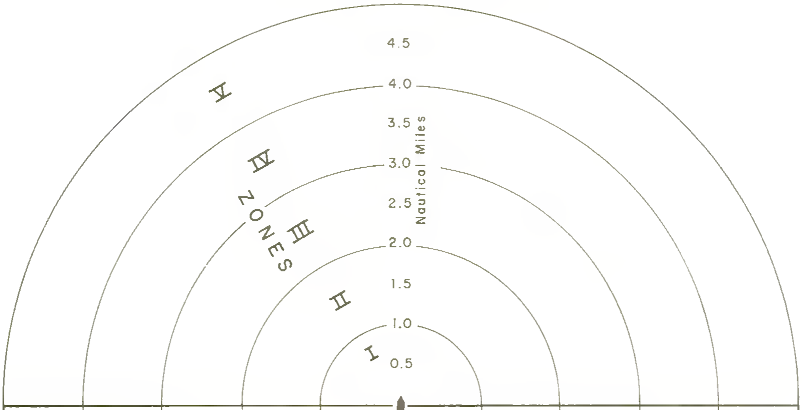
* Revised slightly from version presented at the meetings.



1,4,2,1,	2,4,2,2,	4,5,4,3,	3,5,3,3,	4,3,8	13.5 15.2 15.5	9.75 14.0 21.0 26.75	14.75 31.5 51.25 22.25	2.5 16.0 30.0 10.25	13.5 19.5 37.3 14.5
8	10	16	14	15	44.2	71.5	129.75	58.75	84.8
NUMBER OF REPLICATES					TOTAL SURVEY TIME (Minutes)				

Fig. 2. Placement of the semicircular transects around the ship and summary of effort by transect and zone.

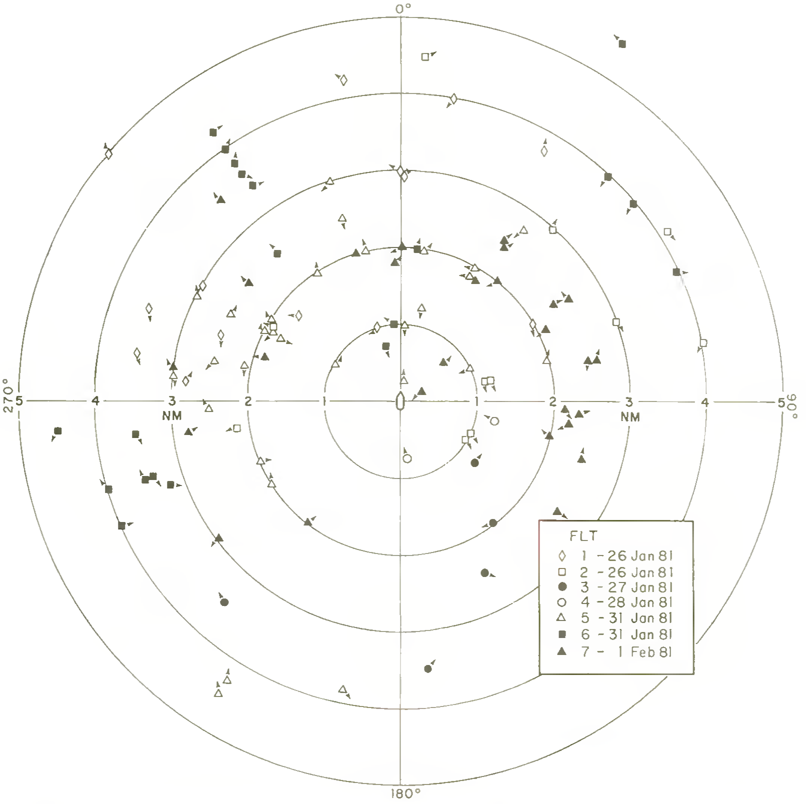


Fig. 3. Locations and swim directions relative to the ship of minke whales observed from helicopter.

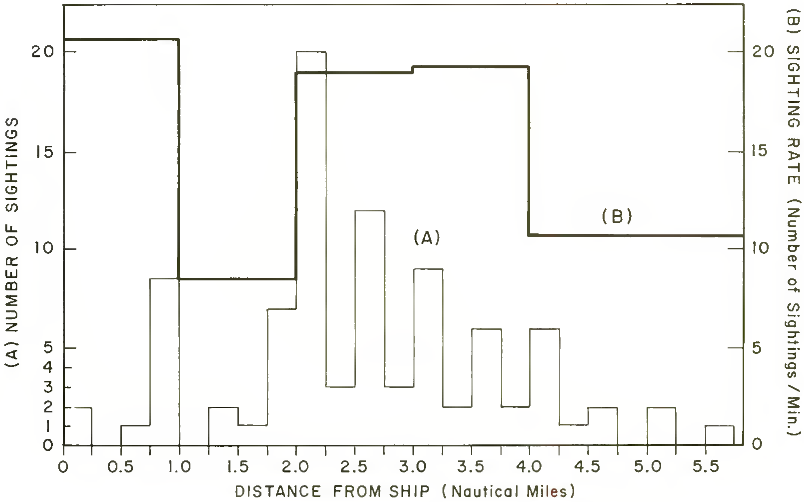


Fig. 6. Distribution of sighting distances (A) and rate of sightings (B) of minke whales observed from helicopter.

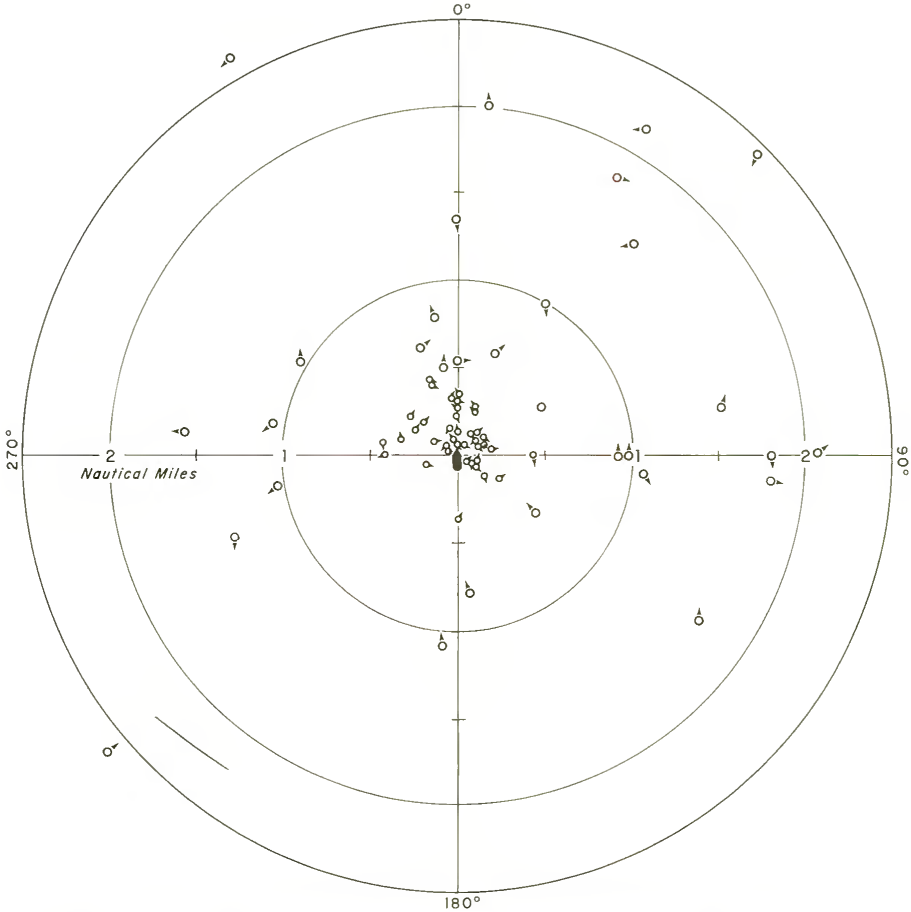


Fig. 7. Estimated locations and swim directions relative to the ship of minke whales reported by shipboard observers.

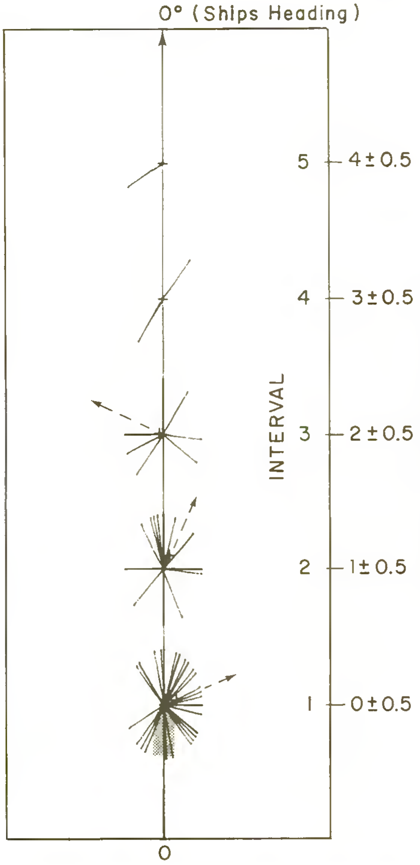


Fig. 8. Estimated swim direction of minke whales observed from shipboard, grouped by distance from the ship (———→ is the mean vector).

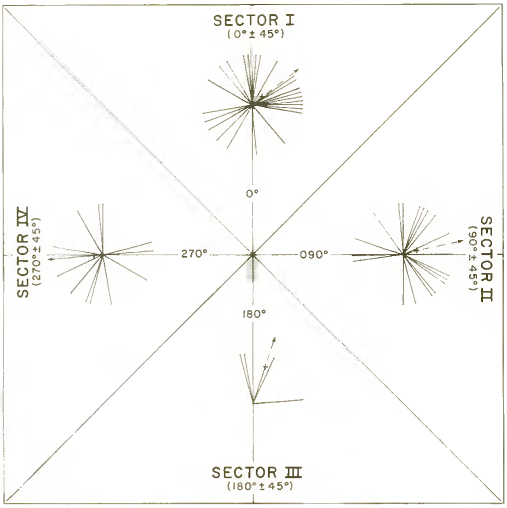


Fig. 9. Estimated swim directions of minke whales observed from shipboard, grouped by sectors relative to the ship (———→ is the mean vector).

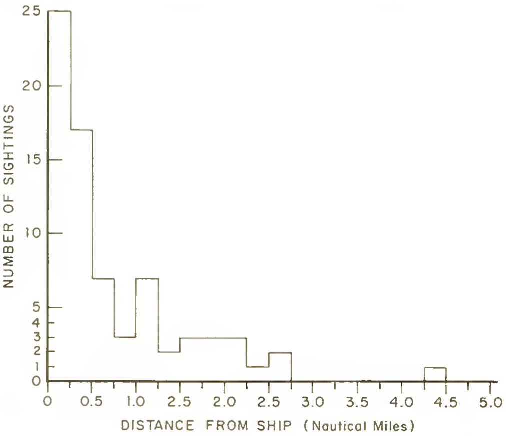


Fig. 10. Distribution of sighting distances from shipboard observations.

However, four instances regarded as fright reactions were observed—lobtailing followed by rapid changes of direction and high-speed swimming; a dispersed but parallel-swimming group's convergence, marked by breaching of all individuals, and then unison sounding; a quick start, promptly followed by sounding; and a rapid acceleration to sustained high speed surface swimming. In three instances, feeding animals, which on initial view were on their sides with the throat distended, righted and sounded or retreated under a nearby floe. Because they were on a meandering course when first encountered these last three whales were not included in this analysis.

The calculated Z values for mean swim vectors by distance interval (Table 1) and sector (Table 2) relative to the ship are all non-significant ($P < 0.05$). From appearance of the data used in analysis there is no reason to suspect bimodality. Therefore, from this result one is unable to reject the null hypothesis that swim directions of minke whales were uniform at all distances and angles with respect to this particular survey vessel at the location and time these experiments were conducted. Similarly, when the rough density indices calculated from number of sighting and survey effort are tested for uniformity of distribution within an approximately 5 nm radius of the ship one is unable to reject the null hypothesis that minke whales are uniformly distributed ($X^2_{0.05} = 0.696$, critical value = 0.711). Because these indices of density are only rough estimates this analysis is of interest principally as corroborative of the Z tests described above.

Table 1

Mean swim vectors, by distance interval from the vessel, of minke whales seen from helicopter

Distance interval	n	Mean vector	Vector length	Z calc.	Critical Z value, $P < 0.05$
1. 0 ± 0.5 nm	2	249.0°	0.14	0.04	2.870
2. 1 ± 0.5 nm	13	341.6°	0.15	0.30	2.940
3. 2 ± 0.5 nm	31	186.3°	0.07	0.16	3.640
4. 3 ± 0.5 nm	29	220.7°	0.01	0.00	3.638
5. 4 ± 0.5 nm	16	0°	0.04	0.02	2.950
6. 5 ± 0.5 nm	4	189.6°	0.12	0.06	2.870

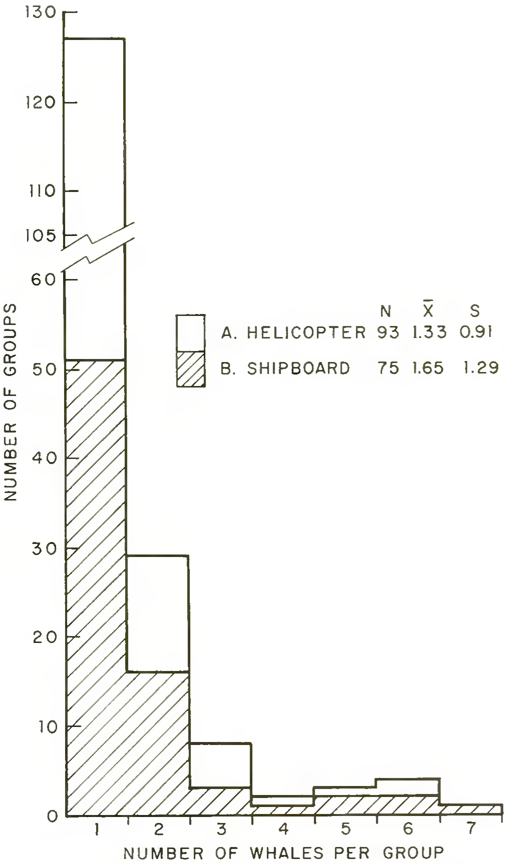


Fig. 11. Distribution of size of minke whale groups observed from helicopter (A) and ship (B).

Table 2

Mean swim vectors, by sector, of minke whales seen from helicopter

Sector	n	Mean vector	Vector length	Z calc.	Critical Z value P < 0.05
1. 0° ± 45°	33	332.9	0.16	0.89	2.978
2. 90° ± 45°	28	152.3	0.15	0.64	2.978
3. 180° ± 45°	4	327.2	0.79	2.48	2.870
4. 270° ± 45°	30	229.1	0.13	0.49	2.970

Ship

As with helicopter observations, calculated Z values for swim vectors of whales seen from the transiting ship are non-significant ($P < 0.05$) when grouped by either distance intervals (Table 3) or sector (Table 4). We were unable to alter course to investigate sightings or cross-check distance estimates. Without verification by more quantitative measurements we have little confidence in accuracy of subjective estimates of distance to whales made from transiting ships. Therefore, the analysis of distance data presented above should be regarded primarily as a demonstration of method and the results only tentatively supportive of those from helicopter observations, in which distance was measured to within 0.05 nm. Swim directions of whales could be accurately estimated from shipboard, particularly under the survey conditions encountered. Vectors to whales were also measured precisely, with reference to a sighting alidade and ship's gyro-compass. Therefore, reliance can be placed in the results of analysis of swim direction by sector, irrespective of sighting distance. Results of analysis of such data from observers aboard the transiting ship support those from analysis of data from helicopter.

Table 3

Mean swim vectors, by distance interval from the vessel, of minke whales seen from shipboard

Distance interval	n	Mean vector	Vector length	Z calc.	Critical Z value. P < 0.05
1. 0 ± 0.5 nm	41	74.9	0.14	0.75	2.980
2. 1 ± 0.5 nm	21	31.4	0.12	0.3	2.960
3. 2 ± 0.5 nm	10	91.5	0.05	—	2.920
4. 3 ± 0.5 nm	2	—	—	—	—
5. 4 ± 0.5 nm	1	—	—	—	—

Table 4

Mean swim vectors, by sector, of minke whales seen from shipboard

Sector	n	Mean vector	Vector length	Z calc.	Critical Z value, P < 0.05
1. 0 ± 45°	32	50.3	0.25	2.042	2.974
2. 90 ± 45°	23	73.7	0.28	1.864	2.960
3. 180 ± 45°	4	18.5	0.78	2.41	2.870
4. 270 ± 45°	16	266.3	0.18	0.513	2.950

Three hundred and seventy eight whales or whale groups were observed from the vessel when it was 'laying-to' or making less than about 1 knot headway. Approximately 150 of those were perceived to be working along the ice-edge or feeding beneath the ice and therefore unmindful of the vessel (Leatherwood, Awbrey, Thomas, Jehl and Evans, 1982). For the remainder there was a significant tendency of the whales to swim towards the vessel ($Z \text{ calc} = 14.65$, critical value $= 2.998$, $P < 0.05$). These results were consistent with observations of Japanese whalers in southern seas (K. Yamamura, pers. comm. July 1981) and Norwegian whalers in the North Atlantic (Mitchell, 1978; Benjaminsen, Berlund, Christensen, Christensen, Huse and Sandnes, 1976) that minke whales are attracted to stationary idling ships.

Collectively, the results of the present investigations support the conclusion that minke whales' swim direction was unaffected by the presence of the transiting ship. Butterworth and Basson (1982) tentatively reported that they could demonstrate no attraction to a whaling-survey vessel from results of parallel ship experiments. However, because of probable measurement imprecisions they placed little reliance on their results. If results similar to those obtained in the present experiment can be verified for survey vessels of the type actually utilized in the population assessments, no correction factor for minke whales response to survey vessel need be introduced in transect models used to estimate minke whale population size from shipboard sightings.

Different classes of vessels produce different acoustic signatures characterized by distinctive frequency spectra, source levels and propagation patterns (Awbrey, Leatherwood, Ljungblad and Evans, in press). At least small cetaceans have learned to respond differentially to 'capture' vessels, taking flight when such vessels approach but seemingly unaffected by other similar vessels (e.g., Leatherwood and Platter, 1975). Finally, whale behavior varies by area and by season and whales may be less perturbed when engaged in such activities as feeding and courting.

Until results of this study are verified conclusively for minke whale responses to survey vessels in areas where population surveys and subsequent whaling are actually conducted the present study should be regarded primarily as a demonstration of methods.

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REFERENCES

Awbrey, F. T., Leatherwood, S., Ljunglad, D. K. and Evans, W. E., in press. Acoustical conditions during purse seining for yellowfin tuna (*Thunnus albacares*). *Fish Bull.* (U.S.).

Batschellet, E. 1972. Recent statistical methods for orientation data. pp. 61–91. *In:* Galler, S. R., Schmidt-Koenig, K., Jacobs, G. J., and Belleville, R. E. (eds). *Animal Orientation and Navigation.* Washington, D.C. N.A.S.A. 606 pp.

Benjaminson, T., Berlund, J., Christensen, D., Christensen, I., Huse, I., and Sandnes, O. 1976. Marking, sightings, and behavior studies of whales in the Barents Sea and at Svalbard. In 1974 and 1975. *Fisken Hav.* 76(2): 9–23.

Best, P. B., and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Burnham, K. P., Anderson, D. R., and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monograph No. 72, 202 pp. (Supplement to *J. Wildl. Manage.* 44(2).)

Butterworth, D. S., Best, P. B. and Basson, M. 1982. Results of analysis carried out during the 1980/81 Southern Hemisphere minke whale assessment cruise. Paper SC/Jn81/MiS5+13+17 (published in this volume).

Cochran, W. G., and Cox, G. 1957. *Experimental Designs*, 2nd ed. John Wiley, New York.

Gambell, R., Best, P. B., and Rice, D. W. 1975. Report on the International Indian Ocean Whale Marking Cruise. *Rep. int. Whal. Commn.* 25: 240–52.

Horwood, J. W. 1981. Results from the IWC/IDCR minke whale marking and sighting cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

International Whaling Commission. 1979. Report of the Scientific Committee. Annex F. *Rep. int. Whal. Commn* 29: 74–83.

International Whaling Commission. 1980. Report of the Scientific Committee. Annex G. *Rep. int. Whal. Commn* 30: 96–103.

International Whaling Commission. 1982. Report of the workshop on the design of sighting surveys (published in this volume).

Leatherwood, S., and Platter, M. F. 1975. Aerial assessment of bottlenose dolphins off Alabama, Mississippi, and Louisiana. pp 46–89 *In:* D. K. Odell, D. B. Siniff, and G. H. Waring. *Tursiops truncatus* assessment workshop. Final Rept. U.S. Marine Mammal Commission, Contract MM5AC 021. Rosenstril School of Marine and Atmospheric Sciences, 4600 Rickenbacker Causeway, Miami, Fl. 33149.

Leatherwood, S., Caldwell, D. K., and Winn, H. E. 1976. *The Whales, Dolphins and Porpoises of the Western North Atlantic; A Guide to their Identification.* N.O.A.A. Tech. Rept., N.M.F.S. Circ. 396. 176 pp.

Leatherwood, S., Reeves, R. R., Perrin, W. F., and Evans, W. E., in press. *Whales, Dolphins and Porpoises of Eastern North Pacific and Arctic waters; a Guide to their Identification.* N.O.A.A. Tech. Rept., N.M.F.S. Circ.

Leatherwood, S., Thomas, J. A., and Awbrey, F. T. 1982. Minke whales off northwestern Ross Island. Antarctic Journal of the United States (in press).

Mitchell, E. D. 1978. Minority statement on southern minke whale stock assessment. *Rep. int. Whal. Commn* 28: 84–5.

SC/Jn81/MiS10 + 31

Southern Hemisphere Marking of Minke Whales

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ABSTRACT

A total of 1,773 minke whales are estimated to have been effectively marked with .410 calibre whale marks in the Southern Hemisphere up to the close of the 1979/80 whaling season as part of the International Whale Marking Scheme. 253 additional whales have been marked with 12-bore marks in the USSR scheme. The distribution of these marked whales is plotted. Details of the 29 marks recovered are given and the movements illustrated by them are discussed. Problems of estimating the numbers of effectively marked whales when using the .410 mark are noted.

NUMBER AND DISTRIBUTION OF MARKED WHALES

International marking scheme

A very few minke whales were marked in the Southern Hemisphere in pre-war years by, or associated with, the Discovery Committee, and in post-war marking under the international whale marking scheme up to 1970 (Brown, 1979 and Table 2). All were marked with the standard Discovery 12-bore whale mark and none of the marks have been returned to date.

From 1971 onwards the small Discovery .410 whale mark has been used in the Southern Hemisphere for marking minke whales in the international scheme programme. A small but gradually increasing number of animals was marked each year until the 1978/79 season when the first Southern Hemisphere minke whale assessment cruise was undertaken. 725 minke whales were effectively marked in the Antarctic in Areas IV (717 whales) and V (8 whales) during this cruise (Best and Butterworth, 1980) and additional marking by Japanese scouting boats brought the season's total up to 765 whales (IWC, 1980). In the 1979/80 season the second minke whale assessment cruise effectively marked 705 minke whales in the Antarctic in Area III (Horwood, 1981). An additional 152 animals were marked in Areas I and II during an international marking scheme cruise by a Soviet vessel in the same season (Ivashin, 1981a).

A total of 1,773 minke whales are estimated to have been effectively marked with .410 marks in the Southern Hemisphere in international scheme programmes from 1971 to the 1979/80 season inclusive; 1,524 of them are in Areas III and IV (Table 1). The distribution of these marked whales by 10° squares is shown in Fig. 1.

A further 474 minke whales are estimated to have been effectively marked during the third minke whale assessment cruise in the Antarctic in Area V during the 1980/81 season but detailed records of this marking are not yet available (Butterworth and Best, 1982).

USSR marking scheme

Minke whales have been marked in small numbers by USSR marking programmes in the Southern Hemisphere in most seasons from the 1957/58 season onwards. Much of the marking has been in Antarctic waters. A total of 253 whales are estimated to have been marked in seasons 1957/58 to 1979/80 inclusive (Table 2). The distribution of these marked whales by 10° squares is shown in Fig. 2 (data from Ivashin, 1981b).

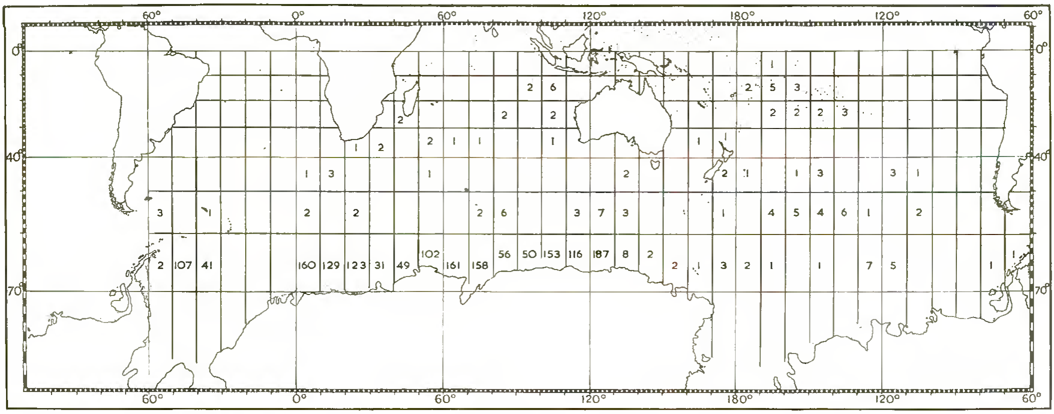

Fig. 1. Distribution of marked minke whales in the Southern Hemisphere – International scheme (.410 marks) 1971–1979/80 season inclusive.

Table 1

Numbers of minke whales estimated to have been effectively marked with .410 whale marks in the Southern Hemisphere (International Marking Scheme 1971–1979/80 inclusive)

	Whaling Areas						
Season	I	II	III	IV	V	VI	All Areas
1971	—	—	1	—	—	—	1
1973/74	—	—	2	—	—	—	2
1975	—	—	1	—	—	—	1
1975/76	1	3	16	—	3	—	23
1976/77	—	—	25	2	1	6	34
1977/78	11	—	20	18	17	24	90
1978/79	—	—	2	732	10	21	765
1979/80	1	151	705	—	—	—	857
Total	13	154	772	752	31	51	1,773

Table 2

Numbers of minke whales estimated to have been effectively marked with 12-bore whale marks in the Southern Hemisphere

	Whaling Areas						
Season	I	II	III	IV	V	VI	All Areas
International Scheme							
1955/56	—	—	—	1	—	—	1
1967/68	—	—	—	5	—	2	7
Total	—	—	—	6	—	2	8
USSR Scheme (1957/58–1979/80 inc.)							
Total	66	28	114	22	15	8	253

All these whales have been marked with the standard USSR whale mark which is essentially the same size as the standard Discovery 12-bore mark.

RETURNED MARKS

International marking scheme

Twenty-five of the .410 marks fired in international marking scheme programmes have so far been returned from 24 minke whales. The marks are listed in Table 3 arranged in year-groups according to date of recovery and in chronological order of firing. In Table 4 the returns from whales marked in each season are tabulated by year-groups.

USSR marking scheme

Four of the marks fired in the USSR marking scheme have been returned. They are listed in Table 5 (data from Dr Ivashin) arranged in year-groups as in Table 3.

It should be noted that the marking positions in Table 3 are those given in the principal marking records of the cruises. They are the positions at which lone whales were marked or, in the case of a school of whales, the position of the school when the first whale in it was marked. Whales subsequently marked from the same school are given the same position, even though they may have moved from this position before being marked.

MOVEMENTS OF MARKED WHALES

The movements shown by the 29 marks returned from the two marking schemes have been plotted. Fig. 3 includes marks returned from whales killed in the same season as marking (0-group). Fig. 4 includes marks returned from whales killed in subsequent seasons (1, 2 and 3-groups).

International scheme marks

The eight marked whales killed in the same season as they were marked (0-group) in Table 3, were all shot less than one month after marking. Seven show only small movements from the marking position within the Area in which they were marked. One (No. 33896) marked just inside the western boundary of Area V moved a short distance westwards into Area IV and was killed close to the eastern boundary of this Area.

There are nine marked whales killed in the season following marking (1-group). Of six whales killed within the same Area as they were marked, three (Nos 34390, 34576, 35170) were killed close to the marking positions in Areas III and IV. The other three whales were killed at varying distances from the marking position, No. 26260/27968 within 10° of longitude, No. 37169 in Area IV approximately 40° westwards and No. 35722 in Area III about 45° eastwards.

The remaining three whales show movements from one Area to another in the course of the year. No. 34559 has moved westwards from Area IV, where it was marked close to the western boundary, across Area III to a position close to the western boundary of this Area. Nos 38820 and 38822 (recovery positions approximate) moved eastwards

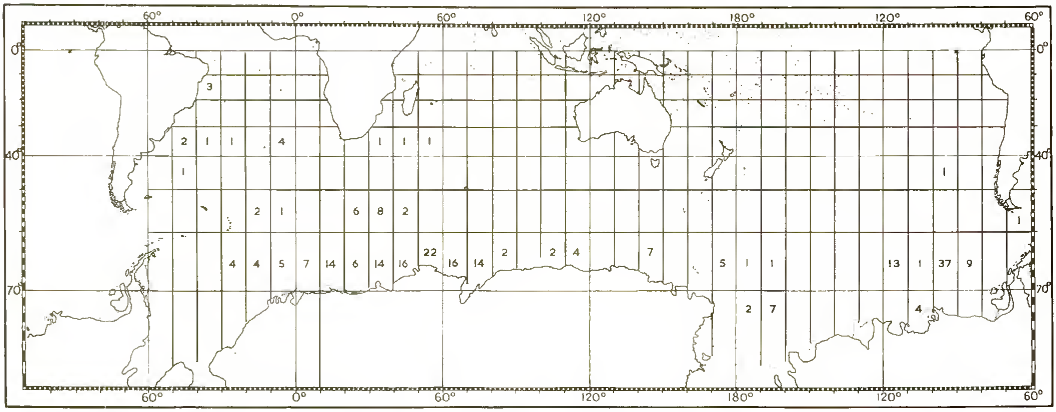

Fig. 2. Distribution of marked minke whales in the Southern Hemisphere – USSR scheme 1957/58–1979/80 inclusive.

Table 3

Marks returned from minke whales in the Southern Hemisphere (International Scheme)

Mark number	Date marked	Date recovered	Time elapsed (years, months)	Position marked	Position recovered	Sex	Length in feet
				0-group			
32344	17.ii.1977	18.ii.1977	0.0	67°02′S, 61°06′E	66°48′S, 59°41′E* (refrigerator vessel)	—	—
34130	12.i.1979	30.i.1979	0.1	68°04′S, 73°56′E	67°46′S, 74°01′E*	—	—
37007	1.ii.1979	19.ii.1979	0.1	64°35′S, 123°11′E	64°51′S, 111°18′E*	—	—
37008	1.ii.1979	19.ii.1979	0.1	64°35′S, 123°11′E	64°48′S, 111°01′E	Female	30
37010	1.ii.1979	19.ii.1979	0.1	64°35′S, 123°11′E	64°51′S, 111°18′E*	—	—
33896	6.ii.1979	25.ii.1979	0.1	65°02′S, 130°18′E	65°18′S, 127°52′E*	—	—
39069	3.i.1981	24.i.1981	0.1	66°25′S, 141°28′E	66°55′S, 142°52′E	Female	28
39176	16.i.1981	3.ii.1981	0.1	63°43′S, 161°10′E	65°48′S, 156°18′E	Female	29
				1-group			
26260 27968	31.xii.1978	19.1.1980	1.1	63°36′S, 95°54′E	64°22′S, 88°42′E	Male	29
34390	5.i.1979	7.i.1980	1.0	65°34′S, 85°04′E	65°41′S, 85°00′E*	—	—
34559	13.i.1979	27.ii.1980	1.0	64°01′S, 71°30′E	69°11′S, 03°56′E	Male	28
34576	14.i.1979	5.iii.1980	1.2	64°45′S, 70°18′E	66°55′S, 71°27′E* (refrigerator vessel)	—	—
37169	5.ii.1979	27.xii.1979	0.11	65°06′S, 128°47′E	65°05′S, 89°27′E*	—	—
35170	9.i.1980	16.xii.1980	0.11	64°12′S, 60°21′E	63°16′S, 62°34′E	Male	26
38820	13.i.1980	12.i.1981	1.0	67°07′S, 66°51′E	67°00′S, 73°00′E* (refrigerator vessel)	—	—
38822	13.i.1980	19.i.1981	1.0	67°07′S, 66°51′E	68°00′S, 77°00′E* (refrigerator vessel)	—	—
35722	6.ii.1980	9.xii.1980	0.10	68°52′S, 11°17′E	62°00′S, 56°00′E* (refrigerator vessel)	—	—
				2-group			
34216	12.i.1979	19.i.1981	2.0	68°04′S, 73°56′E	68°03′S, 77°00′E* (refrigerator vessel)	—	—
34102	14.i.1979	19.xii.1980	1.11	67°15′S, 70°46′E	64°01′S, 59°16′E	Female	28
33975	22.i.1979	4.i.1981	1.11	62°43′S, 104°52′E	64°22′S, 81°00E* (refrigerator vessel)	—	—
34266	11.i.1979	14.i.1981	2.0	67°40′S, 75°15′E	67°00′S, 74°00′E* (refrigerator vessel)	—	—
31461	29.i.1979	5.i.1981	1.11	63°50′S, 116°46′E	63°22′S, 94°58′E	Female	30
31466	29.i.1979	5.i.1981	1.11	63°50′S, 116°46′E*	63°10′S, 95°08′E*	—	—
				3-group			
32985	12.ii.1978	26.i.1981	2.11	67°41′S, 75°45′E	68°00′S, 73°00′E* (refrigerator vessel)	—	—

* Noon position of factory ship.

Table 4

Marked minke whales killed in each year-group (International Marking Scheme)

Season	Number marked	Returned: Same season 0–Gp	First season 1–Gp	Second season 2–Gp	Third season 3–Gp	Total
1971	1	—	—	—	—	—
1973/74	2	—	—	—	—	—
1975	1	—	—	—	—	—
1975/76	23	—	—	—	—	—
1976/77	34	1	—	—	—	1
1977/78	90	—	—	—	1	1
1978/79	765	5	5	6		16
1979/80	857	—	4			4
1980/81	474	2				2
Total	2,247	8	9	6	1	24

from a position close to the eastern boundary of Area III, just into Area IV.

All six of the 2-group returns are from whales marked in Area IV and five of them were killed in the same Area at varying distances from the marking position. Two whales, Nos 34216 and 34266 were killed very close to this position. The remaining whale No. 34102 was marked just inside the western boundary of Area IV and killed in the eastern half of Area III.

The one 3-group return is from a whale killed very close to the marking position in Area IV.

USSR scheme marks

Marks have been returned from four whales marked in the USSR scheme, three in the same season as marking and one in the following season (Table 5). All four whales were marked in the eastern half of Area III. No. 680102 shows a westward movement within the eastern half of the Area of about 14° of longitude in just over two months from mid-December to late February. No. 680115 shows a westward movement of similar extent within eight days from mid-December. No. B713 has moved 60° of longitude southwestwards into the eastern half of Area II in just under two months.

No. B700 shows a return after one year to the area of marking.

Table 5

Marks returned from minke whales in the Southern Hemisphere (USSR scheme)

Mark number	Date marked	Date recovered	Time elapsed (years, months)	Position marked	Position recovered	Sex	Length in feet
				0-group			
680102	16.xii.1976	23.ii.1977	0.2	64°00′S, 63°57′E	66°29′S, 49°58′E	Female	29
680115	17.xii.1976	24.xii.1976	0.0	64°00′S, 65°20′E	65°06′S, 52°04′E	Female	28
B713	2.xii.1979	28.i.1980	0.2	62°23′S, 42°28′E	71°42′S, 17°48′W*	Female	30
				1-group			
B700	7.xii.1978	21.xii.1979	1.0	61°51′S, 39°33′E	64°55′S, 47°47′E*	—	—

* Noon position of factory ship.

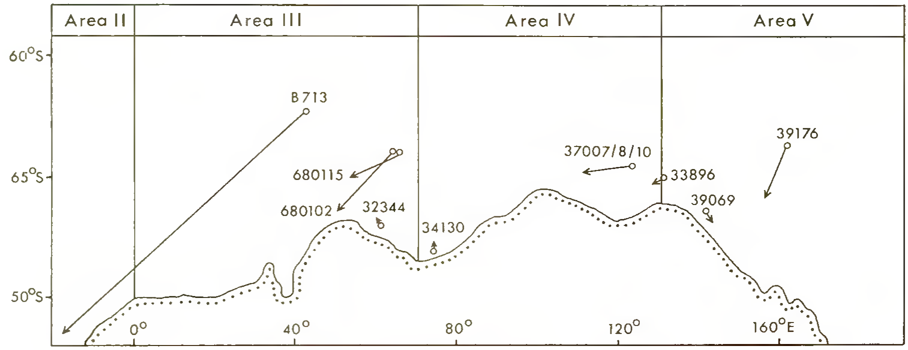

Fig. 3. Movements of minke whales during the whaling season from mark returns (0-group).

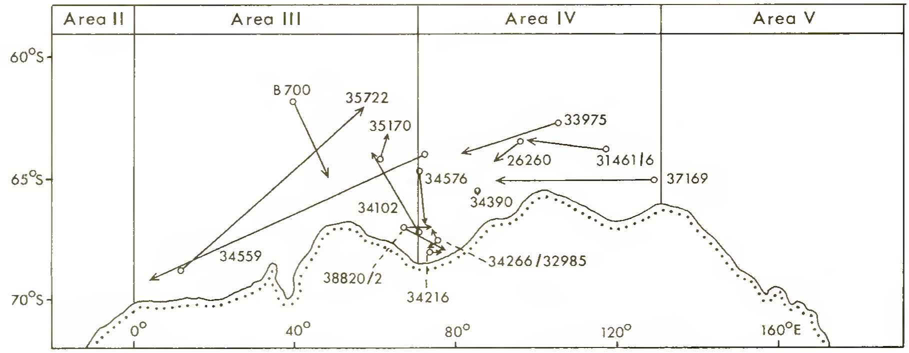

Fig. 4. Movements of minke whales killed one or more years after marking (1, 2 and 3-groups).

Summary

Only tentative conclusions about minke whale movements can be drawn from the small number of returned marks available at present.

There is some evidence of westward movement during the whaling season for whales in both Areas III and IV but as yet only one return (No. B713) shows a large scale movement during the whaling season.

Assuming that these minke whales migrate northward in the autumn and return southwards in the spring, following a migratory cycle similar to that of other balaenopterid species in the Southern Hemisphere, some of the 1-group, 2-group, and the 3-group returns illustrate a return to the Area of marking, including some to very close to the marking position, after one, two and three years. This is comparable to movements shown by mark returns from blue, fin, sei and humpback whales. Alternatively, if these whales have a year-round southern distribution with only small numbers north of the Antarctic Convergence (Laws, 1977), these returns indicate that some animals apparently remain in, or return seasonally to, a restricted area, while others move more widely in Antarctic waters.

Six of the 28 returns show movement from one whaling Area into another. There are westwards movements from Area V to IV, and Area III to II within the whaling season; from Area IV westwards to Area III and Area III eastwards to Area IV (two whales) after one-year, and from Area IV to III after two years. However, five of the six whales were marked and/or killed within 5° of longitude on either side of the boundaries between Areas. Only one whale (No. B713), moving westwards from the eastern half of Area III to the eastern half of Area II within the whaling season, shows a large-scale movement from a position well within an Area, across a boundary between Areas. No conclusions about the validity of the present boundaries between Areas for minke whales can be drawn from this analysis of the available mark returns.

MINKE WHALE MARKING PROBLEMS

Use of 12-bore calibre marks

The standard Discovery 12-bore mark is unsuitable for marking minke whales because of its size and the possibility of seriously injuring animals with it (Brown, 1979). Although a few minke whales have been marked with this mark, only one mark recovery has so far been reported. This was from a whale marked in the North Atlantic in June 1954 and captured in August 1958 when it was recorded as 27 feet long, with the mark found close to the vertebral column. There is evidence that sperm whales of about 21 feet and 33 feet long have been killed by standard marks (Brown, 1975) and it is possible that some at least of the minke whales marked with this mark were seriously injured.

The standard USSR mark is essentially the same size as the standard Discovery 12-bore mark and must also be regarded as unsuitable for marking minke whales, even though four of the marks have been returned after periods ranging from a few days to one year.

In the present paper, records of marking with Discovery 12-bore and USSR standard marks have been kept separate from the marking records using .410 marks.

Use of .410 calibre marks

Even with the .410 mark there is the possibility of injuring minke whales. On each of the three minke whale assessment cruises, a small number of marked whales were recorded as bleeding from the point of entry of the mark, or as blowing blood for a short period. These injuries occurred in spite of a careful code of marking practice restricting the target area to be aimed at on the whale, and a decision not to mark animals below 20 feet in length (Best and Butterworth, 1980; Horwood, 1981). On the second cruise seven whales recorded as hit were believed to have been badly injured and they were not counted in the total of whales effectively marked (Horwood, 1981).

Visibility of the .410 mark

A major problem in using the standard .410 mark is that it is very difficult to see in flight. This considerably increases the difficulty of making reliable decisions as to their fate when fired (Best and Butterworth, 1980; Horwood, 1981). An unsuccessful attempt was made on the 1980/81 cruise to overcome this problem using a new design of streamer mark which would be visible in flight and on the whale, and further experiments are planned.

Estimation of the number of effective hits

Best (1977) has discussed the problem of estimating the numbers of whales which have been effectively marked in relation to the marking of large whales in South African waters. He concluded, on the basis of returns from whales considered to have been double-marked, that a considerable proportion of marks recorded as hits must in fact be incorrectly recorded.

The same problem arises in marking minke whales with the .410 mark (Best and Butterworth, 1980) and is more acute because of the difficulty of seeing this mark in flight.

Examples of the difficulties involved in estimating the number of effective hits can be illustrated from the returns listed in Table 3. Of the 25 marks (from 24 whales) so far returned, there are five cases where the original marking records are, or could be, at variance with the true fate of the marks as shown by the recovered marks.

Nos 32344 (0-group) and 31466 (2-group) were recorded as possible hits but were in fact definite hits and have been added to the total of effective hits. Nos 37007, 37008, 37010 were all fired close together and recorded as hits on three whales of different estimated lengths. The marks were all recovered on the same day and Dr Best in response to my query commented (in litt.), 'The series 37007/8/10 definitely came from three different whales according to the marking record, and the recovery information I obtained from Kato on 20 January (sic) 1979 indicated that 37008 was found in whale 2353 on the flensing platform, 37010 at panning in meat belonging to whales 2340–2350 and 37007 was found loose, and could only be attributed to whales 2325–2364. Clearly 37008 and 37010 were in separate whales, but there is no means of discriminating whether 37010 and 37007 were in the same whale or not. Hence I feel we must accept the marking record'. These marks are therefore regarded as three returns from three different whales in the final records, but there is a possibility that in fact only two whales are involved.

Nos 26260/27968 were both returned from the same whale. The marking record listed them as fired with No. 27956 at three whales of the same estimated size in a group of six whales. No. 26260 was a possible hit and Nos 27968 and 27956 were hits. In this case no change in the number of effective hits (two) is involved since both marks were returned from the same whale. The animal hit by No. 27956 is assumed to be still at large.

According to the marking records No. 34576 was one of three marks all recorded as hits on the same whale. No. 34576 was returned after one year and two months from an unidentified whale, but the other two marks (Nos 34574, 34578) were not returned. Once again no change in the number of whales estimated as effectively marked is involved but the possibility remains that Nos 34574, 34578 were in fact fired at one or two different animals which are still at large, rather than shed during the year or not recovered from the animal marked with No. 34576.

REFERENCES

Best, P. B. 1977. Status of whale stocks off South Africa, 1975. *Rep. int. Whal. Commn* 27: 116–21.

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Brown, S. G. 1975. Marking of small cetaceans using 'Discovery' type whale marks. *J. Fish. Res. Bd Can.* 32(7): 1,237–40.

Brown, S. G. 1979. The marking of minke whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 29: 359.

Butterworth, D. S. and Best, P. B. 1982. Report of the Southern Hemisphere minke whale assessment cruise, 1980/81. Paper SC/Jn81/MiS14+15+19 (published in this volume).

Horwood, J. W. 1981. Results from the IWC/IDCR minke marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

International Whaling Commission. 1980. Japan Progress Report on Cetacean Research June 1978–May 1979. *Rep. int. Whal. Commn* 30: 155–60.

Ivashin, M. V. 1981a. USSR Progress Report on Cetacean Research June 1979–May 1980. *Rep. int. Whal. Commn* 31: 221–6.

Ivashin, M. V. 1981b. Marking of minke whales (*Balaenoptera acutorostrata,* Lac. 1804) in the waters of the Southern Hemisphere (Soviet program of tagging). Paper SC/Jn81/MiS33 presented to the IWC Scientific Committee, June 1981.

Laws, R. M. 1977. The significance of vertebrates in the Antarctic marine ecosystem. pp. 411–438. *In:* G. A. Llano (ed.) *Adaptations Within Antarctic Ecosystems,* Smithsonian Institution, Washington.

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Bias of the CPUE Using Search Time as Effort Measure

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ABSTRACT

The bias of the CPUE = catch/CSW due to the time spent on acquiring operations, ie. catching, handling, towing, and due to 'stop-catch' is investigated. CSW is total search time; stop-catch means halting all search and acquiring operations, ie. the actual whaling, for a part of a day while a backlog of whales is processed at the factory ship. This condition only applies to pelagic whaling. It is shown that, in the presence of a daily variation in whale density and under certain assumptions, the CPUE tends to underestimate the average whale density. In particular, for parameter values corresponding to the Japanese Antarctic minke whaling expedition of 1979/80, the CPUE could have underestimated the density by about 25%. In this case the acquiring operations caused most of the bias while the stop-catch little.

1. INTRODUCTION

Over the years various measures of effort have been used for the CPUE (catch per unit effort) indicator, defined as catch/effort, of whale density. As the amount of information relating to the fishing operations has increased, more refined measures have become possible. Recently Ohsumi (1979) used CSW, or total search time and, at the June 1978 annual meeting of the International Whaling Commission, the Scientific Committee selected search time as a better effort indicator than CHW, or total hours worked, the effort indicator generally in use up to this time. The intuitive reasoning seems very appealing: time spent searching is directly related to the density of whales whereas time spent on other operations is not.

Beddington (1979), Holt (1979) and Fowler (1980) have investigated the bias of the statistic catch/CHW as an estimate or index of density assuming that catch/CSW is proportional to the density. The bias is due to the time spent on the acquiring operations: catching, handling and towing. In this paper it is shown that the bias due to this source, acquiring, is not eliminated in the statistic catch/CSW, and may be quite appreciable. We shall call this source of bias the acquiring operation factor.

Another source of bias investigated here is due to the 'stop-catch', which means halting whale catching operations (as distinguished from processing operations at the factory ship) for part of a day while a backlog of caught whales is processed. This situation, which applies to pelagic operations only, has arisen recently for the Japanese Antarctic minke whaling operation where, because of a reduced quota, the Japanese have switched to using only a single factory ship (Shimadzu, 1980). Because of limited freezing capacity this has resulted in a daily capacity limitation of approximately 50 minke whales. While there has always been a capacity limitation, what is new is that the limit is now frequently reached, resulting in stop-catch orders for those days. This source of bias shall be called the stop-catch factor.

Before going any further let me clarify what I mean by bias. There are many sources of bias of the CPUE as an index or measure of density. The most difficult to deal with is due to the non-random nature of the sample gathered by the whaling operation. In order to assess other sources of bias it is necessary to assume that the searching operation has at least some of the characteristics of random sampling; otherwise, it is impossible to evaluate the bias. The biases investigated here are biases that would persist if random sampling were, in fact, being carried out.

Shimadzu (1980) called attention to the bias resulting from the stop-catch. The intuitive reasoning is that the true density of whales varies from day to day, or local area to local area, resulting in daily variation as the expedition moves through these areas. Stop-catch days tend to occur on days when the density is high. Then these days, with fewer hours worked, do not contribute as heavily as they would to the CPUE if there were no stop-catch.

The influence of catching + handling + towing time on the bias of the CPUE is through the back door, so to speak. It results from the negative correlation between CSW and the catch on a daily basis. This negative correlation is apparent in Figs 1a and b giving the daily catch totals and CSW for the entire 1979/80 and part of the 1976/77 Japanese Antarctic minke whaling expeditions. The data come from Ohsumi and Shimadzu (1980). It arises because the more time spent searching, the less time is available for the acquiring operation in one day. But the acquiring time is approximately proportional to the catch giving rise to a negative correlation between the search time and the catch total on a daily basis. The effect of the stop-catch is also evident in Fig. 1a. (There are fewer points in b because it contains only points for which the CSW was measured directly).

There is an apparent contradiction in the relation between catch and search time as revealed in Fig. 1, on the one hand, and in the commonly used model, catch = cN (search time), where c is a constant and N a measure of population density. The model seems to imply that if the search time is increased the catch will increase proportionately, while the data show the contrary. This apparent contradiction is resolved when it is realized that the points in the graph show the relation between the dependent pair of random variables, daily catch and daily search time, while the model expresses the relationship between averages, i.e. if more hours per day are spent whaling both average search time and average catch will increase.

Other known sources of bias are due to weather variation and seasonal variation (Shimadzu, 1979, 1980; Ohsumi, 1979). These will not be discussed here.

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The model is given in section 2, the results in section 3, and a discussion of the adequacy of the model in section 4. The details of the computations are given in the Appendix.

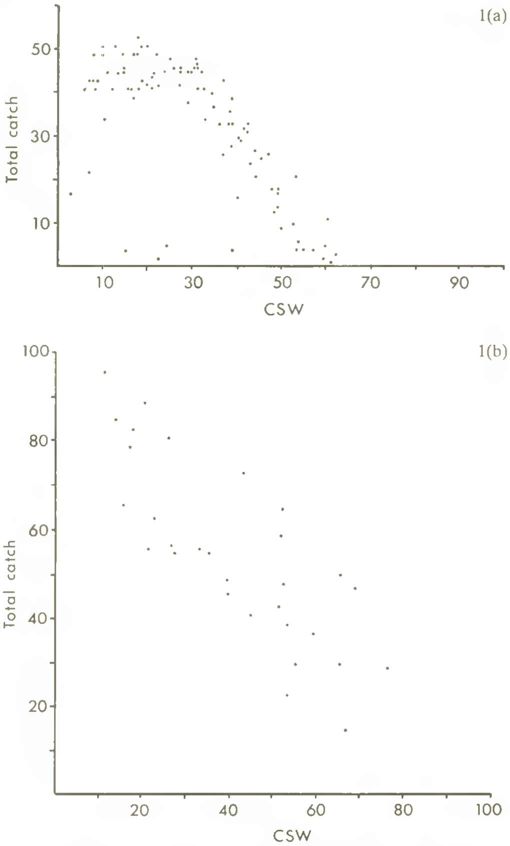

Fig. 1. Daily catch total and CSW for (1a) 1979/80 and (1b) 1976/77 Japanese Antarctic minke whaling expeditions. Each point represents one day.

2. MODEL

The model roughly approximates Japanese minke pelagic whaling, though it is not restricted to this. Descriptions of this whaling are given in Ohsumi (1979) and Shimadzu (1980). It is assumed that we have a factory ship and several catcher boats. Catcher boats operate in a cycle of searching, confirmation, chasing, handling, and towing, and the cycle is repeated, possibly with either the searching or towing parts omitted, without rest breaks until operations cease for the day. In practice, the rest breaks may occur in the middle of the day. It is convenient to collect these times and to shift them to the end of the day in the model. The several operations will be grouped into two categories called phases: a search phase which only includes the above searching operation, and an acquiring phase which includes everything but searching. The two phases alternate and a pair, a searching followed by an acquiring phase, will be called a cycle. In addition the following assumptions are made.

(a) Whales are found in pods of identical size, m, and exactly $h \leq m$ from a pod are taken in the acquiring phase.

(b) The lengths of the search phases are independently, exponentially distributed with parameter u, i.e. with density function ue^{-ut}, $t > 0$. The value u_1 is taken by u on a fraction f of days and the value u_2 on the remaining fraction $1 - f$ of days. These two levels are meant to approximate the distribution of u. Since each search phase ends when a pod is sighted, u is the density of pods.

(c) The daily average length of the acquiring phase is a constant time, ht_a, throughout the season; t_a is the daily average acquiring time per whale.

(d) There are k catcher boats operating independently. Let N_t = total number of whales acquired by time t measured from the start of the day by all catcher boats.

(e) A halt to the day's operations is ordered as soon as either (I), $t = t_0$ or (II), $N_t = n_0$, whichever comes first. For convenience, n_0 is taken as a multiple of h. When the halt is ordered any catcher boats engaged in searching cease operations but boats engaged in acquiring complete the phase (and take h whales each). If (II) occurs first the halt will be called a stop-catch.

For day i let T_i equal the total searching time, including time in interrupted search phases, and let N_i equal the total day's catch.

(f) The pairs of random variables (N_i, T_i) $i = 1,2 \ldots,$ i.e. each day's results, are independent and have the same distribution throughout the season.

The CPUE, based on searching times, is

$$\text{(1)} \qquad \text{CPUE} = \Sigma_{i=1}^{s} N_i / \Sigma_{i=1}^{s} T_i \ ,$$

where s is the number of days spent whaling. The CPUE is here considered as an estimate of the average density $h\bar{u} = h(fu_1 + (1-f)u_2)$. Multiplication by m/h gives the density of whales. The expected value of the CPUE is

$$\text{(2.1)} \qquad E(\text{CPUE}) = \frac{E(\Sigma_i N_i)}{E(\Sigma_i T_i)} + \text{bias due to ratio estimate}$$

By assumption (f) the bias term is of order 1/s (see e.g. Cochran, 1977). Since s is usually large, this bias will be negligible and can be dropped. Again by assumption (f), $E(N_i)$ and $E(T_i)$ are constant for all i, hence $E(\text{CPUE}) = E(N_i)/E(T_i)$, approximately, for any i. Then, by assumption (b), we obtain the elementary expansion, dropping the subscript i,

$$\begin{aligned} E(\text{CPUE}) &= E(N)/E(T) \\ \text{(2.2)} \qquad &= \frac{\Sigma_j [E(N|I,u_j)P(I|u_j) + E(N|II,u_j)P(II|u_j)]\, P(u_j)}{\Sigma_j [E(T|I,u_j)P(I|u_j) + E(T|II,u_j)P(II|u_j)]\, P(u_j)} \end{aligned}$$

where $E(N/I,u_j)$ is the conditional expectation of N given case I and population density u_j, $P(II/u_j)$ is the conditional probability of case II given population density u_j, etc. The right side of (2.2) is evaluated in the Appendix and given in computable form.

3. RESULTS

Parameter values have been chosen which characterize, in so far as possible, Japanese Antarctic minke whaling experience of the period 1975 to 1980 and in particular the expedition of 1979/80, because adequate data are available. Sources are Ohsumi and Shimadzu (1980) and Shimadzu (1980). For 1979/80 we have, approximately: the length of the working day t_0 = 15 hours; the number of catcher boats

$k = 4$; the length of the acquisition time per whale $t_a = 0.75$; the capacity limit $n_0 = 48$.

The number of whales caught per pod, h, is not available though it could be extracted from the catcher's log books. Therefore an indirect method was used to determine h. Shimadzu (1980) reports that for the 1978/79 season 48% of the days were stop-catch days and that for the previous season 43% were. Therefore, after all other parameter values were chosen (only u_1 and u_2 remain), h was chosen by trial and error to give 40–50% stop-catch days or as close to this range as possible; m, the pod size, is not needed. If it is not known the CPUE is proportional to the whale density. This does not affect the bias since it is given as a proportion.

The range of pod density is a problem since the pod densities are not known. An approximation was obtained as follows. For u_1, the low density, a set of values were chosen: $u_1 = 0.25, 0.50, 0.75$ pods per hour. Fortunately, as it turned out, this is not a critical parameter for this particular fishery and, possibly, in general. The ratio u_2/u_1 was inferred from Ohsumi and Shimadzu (1980) in the following manner. For the seasons 1974/75 to 1976/77 (later seasons were not included in order to minimize the bias due to stop-catch; in retrospect this was needless), there were seven series of consecutive operation days ranging from 13 to 31 days in which CSW was measured directly. For each series the daily CPUE values, catch/CSW, were ranked and the first and third quartiles were determined. If it is assumed that catch/CSW is roughly proportional to density, despite biases, then the ratio of quartiles should be an estimate of the ratio of quartiles of the pod density distribution. Moreover, biases present in the CPUE, since they appear in both numerator and denominator, would tend to cancel out. Therefore the ratios, (third quartile) / (first quartile), were taken as estimates of u_2/u_1, the ratio of population quartiles, and the final estimate was the median of these seven values which ranged from 2.6 to 6.8. This gave the value 4.1 which was rounded to 4. Finally the distribution of pod density was approximated by putting 50% of the probability on each of the quartiles u_1 and u_2, i.e. $f = 0.5$.

For these parameter values the percent bias, defined as $100(1 - E(\text{CPUE})/h\bar{u})$, with E(CPUE) given by (2.2), are given in Table 1. The values in parentheses are the corresponding percentages of stop-catch days. The joint effect of the stop-catch and acquiring operation factors is found in the column headed $n_0 = 48$ and the rows labelled $t_a = 0.75$. The percent bias is a constant 25% for all three values of u_1. Thus the CPUE for the parameter values characterizing Japanese Antarctic minke whaling tends to underestimate the density by about 25%. When $n_0 = \infty$ the stop-catch is eliminated with the results given under that column heading. For $t_a = 0.75$ to 1.00 there is almost no difference between the columns. Thus the stop-catch contributes little to the bias for t_a in this range. Only when t_a is small, probably unrealistically small for minke whaling, does the stop-catch make an important contribution. The effect of the stop-catch alone is seen by setting $t_a = 0$ when the resulting operation might be more appropriately called stop-search. The bias increases to about 35%. It is primarily due to an increase in the percentage of stop-catch days which occur almost exclusively on days when u_2 prevails, reducing the contribution of high density days to the CPUE. The stop-catch has little effect when $t_a \geqslant 0.75$. A possible reason is that, as t_a increases, the percentage of stop-catch days decreases causing the stop-catch to have less effect on the bias. It is of some interest to observe that there is a strong interaction between the CSW and stop-catch factors when $t_a < 0.75$.

Table 1

Percent bias of the CPUE and percent stop-catch days (in parentheses) by value of u_1, n_0 and t_a, for $u_2/u_1 = 4$. The percent bias is defined as $100(1 - E(\text{CPUE})/h\bar{u})$. Parameter values are given in section 3.

			n_0	
u_1	h	t_a	48	∞
0.75	0.9	1.00	24 (0)	25 (0)
		0.75	25 (48)	23 (0)
		0.50	28 (50)	19 (0)
		0	36 (53)	0 (0)
0.50	1.3	1.00	26 (0)	26 (0)
		0.75	25 (41)	24 (0)
		0.50	28 (50)	20 (0)
		0	36 (52)	0 (0)
0.25	2.0	1.00	28 (0)	28 (0)
		0.75	25 (10)	25 (0)
		0.50	26 (47)	22 (0)
		0	34 (50)	0 (0)

If the CPUE underestimated the density by a constant amount this would not affect its use as an index of density for the Chapman (1974) Modified DeLury Method or any other method requiring a statistic proportional to the density. Unfortunately this is not the case. Table 2 gives the effect of varying u_2/u_1 with $t_a = 0.75$, $u_1 = 0.5$, and $h = 1.3$. It is seen that u_2/u_1 has a large effect on the bias, ranging from 11% for $u_2/u_1 = 2$ to 33% for $u_2/u_1 = 5$. This implies that the CPUE should either be corrected for the value of u_2/u_1 or a form of CPUE should be devised less sensitive to variations in density. As discussed below, u_2/u_1 is the only parameter having an important effect on the variation of the bias. Considering that corrections of the CPUE for weather and seasonal effects has also been recommended, I hesitate about recommending another correction without a study of the interdependence of these corrections. A better approach might be to seek an inherently less biased statistic.

Table 2

Percent bias of the CPUE and percent stop-catch days as a function of u_2/u_1 for $u_1 = 0.5$, $h = 1.3$, and the remaining parameter values as in Table 1.

u_2/u_1	2	4	5
% bias	11	25	33
% stop-catch	0	41	50

4. DISCUSSION OF ASSUMPTIONS

The main results are that the CPUE = catch/CSW, given the above model and parameter values, tends to underestimate the density of whales by an amount which depends, among other quantities, on the ratio of quartiles u_2/u_1. An important question then is how sensitive are these results to the assumptions and parameter values chosen, besides u_2/u_1 already discussed. Some of these are considered one by one.

t_a. The data of Ohsumi and Shimadzu (1980) show very little variation in the daily average value of t_a except when the catch is very low, which happened only a small percentage of the time within each season. The assumption of constant daily average t_a is, therefore, fairly realistic. The value of t_a is not constant from year to year however, but varies between 0.75 and 1 in recent years. The effect of variation of t_a for each level of u_1 is given in Table 1. The percent bias varies very little except when t_a drops to a low value. The sensitivity of the results to realistic values of t_a is, therefore, small.

Search phases. The assumption of independent, exponentially distributed search times is made for mathematical convenience and is hard to check directly. However, this assumption is not critical because the total daily search time is a sum of the search phase times, and the sums tend to be approximately normally distributed under very general conditions, including some kinds of non-independence of summands. The present analysis could have been done, at the cost of greater complexity, by assuming that the daily search time, which is a sum, is normal, without specifying any particular distribution for the search time phases.

Independent operation of catcher boats. A somewhat more elaborate model could have handled cooperation between boats by specifying that when two (or more) boats cooperate each contributes a searching phase but that the two together contribute only a single acquisition phase with reduced value of t_a, since the two together take less time to acquire the fraction h of the pod. This causes some variation in t_a and k, the number of boats. Moderate variation in t_a has been shown to be not critical. It can be shown that the same is true for k.

Independence of day-to-day results. A more realistic model would allow correlation extending over a few days between the catches. The effect on the bias would be negligible since it would only affect the term 'bias due to ratio estimate' in (2.2). This is small because of the large sample size. This might become a problem if the CPUE were computed for a few days' data only.

More than one pod sighted at a time. When this happens search time for second, third etc., pods may be zero, if these pods stay in the vicinity. This means that there will be a positive probability of zero search time giving rise to a mixed search time distribution. If the probability of zero search time is small, the approximate normality of total search time should still be true; but if it is substantial, the model should be changed. One possibility is to work with groups rather than pods, where a group is any number of pods. But the behaviour of two pods of three whales each may be very different from the behaviour of a single pod of six, so this aspect would have to be explored. I have not done this.

REFERENCES

Beddington, J. R. 1979. On some problems of estimating population abundance from catch data. *Rep. int. Whal. Commn* 29: 149–54.

Chapman, D. G. 1974. Estimation of population size and sustainable yield of sei whales in the Antarctic. *Rep. int. Whal. Commn* 24: 82–90.

Cochran, W. G. 1977. *Sampling Techniques*, 3rd edtn, Wiley, New York.

Fowler, C. W. 1980. A rationale for modifying effort by catch, using the sperm whale of the N. Pacific as an example. *Rep. int. Whal. Commn* (special issue 2): 99–102.

Holt, S. 1979. A simple model of pelagic whaling. *Rep. int. Whal. Commn* 29: 155–7.

Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 407–20.

Ohsumi, S. and Shimadzu, Y. 1980. Catch and effort statistics of minke whaling by the Japanese expeditions in the Antarctic 1971/72–1979/80. Appendix. *Rep. int. Whal. Commn* 31: 363–6.

Shimadzu, Y. 1979. On the effect of meteorological factors on the catch of the minke whales in the Antarctic. *Rep. int. Whal. Commn* 29: 447–9.

Shimadzu, Y. 1980. Basis of fishing effort for the minke whaling in the Antarctic. *Rep. int. Whal. Commn* 30: 425–33.

APPENDIX
EVALUATION OF E(CPUE)

Since h whales from each pod are caught in the acquisition phase, and u is the density of pods per unit search time, we will have E(CPUE) = u if the catch is measured in units of h whales and there is no bias. Accordingly N and n_0 are redefined in this section to be in terms of units of h whales, and t_a is redefined to be the acquisition time per unit. To convert back to units of a single whale the E(CPUE) is multiplied by h.

Let $u = u_1$ or u_2. In case I, when no stop-catch order is issued, boats in the acquiring phase at time t_0 complete that phase and acquire one unit each. The probability that a boat will be so caught is the probability that t_0 will fall in the acquiring phase of the last complete or incomplete cycle. This is approximately $t_a/(t_a + 1/u)$ since $1/u$ is the average search time and t_a the acquiring time per unit. Therefore, by assumptions (c) and (d), the approximate average number of units acquired after t_0 in case I is $kt_a/(t_a + 1/u)$. Letting N' be the number of units acquired up to t_0 (= number of completed cycles) we then have

$$E(N|I,u) = E(N'|I,u) + \frac{kt_a}{t_a + 1/u} \quad . \tag{A.1}$$

For E(N'/I,u) note that case I is equivalent to $N' < n_0$ or $N' \leqslant n_0 - h = n_0'$, say. Therefore

$$\begin{aligned} E(N'|I,u) &= E(N'|N' \leq n_0', u) \\ &= \Sigma_{j=1}^{n_0'} jP(N' = j|u)/P(N' \leq n_0'|u) \quad . \end{aligned} \tag{A.2}$$

$P(N' = j/u)$ is next evaluated. Taking all the boats together let $t_1, \ldots, t_j$ be the lengths of the first j complete cycles. At the end of the j'th cycle one boat has just completed its cycle and the remaining k − 1 boats are in the midst of cycles, assuming operations continue indefinitely. Let $t_{j+1}, \ldots, t_{j+k-1}$ be the lengths of the incomplete cycles of the remaining k − 1 boats up to the end of the j'th cycle. By definition, when j = N', the total time for complete and incomplete cycles is k_{t_0}. Hence any additional completed cycles requires more time or

$$j > N' \text{ if and only if } \Sigma_{m=1}^{j} t_m > kt_0 - \Sigma_{m=j+1}^{j+k-1} t_m \; . \tag{A.3}$$

This is the relationship connecting the number and time for the cycles.

Write $t_m = t_{sm} + t_a$ for any completed cycle, where t_{sm} is the searching time. For any incomplete cycle the searching phase or the acquiring phase may be incomplete. If the latter, which occurs with approximate probability $t_a/(t_a + 1/u)$, substitute the average time $t_a/2$. If the former, it is a property of the exponential distribution that the time, measured from an arbitrary point (i.e., one chosen without regard to the stochastic process of cycles) either forwards or backwards to the next event in question, is exponentially distributed with the same parameter u independently of the other times. In the present case t_0 can be assumed to be an arbitrary time point. Hence the incomplete phase is also exponentially distributed with parameter u. Then, breaking t_m in (A.3) down into a sum of searching and acquiring times, the last inequality in (A.3) can be written.

$$(A.4) \quad \Sigma_{m=1}^{j+k-1} t_{sm} > kt_0 - jt_a - \frac{(k-1)t_a}{t_a + 1/u} \frac{t_a}{2} = z_j \ .$$

The left side of this inequality is a sum of independent exponential random variables all with the same parameter u. There is a slight discrepancy between (A.4) and the corresponding inequality in (A.3) in that $((k-1)t_a^2/2)/t_a + 1/u)$ is an average rather than an actual value, but this substitution has a negligible effect. By a further property of the exponential distribution it follows that

$$2u(\Sigma_{m=1}^{j+k-1} t_{sm})$$

has a chi-square distribution with 2(j+k−1) degrees of freedom. Hence, by (A.4),

$$\begin{aligned}(A.5) \qquad P(N' < j) &= P(\Sigma_{m=1}^{j+k-1} t_{sm} > z_j | u) \\ &= P(\chi^2_{2(j+k-1)} \geqslant 2uz_j) \ .\end{aligned}$$

Now $N' = j$ if $N' \geqslant j$ but $N' < j + 1$. Hence, by (A.5),

$$\begin{aligned}(A.6) \qquad P(N' = j | u) = {} & P(\chi^2_{2(j+k)} \geqslant 2uz_{j+1}) \\ & - P(\chi^2_{2(j+k-1)} \geqslant 2uz_j) \ .\end{aligned}$$

Substituting (A.5) and (A.6) into (A.4) gives E(N/I,u).

For E(T/I,u) the total searching time, T, equals kt_0 less the acquiring time of all boats until time t_0. Hence, approximately, as with (A.4),

$$T = kt_0 - N't_a - \frac{kt_a}{t_a + 1/u} \frac{t_a}{2} \ .$$

Taking expectations and substituting from (A.1), we have

$$(A.7) \quad E(T | I,u) = kt_0 - E(N | I,u)t_a + k(t_a^2/2)/(t_a + 1/u) \ .$$

In case II, when a stop-catch order is issued, one boat has just acquired unit n_0. Hence

$$(A.8) \quad E(N | II,u) = n_0 + (k-1)t_a/(t_a + 1/u) \ ,$$

where, again, the second term on the right is the average contribution of the remaining boats.

The last term is E(T/II,u). A stop-catch is ordered if and only if $N' \geqslant n_0$, where N' is the number of cycles completed by all the boats up to time t_0. By (A.3) and the reasoning leading up to (A.4) the condition is equivalent to

$$(A.9) \quad T = \Sigma_{j=1}^{n_0+k-1} t_{sj} < kt_0 - n_0 t_a - \frac{(k-1)t_a}{t_a + 1/u} \frac{t_a}{2} = t_0'$$

Again, since T is a sum of independent exponential variables, it follows that the expected value of T, subject to the constraint (A.9), is

$$\begin{aligned}(A.10) \quad E(T | II,u) = E(T | T < t_0') &= \frac{1}{2u} E(\chi^2_{2n_1} | \chi^2_{2n_1} < 2ut_0') \\ &= \frac{1}{2u} \int_0^{2ut_0'} xp_1(x)dx / P(\chi^2_{2n_1} < 2ut_0') \ ,\end{aligned}$$

where $n_1 = n_0 + k - 1$ and $p_1(x)$ is the chi-square density with $2n_1$ degrees of freedom. The denominator is $1 - P(I/u)$, which has been previously evaluated. The numerator has the expansion.

$$\frac{1}{2u} \int_0^{2ut_0'} xp_1(x)dx = \frac{n_1}{u} [1 - G(ut_0', n_1)]$$

where

$$G(x,n) = e^{-x}(1 + x + x^2/2! + \ldots + x^n/n!) \ .$$

SC/Jn81/MiS12

A Preliminary Look at the Effect of Concentrating Whale Sightings in a Small Arc Around the Trackline

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ABSTRACT

Line transect population estimation techniques are based in part on estimation of the probability of sighting an animal at varying perpendicular distances from the trackline. While some attention has been paid to different models of the probability of sighting at varying radial distances, to date little attention has been paid to the effects of varying angular concentrations of sighting effort around the trackline. Some preliminary ideas on this topic are presented.

INTRODUCTION

From data presented and discussions at the Sightings Survey Workshop (IWC, 1982), it became apparent that there were several features of minke whale sighting surveys and analyses of their results that were at variance with the 'standard' setup described by Burnham, Anderson and Laake (1980).These included:

(i) The observed estimates of the probability density function (PDF) of perpendicular distance of first sighting had extremely high peaks at zero. Fig. 1 illustrates the histogram estimate of the density obtained from data in Table 13 of Horwood (1980).

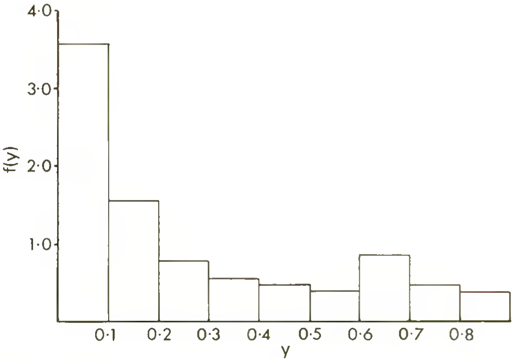

Fig. 1. Estimated PDF of perpendicular sighting distances, from Table 13, Horwood (1980).

(ii) Interconnected with (i) and possibly partially causative, the observed estimates of the PDF of angle of first sighting showed a peak at zero, dropping off quickly as the angle increased. This is illustrated in Fig. 2, which shows the histogram estimate of the density of first sighting angle from data in Table 22 of Horwood (1980).

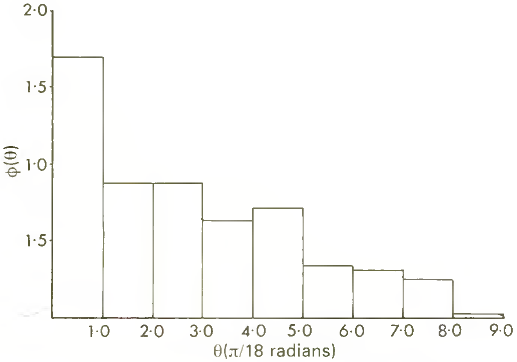

Fig. 2. Estimated PDF of angle of first sighting up to 90 degrees, from Table 22, Horwood (1980).

(iii) Difficulties were encountered in obtaining a satisfactory fit of the available models to the PDF of perpendicular distance of first sighting. Attempts during the meeting to use the Fourier series methods of Burnham *et al.* (1980) suggested that the method may be inappropriate for these data. The need for successive truncation (Best and Butterworth, 1980) when an exponential model was fitted suggested that even this model may not be satisfactory.

In this note, a very preliminary investigation of these problems is attempted, using models developed by Butterworth (1980). In particular, the effect of concentration of sighting effort on a narrow arc about the trackline is examined.

FIRST SIGHTING PDF'S

Following Butterworth (1980), let the probability per unit time of sighting a whale at position (r,θ) be

$$\gamma = f(r)\,h(\theta),$$

where $h(\theta)$ describes the relative concentration of sightings at angle θ from the vessel's track.

Rescaling time so that the velocity of the whale is 1, and given a whale moving at perpendicular distance y from the vessel trackline,

$$\gamma dt = f(r)\, h(\theta)\, dx = f\{(x^2+y^2)^{1/2}\}\, h\{\sin^{-1}\left(\frac{y}{(x^2+y^2)^{1/2}}\right)\}\, dx$$

$$\equiv F(x,y)\, dx.$$

Then the PDF of first sighting at (x,y) given y is

$$P(x|y) = F(x,y) \exp\left(-\int_0^\infty F(x',y)\, dx'\right).$$

Suppose that $f(r) = 0$ for $r > R$, and that whales are uniformly distributed over $0 \leqslant y \leqslant R$. Then the unconditional PDF of first sighting at (x,y) is

$$P(x,y) = \frac{F(x,y)}{R} \exp\left(-\int_x^{(R^2-y^2)^{1/2}} F(x',y)\, dx'\right) \qquad (1)$$

for $x,y \geqslant 0$, $(x^2+y^2)^{1/2} \leqslant R$.

In polar coordinates, the joint PDF of first sighting at (r,θ) is

$$\phi(r,\theta) = \frac{r}{R} f(r)\, h(\theta) \exp$$

$$\left(-\int_r^R \frac{z\, f(z)}{(z^2-r^2\sin^2\theta)^{1/2}}\, h\{\sin^{-1}\left(\frac{r\sin\theta}{z}\right)\}dz\right) \qquad (2)$$

for $0 \leqslant r \leqslant R$, $0 \leqslant \theta \leqslant \pi/2$.

The marginal PDF's of first sighting at perpendicular distance y or at angle θ may be obtained by integration of (1) or (2). Also the probability of first sighting at perpendicular distance y, an important variable in line transect methods, is given by

$$g(y) = 1 - \exp\left(-\int_x^{(R^2-y^2)^{1/2}} F(x',y)\, dx'\right) \qquad (3)$$

Unfortunately, closed form integration of (1) or (2) is rarely possible, at least for functions f(r) and h(θ) that are of interest.

SIMULATION RESULTS

Analytic results not being forthcoming, it is necessary to resort to numerical integration or simulation to examine the effects of varying relative concentrations on small θ.

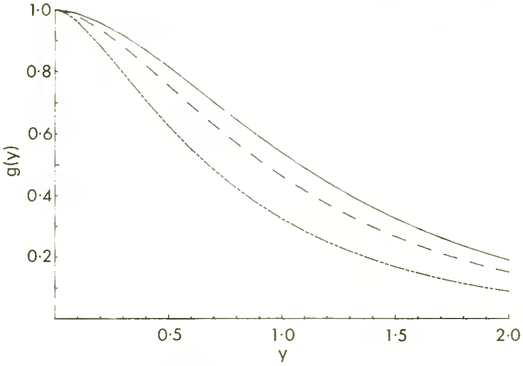

Fig. 3. Probabilities of first sighting at perpendicular distance y, as defined by equation (5).

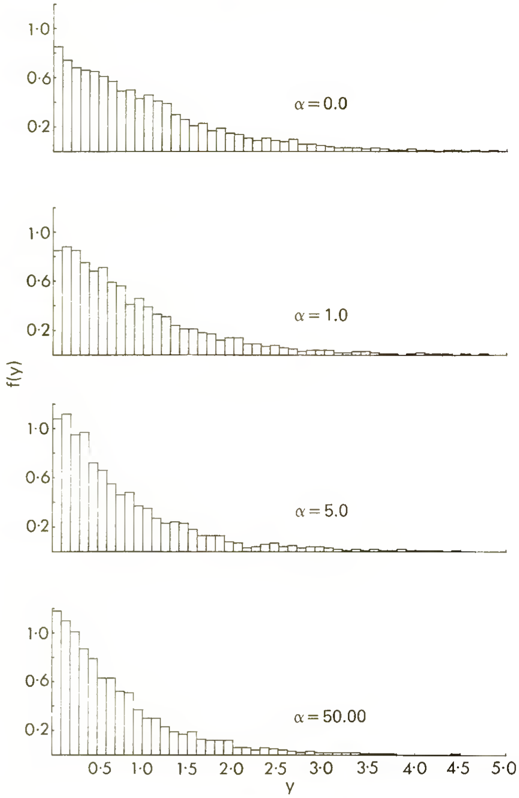

Fig. 4. Estimated PDF's of perpendicular sighting distances from simulation using h(θ) defined in equation (4).

As an example similar to that considered by Butterworth (1980), suppose

$$f(r) = \frac{2}{r} e^{-r}$$

and in addition, suppose that

$$h(\theta) = 1 - \frac{\alpha}{1+\alpha} \cdot \frac{2\theta}{\pi} \qquad 0 < \theta < \pi/2 \qquad (4)$$

Then for increasing $\alpha > 0$, there is increasing concentration on small θ. The probability of first sighting at perpendicular distance y is, from (3)

$$g(y) = 1 - \exp\left(-2\int_y^\infty \frac{e^{-r}}{(r^2+y^2)^{1/2}}\{1 - \frac{2}{\pi}\frac{\alpha}{(1+\alpha)}\sin^{-1}\left(\frac{y}{r}\right)\}dr\right) \qquad (5)$$

The graph of g(y) for differing α is shown in Fig. 3, the integration having been performed numerically. Note the increase in the peak at zero, and the reduced tail area as α increases.

Also, simulation of first sightings of 20,000 whales, uniformly distributed between zero and five units of perpendicular distance from the trackline were carried out using the above functions f(.) and h(.). The resulting histogram estimates of the PDF's of perpendicular distance of first sighting and of first sighting angle are shown in Figs 4 and 5. Fig. 4 indicates a similar pattern of variation with α to Fig. 3. As the relative concentration on small θ

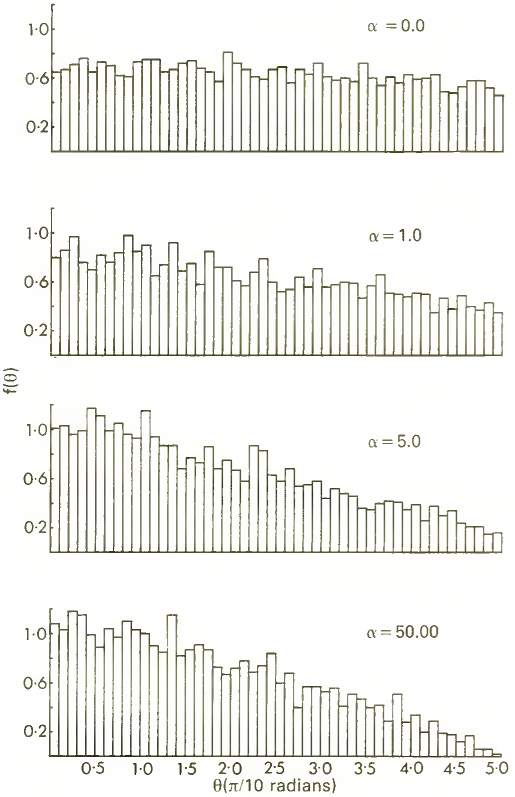

Fig. 5. Estimated PDF's of first sighting angles from simulation using h(θ) defined in equation (4).

increases, the zero peak of the PDF increases and the tail area diminishes. However, even when the relative concentration on θ decreases linearly from 1.0 to almost zero as θ increases from 0 to π/2, the simulated PDF still fails to mirror Fig. 1, with its anomalously high zero peak. As seen in Fig. 5, the first sighting angle PDF is relatively uniform when there is equal relative concentration of angular sighting effort. As the concentration on small θ increases, so does the skew of the first sighting angle PDF. However, even in the extreme case, the skew is less than that illustrated in Fig. 2.

Further attempts were made to generate first sighting PDF's that more closely resembled Figs 1 and 2 by varying the function h(θ). In general, it was possible to simulate more highly skewed PDF's than those in Figs 4 and 5, but rather more difficult to mimic the anomalously high zero peaks of Figs 1 and 2. To accomplish the latter, it was necessary to use discontinuous or nearly discontinuous functions h(θ). Fig. 6 shows PDF's simulated using a function h(θ) that was 1.0 for $0 \leqslant \theta \leqslant \pi/40$, decreased linearly to 0.3 for $\pi/20 \leqslant \theta \leqslant \pi/20$, and thereafter decreased linearly to zero for $\pi/20 \leqslant \theta \leqslant \pi/2$.

DISCUSSION

The author's initial hypothesis in commencing this brief investigation was that at least part of the reason for the high zero peak in the observed first sighting perpendicular distance (PDF) was the observed high concentration on small sighting angles. To the extent possible from the results presented here, this hypothesis cannot be rejected. However, the need to resort to functions h(θ) similar to that used for Fig. 6 indicates a potentially serious problem in analysis of the data.

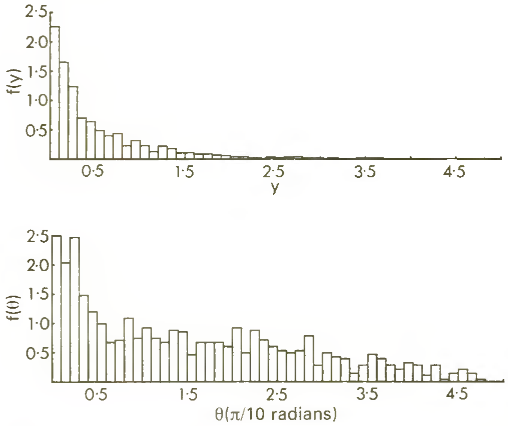

Fig. 6. Estimated PDF's of perpendicular distance of first sighting (upper) and of first sighting angle (lower) using highly peaked h(θ) defined in text.

In order to mimic Fig. 2, it was necessary that almost all sighting effort was concentrated near zero angles from the trackline. This led in turn to a PDF of perpendicular distance of first sighting that was both highly skewed and had an anomalously high zero peak. In that case, it is clear that none of the usual orthogonal series approximations for g(y), such as Fourier series, exponential power series or hermite polynomials, is likely to provide a good fit. Consequently, the resulting population estimates may be seriously biased. One is led to the conclusion that every effort should be made to increase the sighting effort on large angular deviations from the trackline, and that specific account should be taken of unequal angular sighting concentrations of effort in analyses of results of sightings cruises.

It is clear that much work remains to be done in this area. This note completely ignores the problem of whether all whales would be seen on the trackline, even if they never dived, and the associated aspects of modelling f(r), as well as a host of other problems. However it appears that modelling and simulation studies along the lines initiated by Butterworth (1982) and continued here, are at least fruitful areas for future research.

REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 72: 202 pp.

Butterworth, D. S. 1982. A possible basis for choosing a functional form for the distribution of sightings with right angle distances: some preliminary ideas. Paper SS/7 (published in this volume).

Horwood, J. W. 1981. Results from the IWC/IDCR minke whale marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

International Whaling Commission. 1982. Report of the Workshop on the Design of Sighting Surveys (published in this volume).

SC/Jn81/MiS5 + 13 + 17

Results of Analysis of Sighting Experiments Carried Out During the 1980/81 Southern Hemisphere Minke Whale Assessment Cruise*

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ABSTRACT

During the 1980/81 assessment cruise a number of experiments were carried out to investigate effects that could lead to biasses in sighting estimates of minke whale abundance.

A common feature of the experiments was the problem of obtaining sufficient sightings in the time available to achieve results statistically significant at the 5% level.

In the variable speed experiment, the survey vessels travelled at different speeds to investigate the proportion of minke schools on the track-line that are missed at the normal searching speed of 12 knots. The best estimate obtained for the probability of sighting a school on the track-line at this speed, $g_{12}(0)$, was 0.72, which indicates that abundance estimates that neglect this effect should be increased by some 40%. The no. of observations was nevertheless insufficient to reject the hypothesis that $g_{12}(0) = 1$, i.e. that no whales on the track-line are missed.

These variable speed transects were carried out perpendicular to the ice edge, so that the minke school density gradient away from the edge could be investigated simultaneously. The results show a density decline, though not a statistically significant one. The best estimate of the distance over which the density falls by 50% is some 30 nautical miles.

A parallel ship experiment in which two vessels steamed parallel courses 0.3 nautical miles apart was designed to identify possible minke whale reaction to survey vessels through asymmetric sighting distributions. The search for such asymmetries was inconclusive; investigation of the effect of weather conditions on sighting distributions is desirable, as this also probably influences these results.

The best estimate of the proportion of minke schools sighted during the parallel ship experiment that were seen by both vessels was small (0.23). This, together with the absence of significant asymmetries, suggests that abundance estimates assuming no reaction by the whales to the vessel, $g(0) = 1$, and $g(y) = e^{-\lambda y}$, are negatively biassed.

INTRODUCTION

During the IWC workshop on the design of sighting surveys held in Seattle in September 1980 (IWC, 1982), several problems associated with sighting estimates of minke whale populations were identified. These included whether all whales on the track-line are seen, whether whales react to the search vessels, and how rapidly the whale density decreases as one moves away from the edge of the pack-ice.

The workshop also made suggestions on how these effects could be investigated. Transects at different speeds were proposed to ascertain the proportion of whales on the track-line being missed, on the basis that at slower speeds whales would be less likely to avoid detection as they would surface more often while 'within range'. These transects could be executed perpendicular to the pack-ice edge so that the gradient in minke whale density could be investigated simultaneously. It was also suggested that possible asymmetric distributions of sightings with two vessels steaming parallel courses could reveal ship-reaction behaviour by the whales.

Planning for the 1980/81 assessment cruise endeavoured to incorporate experiments along these lines into the cruise programme (IWC, 1980). Whale marking along the pack-ice was allocated to the extra vessel available for the cruise, the *Vdumchivy 34* (V34). The southernmost sighting vessel could thus have more spare time available than on previous cruises where it had to perform both sighting and marking. This additional time was to be utilised on transects away from the ice edge, planned for every alternate day. Speed was to be varied on these transects, so that information would be provided on both the whale density gradient away from the pack-ice, and the proportion of whales on the track-line normally missed. The *Kyo Maru 27* (K27) and *Toshi Maru 11* (T11) fulfilled this role on the first and second legs of the cruise respectively.

In addition, the periods of steaming to and from the factory ship for refuelling were set aside for parallel-ship experiments by the two Japanese vessels, with the V34 to operate at different speeds over these sectors.

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* This paper is a combination, with revisions, of unpublished documents SC/Jn81/MiS5, SC/Jn81/MiS13 and SC/Jn81/MiS17, and also includes a report of analysis of data from the density gradient experiment, carried out subsequent to the July Meeting.

As it was realised that reasonably high numbers of sightings would be needed to obtain statistically significant results, and that these might be difficult to achieve in the time available, experiments were planned for areas of high minke whale density.

This paper provides an analysis of the results obtained from these experiments.

(A) THE VARIABLE SPEED EXPERIMENT

Theory

In line transect theory, $g(y)$ is used to represent the probability of sighting a whale (or whale school) at a right-angle distance y from the track-line. The probability of sighting a whale on the track-line is thus given by $g(0)$, and the assumption that all whales on the track-line are seen corresponds to taking $g(0) = 1$.

This analysis assumes that the whales are stationary, except of course for diving which results in their being potentially sightable only intermittently. At faster vessel speeds there would be fewer opportunities to sight a whale on the track-line while within range, so that $g(0)$ would be expected to be a decreasing function of vessel speed v.

Further, as the vessel speed is decreased to zero, a (stationary) whale on the track-line would eventually be potentially sightable on an infinite number of occasions, suggesting that the limit of $g(0)$ for zero vessel speed would be 1 (sighting certain):

$$\text{i.e. } \begin{aligned} g(0) &= g_v(0) \\ g_o(0) &= 1 \end{aligned} \qquad (1)$$

If the true whale density is D, then line-transect estimates of density at different vessels speeds (D_v) will be related via:

$$\left.\begin{aligned} D_v &= g_v(0)\,D \\ \frac{D_{v1}}{D_{v2}} &= \frac{g_{v1}(0)}{g_{v2}(0)} \end{aligned}\right\} \qquad (2)$$

What is required is an estimate of $g(0)$ at the normal searching speed of 12 knots i.e. $g_{12}(0)$. This can be obtained from relative density estimate measures:

$$\frac{D_v}{D_{12}} = \frac{g_v(0)}{g_{12}(0)} \qquad (3)$$

An extrapolation procedure to $v = 0$ is required so that $g_{12}(0)$ may be calculated from equation (3) using the relation $g_0(0) = 1$.

The hazard-rate model of Butterworth (1982) may be used to provide such a procedure. Assuming that the probability per unit time γ of sighting a whale at distance r and angle θ from the track-line is given by:

$$\gamma = f(r)\,h(\theta) \qquad (4)$$

then the model yields:

$$\left.\begin{aligned} &g(0) = 1 - e^{-\int_0^\infty f(x)h(0)1/v\,dx} \\ &\text{i.e. } g(0) = 1 - e^{-\alpha/v} \qquad \left(\alpha = \int_0^\infty f(x)h(0)dx\right) \end{aligned}\right\} \qquad (5)$$

Assuming α is independent of the vessel speed v, an estimate of relative density D_v/D_{12} then yields an α value estimate from the relation:

$$\frac{D_v}{D_{12}} = \frac{g_v(0)}{g_{12}(0)} = \frac{1 - e^{-\alpha/v}}{1 - e^{-\alpha/12}} \qquad (6)$$

Finally the estimate of $g_{12}(0)$ required is calculated as

$$g_{12}(0) = 1 - e^{-\alpha/12} \qquad (7)$$

Fig. 1 shows plots of the D_v/D_{12} ratio as a function of v for various values of $g_{12}(0)$.

Equations (6) and (7) are based on a number of assumptions which merit further attention. Briefly these assumptions are:

(i) the hazard-rate model is correct;
(ii) α is vessel speed independent;
(iii) whales are stationary;
(iv) whales do not react to the search vessel.

The hazard-rate model assumes that the frequency of the whale's dives is Poisson-distributed. This is unlikely to be the case, but equation (5) may nevertheless provide a reasonable approximation—a simulation study to check this appears desirable.

Vessel speed independence for α requires an invariant $h(0)$ i.e. observers spending the same fraction of their time searching 'forward' whatever the vessel speed. It seems unlikely that $f(r)$ would be dependent on vessel speed, except perhaps in adverse weather conditions.

Whales are generally not stationary, and target motion, albeit random in direction, does also affect density estimates (Koopman, 1956; Best and Butterworth, 1980; Hiby, 1982). Once target motion is allowed in the model, a whale on the trackline at one time will not necessarily remain there. The concept of the probability of sighting a whale on the track-line would therefore require more careful definition.

The effects of target motion and the missing of sighting cues are interrelated, and when target motion effects become substantial, it is not obvious whether the corrective contribution from missing whales on the track-line can be separated out, or whether it would be useful or meaningful to do so.

A complete analysis of these combined effects would probably require a hazard-rate-type model with realistic parametrization of the hazard function γ (equation 4). This is not immediately feasible. Making the stationary whale approximation seems a reasonable first step to take for an initial analysis, although this may not be the case at slower vessel speeds, because target motion effects become more significant as the target speed becomes a larger proportion of the vessel speed (Koopman, 1956).

Finally, the concern in this case about whale reaction to the search vessel refers specifically to possible changes in such behaviour with vessel speed. Leatherwood *et al.* (1982) found no influence on minke swimming directions attributable to the USCGC *Polar Star* steaming at 12 knots. They refer however to reports of minke whales approaching stationary or idling vessels. Again this suggests treating results for low vessel speeds with caution.

Experimental design

Since an extrapolation procedure is being used, it would be desirable to make observations at a number of different vessel speeds. However preliminary calculations indicated there would be difficulty obtaining sufficient sightings during the time available for the experiment, to produce a D_v/D_{12} ratio with suitably small variance for one vessel speed v, let alone a number of such speeds.

Fig. 1 suggests the choice of a low v for better discrimination of $g_{12}(0)$ values. Problems with a low v value are the possible vessel-reaction and target-motion effect on density estimates mentioned above, and the greater time

Fig. 2a.

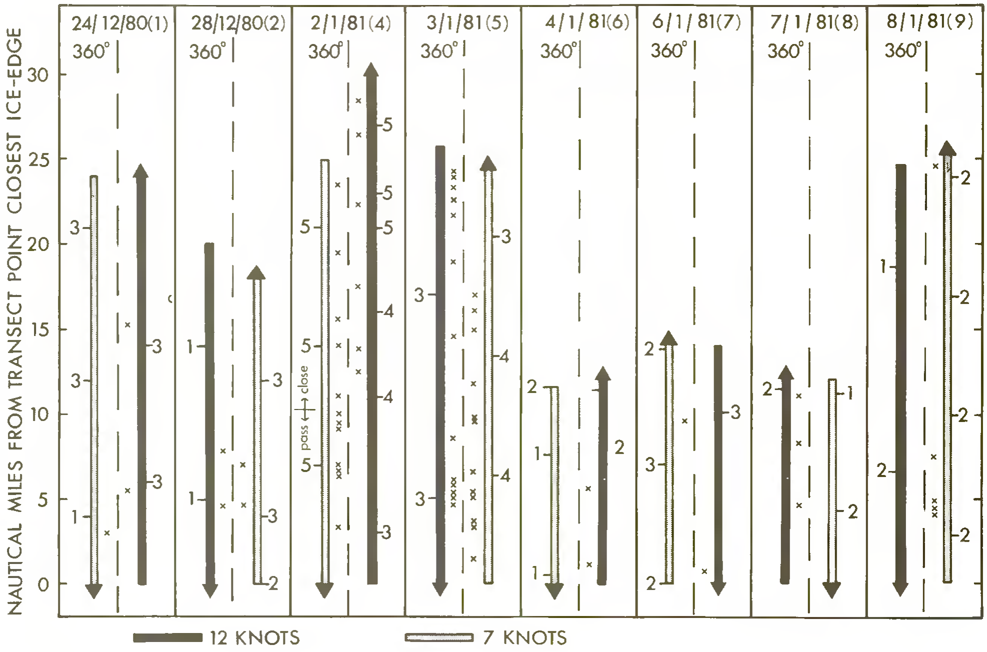

Fig. 2b.

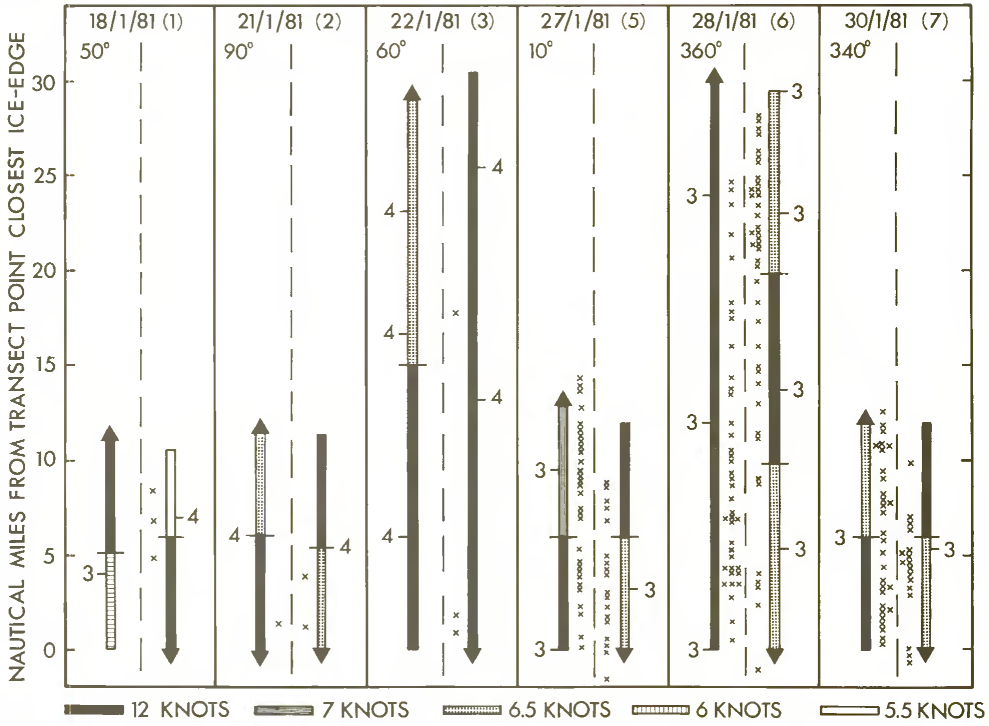

Fig. 2. Distribution of minke whale schools sighted during experiments where the K27 (Fig. 2a) and T11 (Fig. 2b) steamed transects perpendicular to the ice edge. Vessel speed varied over transects as shown in the figures. Whale school positions are marked by (x). The numbers next to the transects indicate the whale sightability index (range 1–5) recorded when the vessel was at that position. The angle under heading for each experiment is the compass direction of the outward transect. The point where the mode of operation changed from closing with to passing sightings is marked on the inward transect for K27 experiment no. 4.

The T11 similarly conducted 7 experiments on the second half of the cruise. Sightings were passed throughout, but in almost all cases the only distance information recorded was the top-man's estimate of radial distance at the time of first sighting.

The V34 passed sightings when conducting this experiment.

Certain problems were experienced at very high minke whale densities (when there might be as many as 10 sightings in less than a minute). It was difficult under these circumstances to confidently distinguish new from old sightings, and to measure right-angle distances when the identity of a group was lost. To reduce confusion in such cases upper bridge sightings were only recorded when it was certain that these were not duplicates of top-man sightings. On the last two experiments (on the T11), one top-man endeavoured to keep track of all the current sightings, and thus was not completely involved in searching. Other problems noted were the effect of differing environmental conditions on the two transects (particularly glare from sun or ice) and the patchiness of minke whale distribution.

Results are shown in Table 1a. For consistency the effective search width has been calculated throughout on the basis of top-man radial distance estimates. Table 1b gives results when speed × time distance estimates are used.

Density estimates are calculated by

$$D = \frac{n}{2Lw} \tag{8}$$

(For the period when K27 closed with sightings, L excludes distances travelled while closing ('secondary effort'), and n incorporates only primary sightings.)

The untruncated negative exponential form for g(y) was used to provide an estimate of w:

$$w = \frac{\sum_{i=1}^{n} y_i}{n-1} \tag{9}$$

Coefficients of variation for density estimates were calculated using the approximate formula:

$$\text{c.v.}(\hat{D}) = \sqrt{\frac{2}{n}}$$

$$\text{hence c.v.}\left(\frac{\hat{D}_V}{\hat{D}_{12}}\right) = \sqrt{\frac{2}{n_{12}} + \frac{2}{n_{12}}} \tag{10}$$

This estimate of variance is probably optimistic (negatively biassed) as it assumes uniform density whereas mean density varied from experiment to experiment, and also conceivably within each experiment with density expected to fall-off away from the pack-ice. Further, line transect estimation is in principle independent of variation in sighting conditions if $g(0) = 1$; anticipating that $g(0)$ may be more than marginally less than 1, this independence would be lost, introducing further uncertainty.

At this time only negative exponential density estimates have been considered. This estimator is probably biassed for minke whale data (Butterworth, 1982a). However the bias itself is not of relevance here as a density ratio is under consideration; only differential bias with variation of vessel speed would be of concern.

Table 1 shows that estimates for the K27 using speed × time distance calculations tend to give larger relative density D_v/D_{12} ratios than those using estimated distances. Also pooling the K27 and T11 results yielded smaller ratios than when considering them separately.

Table 1

Summary of results of variable speed experiment, with untruncated negative exponential used for g(y) in making density estimates; bracketed figures are coefficients of variation.

(a) w calculated from top-man radial distance estimates.

Vessel	Speed	Distance travelled = L (n. miles)	Number minke sightings =5 n	Search half-width = w (n. miles)	Density = D schools/n. mi²	$\frac{D_v}{D_{12}}$
K27	7	132.5	34	0.858	0.150 (0.24)	1.29 (0.36)
	12	139.6	29	0.894	0.116 (0.26)	
T11	5.5–7	85.2	85	1.056	0.472 (0.15)	1.24 (0.21)
	12	145.5	102	0.922	0.380 (0.14)	
V34	4	24	4	0.310	0.269 (0.71)	5.21 (1.08)
	12	36	3	0.807	0.052 (0.82)	
K27	5.5–7	217.7	119	0.992	0.276 (0.13)	1.09 (0.18)
+T11	12	285.1	131	0.909	0.253 (0.12)	

(b) w calculated from y estimates on a (speed × time-to-close) basis, or (speed × time-to-pass) basis.

Vessel	Speed	Distance travelled = L (n. miles)	Number minke sightings = n	Search half-width = w (n. miles)	Density = D schools/n. mi²	$\frac{D_v}{D_{12}}$
K27*	7	45	16	1.018[1]	0.175 (0.39)	3.06 (0.60)
	12	51.2	10	1.712[1]	0.057 (0.46)	
K27**	7	87.5	18	0.443[2]	0.232 (0.35)	1.71 (0.47)
	12	88.4	19	0.793[2]	0.136 (0.32)	
V34	4	24	4	0.168[2]	0.496 (0.87)	13.94 (1.19)
	12	36	3	1.171[2]	0.036 (0.82)	
T11(a)†	5.5–7	217.7	119	0.951	0.287 (0.13)	1.17 (0.18)
+K27(b)	12	285.1	131	0.939	0.245 (0.12)	

* For experiments where sightings mainly closed with ** For experiments where sightings passed

† T11 data from Table 1a pooled with both sets of K27 data from Table 1b

For the Japanese vessels, adopting separate estimates for each vessel and using top-man radial distance data (Table 1a) seems most appropriate. This distance estimate method is used consistently throughout every transect and thus the variance decrease achieved by pooling of the K27 data from experiments where sightings were closed with and experiments where sightings were passed seems better justified.

K27 and T11 carried out these experiments near the pack ice in Areas VW and VE respectively. The densities in these two sub-areas were quite different (see Butterworth and Best, 1982); also the top-men making the distance estimates differed. Accordingly separate density ratios for K27 and T11 rather than pooling the data for both vessels is preferred.

The V34 made a total of only 7 sightings during its part in this experiment. Calculation of w for each of the V34's speeds on the basis of so little data seems inadvisable (the w values for sightings at 4 knots are in any case unrealistically small—see Table 1). Thus w is assumed the same for both speeds, so that the relative density estimate corresponds to the ratio of number of sightings per mile at the two speeds.

Selection on the above basis yields the following values for D_v/D_{12}, with the bracketed range corresponding to one standard error either side of the mean:

K27	v = 7 knots	Density ratio	1.29 (0.83–1.75)
T11	v = 5.5–7 knots	Density ratio	1.24 (0.98–1.50)
V34	v = 4 knots	Density ratio	2.00 (0.47–3.53)

The associated $g_{12}(0)$ values may be found by plotting these values on Fig. 1. All results indicate values less than 1 for $g_{12}(0)$; however the error bars show that the numbers of sightings during the experiments have been insufficient to reject the possibility that $g_{12}(0) = 1$.

In attempting to make an overall best estimate for $g_{12}(0)$, it seems advisable to omit the V34 data point because of its large variance, and the possibility of other effects playing a large role at low vessel speeds (see Theory section).

The $g_{12}(0)$ values corresponding to the K27 and T11 data are 0.64 and 0.75 respectively. An average weighted by the inverses of the variances of the relative density estimates gives $g_{12}(0) = 0.72$.

A detailed variance calculation for this estimate has not been attempted. However inspection of Fig. 1 suggests a one standard error range about the mean of approximately (0.4–1.0) for $g_{12}(0)$.

The extrapolation to $v = 0$ which requires assumption of the hazard rate model, can be avoided by assuming $g_v(0) = 1$ for the lower of the two speeds utilised by each vessel. Weighting the T11 and K27 results as above gives $g_{12}(0) = 0.80$; the assumptions of this calculation indicate this estimate to be positively biassed.

Conclusion

The number of observations during these experiments was insufficient to achieve great accuracy in estimating $g_{12}(0)$. In particular it is not possible to reject the hypothesis that $g_{12}(0) = 1$, i.e. that no whales on the track-line are missed at the normal searching speed of 12 knots. At the other extreme, the results suggest it is unlikely that a large proportion ($\geq 60\%$) of whales on the track-line is being missed.

The best estimate for $g_{12}(0)$ calculated from the results of the experiments is 0.72. This indicates increasing density estimates from the sighting surveys by about 40%, to allow for whales missed on the track-line.

(B) THE DENSITY GRADIENT EXPERIMENT

Experimental plan

In the original cruise plan the southern sighting vessel was scheduled to undertake transects of 50 mile length away from the ice-edge on alternate days, to investigate whether and how rapidly the minke whale density decreased over this distance.

The K27 undertook the experiment on 9 occasions in Area VW. These are shown in Fig. 2a excepting no. 3 on 30/12/80 which was abandoned at an early stage because of poor weather. All transects were in a north-south direction.

In Area VE, the T11 operated predominantly in the Ross Sea, so that outward transect directions were not all due north, but varied between 340° and 90°. The experiment was undertaken on 7 occasions; 6 are shown in Fig. 2b—no. 4 was aborted as a result of encountering an unexpected pack-ice configuration.

Because of weather and logistical constraints, transects were not as long as originally planned. Transect lengths varied from 10 to 30 miles for both vessels, and usually commenced some 3–4 miles from the ice-edge. Two top-men were used on all occasions.

For the first three experiments and most of the fourth (see Fig. 2a), the K27 closed with all primary sightings made on the transects as during normal sighting operations. Thereafter the vessel maintained fixed course and speed on transect sectors, passing rather than closing with sightings. The initial procedure adopted on the K27 means that those transects were not uniformly searched because of portions spent 'off-effort' while closing with sightings. Accordingly experiments no. 1 to no. 4 of the K27 have been excluded from the subsequent analysis.

Analysis

Positions of minke whale schools sighted during the experiments are shown in Fig. 2. Distances along the track-line are measured from the end of each transect nearest to the ice-edge (generally the southernmost point).

For experiments no. 1 to no. 4 of the K27, the vessel position when the sighting was made was calculated from the recorded latitude position, and thereafter on a speed × time basis (as course and speed were constant). To calculate the position of the whale school, a distance $r \cos \theta$ was added to the vessel position, where r was the top-man's estimate of radial distance to the school when sighted, and θ the angle between the school and the ship's course. Accordingly some observations are indicated beyond the ends of transects. Alternatively the time to come abeam of the school could have been used in determining the school's position, but the T11 did not record these data in most cases.

Identification of a density gradient in this experiment assumes that sighting conditions remained constant along each transect. Throughout the cruise a 'sightability' index was recorded each hour on the hour by the officer on watch, and was intended as a measure of the general conditions for sighting whales. The scale used was from 1 to 5 with 1—very poor and 5—excellent. The values recorded are shown in Fig. 2 at the positions at which they were assessed. They suggest that the required constancy was reasonably attained for the T11's experiments; there seems rather more variation for the K27's experiments, indicating that those results should be treated with more caution.

The results of the experiment have been considered in three ways.

(i) Inspection

For the K27, experiments nos 6 to 9 yielded very few sightings, while no. 5 was more successful in this regard, but nevertheless shows no obvious density trend.

The first three experiments of the T11 suffered similarly from a paucity of sightings. The outward leg of experiment no. 6 produced a large number of sightings, and shows a clear density fall-off with distance from the ice-edge; surprisingly however, the reverse leg shows quite the opposite effect, with the main concentration of sightings near the start of transect (i.e. furthest from the ice-edge). This is presumably a reflection of the patchiness of distribution of minke whales.

It is unfortunate that experiments nos 5 and 7 of the T11 did not extend beyond 12 miles in transect length, as the higher densities found on those occasions might have produced the data for a clearer overall picture.

(ii) Identification of density decrease

Because of the small number of sightings on most transects, it is desirable to pool observations as far as possible to decrease the variance of estimates from the data. The varying length of the transects creates a problem in this regard.

The approach used here is to cut each transect at its mid-point into a 'near' half and a 'far' half with respect to the ice-edge, so that all transects may be pooled. There is an end-effect problem as the transect refers to the vessel, while sightings are generally made ahead of the vessel, because of concentration of sighting effort near the track-line (Doi *et al.*, 1982). Thus one expects a relative paucity of sightings near the start of a transect, and also sightings beyond the end of the transect.

The mid-point of the transect is accordingly not an unbiassed measure of the mid-point of the effective length over which schools have been sighted. However since half the transects ended receding from the ice (far), and the other half approaching the ice (near), it seems reasonable to assume this bias disappears when observations are pooled.

The appropriate hypotheses are:

H_0 (null): sightings are equally or more likely to occur in the far sectors as the near sectors (i.e. density uniform or increasing away from the pack-ice).

H_1 (alternative): sightings are more likely to occur in the near sectors than the far sectors (i.e. density decreases away from the pack-ice).

For the K27 (experiments nos 5 to 9), the number of minke school sightings is:

$$\begin{aligned} n\,(\text{near}) &= 23 \\ n\,(\text{far}) &= 14 \end{aligned}$$

Using the normal approximation to the binomial, this yields $P = 0.069$ so that the density decrease is not significant at the 5% level.

For Area VW where the K27's experiments were carried out, the pack-ice edge runs essentially in an east–west direction, and all transects were in north or south directions. However the coast-line for Area VE (the Ross Sea) does not have this uniform direction, and transects were not always north–south because of this. The density distribution of minke schools in the Ross Sea might therefore be qualitatively different from Area VW (indeed the contour plots in Butterworth and Best (1982) for these areas are quite different), and so the density distribution moving away from the pack-ice may also differ for the two areas. Accordingly it seems inappropriate to combine the K27 and T11 data.

Analysing as above for the T11 yields:

$$\left.\begin{aligned} n\,(\text{near}) &= 100 \\ n\,(\text{far}) &= 87 \end{aligned}\right\} P = 0.172$$

indicating again no significant density decrease at the 5% level.

There is though a further problem for the T11, as specific transects were not steamed at a constant speed throughout as for the K27. The analysis of section (A) suggests that more schools are missed at 12 knots than at the lower speed of 5.5 to 7 knots used over some transect sectors. Thus the apparent density distribution shown on these two-speed transects is a distorted representation of the real situation.

To account for this, sightings on the 12 knot sectors have been weighted by a factor 1.24, the appropriate relative density determined for T11 observations at the different speeds as determined in section (A) (see Table 1). This adjustment yields:

$$\left.\begin{aligned} n(\text{near}) &= 118.0 \\ n(\text{far}) &= 93.5 \end{aligned}\right\} P = 0.046$$

This test then does indicate (narrowly) a decline in whale school density away from the pack-ice significant at the 5% level. However the test has not taken into account the variance of the 1.24 adjustment factor used; incorporating this would seem likely to reverse the conclusion.

Data in Ohsumi *et al.* (1970) inferred a tendency for minke school size to increase with latitude. Bisecting transects as above and calculating mean school sizes ($\bar{s}$) for near and far halves yields the following results (bracketed figures are standard errors of the means):

$$\begin{aligned} \text{K27:}\ & \bar{s}(\text{near}) = 2.04\,(0.32) \\ & \bar{s}(\text{far}) = 1.57\,(0.17) \\ \text{T11:}\ & \bar{s}(\text{near}) = 1.61\,(0.08) \\ & \bar{s}(\text{far}) = 1.40\,(0.08) \end{aligned}$$

The indication of a decrease in $\bar{s}$ moving away from the pack-ice is consistent with Ohsumi *et al.*'s data noted above. However the decrease is statistically significant (at the 5% level) only for the T11's observations.

(iii) Exponential decline model

To attempt to quantify the scale on which the minke school density (D) decreases with perpendicular distance (x') from the pack-ice edge, some functional relation must be assumed. The negative exponential form

$$D = k'e^{-\lambda x'} \tag{11}$$

provides a plausible parametrization, and is convenient for analysis as indicated hereunder.

If the transect starts a distance δ from the ice edge, and x measures the distance from the start of the transect, then

$$x' = \delta + x$$

so that

$$\begin{aligned} D &= k'\,e^{-\lambda(\delta + x)} \\ &= k\,e^{-\lambda x} \qquad \text{where } k = k'e^{-\lambda\delta} \end{aligned} \tag{12}$$

i.e. under this assumption the relative density fall-off is independent of the transect starting point, so that observations from different transects may be combined even though they started at different distances from the ice-edge.

Combination is permitted only to the minimum length of all the transects considered, the cut-off 'a'. Maximum likelihood estimators for the truncated negative exponential then apply:

$$\left.\begin{aligned} \hat{\lambda} &= \frac{1}{\bar{x}} \frac{1-e^{-a\hat{\lambda}}-a\hat{\lambda}e^{-a\hat{\lambda}}}{1-e^{-a\hat{\lambda}}} \\ \text{c.v.}\,(\hat{\lambda}) &= \left\{ n\left[1-\frac{(a\hat{\lambda})^2\,e^{-a\hat{\lambda}}}{(1-e^{-a\hat{\lambda}})^2} \right] \right\}^{-\frac{1}{2}} \\ \text{where } \bar{x} &= \frac{1}{n}\sum_{i=1}^{n} x_i \end{aligned}\right\} \qquad (13)$$

n = number of schools sighted

Results are conveniently expressed in terms of a 'half-range' R, the distance over which the density declines by 50%:

$$R = \frac{\ln 2}{\hat{\lambda}} \qquad (14)$$

The results of these calculations are shown in Table 2. Sightings which fell outside transect limits were not included in the calculations. For both vessels two choices of 'a' were made: one to include all transects, and the other to include to the full range of the longer transects. For the T11 the results are shown both with and without the weighting factor for 12 knot observations discussed in (ii) above; again, as no allowance has been made for the weighting factor variance, coefficient of variation estimates for $\hat{\lambda}$ are underestimates for cases with the weighting factor incorporated.

Except for the T11 data for the longer transects, the values calculated for the half-range R are of the order of 30 nautical miles. The greater values calculated for the longer T11 transects arose essentially because of the large cluster of observations near the start of the inward transect for experiment no. 6.

The large coefficients of variation for $\hat{\lambda}$ (all greater than 1) reflect the fact that the density decrease shown by the observations is not statistically significant—negative values for $\hat{\lambda}$ correspond to a density increase. From equation (13) it is clear that an accurate estimate for λ requires not only a large value for n, the number of observations, but preferably also a transect length 'a' such that $\lambda a \gg 1$. This latter is difficult to achieve in practice due to time constraints on the cruises, and the necessity of constant weather (and hence sighting) conditions throughout each transect. Furthermore the negative exponential may not prove a reasonable form to describe the density distribution over a longer distance.

It is interesting to compare these results for the half-range R, with the half-range indicated by the contour map of daily density estimates used in the Area V assessment by Butterworth and Best (1982). Only Area VW was considered here, as the direction away from the pack ice may be consistently considered as north for that sector; Area VE (the Ross Sea) was omitted from consideration because of its more complex topography.

For Area VW the distance northward from the pack-ice over which the density dropped to half that at the pack ice was measured every 2°30′ of longitude on the density contour map (Butterworth and Best, 1982). This set of half-range estimates yielded a mean of 41 n. miles (standard error 8 n. miles) with standard deviation of 28 n. miles.

This mean of 41 n. miles compares reasonably with the density gradient experiment results of some 30 n. miles.

Conclusion

Data collected during the density gradient experiments shows a decline in minke whale density away from the pack-ice, though this decline is not statistically significant at the 5% level.

The best estimate of the distance over which the density falls by 50% (the half-range) is some 30 n. miles, which compares reasonably with an average of some 40 n. miles indicated by the density contour map for Area VW. The large variance in estimates from the density gradient experiment arises from the small number of observations and the shortness of the transects.

The experiments also showed a decrease in mean school size away from the ice edge in both Areas VW and VE, though this result was statistically significant at the 5% level only for Area VE.

(C) THE PARALLEL SHIP EXPERIMENT

Theory

The initial object of this experiment was to try to detect whether whales react to the search vessel. If whales are attracted to or avoid the vessel, particularly if significant movement of this nature takes place before they are first sighted, sighting densities will tend to be over- or under-estimated respectively.

In the experiment as conceived, two similar vessels

Table 2

Fits of data from the density gradient experiment to a negative exponential fall-off of density away from the pack-ice; bracketed figures are coefficients of variation.

Vessel	Experiment Nos	Cut-off = (n. miles)	$\bar{x}$ (n. miles)	$\hat{\lambda}$ (c.v.) (n. miles)$^{-1}$	Half-range = R (n. miles)	R limits ($\lambda \pm$ one standard error) (n. miles)
K27	5; 9	24.50	11.10	0.0232 (1.12)	29.9	14.1 to − 243.0**
K27	5; 6; 7; 8; 9	11.67	5.62	0.0189 (3.15)	36.7	8.9 to − 17.1
T11	3; 6	29.08	14.21	0.0047 (2.80)	148.4	39.0 to − 82.4
T11	3; 6*	29.08	13.74	0.0114 (1.07)	60.6	29.3 to − 832.2
T11	1; 2; 3; 5; 6; 7	10.58	5.09	0.0217 (1.41)	31.9	13.3 to − 78.4
T11	1; 2; 3; 5; 6; 7*	10.58	5.04	0.0264 (1.07)	26.2	12.6 to − 352.7

* Incorporating 1.24 weighting factor for 12 knot sectors.

** Negative R values correspond to density increasing away from the pack-ice.

steam abreast of each other along parallel courses, so that the inter-vessel distance remains constant. If there is a definable reaction to the ship by the whales, a left-right asymmetry in the observations of a single vessel would be found. If ship A is the lefthand one of the pair (see Fig. 3), observations to its right (the 'same' side as the other vessel) would be affected by whales reacting also to ship B on that side, whereas there would be no (or less) reaction to ship B by whales to ship A's left (the 'opposite' side to the other vessel).

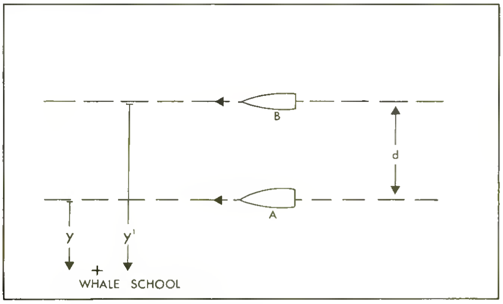

Fig. 3. The parallel ship experiment.

Should asymmetry be found, it would not necessarily be clear whether attraction or avoidance had occurred. For example, attraction could result in ship A observing more whales on the opposite side, as some of the whales on its same side would concentrate instead on ship B, and so be less likely to be sighted at a greater distance. Avoidance could also result in fewer same side sightings for ship A, as whales on that side would move further away to avoid ship B as well. In either of these cases, a relative paucity of sighting in the area between the tracks of the two ships might be expected.

Thus though it may not be possible to distinguish what type of reaction to the ship is occurring if asymmetry is found, the important conclusion would be that there is *some* sort of reaction, which would justify further research effort (e.g. aerial work) to identify the magnitude and direction of the effect. Conversely absence of significant asymmetry would lead to greater confidence in the no-reaction assumption on which current sighting estimates of minke population size are based.

Subsequently it was realised that another parameter that could be estimated in the parallel ship experiment would provide useful information on biases in sighting estimates. This is the double sightings proportion (S) i.e. the proportion of schools sighted by either vessel that is sighted by both vessels.

Assume that a whale school is situated as shown in Fig. 3, and that the probability of its being sighted by vessel A is $g_A(y)$, and $g_B(y')$ by vessel B.

Assuming further that sightings by the two vessels are independent and uncorrelated*, the probability that both vessels sight the school is given by the product:

$$p(\text{doub}) = g_A(y)g_B(y') = g_A(y)g_B(y + d) \qquad (15)$$

where d is the distance between the vessels.

If the vessels and their observation procedures are the same, and the whales are not reacting to the vessels, then

$$g_A(Y) = g_B(Y) = g(Y) \qquad (16)$$

where g(Y) is the sighting probability distribution for a single vessel, so that:

$$p(\text{doub}) = g(y)g(y + d) \qquad (17)$$

Assuming that there is no trend in the distribution of whale schools perpendicular to the vessel tracks, integration over y then gives:

$$S = \frac{\int_{-\infty}^{\infty} g(y)\, g(y + d)\, dy}{\int_{-\infty}^{\infty} g(y)\, dy} \qquad (18)$$

Provided the vessels do not communicate with each other during the experiment, their sightings would be independent in the sense that one vessel would not be able to improve its chances of sighting a particular school because of information received from the other vessel.

Experimental design

The periods of steaming to the factory ship to refuel, and returning to Area VE to recommence the search grid, were set aside for the parallel ship experiment. The K27 and T11 were chosen for the experiment because of their similar vessel characteristics.

Ideally results for a number of different values of the inter-vessel distance d would have been desirable. However preliminary calculations indicated that it would be difficult to obtain sufficient observations for statistically significant results even if only one inter-vessel distance was used throughout the time available for the experiment.

Accordingly it was decided to keep d at one fixed value throughout the experiment. This placed particular importance on the choice of d. If the d chosen was too large, it might be greater than the scale on which ship attraction or avoidance takes place, so that no asymmetry would be detected. On the other hand, if d were chosen too small, whale reaction might be different to the situation where only one vessel is present; for example, the whales might react to the pair of ships as a unit, so again no asymmetry might be apparent.

The closer together the ships, the greater is the number of double sightings that would be expected. Thus the coefficient of variation of the double sightings proportion S decreases as d decreases. With the vessels really close together there could be a psychological effect on the observers' searching pattern through having another vessel on their beam, though as the observers concentrate mainly in the forward direction (Doi *et al.*, 1982), this effect may not be too serious.

The scale on which reaction by minke whales to the vessels might take place could be envisaged as either 'long-range' or 'short-range'. In rough quantitative terms, 'long-range' might correspond to right-angle distances $\gtrsim 2$ n. miles, and 'short-range' to right-angle distances $\lesssim \frac{1}{2}$ n. mile (the effective search half-width observed on previous cruises).

Long-range attraction would result in the vessel moving through areas of greater than normal density. Abundance estimates from line transects:

$$N = \frac{n\,A}{2\,L\,w} \qquad (22)$$

would be positively biassed because the number of sightings n would increase from that expected in the absence of the attraction. Similarly long range avoidance would be likely to yield abundance underestimates.

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* see Appendix I.

Short-range attraction or avoidance would also cause abundance over- or under-estimation respectively, though probably for a different reason. The effective search half-width w in equation (22) would seem likely to be most affected, with attraction leading to its underestimation (and hence to overestimation of abundance).

The observations of previous cruises (Best and Butterworth, 1980; Horwood, 1981) suggest a preponderance of whales actively avoiding or moving away from vessels steaming at the search speed of 12 knots. These conclusions were however without great certainty, because of difficulties in the interpretation of behaviour and in measuring the direction of whale movement. The long-range effects postulated above would require much more whale movement than short-range effects to produce the same bias in abundance estimates. The short-range effect could be caused by a relatively small change in direction of movement by a whale close to the track-line when still quite far ahead of the vessel (conceivably as the whale becomes aware the vessel is heading almost directly towards it). Such a small change might well be undetectable by observations of the type referred to above, so that those observations would seem more likely to reflect long-range effects.

An outstanding feature of previous cruises has been the large peak in the minke whale sightings distribution with perpendicular distance from the track-line (y) on a scale $y \lesssim 0.1$ n. mile (Butterworth, 1982a). The calculation of the effective search half-width w, and hence the minke whale abundance estimates, are very sensitive to this peak. It is therefore important to determine whether this apparent sharp decline in minke whale sighting probability away from the track-line is real, or caused by some other effect.

Short-range attraction to the ship could be such an effect. If the apparent decline in sighting probability is real then, for example, some 50% of the minke whales between $0.1 \leq y \leq 0.2$ n. miles are being missed by the observers, and the double sightings proportion S would be expected to be small. If on the other hand the decline is a reflection of minke whales moving closer to the ship, the proportion missed nearby would be smaller, and S correspondingly larger.

Thus previous data could be interpreted as indicating long-range avoidance and/or short-range attraction, causing abundance under- and/or over-estimation respectively.

The possible short-range effect (and resultant over-estimation) were considered the more important to investigate, indicating the choice of a small value for d (i.e. compared to the effective search half-width ~ 0.5 n. miles). The smaller d the better the estimation of S, but the poorer the prospects of asymmetry detection. Rough calculations of coefficients of variation of parameters of both effects under the assumption of a simple model of ship attraction (Butterworth, 1981), indicated d = 0.3 n. miles as an appropriate compromise choice, which was subsequently adopted for the experiment.

Results

The experiment was conducted on the 9th January when the vessels steamed in a westerly direction to the factory ship to refuel, and subsequently on the 12th to 15th January during steaming generally eastwards towards commencement of the search grid in Area VE. Details are given in Table 3. Unfortunately poor weather curtailed the time available for the experiment on the eastward transit (the experiment was suspended in periods of bad weather).

The vessels steamed parallel 0.3 n. miles apart; their distance from the pack ice was originally 10 miles, but midway through the first day of the experiment (9th January) this was reduced to 5 miles to try to increase the sightings rate (this compares with the average distance of some 3–4 miles from the pack-ice adopted by the southernmost sighting vessel in normal sighting operations). The K27 was nearer the pack-ice for the westward transit, and further away for the eastward transit i.e. K27 was the lefthand vessel throughout the experiment. Each vessel employed two top-men throughout the experiment, except for the first two and last two hours on 9th January, when only one was used on each vessel.

Certain problems were experienced in station-keeping during the experiments. The T11 could not travel at 12 knots because the vibration at that speed interfered with the top-man's ability to hold the binoculars steady: experiments were therefore carried out at 12.2 knots. It was also difficult for one vessel to maintain constant r.p.m. and still keep station: the repeated r.p.m. adjustments thus made could have affected whale reaction to the vessel's approach. In progress along the pack edge, the vessel nearer the pack acted as pace-setter, and during turns along the pack the second vessel had to adjust speed in order to maintain station. Communication between vessels was needed to coordinate station-keeping, but no mention was made of sightings and there was apparently no feedback to the one ship via auditory or visual cues when the other ship made a sighting.

The vessels did not change course to sightings (i.e. they

Table 3

Details of the parallel ship experiment (P = Port: S = Starboard; A = Dead Ahead).

Date	Vessel configuration	Distance steamed in parallel-ship mode (n. miles)	Number minke schools sighted							
			K27				T11			
			P	S	A	Total	P	S	A	Total
9.1.81	T11 ← K27 ←	178	8	2	1	11	8	7	0	15
12.1.81	→ K27 → T11	67	2	0	1	3	1	2	0	3
13.1.81		8	0	0	0	0	0	0	0	0
14.1.81		0	—	—	—	—	—	—	—	—
15.1.81		130	12	18	2	32	12	25	0	37
Total		383	22	20	4	46	21	34	0	55

passed them, and did not close with them). A total of 101 minke whale schools was sighted during the experiment: 46 by the K27 and 55 by the T11. Most sightings (69) were made on the last day of the experiment (15th).

(i) Asymmetries

Unfortunately the T11 did not record time to come abeam of sightings during this experiment. Thus for consistency the y values for minke schools sighted have been calculated using the top-man's estimate of radial distance at the time the school was first sighted.

The resultant distribution of sightings with y on either side of the vessel is shown for the K27 and T11 both separately and combined in Fig. 5.

A number of tests for asymmetries was made, and these are detailed and discussed in Appendix II. The results may be summarised as follows ('significant' refers to a 5% significance level):

(a) More, though not significantly more, sightings were made on the opposite than the same side. Rather than ship reaction asymmetry however, this seems a reflection of the significantly greater number of sightings to the south during the experiment.
This preponderance of southern sightings is generally not reflected for the cruise as a whole. A bias may have arisen as the experiment was carried out in better than average weather conditions during which sun glare may have had a greater effect on sightings.

(b) The perpendicular distance (y) distribution of sightings to same and opposite sides did not differ significantly.

(c) $\bar{y}$ (same) was greater than $\bar{y}$ (opposite) for both vessels, though not significantly so. For both vessels $\bar{y}$ (parallel ship) is greater than $\bar{y}$ (whole cruise), significantly so for the K27. Though this suggests avoidance of the pair of vessels as a unit, the same effect shows for the variable speed experiment, so may rather represent a bias arising from the choice of periods of better weather conditions to conduct experiments.

Overall there are indications of asymmetry in the results of the experiment, though few are statistically significant. It is also noticeable that the sighting distributions (Fig. 5) do not show the marked peak near the track-line evident in normal searching (Butterworth, 1982a).

These effects could arise from better than average weather conditions during the experiment. This aspect requires further study before final conclusions can be drawn.

(ii) Double sightings proportion

It proved more difficult than had been anticipated to identify schools sighted by both vessels, particularly as the T11 failed to record the time to come abeam of each sighting.

The co-ordinates of each school thus had to be calculated from the time the school was first sighted, so that if the school was sighted at different times by the two vessels, identification of double sightings could be confused by an intervening movement of the school. In the calculations, coordinates of K27 sightings were obtained using the estimated angle, vessel speed, and time to come abeam, while angles and radial distances estimated by the top-man were used for the T11. As sightings times were recorded only to the nearest minute, and the vessels steamed at 12 knots, along-track coordinates have a minimal potential error of 0.1 n. miles. The best estimate of school size was also taken into account in identification, but as sightings were not closed with, this estimate was not entirely reliable for schools not passing relatively close to the vessel.

Candidates for double sightings are listed in Table 4. They have been grouped in three categories depending on the difference in coordinates calculated from each of the vessels. These differences are defined by:

Δx = position difference in along-track direction in nautical miles

Δy = position difference in perpendicular-track direction in nautical miles

where the differences are always recorded as positive.

Table 4

Candidates for double sightings in the parallel ship experiment. The classification of categories is explained in the text.

Date	K27 Sighting No./ school size	T11 Sighting No./ school size	Along-track position difference = Δx (n. miles)	Perpendicular-track position difference = Δy (n. miles)	Category
9.1.81	S277/1	S841/2	0.98	0.05	II
	S292/1	S865/1	1.01	1.66	III
	S294/1	S868/1	0.93	0.95	III
	S296/1	S869/1	0.84	0.23	II
12.1.81	S297/3	S873/2	1.01	0.14	II
15.1.81	S304/2	S884/2	0.09	2.34	II
	S305/1	S888/3	1.49	0.41	II
	S306/2	S892/1	1.23	1.05	III
	S309/4	S895/2	0.12	2.04	II
	S313/2	S897/1	0.20	1.92	II
	S314/5	S896/6	0.06	0.16	I
	S317/1	S901/2	0.41	0.13	I
	S318/2	S903/2	1.07	0.66	III
	S319/2	S904/2	1.17	0.42	II
	S323/2	S908/1	1.20	0.13	II
	S327/1	S913/2	0.98	0.27	II
	S328/4	S914/5	0.40	0.18	I
	S333/2	S915/2	0.20	0.20	I
	S334/1	S918/1	0.31	0.36	I
	S339/2	S922/2	0.50	1.99	II
	S342/2	S924/1	0.17	0.29	I

The criteria used for categorisation were:

I (Probable): $\Delta x \leq 0.5$; $\Delta y \leq 0.5$
II (Possible): One of Δx, $\Delta y \leq 0.5$; $\Delta x \leq 1.2$
III (Outside possible): $0.5 < \Delta x \leq 1.2$
(no Δy restriction)

The total of 101 minke school sightings by the two vessels yielded candidates for these categories as follows:

I: 6 candidates
II: 11 candidates
III: 4 candidates

The remaining 59 sightings were considered to have been seen by only one of the two vessels.

Considering (I + ½II) as a best estimate of the number of double sightings, with (I) alone as a lower limit, and (I + II + III) as an upper limit, gives for the observed double sightings proportion:

$$S_{obs} = 0.23 \text{ (limits 0.12 and 0.42)}$$

(The statistical standard error of the estimate of S_{obs} is approximately 0.05).

To compare this with the prediction of S from equation (18) for the generalised exponential

$$g(y) = e^{-\lambda|y|^p}$$

requires an estimate of λ. Estimates of λ and the resultant S values are shown in Table 5 for p = 1 (negative exponential) and p = ½.

Also shown in Table 5 is S′, the value of S adjusted to take into account the fact that not all schools on the trackline are seen, given by:

$$S' = g(0)\,S \qquad (23)$$

where the best estimate from the variable speed experiment $g_{12}(0) = 0.72$ has been used for g(0) in equation (23).

The results in Table 5 show that the negative exponential's prediction for S (which, because of neglect of correlations, we expect to be an underestimate (Appendix I)), is not compatible with the observed range for S_{obs}; all predicted S values are greater than the upper limit for S_{obs} (neglecting statistical errors).

Agreement is improved by taking into account the best estimate of the proportion of whales missed on the track-line. The S^1 value (~0.34) is still rather larger than the best estimate of S_{obs} (0.23), which suggests g(y) falls off more steeply near y = 0 than the negative exponential can represent (see Butterworth, 1982a). Table 5 and Fig. 4 show that using the generalised exponential with p < 1 to parametrize such a steeper fall-off decreases the value of S.

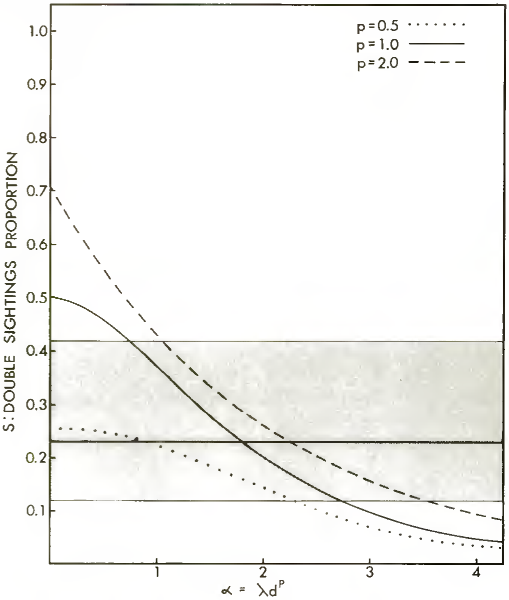

Fig. 4. Plots of the double sightings proportion S evaluated using equation (18) for the generalised exponential model $g(y) = e^{-\lambda|y|^p}$ as a function of the inter-ship distance d. The horizontal straight line is the best estimate of S obtained from the experiment, with the shading corresponding to upper and lower limits (see text).

The low value of S_{obs} is not consistent with 'short-range' ship-seeking causing population overestimation by negatively biassing the effective search half-width.

DISCUSSION AND CONCLUSION

The search for asymmetries in the parallel ship experiment results is inconclusive. Some trends are evident (and may indicate avoidance of the pair of vessels as a unit), but most results are not statistically significant at the 5% level. Those results which are significant may reflect the better than average weather during the periods of the experiment.

Table 5

Estimates of the double sightings proportion S from equation (18) using the generalised exponential $g(y) = e^{-\lambda|y|^p}$ 'Calc' y-values refer to those evaluated on a speed × time-to-close basis; 'Est' refer to evaluations based on the top-man's radial distance estimate. S′ is the S value adjusted to take into account whales missed on the trackline (equation 23)).

p	Sightings considered (all primary minke)	Vessel	λ (n. miles)$^{-p}$	$\alpha = \lambda d^p$ d = 0.3 n. miles	S	S′
1	Whole cruise (y-Calc.)	K27 T11	1.44 1.20	0.43 0.36	0.47 0.47	0.33 0.34
	Parallel ship expt. (y-Est.)	K27 T11	0.85 1.10	0.26 0.33	0.49 0.48	0.35 0.34
0.5	Whole cruise (y-Calc.)	K27 T11	2.92 2.55	1.60 1.40	0.18 0.19	0.13 0.14
	Parallel ship expt. (y-Est.)	K27 T11	2.08 2.34	1.14 1.28	0.21 0.20	0.15 0.15

Table 8

Parameters of perpendicular distance distributions of primary sightings of minke schools by the K27 and T11 during experiments and for whole cruise. Top-man estimates of radial distances have been used throughout to calculate y values. All distances are in n. miles.

	K27				T11			
Cruise sector	Mean $\bar{y}$	Standard error of mean	Standard deviation	Number sightings	Mean $\bar{y}$	Standard error of mean	Standard deviation	Number sightings
Parallel ship experiment								
Same side	1.300	0.218	1.024	22	1.107	0.236	1.079	21
Opposite side	1.066	0.182	0.894	24	0.786	0.117	0.680	34
Both sides	1.178	0.141	0.955	46	0.909	0.116	0.859	55
Variable speed experiments	0.850	0.117	0.974	69	0.971	0.057	0.835	215
Complete cruise	0.688	0.040	0.767	368	0.807	0.029	0.759	681

In summary, the experiment yielded no positive indication of ship-seeking behaviour by minke whales (which would positively bias abundance estimates from sightings). From the results of the experiment, it seems likely that abundance estimates assuming no reaction by the whales to the vessel, all whales on the track-line being seen ($g(0) = 1$), and a negative exponential parameterization of the sighting distribution with perpendicular distance from the track-line ($g(y) = e^{-\lambda y}$), are negatively biassed.

ACKNOWLEDGEMENTS

Correspondence with Dr K. Burnham and Dr P. Hammond, and discussions with Mr J. Horwood are gratefully acknowledged. Dr A. Hiby drew attention to the effect of correlations on the calculation of the proportion of double sightings during the parallel ship experiment. Mr L. Vogel carried out the numerical integrations, and Mr M. du Plessis assisted with computer programming.

REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise 1978/79. *Rep. int. Whal. Commn* 30: 257–283.

Butterworth, D. S. 1981. Some comments on experiments planned for the 1980/81 IWC/IDCR minke whale assessment cruise. Document SC/Jn81/MiS5 presented to the IWC Scientific Committee, June 1981.

Butterworth, D. S. 1982. A possible basis for choosing a functional form for the distribution of sightings with right angle distance: some preliminary ideas. Paper SS/7 (published in this volume).

Butterworth, D. S. 1982a. On the functional form used for g(y) for minke whale sightings, and bias in its estimation due to measurement inaccuracies. Paper SC/Jn81/MiS18 (published in this volume).

Butterworth, D. S. and Best, P. B. 1982. Report of the Southern Hemisphere minke whale assessment cruise, 1980/81. Paper SC/Jn81/MiS14+15+19 (published in this volume).

Daniel, W. W. 1978. *Applied nonparametric statistics.* Houghton Mifflin Company, Boston. 503 pp.

Doi, T., Kasamatsu, F. and Nakano, T. 1982. A simulation study on sighting survey of minke whales in the Antarctic. Paper SC/Jn81/MiS29 (published in this volume).

Hiby, A. R. 1982. The effect of random whale movement on density estimates obtained from whale sightings surveys. Paper SC/Jn81/MiS7 (published in this volume).

Horwood, J. W. 1981. Results from the IWC/IDCR minke marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

International Whaling Commission. 1980. Report of planning meeting for the IWC/IDCR minke whale assessment cruise, Tokyo, 1–4 October 1980. Unpublished.

International Whaling Commission. 1982. Report of the workshop on the design of sightings surveys, Seattle, 11–16 September 1980. SC/33/Rep 2 (published in this volume).

Koopman, B. O. 1956. The theory of search 1. Kinematic Bases. *Ops. Res.* 4: 324–46.

Leatherwood, S., Awbrey, F. T. and Thomas, J. A. 1982. Minke whale response to a transiting survey vessel. Paper SC/Jn81/MiS9 (published in this volume).

Ohsumi, S., Masaki, Y. and Kawamura, A. 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 22: 75–125.

Appendix 1

THE EFFECT OF CORRELATION OF SIGHTINGS OF THE TWO VESSELS IN THE PARALLEL SHIP EXPERIMENT ON CALCULATION OF THE DOUBLE SIGHTINGS PROPORTION S

Equation (18) for the double sightings proportion

$$S = \frac{\int_{-\infty}^{\infty} g(y)\, g(y+d)\, dy}{\int_{-\infty}^{\infty} g(y)\, dy} \tag{18}$$

is derived on the assumption that the sightings of the two vessels are uncorrelated.

This is unlikely to be true in practice. For example, the various whale schools (i: $i = 1 \ldots n$) in the area in which the experiment is conducted, will have distinct attributes that may result in different sighting probability distributions ($g^i(y)$). One reason for this would be varying school sizes, with a larger school more likely to be sighted at a given perpendicular distance than a smaller school. The g(y) specified in equation (16) would be an average over all the schools:

$$g(y) = \frac{1}{n} \sum_{i=1}^{n} g^i(y) \tag{A1}$$

Taking this into account, the double sightings proportion is given rather by $\tilde{S}$ where

$$\tilde{S} = \frac{\int_{-\infty}^{\infty} \left[\frac{1}{n} \sum_{i=1}^{n} g^i(y)\, g^i(y+d)\right] dy}{\int_{-\infty}^{\infty} \left[\frac{1}{n} \sum_{i=1}^{n} g^i(y)\right] dy} \tag{A2}$$

Now

$$\frac{1}{n}\sum_{i=1}^{n} g^i(y)\, g^i(y+d) = g(y)\, g(y+d) + \frac{1}{n}\sum_{i=1}^{n}\left[g^i(y)-g(y)\right]\left[g^i(y+d)-g(y+d)\right] \qquad (A3)$$

so that

$$\tilde{S} = \frac{\int_{-\infty}^{\infty}\left\{g(y)\, g(y+d) + \frac{1}{n}\sum_{i=1}^{n}\left[g^i(y)-g(y)\right]\left[g^i(y+d)-g(y+d)\right]\right\}dy}{\int_{-\infty}^{\infty} g(y)\, dy}$$

$$= S + \frac{\int_{-\infty}^{\infty}\left\{\frac{1}{n}\sum_{i=1}^{n}\left[g^i(y)-g(y)\right]\left[g^i(y+d)-g(y+d)\right]\right\}dy}{\int_{-\infty}^{\infty} g(y)\, dy} \qquad (A4)$$

If one whale school is more likely to be sighted at a particular perpendicular distance y than another (e.g. smaller) school, it seems reasonable to assume this would be true for any perpendicular distance (Y):

i.e. $g^i(y) > g^j(y) \rightarrow g^i(Y) \geqslant g^j(Y)$ for all Y

and therefore

$$\left.\begin{array}{l} g^i(y) > g(y) \rightarrow g^i(y+d) \geqslant g(y+d) \\ g^i(y) < g(y) \rightarrow g^i(y+d) \leqslant g(y+d) \end{array}\right\}$$

so that

$$[g^i(y) - g(y)]\,[g^{i(y+d)-g(y+d)}] \geqslant 0 \qquad (A5)$$

One may therefore deduce from equation (A4) that

$$\bar{S} \geqslant S \qquad (A6)$$

i.e. correlation between the sightings of the two vessels results in equation (18) underestimating the double sightings proportion.

Appendix II

TESTS FOR ASYMMETRIES IN SIGHTINGS MADE DURING THE PARALLEL SHIP EXPERIMENT

Note that throughout this section 'statistically significant' will be used to mean 'statistically significant at the 5% level'. Unless otherwise indicated, values of P are the probability of the result obtained or one more extreme occurring under the null hypothesis. Confidence intervals recorded are 95% confidence intervals.

(a) Number of observations

If there was no reaction to the vessel, equal numbers of observations on same and opposite sides would be expected, i.e. $\rho = ½$ where ρ is the proportion of observations on the opposite side.

Omitting sightings dead ahead, the experiment yielded:

$$\left.\begin{array}{l} n\ (\text{opposite}) = 56 \\ n\ (\text{same}) = 41 \end{array}\right\} \quad \hat{\rho} = \frac{56}{97} = 0.577$$

$$\text{Testing:} \left\{\begin{array}{l} H_0 : \rho = 0.5 \\ H_1 : \rho \neq 0.5 \end{array}\right. \qquad (A7)$$

and using the normal approximation to the binomial yields $P(z \geqslant 1.52 \mid \rho = 0.5) = 0.064$, so that H_0 cannot be rejected. The confidence limit for ρ is $0.479 \leqslant \rho \leqslant 0.676$.

Though not statistically significant, the value of $\hat{\rho}$ is nevertheless quite large. Rather than a same/opposite side asymmetry however, this seems a reflection of a greater number of sightings to south than north during the experiment:

$$\left.\begin{array}{l} n\ (\text{north}) = 36 \\ n\ (\text{south}) = 61 \end{array}\right\} \quad \hat{\rho}' = \frac{61}{97} = 0.629$$

where ρ' refers to the proportion of observations to the south.

$$\text{Testing:} \left\{\begin{array}{l} H_0 : \rho' \leqslant 0.5 \\ H_1 : \rho' > 0.5 \end{array}\right. \qquad (A8)$$

as above yields $P = 0.006$ so that the proportion of observations to the south was significantly larger. Confidence limits for ρ' are $0.533 \leqslant \rho' \leqslant 0.725$.

Two factors could be expected to give rise to a preponderance of southern sightings: the density gradient away from the pack-ice, and sightability differences with glare from the sun on the northern side making sightings more difficult on that side.

It seems unlikely however that the density gradient could produce an effect of sufficient magnitude to account for the result of this experiment. The mean sighting distance (~ 1 n. mile) is much less than the density half-range of some 30 n. miles indicated by the analysis of section B. Furthermore the distance of the vessels from the ice edge (~ 5 n. miles) is also considerably larger than the mean sighting distance, so that a possible concentration of whales right at the ice edge would not have influenced observations.

If sun orientation is the reason for the southern preponderance, this should also show in observations throughout the cruise. Table 6 summarises primary sightings of minke schools throughout the cruise seen to port, starboard, and dead ahead of each vessel. Since the vessels travelled in an overall westward direction for the first half of the cruise, and an overall eastward direction for the second half, as a first approximation one may take observations to port as 'southern' for the first cruise leg, and 'northern' for the second. (This approximation is poorer for the northern vessels (Leg 1—T11; Leg 2—K27) as they were working a grid and spent a considerable portion of their time on north/south transects.). The Table gives the proportion of 'southern' sightings and the associated P value under (A8).

Following the significant preponderance of southern sightings during the parallel ship experiment, it is perhaps surprising that Table 6 shows significant results only for V34, arising from observations on the second half of the cruise. In particular the observations from the K27 on the first half of the cruise show no significant result; this would have been expected to be the most similar to the parallel-ship case, as nearly the same area (principally Area VW near the pack-ice) was covered in both cases.

A possible reason for the significant result in the parallel-ship case is bias arising from confining experiments to periods of better weather. The 15th and particularly the 9th of January (when partly cloudy conditions prevailed for most of the day) on which most of the sightings during this experiment were made, were days of better than average weather conditions.

Cruise notes kept by Best refer to better sighting conditions to the south early on the 9th January because of highlighting against a bright background sky arising from reflection off the ice edge. Shortly after mid-day problems of sun glare to the north are noted. On the 15th, particularly calm sea conditions prevailed, so that although the weather was mainly overcast, glare on the northern side may have been a factor.

Sun glare may therefore have had a greater effect at these times than over the cruise as a whole. The influence of weather conditions on sightings merits further attention.

On the other hand the result may be a reflection of patchiness in the minke whale distribution.

(b) Perpendicular distance distribution of observations

Fig. 5a shows the distribution of sightings with perpendicular distance y either side of the vessel for both the K27 and T11. The χ^2 test of homogeneity is used here to check the hypothesis (H_0) that observations from the same and opposite sides are from the same distribution.

Observations have been grouped as indicated in Table 7 for calculation of χ^2 (the 4 observations dead ahead by the K27 have been divided 2 to either side in Fig. 5 and Table 7). Calculations yield:

K27: $\chi^2_2 = 2.93$ $P = 0.231$
T11: $\chi^2_2 = 5.57$ $P = 0.350$

Thus the test does not indicate a significant distribution asymmetry in either case.

(c) Mean perpendicular distance of observations

Mean perpendicular distances of sightings ($\bar{y}$) on same and opposite sides during the experiment are listed in Table 8. (Again the 4 dead ahead observations for the K27 have been divided 2 to each side.)

In the absence of reaction to the vessel one would expect $\bar{y}$ (same) $\equiv \bar{y}_s$ to equal $\bar{y}$ (opposite) $\equiv \bar{y}_0$. A t-test can only be used for the K27, as the F-test indicates significantly different variances for same and opposite sides of the T11. The K27 data yield:

$$t_{44} = 0.827 : P(t_{44} \geqslant 0.827 \mid \bar{y}_s = \bar{y}_0) = 0.21$$

indicating no significant differences of means.

The non-parametric Mann-Whitney test has also been used to test $\bar{y}_s = \bar{y}_0$, though strictly the assumption of this test that the distribution functions differ (if at all) only with respect to location, is questionable. Using the large sample approximation corrected for ties (Daniel, 1978) gives:

K27: $n_1 = 20$ $n_2 = 22$ $T = 262$
$z = 1.06$ $P(z \geqslant 1.06 \mid \bar{y}_s = \bar{y}_0) = 0.145$
T11: $n_1 = 21$ $n_2 = 34$ $T = 384$
$z = 0.47$ $P(z \geqslant 0.47 \mid \bar{y}_s = \bar{y}_0) = 0.319$

Thus though $\bar{y}_s > \bar{y}_0$ for both vessels, an effect vessel reaction plausibly might produce, the difference is not significant.

Avoidance of the pair of vessels as a unit might produce a larger $\bar{y}$ during the experiment than for the cruise as a whole. As sample sizes are quite large in this case (see Table 8), the normal approximation has been used to test:

$$\begin{cases} H_0\text{: } \bar{y} \text{ (parallel ship)} \leqslant \bar{y} \text{ (whole cruise).} \\ H_1\text{: } \bar{y} \text{ (parallel ship)} > \bar{y} \text{ (whole cruise).} \end{cases} \quad \text{(A9)}$$

This gives results:

K27: $z = 3.345$ $P = 0.0004$
T11: $z = 1.249$ $P = 0.105$

It is tempting to see these results as indicating avoidance of the vessels as a pair. However testing hypotheses similar to (A9) for the variable speed experiment yields:

K27: $z = 1.308$ $P = 0.095$
T11: $z = 3.305$ $P = 0.0005$

While it is possible that $\bar{y}$ would increase for the slower speed sectors during this experiment, Table 1 does not indicate major differences.

It seems therefore that there may be some other common factor that leads to a $\bar{y}$ increase during experiments. This factor might be weather conditions. Because of the need for a large number of sightings in experiments to obtain significant results, there was a tendency to carry out experiments (both parallel ship and variable speed) only in good weather conditions. This selection effect could bias certain variables observed during experiments compared to the cruise as a whole (cf. the postulated reason for the north/south asymmetry during the parallel ship experiment discussed in section (a)).

A more detailed study of the effects of weather conditions on sighting distances merits attention.

SC/Jn81/MiS14+15+19

Report of the Southern Hemisphere Minke Whale Assessment Cruise, 1980/81[1]

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ABSTRACT

Three scouting boats (two Japanese and one Soviet) undertook a systematic marking and sighting cruise for minke whales (*Balaenoptera acutorostrata*) in Antarctic Area V (130°E–170°W), including that part of the Ross Sea east of 170°W, from 17 December 1980 to 12 February 1981. A total of 473 minke and 12 sperm whales was marked. Tests of a .410 streamer mark were generally unsuccessful. Two marked minke whales were subsequently recaptured in Area VW, from which a population estimate for the region 130°–165°E is obtained of 30,375 ± 15,026 (S.D.).

Population estimates for Area V are also obtained from sighting data using line transect methodology. The analysis shows that blows were the commonest sighting cue, and were generally seen at greater distances than other cues. Observations of the relative headings of ship and whale at the time of sighting provides no evidence of ship-seeking by minke whales. Attempts to improve the accuracy of right-angle distance measurement produce a smaller peak in the frequency of sightings near the trackline than on previous cruises, because of a delayed turn procedure introduced when the initial angle of sighting was 15° or less. Average perpendicular distances from the trackline are also greater because of the incorporation of an estimate of shortfall i.e. the distance from the whale at which half-speed was called.

Although the mean sighting angle is similar for all three vessels, the distribution of angles from 0 to 50° is flatter for the Soviet vessel than the Japanese vessels, partly as a result of the larger proportion of sightings from the upper bridge on the Soviet vessel, but also from an apparent difference in searching technique. A greater proportion of sightings on the trackline may therefore have been missed by the Soviet vessel, so producing an underestimate of whale density compared to those from the Japanese vessels. The observations for one Japanese vessel (T11) also indicate a bias in the choice of sightings closed with, resulting in an atypical distribution of calculated perpendicular distances.

Daily density estimates from the two Japanese vessels (using primary sightings only) are plotted against the noon position of the vessel on an equal-area projection chart, density contours drawn by hand and the number of schools present calculated (using a digitiser) as 7,219 for Area VW (130°–160°E) and 37,342 for Area VE (160°E–170°W). The Universal Kriging technique is applied to the same daily density estimates, and yields very similar results (Area VW 6,310 and Area VE 35,695 schools). The mean school size of 2.19 ± 0.32 used to obtain total population estimates from these figures is derived from the regression of school size against perpendicular distance from the trackline. This value may be an underestimate because of the poor fit to the regression and the much higher values for distance intervals close to the trackline.

Several correction factors are applied to these population estimates. For target motion (estimated at 5 knots) a factor of −4% is used, while the percentage of takeable animals (average of estimates from all three vessels) is 65.4%. The use of a negative exponential to describe the distribution of right-angle distances from the trackline is considered (in the case of two of the vessels) to underestimate density because of a larger number of observations at both very small and very large distances than predicted by this form. Data for the third vessel (T11) show no such effect, apparently because of the non-random selection of sightings for which calculated distances are available. If the negative exponential is truncated at 0.4 n. miles a substantially improved fit to the data is obtained for the other Japanese vessel (K27) and if similar treatment is given to the distribution of estimated rather than calculated distances for the T11 an average conversion factor 'e' of 1.87 is obtained for the two Japanese vessels. Using a simulation procedure ('smearing'), allowance for inaccuracies in reporting of angle, speed, closure time and shortfall can be made, producing in general a better fit of the data to both untruncated and truncated negative exponential distributions. This reduces the mean value of 'e' to 1.47.

Finally the probability of sighting a minke whale school on the trackline is assessed from variable speed experiments carried out on the cruise as 0.72.

Assuming an average school size of 2.19 and adopting all five correction factors above gives final estimates for the exploitable populations of 20,184 ± 4,408 (Area VW) and 104,911 ± 16,600 (Area VE), for a total Area V estimate of 125,193 ± 17,174 whales. The standard deviation estimates are based on results obtained from the Kriging procedure in a manner which renders them negatively biased. Aspects of this abundance estimation technique needing investigation are listed.

INTRODUCTION

This was the third cruise organised under the auspices of the IWC to assess stocks of the southern minke whale. Previous cruises (to Areas III and IV of the Antarctic) have been described and the results analysed by Best and Butterworth (1980), Best and Ohsumi (1980), Horwood (1981) and Horwood, Best and Ohsumi (1981). This report describes the cruise and the data collection, and presents an assessment of the minke whale population in Area V.

PLANNING

At the 32nd IWC meeting in June 1980, the scientific committee agreed that the programme of minke whale sighting and marking in the Antarctic should continue, and appointed a sub-committee to consider preliminary plans. It was decided that the 1980/81 cruise should be to Area V (130°E–170°W), and that catching operations should start some time after the completion of the research. Japan offered to provide two research vessels, as in previous cruises, and the USSR stated that it would make one vessel available. This meant that for the first time three vessels would be available.

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[1] A combination of papers MiS14, 15 and 19, and revised since the June 1981 meeting.

At a special meeting of the scientific committee held in Seattle, USA, in September 1980 to consider the design of sighting surveys, several suggestions were made as to the deployment of the vessels. In particular it was recommended that several ancillary experiments should be carried out to determine (a) if the assumption that all whales on the trackline are seen is correct, (b) whether whales react positively to the approach of the research vessel by seeking or avoiding it, and (c) the rate of decline (or 'gradient') in minke whale density away from the pack ice edge. The collection of data on observer searching behaviour was also recommended, in relation to the apparent rapid fall-off in searching efficiency from the trackline.

These suggestions were taken up at the planning meeting for the cruise held in Tokyo from 1 to 4 October 1980. The provision of three vessels instead of two effectively released one vessel for experimental sighting work. It was decided to deploy two vessels on the pack edge, one (the Soviet vessel) principally for marking and the second principally as a sighting vessel with additional responsibility for experimental work. The third vessel (as in previous cruises) was to operate north-south legs away from the pack ice at 5° of longitude intervals, and would be engaged in both sighting and marking. The two Japanese vessels would exchange roles halfway through the cruise.

As in previous cruises, the survey area would be divided in half longitudinally for logistical reasons. Area VW (130°–160°E) would be surveyed first, the survey vessels starting at 160°E and moving westwards, steaming from 130°E to rendezvous with a factory ship for refuelling somewhere in the eastern half of Area IV. After refuelling the vessels would return to 160°E to commence surveying Area VE (160°E–170°W). The decision on whether to enter the Ross Sea or not would depend on ice conditions prevailing at the time.

The main experiments planned were (a) variable speed (to examine the assumption that all animals on the trackline were seen), (b) parallel ship (to investigate whale reaction to the vessels), (c) dive times (to examine the frequency and duration of visual cues provided by schools of different size and under different environmental conditions), and (d) observer behaviour (to examine the patterns of searching used). Details of experiments (a) and (b) are presented in Butterworth *et al.* (1982), (c) in Joyce (1982) and (d) in Doi *et al.* (1982), but two features are significant. For each variable speed experiment it was decided to run two parallel legs away from the pack ice, one at normal searching speed (12 knots) and the other at a slower speed (6–7 knots), as this configuration would also enable investigation of the gradient of minke whale density from the pack edge outwards. For the parallel ship experiments it was decided for comparability to use the two Japanese vessels, and the experiments were planned for the transit periods to and from the factory ship for refuelling, as this would create least interference with the normal work schedule for the vessels.

Pre-cruise meetings were held in Wellington, New Zealand, from 11–16 December 1980. Due to the late arrival of the USSR vessel, Soviet personnel could only participate in the last two days of the meeting. The deployment of the vessels proposed at the Tokyo meeting was approved, with the proviso that the Soviet vessel remain at least one day's steaming (*c.* 60 miles) behind the Japanese vessel on the ice edge. This was to prevent any interference with the sighting operation that might be caused by the marking vessel. It was also agreed that all three vessels should refuel at the *Nisshin Maru no. 3*.

Prior agreement had been obtained from the USSR and Japanese governments that whaling operations in Areas VW and VE would not commence until after the research had been completed in these respective areas.

PARTICIPANTS AND FINANCIAL SUPPORT

The two Japanese vessels provided were the same as in 1979/80, namely *Kyomaru 27* (730 tons) and *Toshimaru 11* (740 tons). The Soviet vessel was the *Vdumchivyi 34* (718 tons). Ten scientists participated from six nations, namely—

P. B. Best (Sea Fisheries Institute, Cape Town, South Africa)—cruise leader
P. Ensor (Fisheries Research Division, Wellington, New Zealand)
D. Hembree (Western Australian Museum, Perth, Australia)
G. Joyce (National Marine Fisheries Service, Seattle, USA)
F. Kasamatsu (Nippon Kyodo Hogei Kaisha, Tokyo, Japan)
H. Kato (Whales Research Institute, Tokyo, Japan)
N. Miyazaki (National Science Museum, Tokyo, Japan)
A. A. Rovnin (AzcherNIRO, Odessa, USSR)
R. Rowlett (National Marine Fisheries Service, Seattle, USA)
L. Tsunoda (National Marine Fisheries Service, Seattle, USA).

For the first half of the cruise, Best, Joyce and Kasamatsu travelled on *K 27*, Tsunoda, Ensor and Miyazaki on *T 11* and Hembree, Kato, Rovnin and Rowlett on *V 34*. Best and Hembree exchanged positions for the second half of the cruise.

Financial support for the project was provided principally by the Japanese and Soviet governments, who offered the services of their scouting vessels free (estimated in the case of the two Japanese vessels to represent an expenditure of ca US $1,200,000). Further support was provided by the South African Department of Agriculture and Fisheries (R24,000), and the Australian National Parks and Wildlife Service (A $6,000).

NARRATIVE OF THE CRUISE

Area VW. All three ships left Wellington, New Zealand, at 1100 h on 17 December, three days later than originally planned due initially to a dock strike and subsequently to the late arrival of the *V 34*. However, unusually fine weather between Wellington and the Antarctic enabled the ships to put on speed and arrive at their starting positions on 160°E on schedule (22 December for *K 27* and *V 34* and 23 December for *T 11*).

This sector of the cruise was characterised by many periods of poor or very poor visibility, due to snow and fog. The operations of the southern vessels (*K 27* and *V 34*), for instance, were restricted by bad weather on 15 of the 18 available days, and *K 27* spent 85 searching hours (or nearly 30% of the total available searching time) drifting on standby, in addition to frequently steaming with topman down during periods of poor visibility in order to cover the ground. The generally poor weather adversely affected both the sighting and marking programmes, so that fewer

WHALING OPERATIONS

The *Nisshin Maru no. 3* entered Area VW on 19 January, eleven days after research was completed, and she caught 69.6% of her Area V quota in this sector. She entered Area VE from the west on 6 February, one day after research was completed (on the eastern side) in this sector. The *Sovietskaya Ukraina* entered Area V from the west on 9 February, four days after research was completed in Area VE. Both whaling expeditions therefore honoured the agreements concerning restrictions of operations in the research area.

RESULTS—MARKING

All marking was carried out with 'Discovery' whale marks, .410 marks being used for minke whales and 12 bore marks for sperm whales. These were the only target species. All marks were sprayed with a dilute solution of Hibitane (chlorhexidine gluconate) before firing. The marking procedure was as described previously (Best and Butterworth, 1980; Horwood, 1981) and the results of all marks fired are given in Table 1.

A total of 473 minke whales and 12 sperm whales was marked, and a further 4 marked minke whales (or 0.8% of those hit) were scored as invalid because the mark struck the whale in a vulnerable position (B1 or B2—see Kato, 1981) and at a bad angle: two of these were seen with blood-tinged blows following marking. Thirteen minke whales were double-marked, although deliberate double-marking was not undertaken. Furthermore, any whale struck with two Possible Hits was not fired at again.

The number of minke whales marked from the *V 34* was greatest because this vessel was stationed on the pack edge throughout the cruise. The disparity between the numbers marked by the two Japanese vessels arose because the *K 27* undertook some marking on its southern leg in order to boost the number marked in Area VW, whereas the *T 11* did virtually no marking on its southern leg.

The hit rate from the *K 27* (59.6%) was the second highest recorded on the three cruises to date, being only surpassed by the *T 18* in 1978/79 (64.3%). The latter rate was originally viewed with some suspicion (Best and Butterworth, 1980), but it is interesting to note that the principal marksman on the *K 27* was the same individual as on the *T 18*, so presumably his marksmanship was unusually good. The hit rate for the *V 34* (33%) was the lowest recorded on any of the cruises to date, but unfamiliarity with the .410 mark and lack of a specialist marksman undoubtedly contributed to this result.

The proportion of marks that ricocheted was higher on all the boats than on any previous cruise, the highest previous rate being 3.7% by the *T 11* in 1979/80 (Horwood, 1981). This appeared to be due to the poor performance of some of the new marks provided, in one batch of which 18% of the marks hitting the whale ricocheted. On several occasions three splashes were seen near the whale upon firing, one of which was very large, and the mark could sometimes be seen cartwheeling through the air. It appeared as though the marks were disintegrating before striking the whale. With the generous cooperation of the Japanese television company NHK, an high-speed cine film was taken later of some of these marks being fired at minke whale carcases on board the *Nisshin Maru no. 3*, and this clearly showed that the marks were disintegrating and tumbling in flight. The manufacturers (Holland and Holland Co. Ltd) later confirmed this with test-firings on their range in London, from which it transpired that the marks were breaking up inside the barrel of the gun. The lead nose was coming back down the tube of the mark and out of the rear end of the mark, and firing at 3 yards range through a paper screen produced three separate holes from the lead nose, the tube and the wadding. This apparently was a powder problem (S. G. Brown, *in litt.* 5 August 1981).

On both previous cruises, participants had complained about the poor visibility of the .410 mark in flight and the consequent difficulty in correctly recording the fate of marks fired. One of the recommendations was that a suitable streamer should be developed. For the 1980/81 cruise, therefore, a batch of 400 streamer .410 marks was prepared. These marks consisted of a 52 cm long braided dacron leader attached at one end to a rivet placed through the barrel of the mark 2.5 cm behind the head, and at the other end to the streamer, a 9 cm long by 1.3 cm wide strip of orange-coloured plastic reinforced with nylon. The other end of the streamer was attached by a short length of dacron to a washer (part of the cartridge packing) and thence to the lip of the cartridge case. The leader and streamer were packed into the barrel of the mark when the

Table 1

Results of all marks fired on 1980/81 cruise

			Verdict[2]							Whales marked	
Type of mark	Vessel	No. fired[1]	H	PH	HP	NV	R	M	MF	Minke	Sperm
.410	*K 27*	302	180	45	10	2	29	36	0	179	—
			(59.6)	(14.9)	(3.3)	(0.7)	(9.6)	(11.9)	(0)		
	T 11	67	32	5	1	1	5	22	1	31	—
			(47.8)	(7.5)	(1.5)	(1.5)	(7.5)	(32.8)	(1.5)		
	V 34	843	278	108	13	21	46	371	6	263[3]	—
			(33.0)	(12.8)	(1.5)	(2.5)	(5.5)	(44.0)	(0.7)		
12 bore	*K 27*	8	3	0	5	0	0	0	0	—	3
			(37.5)	(0)	(62.5)	(0)	(0)	(0)	(0)		
	T 11	0	0	0	0	0	0	0	0	—	0
	V 34	13[4]	9	1	2	0	0	1	0	—	9
			(69.2)	(7.7)	(15.4)	(0)	(0)	(7.7)	(0)		

[1] In addition, 16 marks used in test-firing experiments and 2 dismantled.

[2] Hit, Possible Hit, Hit Protruding, No Verdict, Ricochet, Miss, Misfire.

[3] Excluding 4 invalid hits. [4] All USSR series.

cartridge was loaded. A total of 105 such marks was fired on the cruise, of which only 8 were recorded as streaming successfully (Table 2). However, as it was only really possible to see the streamers after a hit, their success rate should perhaps be considered only from the proportion that streamed after hitting the whale (25%).

Reasons for the failure of the marks could be attributed either to insufficient length of the leader or to insufficient drag to enable the streamer to be pulled out of the mark before it struck the whale. On the occasions that the streamer did function according to design it was apparently highly visible at up to 50 m from the ship, despite its small size. Development of a suitable streamer remains an item of high priority for more effective marking.

Table 2

Results of streamer marks fired, 1980/81

Vessel	No. fired	Verdict (no. streamed)						
		H	PH	HP	NV	R	M	MF
K 27	8	5 (1) (62.5)	1 (12.5)	0 (0)	0 (0)	0 (0)	2 (25.0)	0 (0)
T 11	10	5 (0) (50.0)	0 (0)	0 (0)	0 (0)	1 (10.0)	3 (30.0)	1 (10.0)
V 34	87	22 (7) (25.3)	15 (17.2)	0 (0)	5 (5.7)	5 (5.7)	36 (41.4)	4 (4.6)
Total	105	32 (8)	16	0	5	6	41	5

The position of the hits is shown in Table 3 in relation to regions of the whale as defined by Kato (1981). If the regions A and B (corresponding to the anterior half of the animal) and E (belly) are considered undesirable target areas, as damage to the whale may be incurred, *T 11* appears to have been the most effective vessel with no such hits, *K 27* the next most effective with 5.6% of hits and *V 34* the least effective with 17.9% of hits in this region. Both Japanese vessels showed a distinct improvement in the placement of their shots compared to 1979/80 (Horwood, 1981), when the proportion of such hits was 5.1% for *T 11* and 12.2% for *K 27* (all strikes included).

The sizes of the marked whales (Table 4) were usually estimated by the boatswain from the barrel (*K 27* and *T 11*) or by the officer on watch from the upper bridge (*V 34*). The size composition of the minke whales marked by *K 27* and *V 34* was similar (mean lengths identical at 27.5 ± 0.1 (s.e.) feet), with the per cent takeable (⩾ 27 feet long) in these samples 90.5% and 80.5% respectively. The whales marked by *T 11,* however, were smaller (mean length 26.5 ± 0.2 feet), with a per cent takeable of only 45.2%. This may reflect either a difference in size classification or a difference in size distribution (80.6% of *T 11*'s whales were marked when it was the northern boat, away from the pack ice).

Table 3

Strike position on minke whale's body of all hits recorded

Position	Vessel					
	K 27		*T 11*		*V 34*	
	n	(%)	n	(%)	n	(%)
D1	24	(13.4)	3	(9.4)	26	(9.5)
D2	14	(7.8)	10	(31.3)	20	(7.3)
D3			5	(15.6)	3	(1.1)
C1	64	(35.8)	5	(15.6)	95[1]	(34.5)
C2	67[2]	(37.4)	9	(28.1)	77	(28.0)
C3					5	(1.8)
B1p	10	(5.6)			33[3]	(12.0)
B1a					14	(5.1)
B2					1[4]	(0.4)
A					1	(0.4)
Total	179		32		275	

[1] One C1/C2. [2] One C2/D2. [3] One B1a/B1p. [4] B1a/B2.

Figs 2a and b show the distribution of marked minke whales by one-degree squares of latitude and longitude in Area VW (130°–160°E) and Area VE (160°E–170°W) respectively. Fig. 2b also includes those whales marked east of 170°W in the Ross Sea, that could realistically be considered as from the same population as those in the rest of the Ross Sea. Also included on both figures are the subsequent catches of minke whales by one-degree square for Japan, kindly provided by the second inspector on the *Nisshin Maru no. 3*, Mr T. Miyashita. USSR catches are given by ten-degree square from data sent to the Bureau of International Whaling Statistics.

Table 4

Lengths of marked minke whales, 1980/81

Length (m)	*V 34*	Length (ft)	*K 27*	*T 11*	*V 34* (converted)	Total
6.8	1	21	1			1
6.9	—	22	—		1	1
7.0	2	23	2		2	4
7.1	—	24	—		8	8
7.2	1	25	3	4	16	23
7.3	1	26	11	13	23	47
7.4	6	27	66	9	55	130
7.5	9	28	77	5	95	177
7.6	4	29	11		43	54
7.7	3	30	8		13	21
7.8	3	31			1	1
7.9	1					
8.0	19	Total	179	31	257	467
8.1	8					
8.2	30					
8.3	17					
8.4	31					
8.5	30					
8.6	34					
8.7	25					
8.8	15					
8.9	3					
9.0	6					
9.1	—					
9.2	7					
9.3	—					
9.4	1					
Total	257					

Only two marks were recovered from this cruise, both on the *Nisshin Maru no. 3* (Table 5). One was marked in Area VW and recovered there 21 days later, while the second was marked on the western edge of Area VE and recovered on the eastern edge of VW 18 days later. For the purposes of analysis, therefore, the division between Areas has been shifted 5° east, so that whales marked in the sector 160°–165°E are considered available to any catching in Area VW. As marking west of 165°E was completed by 18 January, the day before the *Nisshin Maru no. 3* entered Area V from the west, this action seems reasonable.

Table 5

Mark recoveries from 1980/81 cruise in 1980/81 whaling season

Mark no.	Date found	Where found	Tissue	Platform no. of whale	Length (est.) (m)	Sex	Position killed (Position marked)	Date killed (Date marked)	Size of school
39069	24.1.81	Flensing	Meat (remote from bone)	1919	8.6 (8.6)	F	66°55′S 142°52′E (66°25′S 141°28′E)	24.1.81 (3.1.81)	2 (100)[1]
39176	3.2.81	Meat-cutting	,,	2219	8.7 (—)[2]	F	65°48′S 156°18′E (63°43′S 161°10′E)	3.2.81 (16.1.81)	3 (6)

[1] In several subgroups. [2] Mark recorded as a miss.

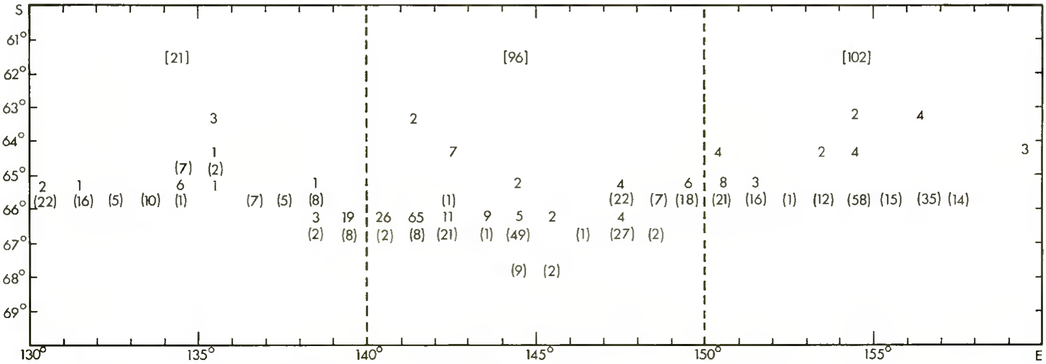

Fig. 2a. Distribution of marked minke whales and Japanese catch (in round brackets) by one-degree square, and of Soviet catch (in square brackets) by ten-degree square, Area VW.

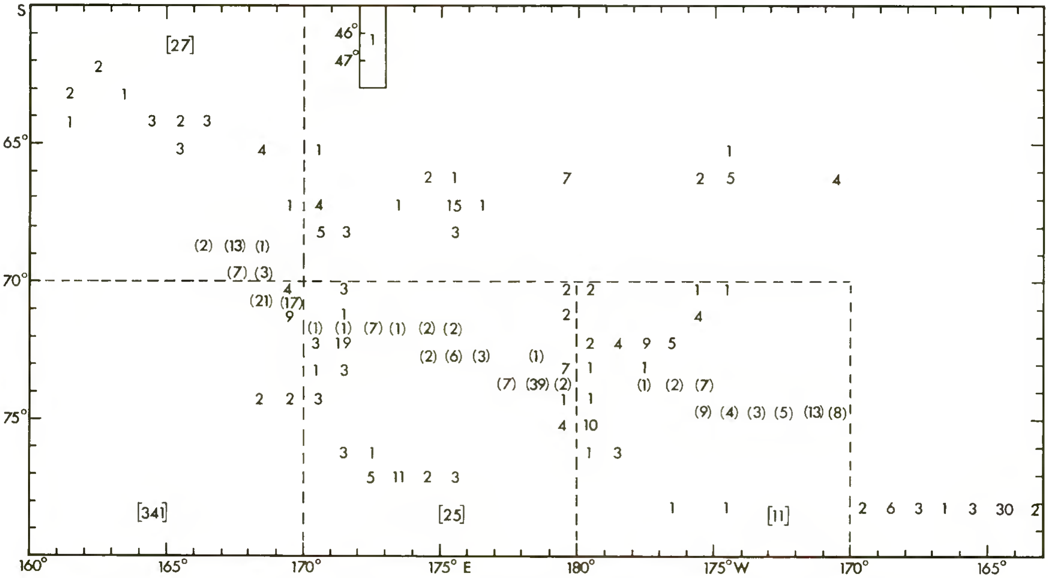

Fig. 2b. Distribution of marked minke whales and Japanese catch (in round brackets) by one-degree square, and of Soviet catch (in square brackets) by ten-degree square, Area VE + Ross Sea.

An estimate of the population size in the 'western sector' (130°–165°E) can then be obtained using the Petersen estimate as modified by Chapman (1951),

$$N = \frac{(n_1 + 1)(n_2 + 1)}{m_2 + 1} - 1$$

where N = estimated population size
n_1 = number of whales marked
n_2 = number of whales recaptured
and m_2 = number of marked whales recaptured.
If $n_1 = 0.95 \times 219$ (assuming a 5% tagging mortality)
$n_2 = 435$ (Japanese catch only)
and $m_2 = 2$
then $N = 30\,375$

with a standard deviation (see Best and Butterworth, 1980) of 15,026.

The validity of the assumptions inherent in such a marking estimate for whales has been discussed by Best and Butterworth (1980), but the overriding concern in this instance is the small number of recoveries, producing a large variance and a possible bias (Robson and Regier, 1964). In addition, the Soviet catch has been excluded, as the exact distribution of catches relative to marks was unknown. Inclusion of these catches would greatly increase the estimate because there were no reported recoveries.

No marks were recovered in Area VE east of 165°E, and although a population size could be calculated that would give a fixed probability of capturing no marked whales (Horwood, 1981), in this instance the dissimilar distribution of marked whales and catches (at least from the Japanese expedition—Fig. 2b) makes the assumption of equal availability of all marked animals rather unlikely.

No population estimate from marking is therefore considered possible for the 'eastern sector'.

RESULTS—SIGHTING

Methods

The standard searching speed used on all vessels was 12 knots, though this could vary depending on the weather and (especially) ice conditions. A constant watch was kept (weather permitting) for a maximum of 16 hours each day (typically 0400–2000 h), depending on the amount of available daylight. There was always one man on watch in the barrel while the vessel was in searching mode: on the Japanese vessels two topmen were used from 0600 to 1800 h when weather permitted, but there was never more than one on the *V 34*. Furthermore, on the Japanese vessels there was always at least one additional crew member (usually the captain) looking for whales from the upper bridge. This was not always the case with the *V 34*. On the Japanese vessel all these observers (and particularly those in the barrel) used 7 × 50 binoculars for scanning the sea ahead of and up to 90° each side of the vessel, provided sea conditions permitted and visibility was not seriously reduced by fog or snow. On the *V 34* use of binoculars was less systematic. At least one researcher was scheduled to be on watch on the upper bridge throughout the day. All data on sightings of cetaceans were relayed to the researchers via inter-com facilities available in the barrel, and recorded on the Sighting Record form (Appendix 1).

The Searching Effort and Weather Record forms were completed by the officer-on-watch (Appendix 1).

The data forms used were essentially the same as those in use in 1979/80 (Horwood, 1981), but with some important changes. On the Weather Record, a column was added for recording 'sightability'. This was meant to define the general conditions for spotting whales, as either 'very poor', 'poor', 'moderate', 'good', or 'excellent', and was to be recorded by the captain and/or officer of the watch. Significant changes were made to the Sighting Record to allow for more accurate recording (to the nearest second rather than minute) of the time taken to close or pass a whale, to record the 'shortfall' when closing with a whale, to document the event that took place (i.e. passed, closed, closed after a delay, or partially closed), and to provide for more accurate measurement of the sighting angle. The latter was achieved by including a requirement that if the initial angle of sighting was less than 15°, the vessel should maintain its original course until the angle exceeded 15°, when the vessel would turn and close with the whale (and a second angle could be measured). Provision therefore had to be made in these instances for the second angle estimate to be recorded, and for a distinction to be made between the time taken to close with the whale and the time from the initial sighting until turning onto the whale. No major changes were made to the Effort Record.

The format of all three Records was, however, changed slightly to facilitate encoding and subsequent punching of the data.

For clarification, the following terms used throughout this paper are defined here.

'Sighting type'—either (1) primary or (2) secondary. Primary sightings are those made when the vessel is in full searching mode (i.e. with topman aloft), is travelling at searching speed (usually 12 knots), and is not engaged in any other activity (such as closing with or chasing a whale). All other sightings are secondary.

'Sighting status'—either (1) species positively identified and school size confirmed, (2) species positively identified but school size unconfirmed, (3) species unknown or doubtful but school size confirmed, or (4) both species and school size unknown.

'Calculated distances'—vessel speed is multiplied by the time taken to close with a sighting to give the calculated radial distance (r) to the sighting, which in turn is used in the formula $y = r \sin \theta$ to provide the calculated perpendicular distance (y) of the sighting from the track-line, where θ is the angle between the original sighting and the vessel's track.

'Estimated distances'—the topman's estimate of the radial distance of the whale school when sighted is used (in combination with the angle between the original sighting and the vessel's track) to give estimated values for r and y.

'P value'—where quoted this refers to the probability of the event observed or one more extreme occurring under the appropriate null hypothesis. Events are termed statistically significant if $P \leq 0.05$.

Summary of all cetacean species seen

Excluding periods during parallel ship experiments (when some of the sightings made by the vessels involved may have been duplicates), a total of 11,008 cetaceans was seen during the cruise, of which 69.2% were minke whales (Table 6). However as the *V 34* followed the southernmost Japanese vessel along the ice edge throughout the cruise, some of the sightings made by this vessel may be duplicates of those seen by the *K 27* or *T 11*. A more accurate (but probably minimum) estimate of the total number of sightings is therefore a combination of those made by the two Japanese vessels (7,523, of which 66.4% were minke whales).

The distribution of all status 1 and 2 sightings (apart from those of ziphiids, for which all sightings have been combined because of the difficulty of positive identification) are given in Figs 3a–d for minke whales, Figs 4a–d for large whales excluding minke whales, and Figs 5a–d for small Cetacea. Those for the Japanese vessels are combined and plotted separately from those for the *V 34*. Only 'best estimates' of school size have been used throughout. Unless otherwise stated further discussion in this paper is limited to sightings of minke whales, and results quoted are for primary sightings of the minke whales for cases where the species was positively identified (i.e. sighting status (1) or (2)). Periods during which experiments took place are excluded.

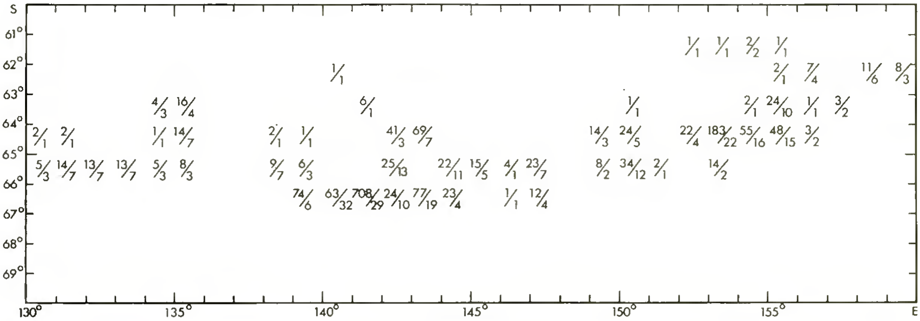

Fig. 3a. Sightings of minke whales from *K 27* and *T 11* by one-degree square, Area VW (no. of animals/no. of sightings).

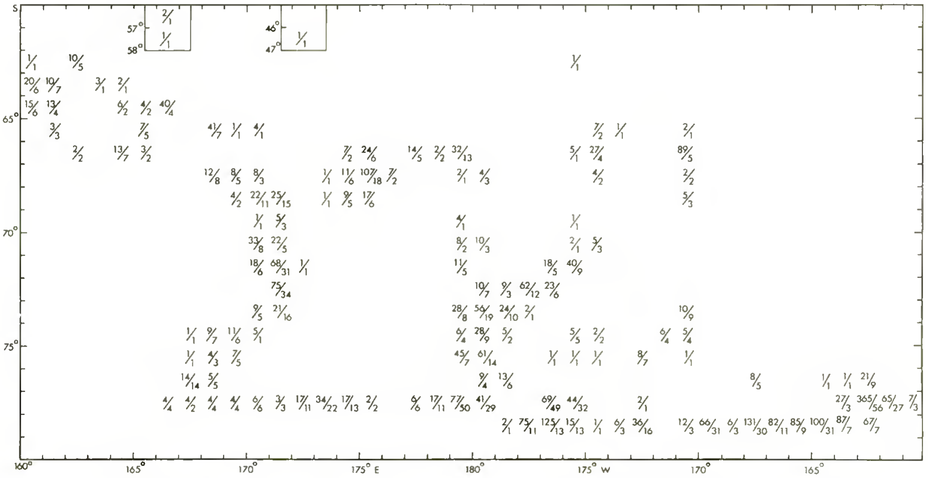

Fig. 3b. Sightings of minke whales from *K 27* and *T 11* by one-degree square, Area VE + Ross Sea (no. of animals/no. of sightings).

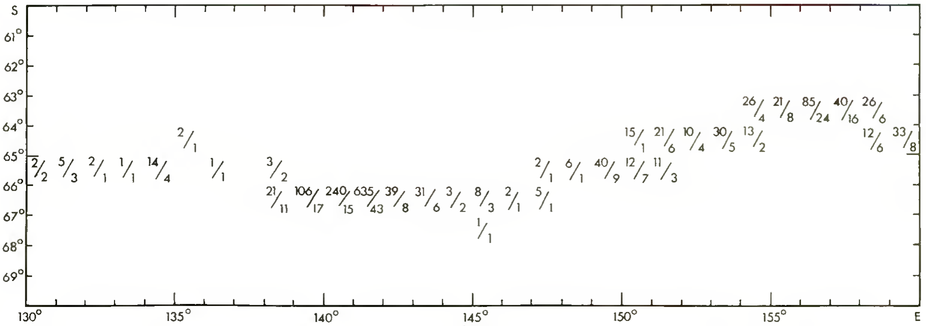

Fig. 3c. Sightings of minke whales from *V 34* by one-degree square, Area VW (no. of animals/no. of sightings).

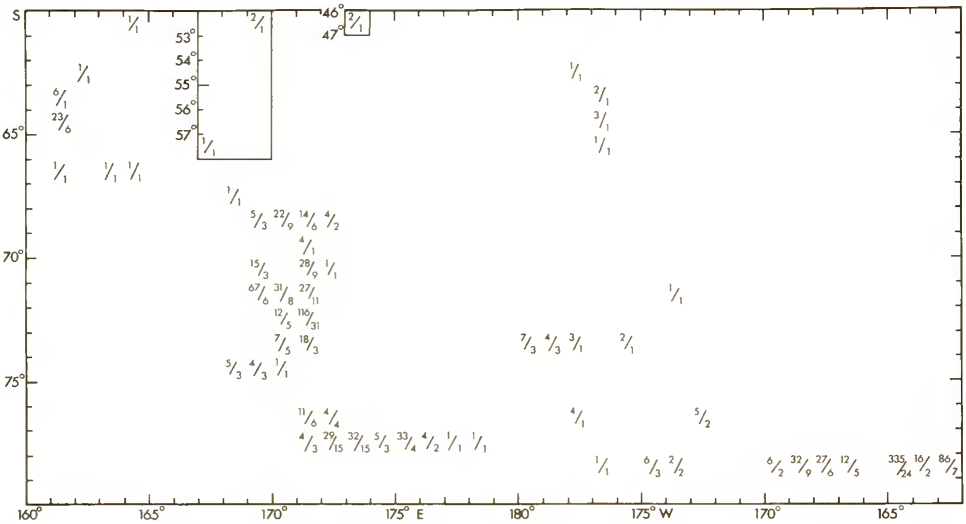

Fig. 3d. Sightings of minke whales from *V 34* by one-degree square, Area VE + Ross Sea (no. of animals/no. of sightings).

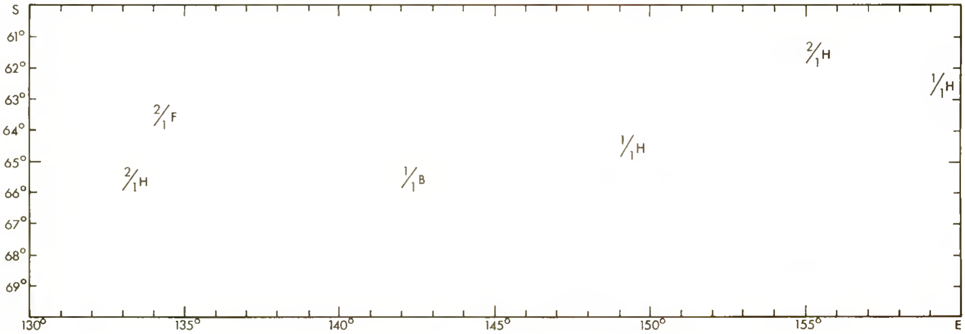

Fig. 4a. Sightings of large Cetacea (excluding minke) from *K 27* and *T 11* by one-degree square, Area VW (B = blue, F = fin, H = humpback).

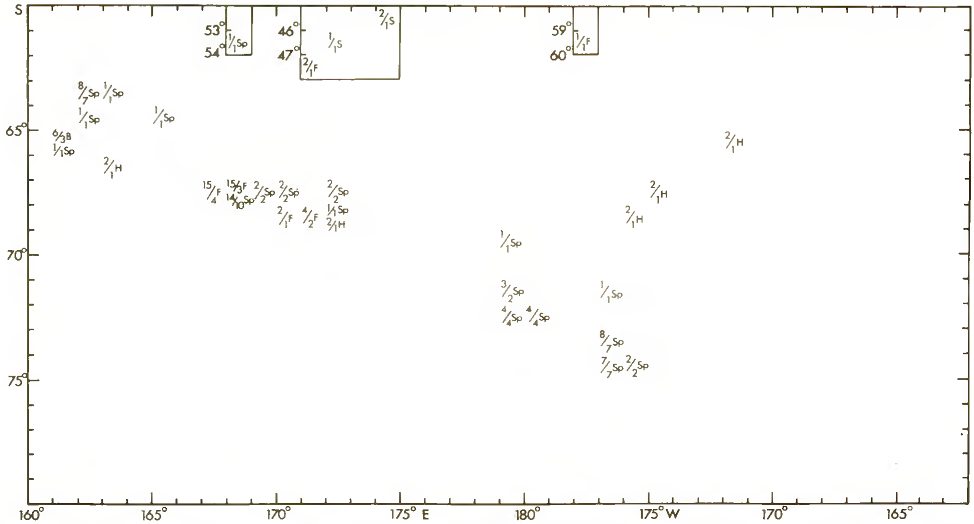

Fig. 4b. Sightings of large Cetacea (excluding minke) from *K 27* and *T 11* by one-degree square, Area VE + Ross Sea (B = blue, F = fin, S = sei, H = humpback, Sp = sperm).

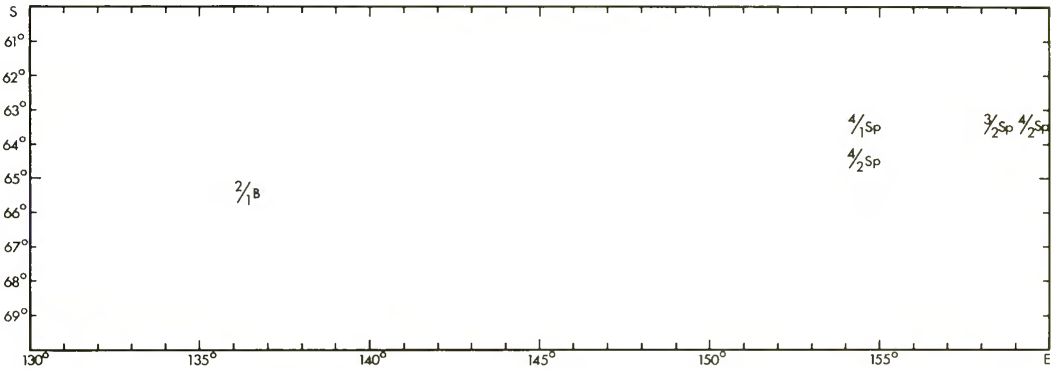

Fig. 4c. Sightings of large Cetacea (excluding minke) from *V 34* by one-degree square. Area VW (B = blue, Sp = sperm).

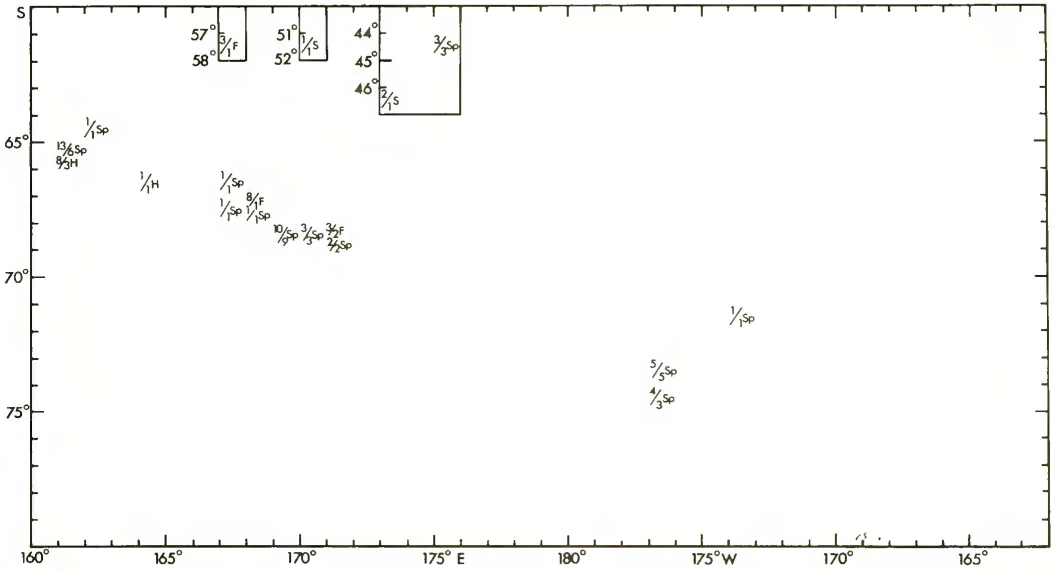

Fig. 4d. Sightings of large Cetacea (excluding minke from *V 34* by one-degree square, Area VE + Ross Sea (F = fin, S = sei, H = humpback, Sp = sperm).

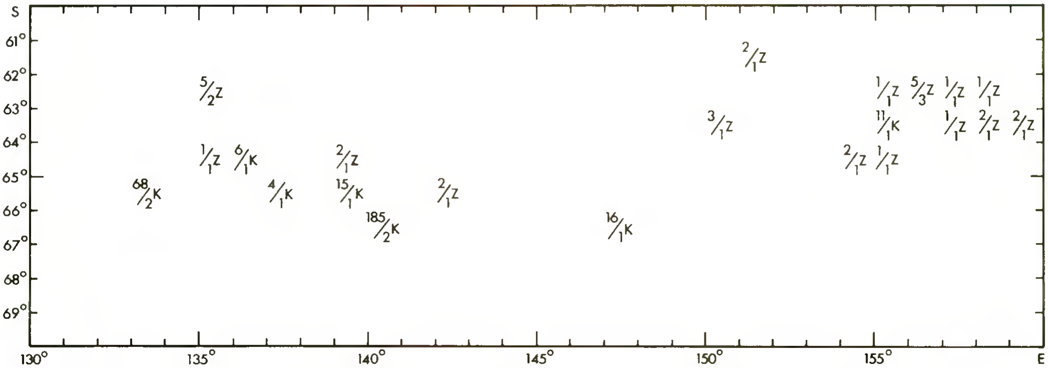

Fig. 5a. Sightings of small Cetacea from *K 27* and *T 11* by one-degree square. Area VW (K = killer, Z = ziphiid).

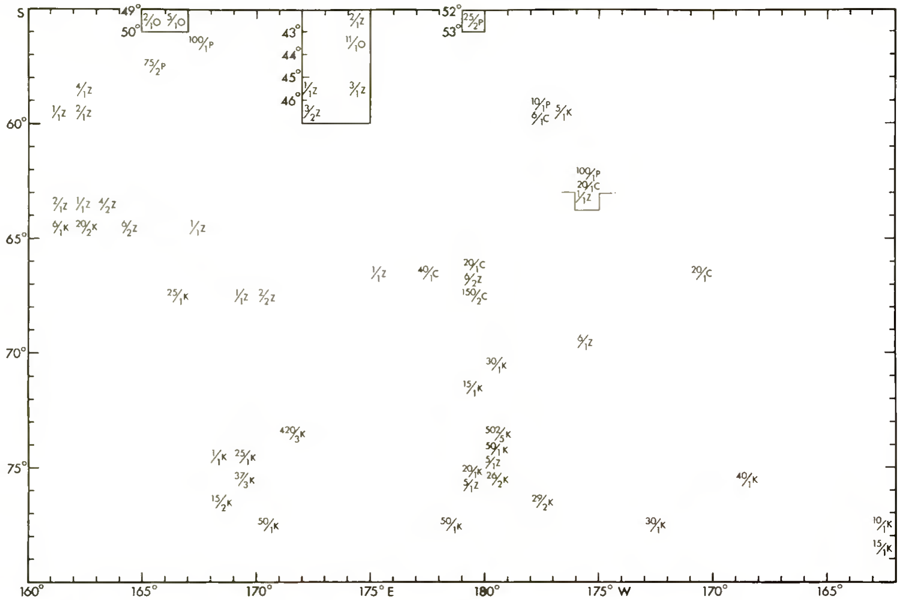

Fig. 5b. Sightings of small Cetacea from *K 27* and *T 11* by one-degree square, Area VE + Ross Sea (K = killer, Z = ziphiid, P = pilot, C = hourglass dolphin, O = dusky dolphin).

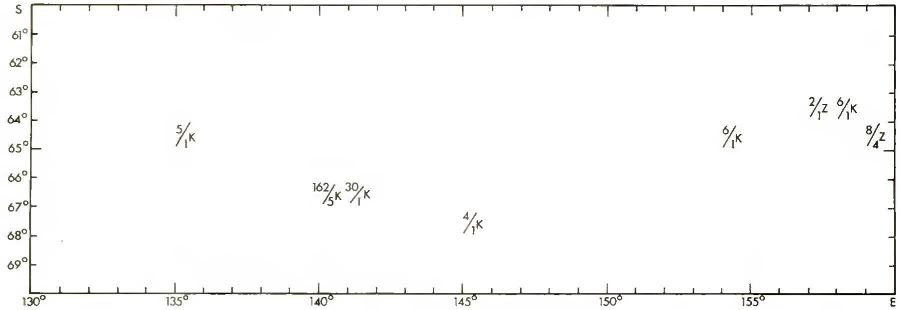

Fig. 5c. Sightings of small Cetacea from *V 34* by one-degree square, Area VW (K = killer, Z = ziphiid).

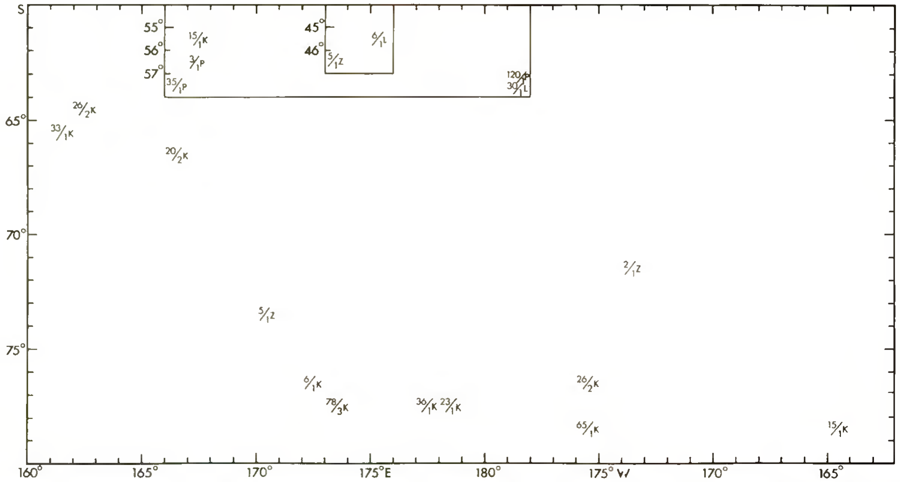

Fig. 5d. Sightings of small Cetacea from V 34 by one-degree square, Area VE + Ross Sea (K = killer, Z = ziphiid, P = pilot, L = right-whale dolphin).

Table 6

Cetaceans seen, 130°E–160°W, 1980/81[1]

	K 27 + *T 11*		*V 34*	
Species	No. of animals	No. of sightings	No. of animals	No. of sightings
Blue	7	4	2	1
Fin	41	13	14	4
Sei	3	2	3	2
Humpback	16	9	9	4
Minke	4,994	1,405	2,625	491
Sperm	64	57	60	43
Killer	1,726	43	556	26
Ziphiid	88	43	22	8
Pilot	310	7	158	3
Hourglass dolphins	256	7	—	—
Right-whale dolphins	—	—	36	2
Dusky dolphins	18	3	—	—

[1] Status 1 and 2 sightings only, except for Ziphiids where all sightings combined.

Cues for sightings

These were classified as a blow, a jump or splash, the animal itself, a slick or rings (produced by an animal swimming just below the surface), or the animal and a blow seen simultaneously. The frequency of these cues is shown in Table 7.

The results for the *K 27* are typical of those of the 1978/79 cruise (Best and Butterworth, 1980—Table 8). Blows constitute a greater proportion of the cues near the pack ice. This at least partly reflects the better weather and sea conditions normally encountered close to the pack ice.

The *T 11*'s results are quite different. Near the pack ice the proportion of blows is much lower than might have been expected. A possible reason for this is that weather conditions in the Ross Sea were particularly good; in the absence of wind minke behaviour appears to change with the whales not blowing as strongly, so that cues become mainly the animal itself. The near complete predominance of blows for the *T 11*'s northern sector is also surprisingly dissimilar to the *K 27*'s and previous results.

Results for the *V 34* are similar to those of the Japanese vessel in the corresponding sector, except for a tendency to record a greater proportion of simultaneous blow and animal cues.

Table 8 shows mean radial distances of sightings for the various cues. Estimated distances have been used as there were a large number of primary sightings in the Ross Sea with which the *T 11* did not close because of time constraints, so that calculated distances are not available for those sightings.

Ignoring the very few jumps seen, blows were the sighting cues seen at the greatest distance by all vessels, followed by the animal itself, and then slicks or rings. The results for the *K 27* and *V 34* are similar both in Area VW where these two vessels each operated along the ice edge, and in Area VE where the *K 27* operated to the north. The distances are slightly larger in Area VE—perhaps a reflection of better weather conditions.

Table 7

Frequency of different cues for sightings of minke whales

	K 27				*T 11*				*V 34*			
	North VE—Leg 2		South VW—Leg 1		North VW—Leg 1		South VE—Leg 2		South VW—Leg 1		South VE—Leg 2	
Cue	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
1 (Blow)	106	(67.5)	75	(81.5)	47	(90.4)	212	(59.4)	75	(73.5)	105	(57.4)
2 (Jump or splash)	3	(1.9)	2	(2.2)	1	(1.9)	0	(0)	1	(1.0)	0	(0)
3 (Animal)	40	(25.5)	12	(13.0)	1	(1.9)	130	(36.4)	11	(10.8)	63	(34.4)
4 (Slick or rings)	4	(2.6)	1	(1.1)	1	(1.9)	11	(3.1)	1	(1.0)	3	(1.6)
5 (Blow and animal)	4	(2.6)	2	(2.2)	2	(3.9)	4	(1.1)	14	(13.7)	12	(6.6)
Total	157		92		52		357		102		183	

Table 8

Estimated mean radial distances (n. miles) of minke whale sightings from different cues, and the associated standard errors of these means

	K 27				*T 11*				*V 34*			
	North VE—Leg 2		South VW—Leg 1		North VW—Leg 1		South VE—Leg 2		South VW—Leg 1		South VE—Leg 2	
Cue	$\bar{r}$	(s.e.m.)	$\bar{r}$	(s.e.m.)	$\bar{r}$	(s.e.m.)	$\bar{r}$	(s.e.m.)	$\bar{r}$	(s.e.m.)	$\bar{r}$	(s.e.m.)
1 (Blow)	1.59	(0.09)	1.45	(0.11)	1.36	(0.14)	1.91	(0.07)	1.43	(0.09)	1.58	(0.10)
2 (Jump or splash)	2.83	(0.73)	0.10	(0.02)	1.20	(—)	—	(—)	0.10	(—)	—	(—)
3 (Animal)	0.73	(0.11)	0.32	(0.06)	0.30	(—)	1.37	(0.07)	0.53	(0.18)	0.89	(0.08)
4 (Slick or rings)	0.59	(0.17)	0.03	(—)	0.20	(—)	0.26	(0.07)	0.25	(—)	0.01	(0.003)
5 (Blow and animal)	0.84	(0.42)	0.60	(0.40)	0.25	(0.15)	0.45	(0.35)	0.78	(0.19)	0.55	(0.11)

The distances for the *T 11* in Area VE are distinctly larger than those for the *V 34*, which could be a reflection of greater sighting efficiency of the *T 11* with two topmen usually in the barrel compared to one only for the *V 34*.

Possible whale reaction to survey vessels

The possibility of whale reaction to the vessel has been investigated by the method introduced by Horwood (1981). Information recorded on the ship's heading and that of the whale when sighted, together with whether the sighting was made to port or starboard, allows determination of whether the whale's course was convergent (would cross the vessel's trackline), divergent, parallel or anti-parallel to the ship.

Results are shown in Table 9. Unlike Horwood's Table 10, observations recorded as on the trackline have been listed separately. This is because a bias is introduced by taking all such sightings as divergent; though these sightings are recorded as being at 0° to the trackline, they would in actuality be marginally to one side or the other, so could be either converging or diverging.

The overall proportion of whales diverging (excluding sightings on the trackline) is given in Table 10. As in the 1979/80 cruise this proportion is consistently greater than 0.5, with the effect being more marked for the *T 11* and *V 34*. Though not statistically significant for any vessel separately, the proportion for all three vessels combined is significantly different from 0.5 ($P = 0.006$).

Strangely the greater contribution towards this difference appears to come from distant sightings for the Japanese vessels, but from nearby sightings for the *V 34* (see Table 10). The engine-types on the *V 34* and the Japanese vessels are different, which could conceivably produce such an effect.

Superficially this result seems to indicate ship avoidance by the whales. However a simulation study using a hazard-rate model (e.g. Butterworth, 1982; Hiby, 1982) merits attention before definite conclusions are drawn, as it is conceivable that in such a model the distributions of converging and diverging sightings could differ even in the absence of vessel-reaction by the whales. Such a model may also cast light on an apparent tendency for the whale's heading to make an angle less rather than greater than 90°

Table 9

Distribution of relative angles of whales and vessel headings for minke whale sightings (C—convergent; D—divergent; O—on track line)

	K 27						*T 11*						*V 34*					
	South VW—Leg 1			North VE—Leg 2			North VW—Leg 1			South VE—Leg 2			South VW—Leg 1			South VE—Leg 2		
Angle (degrees)	C	D	O	C	D	O	C	D	O	C	D	O	C	D	O	C	D	O
1–9	3	2	0	4	0	1	0	0	0	6	1	0	0	1	0	2	2	0
10–19	2	1	0	4	1	0	0	1	0	8	2	0	0	1	0	1	1	0
20–29	2	1	0	4	3	0	5	4	0	4	15	0	0	0	1	1	2	0
30–39	3	3	0	9	4	5	1	1	0	21	12	3	6	1	1	1	3	1
40–49	1	1	1	1	2	2	0	2	0	8	2	1	3	2	0	1	1	2
50–59	3	3	0	1	5	1	2	5	0	14	22	2	2	3	0	0	4	1
60–69	1	3	0	0	2	3	0	0	0	8	10	0	1	0	1	2	3	1
70–79	1	0	0	0	5	0	0	2	0	7	10	0	1	1	0	10	10	1
80–89	2	2	5	5	13	5	1	1	1	29	32	0	6	3	1	3	6	4
90–99	1	3	2	3	4	0	0	1	0	5	8	0	0	1	0	3	3	0
100–109	3	2	3	3	3	1	0	1	0	6	13	3	1	4	0	2	4	1
110–119	1	3	0	1	3	0	2	3	0	2	4	0	1	3	0	3	4	2
120–129	4	5	3	1	4	0	1	2	0	3	9	0	0	3	0	2	4	2
130–139	0	0	1	1	0	0	1	0	0	5	8	0	0	3	0	5	2	1
140–149	0	1	1	2	2	1	1	1	1	3	4	1	1	1	0	0	1	0
150–159	3	2	1	3	2	1	2	1	0	3	2	0	0	2	1	0	2	1
160–169	1	1	0	0	0	0	0	0	0	1	2	0	2	2	0	2	0	2
170–179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	31	33	17	42	53	20	17	25	2	136	162	10	24	32	5	38	53	19
Parallel		4			8			1			14			3			5	
Anti-parallel		6			13			2			5			0			6	
Milling		0			9			3			21			9			27	

Table 10

The proportion ρ of minke whales sighted over the whole cruise that were diverging from the trackline. Sightings on the trackline, moving parallel or anti-parallel, or milling are excluded. The P value corresponds to the null hypothesis $H_o : \rho = ½$. Estimated distances have been used for the radial distance r and perpendicular distance from the trackline y (C—convergent; D—divergent).

Observations considered	*K 27*				*T 11*				*V 34*			
	C	D	ρ	P	C	D	ρ	P	C	D	ρ	P
Whole cruise	73	86	0.541	0.301	153	187	0.550	0.065	62	85	0.578	0.059
$r < 1.0$ n.m.	29	31	0.517	0.793	42	48	0.533	0.531	28	42	0.600	0.094
$r \geqslant 1.0$ n.m.	44	55	0.556	0.265	111	139	0.556	0.077	34	43	0.558	0.309
$y < 0.5$ n.m.	41	41	0.500	1.000	82	85	0.509	0.813	29	51	0.638	0.014
$y \geqslant 0.5$ n.m.	31	45	0.592	0.109	71	102	0.590	0.018	33	34	0.507	0.908

to the vessel's track (see Table 9, particularly the *T 11*), though Horwood's data did not show this effect.

This together with the difficulty of accurate assessment of the whale's heading (see Horwood, 1981) render a conclusion of vessel avoidance premature. Certainly, however, there is no direct indication of ship-seeking, which could lead to abundance overestimation.

The accuracy of calculated y values

A feature of previous cruises has been the large peak at $y = 0$ in the distribution of perpendicular distances (y) of sightings from the trackline (Butterworth, 1982a). The calculation of the effective search half-width for whale density estimates is very sensitive to this peak, which arose primarily from sightings for which the angle to the trackline was recorded as 0°.

To attempt to calculate y values more accurately, particularly for sightings close to the trackline, four new features were introduced into the procedure for closing with a whale sighted (see Fig. 6).

(i) If the initial angle of sighting $\theta_1 < 15°$, the vessel delayed turning until the sighting angle increased beyond 15° (in some cases this never occurred so that no subsequent turn was made—see 'on trackline' sightings listed in Tables 11 and 12).

(ii) Closure times from A to B (t_{AB}) and B to C (t_{BC}) were measured correct to the nearest second rather than nearest minute as previously.

(iii) A 'shortfall' was recorded, being the estimated distance by which the vessel was short of the sighting position, either when half-speed was called before reaching the sighting, or if the vessel failed to close completely with the sighting.

(iv) Further to the topman's initial estimate of the angle of the sighting to the trackline (θ_1), further estimates were made (θ_1*—immediate turn; θ_2—delayed turn) by taking compass reading differences between the vessel's initial and final courses.

Calculated distances were accordingly evaluated as follows:

$$BW = v_{BC} \,.\, t_{BC} + \text{shortfall} \qquad (1)$$

$$y = \begin{cases} BW \sin \theta_1{}^* \text{ (immediate turn)} & (2a) \\ BW \sin \theta_2 \text{ (delayed turn)} & (2b) \end{cases}$$

This value of y, calculated taking into account all the newly introduced features, was used in the estimation of effective search half-widths, and is referred to as 'New y' (Table 11).

To assess the effect of the introduction of the four new features, an 'Old y' has also to be calculated, being an estimate of the value that would have resulted from the

Table 11

Comparison of perpendicular distance distributions for various methods of calculating y (see text). The bracketed figures are the associated percentage corrections to density estimates compared to those evaluated using 'New y'. For $\bar{y}$ the correction factor relates to a density estimate using the untruncated negative exponential for g (y). The factor e is for converting the untruncated negative exponential density estimate to one truncated at 0.4 nautical miles. n ($y < 0.1$) refers to the number of sightings within 0.1 nautical miles of the trackline, with the density correction relating to a Kelker strip of that half-width (n ($y < 0.2$) similarly). The total number of sightings for each cruise leg for each vessel is distinguished: I—immediate turn; D—delayed turn; O—on trackline

	ȳ (nautical miles)			e		
Calculation method	*K 27*—Leg 1	*K 27*—Leg 2	*V 34*—Leg 2	*K 27*—Leg 1	*K 27*—Leg 2	*V 34*—Leg 2
New y	0.655	0.783	0.730	1.749	2.370	2.010
Old y	0.513 (+28)	0.635 (+23)	0.696 (+5)	3.563 (+104)	2.389 (+1)	2.608 (+30)
New y, but close-time to nearest minute	0.656 (−0)	0.781 (+0)	0.723 (+1)	1.501 (−14)	2.291 (−3)	2.115 (+5)
New y, but shortfall zero	0.535 (+22)	0.643 (+22)	0.658 (+11)	1.640 (−6)	2.138 (−10)	2.569 (+28)
New y, but no second estimate of angle for immediate turn	0.678 (−3)	0.792 (−1)	0.789 (−7)	1.801 (+3)	2.572 (+9)	1.371 (−32)
New y, but no delayed turn	0.594 (+10)	0.769 (+2)	0.711 (+3)	5.353 (+206)	2.795 (+18)	3.014 (+50)
	n (y < 0.1)			n (y < 0.2)		
	K 27—Leg 1	*K 27*—Leg 1	*V 34*—Leg 2	*K 27*—Leg 1	*K 27*—Leg 2	*V 34*—Leg 2
New y	9	27	16	13	29	19
Old y	20 (+122)	32 (+19)	17 (+6)	22 (+69)	38 (+31)	24 (+26)
New y, but close-time to nearest minute	8 (−11)	27 (0)	16 (0)	13 (0)	30 (+3)	19 (0)
New y, but shortfall zero	12 (+33)	29 (+7)	17 (+6)	17 (+31)	34 (+17)	24 (+26)
New y, but no second estimate of angle for immediate turn	9 (0)	27 (0)	12 (−25)	14 (+8)	30 (+3)	16 (−16)
New y, but no delayed turn	18 (+100)	30 (+11)	20 (+25)	19 (+46)	31 (+7)	22 (+16)
Number of sightings:						
I	28	89	51			
D	12	11	7			
O	4	12	12			
Total	44	112	70			

procedure of the previous two cruises. To obtain this the shortfall was taken to be zero, and t_{AB} and t_{BC} replaced by t'_{AB} and t'_{BC} where the latter two values are rounded to the nearest minute. Only θ_1, the topman's initial estimate of sighting angle, was used.

Hence:

$$BW' = v_{BC} \cdot t'_{BC} \tag{3a}$$

$$AB' = v_{AB} \cdot t'_{AB} \tag{3b}$$

$$y = \begin{cases} BW' \sin\theta_1 \text{ (immediate turn)} & \text{(4a)} \\ \left[AB' \sin\theta_1 + \sqrt{BW'^2 - (AB' \sin\theta_1)^2}\right] \sin\theta_1 \text{ (delayed turn).} & \text{(4b)} \end{cases}$$

Results are given in Table 11. Only the *K 27* (both legs) and the *V 34* (2nd leg) are shown as not all of the new features were incorporated in data recorded for the other vessel-legs. The 'New y' distribution is wider (larger $\bar{y}$) and less peaked near $y = 0$ compared to 'Old y'. The larger $\bar{y}$ for 'New y' produces a lower density estimate using the untruncated negative exponential for g(y). The smaller peak is reflected by lower Kelker strip estimates of density for small strip widths, and also by a smaller conversion factor 'e' for truncating the negative exponential at 0.4 n. miles.

To identify which of the new features is most responsible for these changes, four intermediate values of y were calculated, being essentially each 'New y' but without one of the four new features.

(a) 'New y', but close-time correct to nearest minute.
Replace t_{BC} by t'_{BC} in equation (1).

(b) 'New y', but shortfall zero.
Put shortfall = 0 in equation (1).

Table 12

As for Table 11, but neglecting second estimates (from compass heading changes) of angles for immediate turns

	$\bar{y}$ (nautical miles)					
Calculation method	*K 27*—Leg 1	*K 27*—Leg 2	*T 11*—Leg 1	*T 11*—Leg 2	*V 34*—Leg 1	*V 34*—Leg 2
New y	0.582	0.727	0.850	0.738	0.563	0.795
Old y	0.444 (+31)	0.578 (+31)	0.758 (+12)	0.633 (+17)	0.441 (+28)	0.705 (+13)
New y, but close-time to nearest minute	0.584 (−0)	0.726 (+0)	0.863 (−2)	0.735 (+0)	0.570 (−1)	0.790 (+1)
New y, but shortfall zero	0.478 (+22)	0.589 (+23)	0.748 (+14)	0.635 (+16)	0.439 (+28)	0.721 (+10)
New y, but no delayed turn	0.533 (+9)	0.716 (+2)	0.846 (+0)	0.738 (0)	0.559 (+1)	0.777 (+2)
	e					
	K 27—Leg 1	*K 27*—Leg 2	*T 11*—Leg 1	*T 11*—Leg 2	*V 34*—Leg 1	*V 34*—Leg 2
New y	2.216	2.634	1.064	0.972	1.399	1.229
Old y	3.453 (+56)	2.581 (−2)	1.333 (+25)	1.140 (+17)	1.400 (+0)	2.161 (+76)
New y, but close-time to nearest minute	2.280 (+3)	2.544 (−3)	0.898 (−16)	1.026 (+6)	1.284 (−8)	1.422 (+16)
New y, but shortfall zero	2.130 (−4)	2.382 (−10)	1.238 (+16)	1.075 (+11)	1.598 (+14)	1.746 (+42)
New y, but no delayed turn	4.585 (+107)	2.978 (+13)	1.228 (+15)	0.972 (0)	1.563 (+12)	1.841 (+50)
	n (y < 0.1)					
	K 27—Leg 1	*K 27*—Leg 2	*T 11*—Leg 1	*T 11*—Leg 2	*V 34*—Leg 1	*V 34*—Leg 2
New y	14	34	5	15	8	12
Old y	25 (+79)	42 (+24)	7 (+40)	19 (+27)	12 (+50)	17 (+42)
New y, but close-time to nearest minute	13 (−7)	35 (+3)	5 (0)	16 (+7)	8 (0)	11 (−8)
New y, but shortfall zero	17 (+21)	40 (+18)	7 (+40)	23 (+53)	11 (+38)	14 (+17)
New y, but no delayed turn	23 (+64)	37 (+9)	6 (+20)	15 (0)	9 (+13)	16 (+33)
	n (y < 0.2)					
	K 27—Leg 1	*K 27*—Leg 2	*T 11*—Leg 1	*T 11*—Leg 2	*V 34*—Leg 1	*V 34*—Leg 2
New y	22	43	10	31	15	19
Old y	31 (+41)	53 (+23)	12 (+20)	35 (+13)	20 (+33)	24 (+50)
New y, but close-time to nearest minute	22 (0)	43 (0)	9 (−10)	30 (−3)	16 (+7)	16 (0)
New y, but shortfall zero	27 (+23)	49 (+14)	11 (+10)	37 (+19)	18 (+20)	24 (+44)
New y, but no delayed turn	28 (+27)	45 (+5)	10 (0)	31 (0)	16 (+7)	19 (+19)
Number of sightings:						
I	38	112	42	127	41	57
D	12	11	1	0	1	7
O	4	12	0	0	2	12
Total	54	135	43	127	44	76

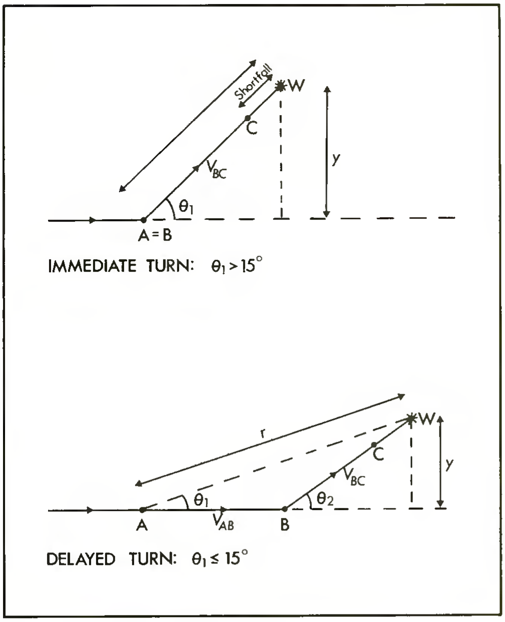

Fig. 6. Immediate and delayed closure with a whale (W) to determine calculated distance. The whale is first sighted from position A where the topman estimates the radial distance to the whale (r) and its angle from the trackline (θ_1). If $\theta_1 > 15°$ the vessel turns onto the sighting immediately; otherwise the vessel maintains its original course until the angle to the whale exceeds 15° when the turn is made (B). The vessel closes with the whale at a speed v_{BC}. At point C half-speed is called, with the distance remaining to the whale then being estimated (CW = Shortfall). For delayed turns θ_2 is the difference in compass headings between the vessel's initial and final courses. For immediate turns, this difference is also taken (θ_1^*), being a revised value of the topman's initial estimate θ_1.

(c) 'New y', but no second estimate of angle for immediate turn.

Replace θ_1^* by θ_1 in equation (2a).

(d) 'New y', but no delayed turn.

For delayed turns put

$$AB = v_{AB} \cdot t_{AB}$$

$$y = [AB + BW \cos \theta_2] \tan \theta_1.$$

Table 11 (which incorporates only sightings for which both 'New y' and 'Old y' can be calculated) shows that measuring times to the nearest second rather than minute, and replacing θ_1 by θ_1^* for immediate turns, have little effect. The increase in $\bar{y}$ results almost entirely from the introduction of shortfall. However the delayed turn procedure has the greatest effect in reducing the peak in the distribution of sightings near $y = 0$.

Absence of recording of θ_1^* was the main reason precluding an extension of Table 11 to the *T 11* and *V 34* (1st leg). However to allow comparisons from those data as well, Table 12 has been constructed in a manner nearly identical to Table 11, but replacing θ_1^* by θ_1 in equation (2a).

The results of Table 12 are similar to those of Table 11. The new procedures increase $\bar{y}$ by an average of 21%, arising primarily from the introduction of shortfall. Recording times to the nearest second has minimal effect. Hardly any delayed turns were executed on the additional vessel-legs now considered, and for these legs both recording of the shortfall and taking the times more accurately contribute to diminishing the distribution peak near $y = 0$.

Overall it seems that the new procedures, designed to increase accuracy, do lead to significant y-distribution differences, and therefore should be retained. Against this one must weigh the fact that the delayed turn can lead to operational ambiguities and data-validation complexities.

Delayed-turn calculated distance evaluations are likely to be more affected than immediate turns by movement of the whale between first sighting and closure (for immediate turns the movement would result in a curved path AW with relatively small effect on r and hence y; for delayed turns θ_2 and hence y could be significantly altered). However assuming there is no consistent vessel attraction or avoidance, this effect should cancel (at least to first order) when averaging over a large number of sightings, in the same way use of calculated distances for immediate turns is assumed to approximate on average a stationary whale situation.

Angular distribution of sightings

Table 13 shows the distribution of primary sightings of all whale species from various vantage points on each of the vessels. For the Japanese vessels the proportion of sightings made from the barrel (~ 75%) is considerably greater than on the *V 34* (~ 50%). This is probably a reflection of the larger number of topmen usually on watch on the Japanese vessels.

Table 13

Number of primary sightings of all whale species seen from various vantage points

	K27				*T11*				*V34*			
	North VE—Leg 2		South VW—Leg 1		North VW—Leg 1		South VE—Leg 2		South VW—Leg 1		South VE—Leg 2	
Vantage point	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
Barrel (topman)	149	(59.6)	164	(75.6)	86	(78.9)	540	(81.6)	66	(44.9)	129	(51.2)
Upper bridge	95	(38.0)	52	(24.0)	19	(17.4)	114	(17.2)	79	(53.7)	121	(48.0)
Other	6	(2.4)	1	(0.5)	4	(3.7)	8	(1.2)	2	(1.4)	2	(0.8)
Total	250		217		109		662		147		252	

The angular distribution of minke whale sightings is shown in Fig. 7 and Table 14. The angle of sighting used in these distributions is θ_1, the topman's initial estimate. Certain features emerge from these distributions.

(a) Though the average sighting angle does not differ significantly between the three vessels (*K 27*: 32.5°; *T 11*: 32.6°; *V 34*: 36.1°), the *V 34* distribution is flatter over the range (0°–50°) than those for the *K 27* and *T 11* which are very similar to each other. A χ^2 test of homogeneity indicates the *V 34* distribution is significantly different from that for the two Japanese vessels combined ($\chi^2_{10} = 27.2$; $P = 0.002$).

This difference is caused partly by the greater proportion of upper bridge sightings on the *V 34*. It is believed that topmen tend to concentrate their sighting effort near the trackline whereas upper-bridge observers scan the angular range more uniformly.

Table 14

Distribution of angle from the trackline of sightings of primary confirmed minke schools. The sub-set 'y-calculable' refers to those sightings for which y may be calculated on a speed × time-to-close basis

(a) *K 27*

	Leg 1: VW—South						Leg 2: VE—North					
	All primary confirmed		y-calculable		Topman sightings		All primary confirmed		y-calculable		Topman sightings	
Angular range	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
0°–2°	20	(21.7)	16	(20.0)	16	(23.5)	24	(15.0)	22	(14.4)	21	(23.0)
3°–7°	1	(1.1)	1	(1.3)	1	(1.5)	5	(3.1)	4	(2.6)	3	(3.4)
8°–12°	7	(7.6)	7	(8.8)	6	(8.8)	13	(8.1)	13	(8.5)	8	(9.0)
13°–17°	13	(14.1)	11	(13.8)	13	(19.1)	9	(5.6)	9	(5.9)	7	(7.9)
18°–22°	6	(6.5)	6	(7.5)	4	(5.9)	21	(13.1)	20	(13.1)	10	(11.2)
23°–27°	5	(5.4)	5	(6.3)	2	(2.9)	5	(3.1)	5	(3.3)	3	(3.4)
28°–32°	5	(5.4)	4	(5.0)	2	(2.9)	18	(11.3)	16	(10.5)	7	(7.9)
33°–37°	3	(3.3)	3	(3.8)	3	(4.4)	4	(2.5)	4	(2.6)	1	(1.1)
38°–42°	3	(3.3)	3	(3.8)	1	(1.5)	9	(5.6)	9	(5.9)	6	(6.7)
43°–47°	10	(10.9)	9	(11.3)	7	(10.3)	10	(6.3)	10	(6.5)	4	(4.5)
48°–52°	4	(4.4)	4	(5.0)	4	(5.9)	8	(5.0)	8	(5.2)	4	(4.5)
53°–57°	1	(1.1)	1	(1.3)	1	(1.5)	0	(0)	0	(0)	0	(0)
58°–62°	2	(2.2)	2	(2.5)	0	(0)	3	(1.9)	3	(2.0)	1	(1.1)
63°–67°	0	(0)	0	(0)	0	(0)	1	(0.6)	1	(0.7)	1	(1.1)
68°–72°	2	(2.2)	2	(2.5)	2	(2.9)	11	(6.9)	11	(7.2)	5	(5.6)
73°–77°	0	(0)	0	(0)	0	(0)	1	(0.6)	1	(0.7)	0	(0)
78°–82°	2	(2.2)	1	(1.3)	0	(0)	2	(1.3)	2	(1.3)	1	(1.1)
83°–87°	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
88°–92°	8	(8.7)	5	(6.3)	6	(8.8)	14	(8.8)	13	(8.5)	6	(6.7)
⩾93°	0	(0)	0	(0)	0	(0)	2	(1.3)	2	(1.3)	1	(1.1)
Total	92		80		68		160		153		89	

(b) *T 11*

	Leg 1: VW—North						Leg 2: VE—South					
	All primary confirmed		y-calculable		Topman sightings		All primary confirmed		y-calculable		Topman sightings	
Angular range	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
0°–2°	3	(5.7)	2	(4.4)	3	(6.3)	25	(7.0)	5	(3.5)	23	(8.1)
3°–7°	9	(17.0)	7	(15.6)	8	(16.7)	40	(11.2)	20	(14.0)	36	(12.7)
8°–12°	3	(5.7)	3	(6.7)	3	(6.3)	33	(9.2)	14	(9.8)	28	(9.9)
13°–17°	4	(7.6)	4	(8.9)	4	(8.3)	31	(8.7)	13	(9.1)	30	(10.6)
18°–22°	4	(7.6)	3	(6.7)	4	(8.3)	31	(8.7)	16	(11.2)	21	(7.4)
23°–27°	0	(0)	0	(0)	0	(0)	23	(6.4)	10	(7.0)	19	(6.7)
28°–32°	4	(7.6)	4	(8.9)	4	(8.3)	34	(9.5)	15	(10.5)	22	(7.8)
33°–37°	3	(5.7)	2	(4.4)	2	(4.2)	19	(5.3)	6	(4.2)	17	(6.0)
38°–42°	3	(5.7)	3	(6.7)	2	(4.2)	22	(6.2)	10	(7.0)	17	(6.0)
43°–47°	2	(3.8)	2	(4.4)	1	(2.1)	10	(2.8)	4	(2.8)	8	(2.8)
48°–52°	3	(5.7)	3	(6.7)	3	(6.3)	20	(5.6)	7	(4.9)	15	(5.3)
53°–57°	0	(0)	0	(0)	0	(0)	8	(2.2)	2	(1.4)	4	(1.4)
58°–62°	2	(3.8)	2	(4.4)	2	(4.2)	11	(3.1)	3	(2.1)	8	(2.8)
63°–67°	2	(3.8)	2	(4.4)	2	(4.2)	2	(0.6)	2	(1.4)	2	(0.7)
68°–72°	4	(7.6)	3	(6.7)	3	(6.3)	15	(4.2)	5	(3.5)	12	(4.2)
73°–77°	0	(0)	0	(0)	0	(0)	3	(0.8)	2	(1.4)	2	(0.7)
78°–82°	4	(7.6)	2	(4.4)	4	(8.3)	11	(3.1)	5	(3.5)	7	(2.5)
83°–87°	0	(0)	0	(0)	0	(0)	2	(0.6)	0	(0)	2	(0.7)
88°–92°	3	(5.7)	3	(6.7)	3	(6.3)	14	(3.9)	4	(2.8)	9	(3.2)
⩾93°	0	(0)	0	(0)	0	(0)	4	(1.1)	0	(0)	2	(0.7)
Total	53		45		48		358		143		284	

Table 14—*continued*

(c) *V 34*

	Leg 1: VW—South						Leg 2: VE—South					
	All primary confirmed		y-calculable		Topman sightings		All primary confirmed		y-calculable		Topman sightings	
Angular range	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
0°–2°	5	(4.9)	3	(5.8)	2	(5.1)	29	(15.8)	15	(14.3)	16	(18.8)
3°–7°	3	(2.9)	3	(5.8)	1	(2.6)	5	(2.7)	0	(0)	1	(1.2)
8°–12°	6	(5.8)	5	(9.6)	4	(10.3)	14	(7.6)	6	(5.7)	10	(11.8)
13°–17°	8	(7.8)	4	(7.7)	4	(10.3)	7	(3.8)	4	(3.8)	3	(3.5)
18°–22°	13	(12.6)	4	(7.7)	6	(15.4)	23	(12.5)	14	(13.3)	9	(10.6)
23°–27°	3	(2.9)	1	(1.9)	0	(0)	8	(4.4)	3	(2.9)	3	(3.5)
28°–32°	12	(11.7)	6	(11.5)	3	(7.7)	18	(9.8)	13	(12.4)	10	(11.8)
33°–37°	4	(3.9)	1	(1.9)	3	(7.7)	4	(2.2)	3	(2.9)	2	(2.4)
38°–42°	17	(16.5)	9	(17.3)	6	(15.4)	13	(7.1)	5	(4.8)	4	(4.7)
43°–47°	6	(5.8)	2	(3.9)	2	(5.1)	10	(5.4)	8	(7.6)	3	(3.5)
48°–52°	6	(5.8)	5	(9.6)	1	(2.6)	15	(8.2)	11	(10.5)	10	(11.8)
53°–57°	0	(0)	0	(0)	0	(0)	2	(1.1)	2	(1.9)	0	(0)
58°–62°	3	(2.9)	2	(3.9)	1	(2.6)	11	(6.0)	7	(6.7)	9	(10.6)
63°–67°	0	(0)	0	(0)	0	(0)	1	(0.5)	1	(1.0)	0	(0)
68°–72°	2	(1.9)	2	(3.9)	1	(2.6)	0	(0)	0	(0)	0	(0)
73°–77°	0	(0)	0	(0)	0	(0)	1	(0.5)	0	(0)	0	(0)
78°–82°	1	(1.0)	0	(0)	0	(0)	5	(2.7)	2	(1.9)	2	(2.4)
83°–87°	1	(1.0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
88°–92°	9	(8.7)	4	(7.7)	3	(7.7)	13	(7.1)	7	(6.7)	3	(3.5)
≥93°	4	(3.9)	1	(1.9)	2	(5.1)	5	(2.7)	4	(3.8)	0	(0)
Total	103		52		39		184		105		85	

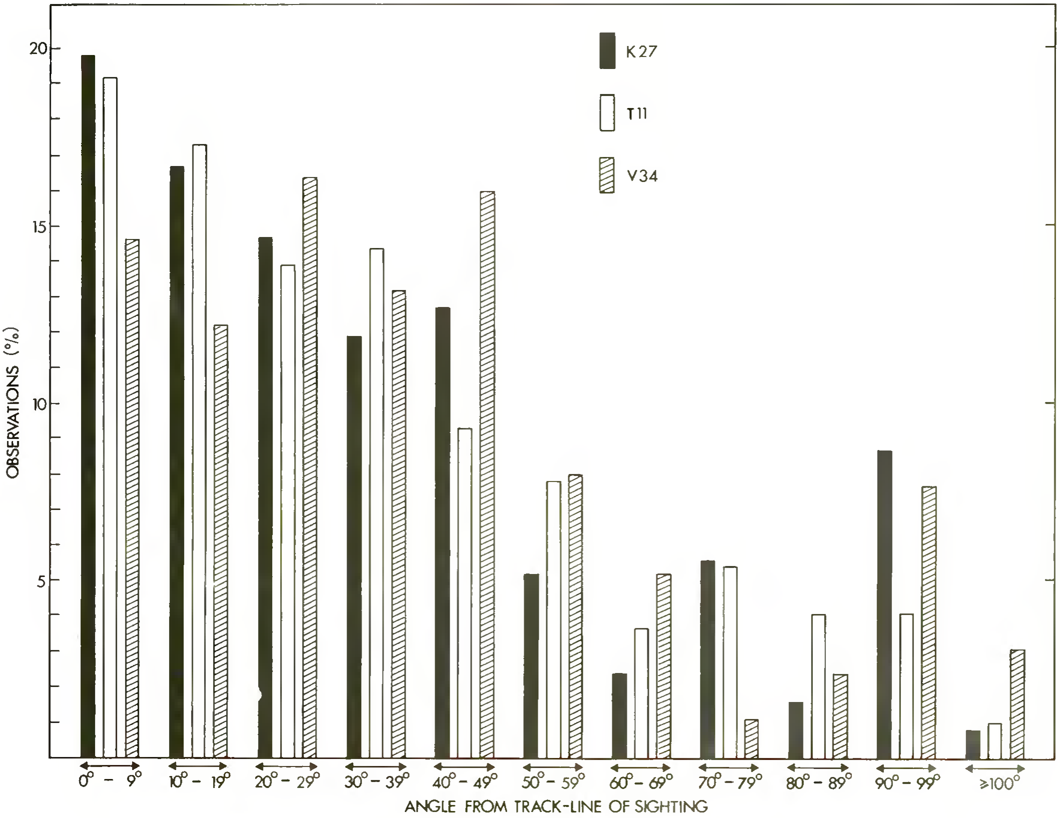

Fig. 7. Distribution of angle from the trackline of primary minke sightings over the whole cruise by each vessel.

However even if the observations of the topmen alone are considered, a significant difference between the Japanese vessels and the *V 34* remains ($\chi^2_8 = 16.1$; $P = 0.041$). It is understood that Russian topmen use binoculars to a lesser extent, and possibly therefore spread their sighting effort over a wider angular range than the Japanese. In addition, when two topmen were present on the Japanese vessels, space limitation in the barrel made it difficult for the topmen to search at large angles from the trackline with binoculars without interfering with each other. This feature, together with the lower proportion of sightings by the *V 34* topmen, suggests that *V 34* sighting results may underestimate density through missing a larger fraction of sightings 'on the trackline' than the Japanese (i.e. $g(0)$ (*V 34*) $<$ $g(0)$ (*K 27*/*T 11*)).

(b) The *K 27* and *V 34* which almost always recorded angles as exact multiples of 5°, show a distinct preference for even over odd multiples. This effect was noticed on previous cruises (Butterworth, 1982a).

On the other hand the *T 11* attempted to record particularly the smaller angles more accurately, and a preference for multiples of 10° only becomes apparent for angles $\gtrsim 60°$. It is possible that the importance of accurate recording of small angles on this vessel was over stressed and led to a bias, as Table 14b indicates an unrealistic depression in the *T 11*'s angular distribution over the range 0°–2°.

All three vessels show a tendency to record sightings exactly at 90°.

(c) The *K 27* closed with most primary sightings, and y-calculated values are available for 92% of the primary sightings. However for the *V 34* (55%) and *T 11* (46%) the proportions for which y-calculated values may be obtained are much smaller because of a combination of not closing with all primary sightings, and failure to record data on the closure.

Examination of Table 14b suggests a bias may arise in the y-calculated distribution for the *T 11* through a non-random choice of sightings to close with. The lack of sightings in the 0°–2° range among *T 11* events for which y-calculated values are available is even more marked than for the *T 11*'s sightings as a whole, and indicates a bias against closing with sightings near the trackline. Comparing the distributions of *T 11* sightings with and without y-calculated values available, over a small angular range 0°–12°, yields a significant difference ($\chi^2_2 = 6.6$; $P = 0.037$).

These results suggest that *V 34* density estimates may be negatively biased compared to those of the *K 27* and *T 11*, and that the y distribution for the *T 11* may be atypical of distributions observed in previous cruises.

SIGHTING ASSESSMENT OF POPULATION SIZE

The method used here has as far as possible been kept the same as in 'contouring' estimates for previous cruises (Area IV: Best and Butterworth, 1980; Area III: Butterworth, 1982) to maintain comparability of estimates.

Number of schools (contouring)

Daily mean school density estimates (D) were calculated from the number of primary sightings (n) by the *K 27* and *T 11* on each day. The untruncated negative exponential $g(y) = e^{-\lambda y}$ was used to obtain the effective search half-width, with the parameter λ being separately estimated for each vessel for each leg of the cruise. The variable L was

Table 15a

Daily estimates of minke whale density from sightings by *Kyomaru 27*. The primary sightings and primary effort listed exclude periods during which experiments were conducted. The effective search half-width has been calculated assuming an untruncated negative exponential for g(y), and using primary sightings for which y values may be calculated on a speed × time-to-close basis. The density standard deviation estimates quoted are calculated from an approximate expression for the coefficient of variation

$$\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$$

where n_1 is the number of primary sightings on the day concerned, and n_2 the number of sightings from which the effective search half-width for that cruise leg was calculated

Date	Noon position	Primary sightings	Density sch/mile²	Standard dev.	Prim. eff. naut. miles
Leg 1. Eff. search half-width 0.694 n. miles (No. obs. 98)					
17.12.1980	41.34S 174.45E	0	0.000	No est.	79.0
18.12.1980	46.48S 172.12E	1	0.004	0.004	193.2
19.12.1980	52.15S 169.06E	0	0.000	No est.	133.9
20.12.1980	57.36S 165.47E	0	0.000	No est.	196.5
21.12.1980	62.22S 162.41E	6	0.040	0.017	107.3
22.12.1980	63.32S 158.25E	0	0.000	No est.	10.5
23.12.1980	63.18S 158.00E	0	0.000	No est.	30.2
24.12.1980	62.45S 156.07E	3	0.048	0.028	45.3
25.12.1980	63.20S 156.12E	0	No est.	No est.	0.0
26.12.1980	64.06S 155.17E	14	0.329	0.094	30.6
27.12.1980	64.32S 153.21E	20	0.189	0.046	76.1
28.12.1980	64.44S 152.28E	4	0.114	0.058	25.2
29.12.1980	65.23S 150.46E	10	0.174	0.058	41.5
30.12.1980	65.18S 149.15E	3	0.048	0.028	45.0
31.12.1980	66.02S 147.31E	3	0.048	0.028	44.8
1. 1.1981	66.46S 144.09E	2	0.176	0.125	8.2
2. 1.1981	66.20S 141.43E	4	0.132	0.067	21.8
3. 1.1981	66.03S 140.22E	5	0.205	0.094	17.6
4. 1.1981	65.30S 138.36E	1	0.011	0.011	63.6
5. 1.1981	65.10S 136.03E	3	0.022	0.013	97.0
6. 1.1981	64.55S 135.27E	6	0.121	0.051	35.8
7. 1.1981	65.02S 132.48E	5	0.082	0.038	43.9
8. 1.1981	64.49S 130.54E	2	0.023	0.016	63.1
9. 1.1981	65.09S 122.41E	1	0.067	0.068	10.7
Leg 2. Eff. search half-width 0.694 n. miles (No. obs. 154)					
12. 1.1981	65.19S 130.25E	0	No est.	No est.	0.0
13. 1.1981	65.45S 139.42E	0	No est.	No est.	0.0
14. 1.1981	64.44S 151.00E	0	No est.	No est.	0.0
15. 1.1981	63.50S 158.39E	5	0.077	0.035	46.5
16. 1.1981	63.46S 162.02E	4	0.029	0.014	100.8
17. 1.1981	65.01S 164.53E	10	0.067	0.022	107.4
18. 1.1981	65.02S 168.00E	7	0.065	0.025	78.0
19. 1.1981	65.51S 170.13E	1	0.062	0.062	11.6
20. 1.1981	68.00S 171.14E	4	0.028	0.014	102.2
21. 1.1981	67.59S 175.31E	9	0.163	0.056	39.8
22. 1.1981	67.12S 175.06E	12	0.102	0.031	84.6
23. 1.1981	66.30S 179.22E	2	0.048	0.034	30.0
24. 1.1981	66.43S 179.14E	11	0.100	0.031	79.0
25. 1.1981	68.23S 179.39W	2	0.042	0.030	34.4
26. 1.1981	70.33S 179.42W	9	0.065	0.022	100.0
27. 1.1981	72.48S 179.52E	10	0.086	0.028	84.1
28. 1.1981	74.48S 179.48E	11	0.077	0.024	103.0
29. 1.1981	75.56S 179.44W	16	0.219	0.057	52.7
30. 1.1981	74.21S 179.06W	8	0.040	0.014	145.5
31. 1.1981	72.28S 177.29W	21	0.278	0.065	54.3
1. 2.1981	70.46S 174.56W	7	0.111	0.043	45.2
2. 2.1981	68.56S 175.05W	0	No est.	No est.	0.0
3. 2.1981	66.51S 174.56W	6	0.128	0.053	33.6
4. 2.1981	65.58S 170.45W	3	0.031	0.018	69.6
5. 2.1981	67.34S 170.30W	3	0.035	0.021	61.0
6. 2.1981	68.18S 170.56W	0	No est.	No est.	0.0
7. 2.1981	63.30S 174.46W	0	0.000	No est.	27.2
8. 2.1981	58.44S 177.31W	0	0.000	No est.	100.8

Table 15b

Daily estimates of minke whale density from sightings by the *Toshimaru 11*, calculated as for Table 15a

Date	Noon position	Primary sight-ing	Density sch/mile^2	Standard dev.	Prim. eff. naut. miles
Leg 1. Eff. search half-width 0.851 n. miles (No. obs. 45)					
17.12.1980	41.37S 174.51E	0	0.000	No est.	55.2
18.12.1980	45.56S 173.24E	0	0.000	No est.	113.9
19.12.1980	48.45S 167.24E	0	0.000	No est.	98.8
20.12.1980	52.17S 167.26E	0	0.000	No est.	127.8
21.12.1980	56.31S 167.16E	2	0.008	0.006	148.9
22.12.1980	59.14S 162.06E	0	0.000	No est.	136.2
23.12.1980	61.24S 159.59E	0	0.000	No est.	1.5
24.12.1980	63.09S 159.33E	5	0.023	0.011	129.9
25.12.1980	62.44S 158.44E	0	No est.	No est.	0.0
26.12.1980	62.14S 156.45E	0	0.000	No est.	75.4
27.12.1980	61.23S 153.22E	4	0.020	0.010	117.1
28.12.1980	61.54S 149.53E	0	0.000	No est.	28.2
29.12.1980	63.09S 150.02E	0	0.000	No est.	36.6
30.12.1980	64.23S 150.39E	2	0.062	0.045	19.0
31.12.1980	64.54S 147.49E	1	0.009	0.009	64.5
1. 1.1981	65.19S 145.04E	6	0.223	0.097	15.8
2. 1.1981	66.00S 143.56E	15	0.181	0.054	48.8
3. 1.1981	64.56S 142.18E	10	0.051	0.018	114.5
4. 1.1981	63.25S 141.21E	1	0.006	0.006	102.2
5. 1.1981	64.01S 140.04E	1	0.026	0.027	22.4
6. 1.1981	63.39S 135.06E	5	0.024	0.011	123.6
7. 1.1981	62.02S 133.22E	0	0.000	No est.	178.4
8. 1.1981	63.19S 130.01E	0	0.000	No est.	75.0
9. 1.1981	65.09S 122.42E	1	0.060	0.061	9.8
Leg 2. Eff. search half-width 0.712 n. miles (No. obs. 144)					
12. 1.1981	65.19S 130.25E	0	No est.	No est.	0.0
13. 1.1981	65.45S 139.44E	0	No est.	No est.	0.0
14. 1.1981	64.43S 150.58E	0	No est.	No est.	0.0
15. 1.1981	63.50S 158.39E	4	0.059	0.030	47.6
16. 1.1981	64.14S 162.10E	6	0.028	0.012	152.0
17. 1.1981	66.23S 162.51E	5	0.023	0.011	150.9
18. 1.1981	67.05S 167.11E	6	0.038	0.016	110.8
19. 1.1981	68.26S 169.40E	5	0.037	0.017	95.0
20. 1.1981	68.45S 171.25E	14	0.081	0.023	122.1
21. 1.1981	70.29S 169.56E	4	0.022	0.011	128.7
22. 1.1981	71.17S 172.09E	20	0.226	0.054	62.2
23. 1.1981	72.49S 171.36E	31	0.207	0.041	105.4
24. 1.1981	74.41S 168.13E	19	0.092	0.022	145.7
25. 1.1981	76.24S 168.02E	20	0.098	0.023	142.8
26. 1.1981	77.10S 170.32E	15	0.105	0.028	100.8
27. 1.1981	77.40S 177.32E	15	0.194	0.053	54.2
28. 1.1981	77.36S 175.59W	34	0.353	0.067	67.6
29. 1.1981	78.17S 168.07W	65	0.865	0.129	52.8
30. 1.1981	77.49S 162.20W	31	0.345	0.068	63.2
31. 1.1981	76.13S 164.02W	19	0.167	0.041	80.0
1. 2.1981	75.42S 168.16W	6	0.024	0.010	177.8
2. 2.1981	75.03S 175.50W	8	0.067	0.024	84.2
3. 2.1981	74.42S 178.21W	0	No est.	No est.	0.0
4. 2.1981	74.17S 175.30W	15	0.080	0.022	131.4
5. 2.1981	73.32S 170.39W	16	0.102	0.027	110.6
6. 2.1981	68.33S 171.03W	0	No est.	No est.	0.0
7. 2.1981	63.31S 174.52W	0	0.000	No est.	29.0
8. 2.1981	58.44S 177.45W	0	0.000	No est.	99.6

obtained from the distance steamed in searching mode each day (i.e. excluding periods when steaming with topman down, confirming, chasing, or experimenting).

The results are shown in Table 15. Only identified primary sightings for which y-calculated values were available were used to obtain values of λ:

$$\lambda = \frac{N-1}{\sum_{i=1}^{N} y_i}$$

Table 16

Estimates of number of minke whale schools from area between density contours

Density interval Schools/100 mi.^{2}	Area VW: Area (mi.^{2})	Area VW: No. of schools	Area VE: Area (mi.^{2})	Area VE: No. of schools
0–1	29,073	145.4	13,096	65.5
1–2	18,959	284.4	30,424	456.4
2–3	12,697	317.4	32,033	800.8
3–4	9,705	339.7	29,203	1,022.1
4–5	8,400	378.0	23,260	1,046.7
5–6	4,269	234.8	21,981	1,209.0
6–7	2,721	176.9	20,539	1,335.0
7–8	3,078	230.9	17,969	1,347.7
8–9	5,109	434.3	20,962	1,781.8
9–10	4,858	461.5	16,972	1,612.3
10–11	2,701	283.6	13,956	1,465.4
11–12	2,098	241.3	10,359	1,191.3
12–13	2,469	308.6	9,797	1,224.6
13–14	1,385	187.0	8,227	1,110.6
14–15	1,394	202.1	6,582	954.4
15–16	1,638	253.9	5,493	851.4
16–17	1,810	298.7	5,091	840.0
17–18	2,235	391.1	4,713	824.8
18–19	2,194	405.9	5,532	1,023.4
19–20	2,688	524.2	4,806	937.2
20–21	1,892	387.9	4,825	989.1
21–22	951	204.5	4,706	1,011.8
22–23	941	211.7	12,929	2,909.0
23–24	236	55.5	2,582	606.8
24–25	191	46.8	2,547	624.0
25–26	200	51.0	2,028	517.1
26–27	150	39.8	1,934	512.5
27–28	144	39.6	1,861	511.8
28–29	88	25.1	1,694	482.8
29–30	55	16.2	1,592	469.6
30–31	29	8.8	1,354	413.0
31–32	24	7.6	1,319	415.5
32–33	77	25.0	1,328	431.6
33–34			1,514	507.2
34–35			1,177	406.1
35–40			1,975	740.6
40–45			1,492	634.1
45–50			1,449	688.3
50–55			1,254	658.4
55–60			1,368	786.6
60–65			1,157	723.1
65–70			760	513.0
70–75			555	402.4
75–80			268	207.7
80–85			61	50.3
85–90			33	28.9
Total	124,459	7,218.8	354,757	37,341.6

where N is the number of such sightings for the appropriate vessel and cruise leg. For the *K 27* (leg 1) these include a few sightings closed with during the initial stages of the variable speed experiment (Butterworth, Best and Basson, 1982), whereas values of n and L used to estimate density

$$D = \frac{n\lambda}{2L}$$

exclude all experimental sightings. Exclusion of these experimental sightings in the calculation of λ for *K 27* (leg 1) would increase the overall abundance estimate by only a few per cent.

These density estimates were plotted at the vessel's noon position for the appropriate day, and a density contour map drawn by hand (Fig. 8). The area between successive contours was measured using a digitiser; multiplying this area by the average of the density values for the two contours concerned, and summing over all contours, yields an estimate for the total number of minke whale schools.

Results are shown in Table 16. Area VW was taken to be the area between longitudes 130°E and 160°E, and south of latitude 60°S. Area VE was taken as the area between longitudes 160°E and 170°W plus that section of the Ross Sea east of 170° W. The northern boundary was taken as latitude 63°S west of 170°E, and 65°S east of 170°E, as there were no daily density data points north of that area to permit contouring.

The totals for the two sub-areas are as follows:

Number of schools:	Area VW (Long. 130°–160°E)	7,219
	Area VE (Long. 160°E–170°W)	37,342
	Total for Area V	44,561

It was decided to omit the *V 34* sighting data from the density contouring because of possible non-comparability. As discussed in the section on angular distribution of sightings, a large fraction of the *V 34* sightings were made from the upper bridge where the number of observers varied considerably from time to time. This 'non-standardisation' of sighting effort would not affect density estimates if all whales on the trackline were nevertheless being sighted (g(0) = 1). However the variable speed experiment (Butterworth, Best and Basson, 1982) indicated that g(0) < 1 for the Japanese vessels, and the angular distribution of sightings for the *V 34* suggests that its g(0) would be smaller still.

Fig. 8a. Contours of equal density of minke whales in Area VW (expressed as number of schools per 100 nautical miles^2) drawn on a Lamberts Equal Area Projection (normal aspect). Dots represent the noon positions of the *K 27* and *T 11* on days on which searching was conducted (cruise leg 1); the contouring is based on the daily average density estimates plotted at these points. The ice edge is based on data from the *K 27*. Noon positions of the *V 34* are marked with crosses.

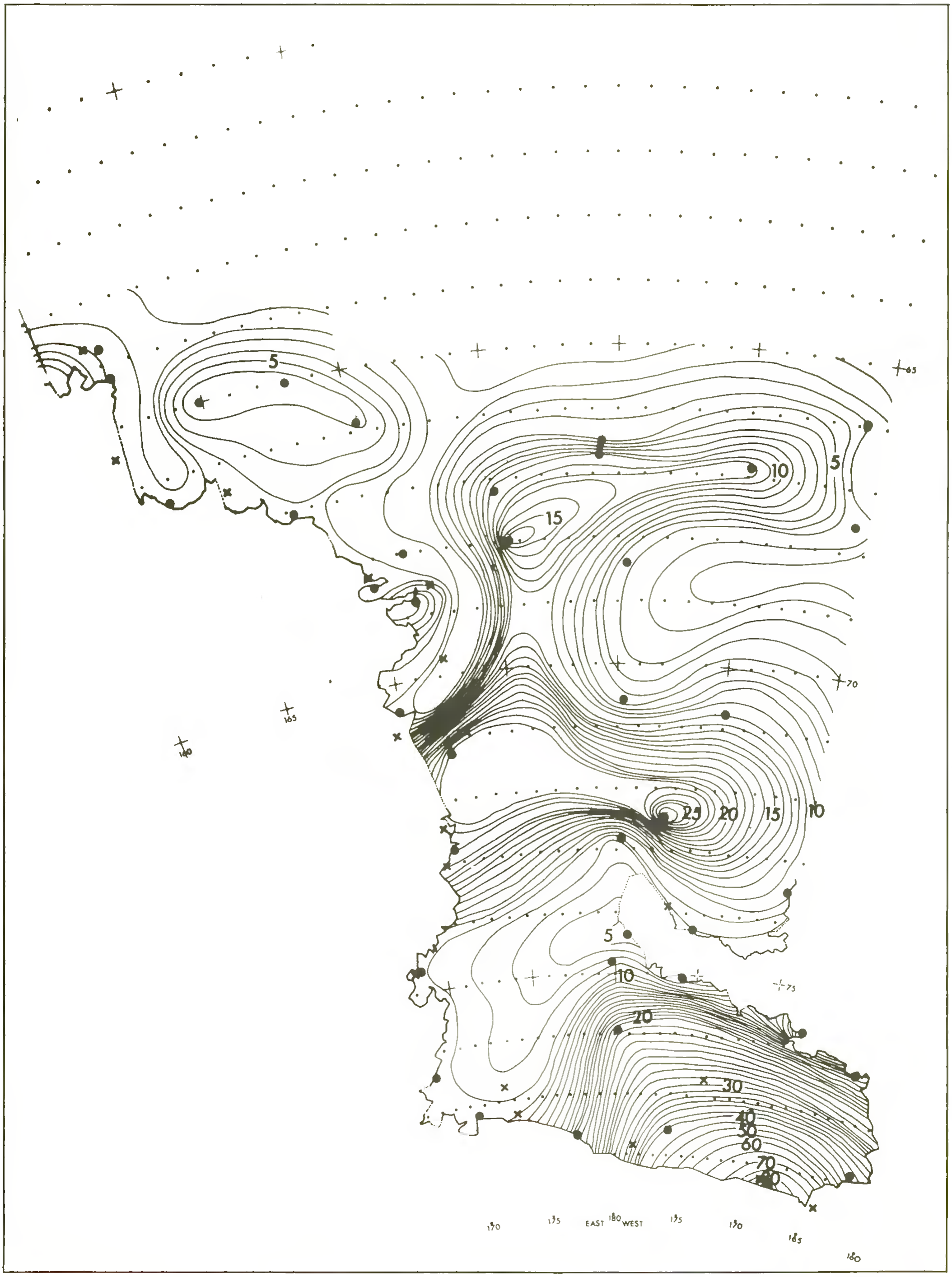

Fig. 8b. Contours of equal density of minke whales in Area VE (cruise leg 2) as for Fig. 8a. The ice edge is based on data from the *T 11*.

Table 17

Daily estimates of minke whale density from sightings by the *Vdumchivyi 34*, calculated as for Table 15a. Bracketed figures following density estimates refer to density values at those positions measured on the density contour maps (Fig. 8a, 8b) constructed from density estimates by the *Kyomaru 27* and *Toshimaru 11*

Date	Noon position	Primary sightings	Density sch/mile²	Standard dev.	Prim. eff. naut. miles
Leg 1. Eff. search half-width 0.518 n. miles (No. obs. 52)					
18.12.1980	46.40S 172.47E	1	0.005	0.005	183.6
19.12.1980	51.38S 170.10E	1	0.006	0.006	154.2
20.12.1980	56.32S 167.35E	1	0.005	0.006	176.9
21.12.1980	61.34S 163.53E	1	0.006	0.006	160.0
22.12.1980	64.03S 159.57E	0	No est.	No est.	0.0
23.12.1980	64.19S 159.53E	3	0.052 (0.065)	0.031	56.3
24.12.1980	63.53S 157.16E	4	0.031 (0.015)	0.016	125.4
25.12.1980	63.07S 157.20E	0	No est.	No est.	0.0
26.12.1980	63.15S 156.43E	4	0.182 (0.090)	0.095	21.2
27.12.1980	63.35S 155.50E	16	0.237 (0.160)	0.068	65.3
28.12.1980	64.22S 153.10E	4	0.059 (0.190)	0.031	65.5
29.12.1980	64.54S 153.04E	1	0.044 (0.180)	0.044	22.0
30.12.1980	65.03S 151.38E	3	0.037 (0.175)	0.022	79.2
31.12.1980	65.27S 149.29E	5	0.126 (0.070)	0.059	38.2
1. 1.1981	66.02S 147.38E	3	0.058 (0.045)	0.035	49.7
2. 1.1981	66.44S 144.16E	9	0.107 (0.180)	0.038	81.6
3. 1.1981	66.28S 141.28E	13	0.334 (0.170)	0.104	37.5
4. 1.1981	66.16S 141.04E	8	0.234 (0.185)	0.089	33.0
5. 1.1981	66.22S 139.18E	13	0.225 (0.160)	0.070	55.9
6. 1.1981	65.26S 137.32E	4	0.030 (0.015)	0.016	129.2
7. 1.1981	65.00S 134.30E	1	0.086 (0.125)	0.087	11.3
8. 1.1981	65.22S 130.54E	6	0.066 (0.050)	0.029	87.2
9. 1.1981	65.14S 124.10E	2	0.014	0.010	134.8
Leg 2. Eff. search half-width 0.773 n. miles (No. obs. 105)					
12. 1.1981	65.18S 128.59E	3	0.027	0.016	71.0
13. 1.1981	65.27S 138.56E	1	0.009	0.009	75.3
14. 1.1981	65.08S 148.38E	17	0.130	0.034	84.3
15. 1.1981	63.40S 157.37E	20	0.079	0.019	164.3
16. 1.1981	63.41S 161.32E	1	0.004 (0.035)	0.004	152.7
17. 1.1981	65.27S 161.25E	6	0.037 (0.045)	0.016	104.2
18. 1.1981	66.28S 165.05E	2	0.010 (0.035)	0.007	136.1
19. 1.1981	67.13S 168.15E	0	No est.	No est.	0.0
20. 1.1981	68.19S 169.48E	4	0.021 (0.035)	0.011	123.2
21. 1.1981	68.33S 172.12E	9	0.062 (0.045)	0.022	93.8
22. 1.1981	69.44S 172.20E	8	0.042 (0.020)	0.015	124.4
23. 1.1981	70.59S 170.47E	1	1.078 (0.115)	1.083	0.6
24. 1.1981	71.05S 170.50E	0	No est.	No est.	0.0
25. 1.1981	72.26S 171.07E	18	0.374 (0.215)	0.096	31.1
26. 1.1981	70.48S 169.44E	12	0.121 (0.025)	0.037	64.4
27. 1.1981	73.01S 170.57E	15	0.203 (0.190)	0.056	47.8
28. 1.1981	74.43S 168.06E	7	0.039 (0.095)	0.015	115.2
29. 1.1981	76.47S 172.30E	12	0.130 (0.085)	0.040	59.6
30. 1.1981	77.51S 178.33W	5	0.027 (0.320)	0.012	119.2
31. 1.1981	78.14S 168.50W	5	0.225 (0.820)	0.103	14.4
1. 2.1981	78.30S 164.28W	8	0.223 (0.680)	0.082	23.2
2. 2.1981	76.41S 173.52W	3	0.012 (0.295)	0.007	162.8
3. 2.1981	77.15S 173.05E	19	0.284 (0.100)	0.071	43.2
4. 2.1981	74.11S 176.35E	0	No est.	No est.	0.0
5. 2.1981	73.56S 177.01W	7	0.049 (0.080)	0.019	91.8
6. 2.1981	70.22S 173.58W	0	No est.	No est.	0.0
7. 2.1981	64.17S 176.27W	1	0.010	0.010	63.6
8. 2.1981	58.57S 178.38W	0	0.000	No est.	91.4

Table 17 shows daily density estimates for the *V 34* calculated in the same manner as for the *K 27* and *T 11*. Also given where available are the density estimates from the contour maps (Fig. 8) at the same position.

These comparative values have been plotted in Fig. 9. For regression purposes a log-log plot has been used to take into account in an approximate manner the fact that higher density estimates generally have larger standard errors associated with them (this applies to the contour estimates as well as the *V 34* estimates, as the former are based on daily estimates from the *K 27* and *T 11*). This transformation prevents the regression fit being unreasonably sensitive to a few outliers amongst the data points.

Denoting densities by D, the regression line fitted is of the form

$$\log_{10} D(V34) = \log_{10} D(\text{contour}) + c$$

$$\text{i.e. } D(V34) = \mu\, D(\text{contour}).$$

The fit yields $\mu = 0.81$ with a one standard error range (0.48, 1.38) and correlation coefficient appropriate to the relationship assumed $r = +0.17$.

Fig. 9 also shows a regression line resulting when five 'outlier' observations (corresponding to very large values of D (*V 34*) or D (contour), and concerning principally four large values of D (contour) in the south-east corner of the Ross Sea) are removed. The value of μ increases to 0.96 with range (0.58, 1.58), and r improves to +0.57.

There is thus a marginal indication that the *V 34* density estimates are negatively biased compared to those of the Japanese vessels (as $\mu < 1$), but in view of the large standard error for the μ estimate, this result is in no way conclusive.

Number of schools (Universal Kriging)

A problem of the contour method of estimating the number of schools is that no associated variance estimate is provided.

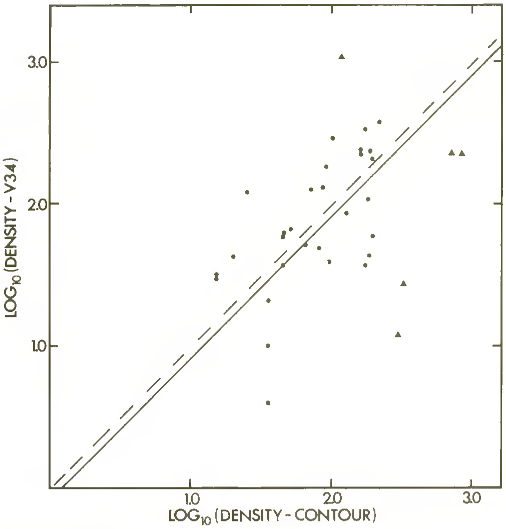

Fig. 9. Plot of logarithms of daily minke whale school density estimates from the *V 34* data plotted against the logarithm of the density at the appropriate position read from the density contour plots (Fig. 8) based on the *K 27* and *T 11* data. The solid line is a least squares fit to the data of the form

Density (*V 34*) = μ × Density (Contour)

Five 'outlier' observations corresponding to very large values of either density have been marked by triangles. The dotted line is a least squares fit omitting these outliers.

To attempt to remedy this, the technique of Universal Kriging (Matheron, 1969) has been applied. This technique was developed for geological (mineral deposit) survey estimation—the problem arising is in principle the same as in whale-sighting survey estimation.

The technique assumes that a data point (daily whale density estimate) is a random function which is the sum of two components:

$$Z(x) = m(x) + Y(x)$$

(i) $m(x)$ is a deterministic component (the 'drift'), which represents the expectation value of $Z(x)$ at x, and which is expressed as a linear combination of basic functions.

(ii) $Y(x)$ is a random function whose spatial structure is characterised by a semi-variogram

$$\gamma(h) = \tfrac{1}{2}\,\mathrm{Var}\,(Z(x + h) - Z(x))$$

This (spatial correlation) reflects the fact that information from a point measurement deteriorates as one moves away from that point.

The technique has been applied using the computer package BLUE PACK (Best Linearised Unbiased Estimator) developed by Centre de Morphologie Mathematique de Fontainebleau, and run for the authors by courtesy of a local company.

The package provides an estimate of the average density over a rectangular block, plus the associated standard deviation. The input points (daily densities) are weighted by the inverse of their variance estimates. (In cases of a zero density estimate—no primary minke sightings on that day—variances similar to those for days with only one such sighting were assumed).

Square blocks of size $(48.1)^2 = 2{,}318$ nautical miles^2 were used on a Lambert's equal area projection. For blocks intersected by the ice edge or an Area boundary, an estimate was made of the proportion of the block within the boundary, which was taken into account when the average densities were multiplied by block areas and added to give abundance estimates.

For Area VE the northern boundary was taken as defined in the previous section. To bound Area VW to the north, blocks for which a negative density was estimated were excluded (i.e. giving an effective zero density contour line).

Results are shown in Table 18. Using daily density values for the Japanese vessels only yields for the two sub-areas the following estimates:

Number of schools:	Area VW:	6,310
	Area VE:	35,695
	Total for Area V:	42,005

These compare favourably with the contouring estimates (7,219 and 37,342).

The overall estimate of variance (shown as a standard deviation in Table 18) was calculated by summing the squares of the standard deviation estimates for each block (adjusted where necessary for the proportion of the block in the Area). This yields a negatively biased estimate of the overall variance, as such summation assumes independence of the densities for adjacent blocks, whereas the Kriging procedure invokes a spatial correlation.

The ranges of the semi-variograms (fitted by the package, and representing this spatial correlation) are shown in Table 18. They are much larger than the block size used, indicating covariance contributions to the overall variance may be significant. To check this the analysis was repeated doubling the block size, which leads to overall standard deviation estimate increases of some 50%. (Note: increasing the block size makes abundance estimates for blocks not completely in the Area less accurate.)

Table 18

Universal Kriging estimates of the number of minke whale schools derived from daily density estimates

Area	Vessel data used	Block size (n. miles)^2	Number of schools	Standard deviation	Coeff. variation (%)	Range of semi-variogram (n. miles)
VW	*K 27 + T 11*	$(48.1)^2$	6,310	639	10.1	176
	K 27 + T 11	$(96.3)^2$	6,809	1,094	16.1	176
	K 27 + T 11 + V 34	$(48.1)^2$	Program divergence			
VE	*K 27 + T 11*	$(48.1)^2$	35,695	1,325	3.7	419
	K 27 + T 11	$(96.3)^2$	35,332	2,152	6.1	419
	K 27 + T 11 + V 34	$(48.1)^2$	33,365	1,555	4.7	235

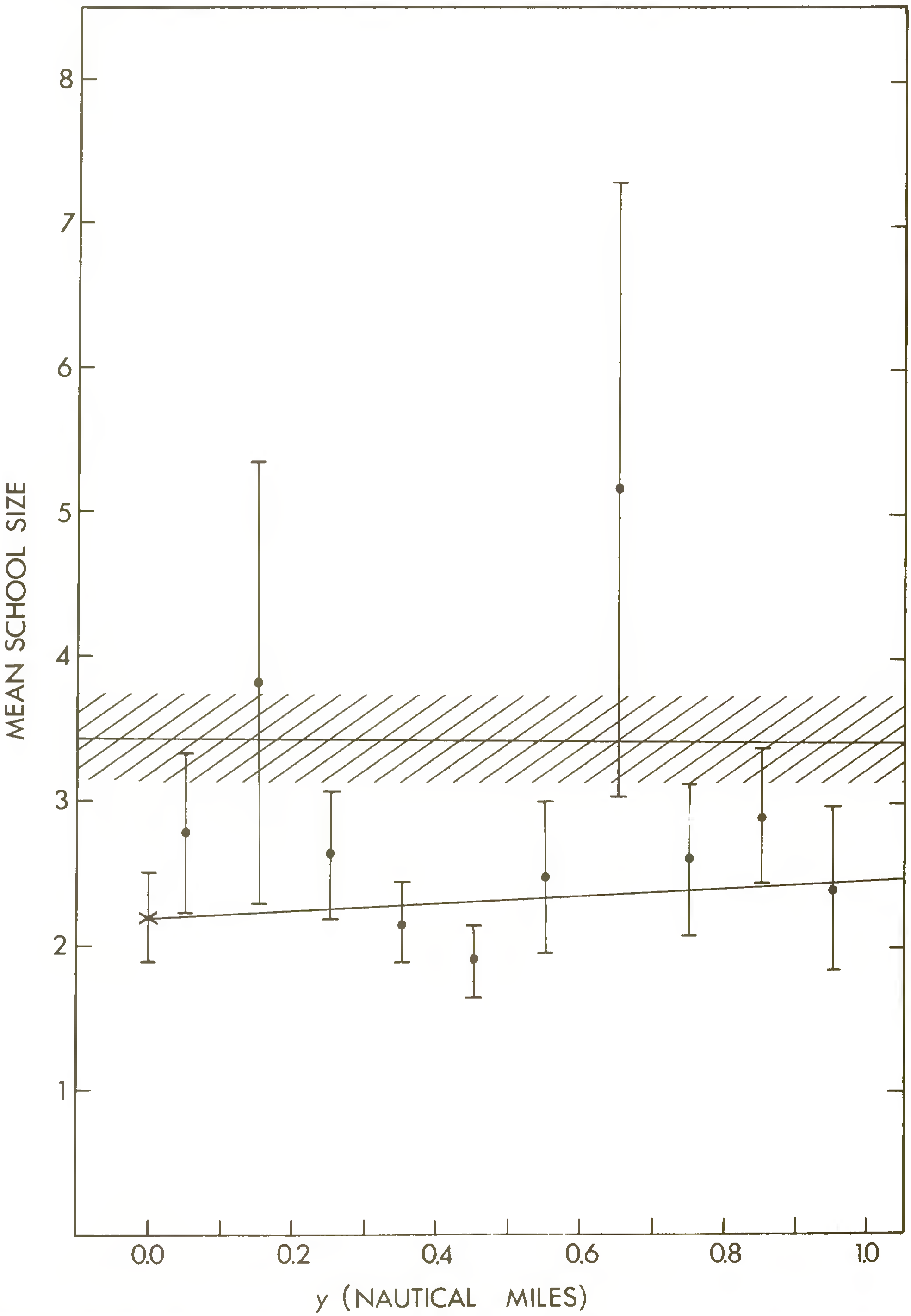

Fig. 10. Mean school sizes of minke whale schools in bands of width 0.1 nautical miles from the trackline as determined from calculated y values for primary sightings by both *K 27* and *T 11* throughout the cruise. The values are plotted against the distance of the band centre from the trackline, and the errors bars represent the standard error of each mean. The horizontal band is the mean and associated standard error for all primary sightings (irrespective of their y-values) by the two vessels. The weighted least squares straight line fit is shown, with the associated extrapolated value $\bar{s}(0)$ at $y = 0$ and its standard error.

The standard deviation figures given in Table 18 can thus be regarded only as lower limits. BLUE PACK has a facility for estimation within a polygonal boundary; this has the potential to overcome this problem and merits further attention.

Adding the *V 34* density data for Area VE decreases the abundance estimate by some 7% (perhaps a result of the *V 34* missing a greater proportion of whales on the trackline than the Japanese vessels). Despite the additional data the standard deviation estimate increases, possibly a reflection of the large residual noise in the relation between Japanese vessels' and *V 34*'s density estimates (see Fig. 9).

For Area VW addition of the *V 34*'s data led to unrealistic estimates, with the drift component failing to represent the density fall-off to the north adequately. The reason for this is not fully understood. It may be that the information from the relatively few data points to the north is 'swamped' by the larger number of points (with fluctuating values) near the ice edge.

In summary, the above utilisation of the Kriging technique should be regarded as preliminary only, but meriting further attention.

Mean school size

In assessing mean school sizes, only sightings for which the school size was recorded as confirmed were taken into account. In validating the data, minke whale sightings would have their confirmed status rejected if the distance of closest approach to the school was greater than 0.25 nautical miles. 'Best' estimates of school size were used in calculating the means.

The observed mean school size is a biased estimate of the true average as larger schools are more likely to be sighted, particularly away from the trackline. To take this into account the regression technique of Best and Butterworth (1980) and Butterworth (1982b) has been applied.

Results are given in Table 19. Combining the data from the Japanese vessels yields a regression fit (see Fig. 10):

$$\bar{s}(y) = 2.19 + 0.28\,y \quad \text{(y in nautical miles)}$$

with a corresponding estimate of the true mean school size of

$$\bar{s}(0) = 2.19 \pm 0.32$$

where the error quoted refers to one standard error of the mean.

If observations from the *V 34* are also incorporated, this estimate is amended to

$$\bar{s}(0) = 2.37 \pm 0.27.$$

The correlation coefficient for the fit is low ($r = +0.16$), and even smaller ($r = +0.07$) if the *V 34*'s observations are taken into account. Thus as was the case for Area III ($r = +0.28$: Butterworth, 1982b), the justification for the regression procedure is in doubt, unlike the Area IV case ($r = +0.85$) (Best and Butterworth, 1980).

Using instead a mean school size for sightings with y less than 1.0 or 0.5 nautical miles (see Table 19 and Fig. 11) yields values for $\bar{s}$ of 2.89 and 2.75 respectively from data from the Japanese vessels (including the *V 34* marginally decreases these values). These values are less than the mean school size of 3.43 for all primary sightings.

Fig. 11 shows that the mean school size within a particular perpendicular distance y from the vessel does not drop below 2.7, suggesting that the regression technique underestimates in this case.

Correction/Conversion factors

(*a*) *Target motion*

Best and Butterworth (1980) used a multiplicative correction factor of 0.96 (−4%) to correct for this effect. This was based on a fixed detection radius model, with whale detection within that radius assumed to be certain. Minke whales were assumed to move at an average speed of 5 knots, compared to a searching speed of 12 knots.

Provision was made on the sighting record form for estimated swimming speeds for undisturbed whales to be recorded. Such estimates are difficult to make, and values for minke whales were recorded on a total of only 11 occasions (*K 27*: 4; *T 11*: 1; *V 34*: 6). The average of these estimates was 2.9 knots with a range of 2.0 to 4.5 knots.

Table 19

Estimates of mean school size from primary sightings of minke whales (where y is calculable on a speed × time-to-close basis)

										Regression fit				
	$\bar{s}$ (no y restriction)			$\bar{s}$ ($y < 1.0$ n. miles)			$\bar{s}$ ($y < 0.5$ n. miles)			$\bar{s}$ ($y = 0$)				
Vessel/ cruise-sector	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Equation for $\bar{s}(y)$	Correlation coefficient r
K 27														
Leg 1	4.50	0.79	98	2.95	0.31	76	3.11	0.39	56	2.66	0.30	68	$2.66 - 0.57\,y$	−0.34
Leg 2	3.37	0.33	153	2.84	0.39	109	2.53	0.53	76	2.09	0.40	100	$2.09 + 1.14\,y$	+0.39
Both legs	3.81	0.37	251	2.88	0.26	185	2.77	0.34	132	2.91	0.38	185	$2.91 - 0.22\,y$	−0.09
T 11														
Leg 1	3.22	0.74	45	2.45	0.56	31	2.38	0.67	21	1.81	0.62	15	$1.81 - 0.96\,y$	−0.49
Leg 2	2.84	0.62	144	3.04	0.82	109	2.83	1.03	70	1.68	0.39	105	$1.68 - 0.80\,y$	−0.26
Both legs	2.93	0.51	189	2.91	0.65	140	2.73	0.81	91	1.72	0.34	136	$1.72 - 0.15\,y$	−0.07
V 34														
Leg 1	3.17	0.35	52	2.71	0.26	42	2.66	0.32	32	3.25	1.04	20	$3.25 - 6.67\,y$	−1.00
Leg 2	2.83	0.26	105	2.46	0.27	74	2.37	0.34	46	1.82	0.44	65	$1.82 + 0.91\,y$	+0.34
Both legs	2.94	0.21	157	2.55	0.20	116	2.49	0.24	78	2.20	0.31	108	$2.20 + 0.60\,y$	+0.32
K 27 + T 11														
Both legs	3.43	0.30	440	2.89	0.32	325	2.75	0.39	223	2.19	0.32	325	$2.19 + 0.28\,y$	+0.16
All 3 vessels, both legs	3.31	0.23	597	2.80	0.24	441	2.68	0.29	301	2.37	0.27	441	$2.37 + 0.11\,y$	+0.07

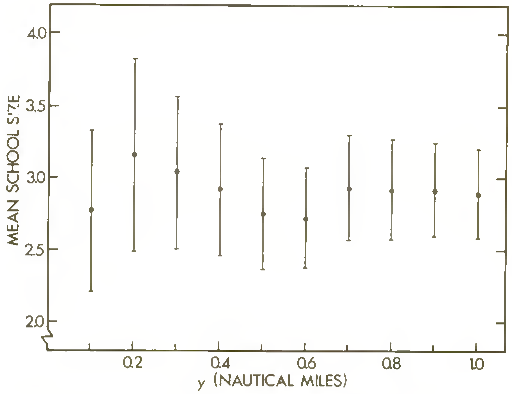

Fig. 11. Mean school sizes for all primary minke whale sightings within a distance y from the trackline, and the associated standard errors, for sightings by the *K 27* and *T 11* throughout the cruise.

Such an average speed yields a correction factor of 0.985 in terms of the model referred to above. However in view of the paucity of the information on swimming speeds, it seems wiser to continue to use the 0.96 factor (corresponding to the extreme of the whale speed range rather than the average) until further data become available.

(*b*) *Percentage takeable*

The average proportions of takeable minke whales (> 27 feet in length) as observed by each vessel are listed in Table 20. Both primary and secondary sightings, but only those with status 1, were taken into account. Quite wide discrepancies between the vessels are apparent, values for the *T 11* generally being substantially lower than those for the other two vessels. The *T 11*'s data may be erroneous: of the 31 minke whales marked by this vessel, none was estimated to be larger than 28 feet long, while 10.6% of the *K 27*'s and 22.2% of the *V 34*'s marked whales were of this size (Table 4). In Area V during the 1980/81 season, 50.7% of the whales landed by the Japanese and 66.5% of those landed by the USSR were more than 28 feet long. The absence of large whales in the *T 11*'s data suggests that sizes were generally underestimated on this vessel, so that *T 11* estimates for percentage takeable are probably too low.

However to counteract the possibility that the *K 27* and *V 34*'s length data were biased upwards (and until more marked animals are recovered), an average of the percentages for each of the vessels (65.4%) seems the most appropriate figure to use.

(*c*) *Functional form used for g(y)*

Analyses of the minke whale sighting distribution for previous cruises (Best and Butterworth, 1980; Butterworth, 1982a; and Butterworth, 1982b) indicated that the untruncated negative exponential form for g(y) was inadequate for fitting the data. This was because there were more observations both at very large and very small y than the negative exponential would indicate, so that the fit underestimated abundance by overestimating the effective search half-width.

Data from this cruise for y-calculated are shown in Table 21 and Fig. 12. The *K 27* and to a lesser extent the *V 34* show results typical of previous years with the negative exponential underestimating the pronounced peaks for $0 \leq y < 0.1$ nautical miles in the histograms. The *T 11* on the other hand shows no such effect.

As in previous analyses, a negative exponential truncated at 0.4 nautical miles has been fitted to the data to offset the biases discussed above. The results are shown in Table 22 and Fig. 12. In this case however, only the *K 27*'s fit is substantially improved.

The conversion factor 'e' for changing abundance estimates from the untruncated to truncated (at 0.4 nautical miles) fit averaged 2.06 for the 1978/79 cruise, and 2.35 for the 1979/80 cruise. Values for 'e' (calculated using maximum likelihood estimators) shown in Table 22 for the *K 27* and *V 34* are not dissimilar to values found in those earlier cruises. For the *T 11* though the values for 'e' are less than one, essentially reflecting the absence of a pronounced peak in the *T 11*'s distribution at $y = 0$.

In an earlier section on the angular distribution of sightings, attention was drawn to a bias in the *T 11*'s case in the subset of primary sightings chosen to close with (which closure is required to obtain a y-calculated value).

To ascertain the effect of such possible bias, Table 23 shows the distribution of estimated y values both for all primary sightings, and for the subset for which y-calculated values are available.

Both such distributions for the *K 27* are similar to the y-calculated distribution. On cruise leg 2 the *T 11* and *V 34* both show a marked enhancement of the distribution peak at $y = 0$ when all primary sightings are taken into account with the value of 'e' increased by about 40% in each case. The estimated distance data for the *T 11* on leg 1 shows a pronounced peak unlike the calculated distances.

In the circumstances, in assessing the best value to take for 'e' for the Japanese vessels, it seems more appropriate to use the estimated distance data for all sightings rather than the calculated distances for the *T 11* (though still retaining the calculated distance data for the *K 27*). An average of 1.84, 2.35, 1.93 and 1.34 then yields $e = 1.87$ (compared to 1.50 if y-calculated was used throughout).

Table 20

Average minke whale percentage takeable recorded by the three vessels

Vessel	Leg 1 %	Leg 1 (no. obs)	Leg 2 %	Leg 2 (no. obs)	Whole cruise %	Whole cruise (no. obs)
K 27	67.6	(151)	74.3	(200)	70.6	(351)
T 11	32.5	(58)	48.7	(284)	44.3	(342)
V 34	87.3	(135)	74.8	(178)	81.4	(313)

(*d*) *Allowance for data inaccuracies ('smearing')*

Butterworth (1982a) shows that inaccuracies in the values of angle, speed, and closure time used to obtain y-calculated values lead to a bias in the estimation of g(y), and accordingly a bias in abundance estimates. Density values obtained from y-estimated values are similarly affected.

To quantify this effect, a simulation procedure termed 'smearing' was introduced in Butterworth (1982a), wherein data from 1978/79 and 1979/80 were considered. Because of the new features introduced into the closure procedure for this cruise (see previous section 'The accuracy of calculated y values'), the smearing procedure had to be somewhat amended to deal with the 1980/81 data.

Calculated y values were dealt with as follows (see Fig. 6 and equations (1) and (2)):

$$\text{BW (max)} = v_{BC(\max)} \cdot t_{BC}\,(\max) + \text{shortfall (max)}$$
$$\text{BW (min)} = v_{BC(\min)} \cdot t_{BC}\,(\min) + \text{shortfall (min)}$$

where
$$\begin{cases} v_{BC}\,(\max) = v_{BC} + \tfrac{1}{2}\Delta v \\ v_{BC}\,(\min) = v_{BC} - \tfrac{1}{2}\Delta v \end{cases}$$

$$\begin{cases} t_{BC}\,(\max) = t_{BC} + \tfrac{1}{2}\Delta t \\ t_{BC}\,(\min) = \begin{cases} t_{BC} - \tfrac{1}{2}\Delta t & \text{for } t_{BC} > \tfrac{1}{2}\Delta t \\ 0 & \text{for } t_{BC} < \tfrac{1}{2}\Delta t \end{cases} \end{cases}$$

$$\begin{cases} \text{shortfall}\,(\max) = \text{shortfall} + \tfrac{1}{2}\Delta s \\ \text{shortfall}\,(\min) = \begin{cases} \text{shortfall} - \tfrac{1}{2}\Delta s & \text{for shortfall} > \tfrac{1}{2}\Delta s \\ 0 & \text{for shortfall} < \tfrac{1}{2}\Delta s \end{cases} \\ \text{with } \Delta s = \begin{cases} 0.5\,(\text{shortfall}) & \text{for shortfall} > 0.08 \text{ nautical miles} \\ 0.04 & \text{for shortfall} < 0.08 \text{ nautical miles} \end{cases} \end{cases}$$

If then

$$\theta_{\max} = \begin{cases} \theta_1^* + \Delta\theta/2 & \text{(immediate turn)} \\ \theta_2 + \Delta\theta/2 & \text{(delayed turn)} \end{cases}$$

and
$$\theta_{\min} = \begin{cases} \theta_1^* - \Delta\theta/2 & \text{(immediate turn)} \\ \theta_2 - \Delta\theta/2 & \text{(delayed turn)} \end{cases}$$

(where 0_1 would be used for immediate turns in cases where θ_1^* was not recorded) extreme possible values for y-calculated were obtained from:

$$\begin{cases} y\,(\max) = BW\,(\max) \sin\theta_{\max} \\ y\,(\min) = \begin{cases} BW\,(\min) \sin\theta_{\min} & \text{for } \theta_{\min} > 0 \\ BW\,(\max) \sin\theta_{\min} & \text{for } \theta_{\min} < 0 \end{cases} \end{cases}$$

Finally the simulated y value was taken to be

$$y' = y\,(\min) + \alpha\,[y\,(\max) - y\,(\min)]$$

where α is a random number chosen uniformly from the range [0,1].

This method of smearing y between its extreme values rather than smearing the component observations of speed, time, distance and angle, was preferred because of undesirable properties of the latter procedure for cases with both closure time and angle zero (see Butterworth, 1982a).

The range of the velocity inaccuracies Δv was taken to be 1 knot as closure speeds were recorded to the nearest knot.† Though closure times were normally recorded to

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† The nearest ½-knot was requested, but there seems to have been a tendency for integral values to be preferred.

Table 21

Frequency distribution of calculated right-angle distances y for minke whales fitted to an untruncated negative exponential $g\,(y) = e^{-\lambda y}$

	K27				*T11*				*V34*			
	Leg 1: VW—South		Leg 2: VE—North		Leg 1: VW—North		Leg 2: VE—South		Leg 1: VW—South		Leg 2: VE—South	
Distance interval (n. miles)	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
$0 \leq y < 0.1$	20	13.1	38	20.6	5	5.1	15	18.8	12	9.3	20	12.9
$0.1 \leq y < 0.2$	9	11.0	13	17.8	5	4.5	18	16.3	8	7.6	4	11.3
$0.2 \leq y < 0.3$	9	9.2	9	15.4	3	4.0	12	14.2	4	6.3	8	9.9
$0.3 \leq y < 0.4$	3	7.7	11	13.4	3	3.6	9	12.3	4	5.2	8	8.7
$0.4 \leq y < 0.5$	8	6.5	5	11.6	5	3.2	15	10.7	4	4.2	6	7.6
$0.5 \leq y < 0.6$	7	5.4	7	10.0	4	2.8	10	9.3	3	3.5	7	6.7
$0.6 \leq y < 0.7$	2	4.6	12	8.7	0	2.5	10	8.1	3	2.9	11	5.9
$0.7 \leq y < 0.8$	0	3.8	5	7.5	2	2.2	7	7.0	2	2.3	2	5.2
$0.8 \leq y < 0.9$	4	3.2	4	6.5	4	2.0	8	6.1	1	1.9	5	4.5
$0.9 \leq y < 1.0$	4	2.7	5	5.6	0	1.7	4	5.3	1	1.6	3	4.0
$y \geq 1.0$	15	14.0	44	36.0	14	13.5	35	35.1	10	7.3	31	28.5
λ (n. miles^{-1})	1.758		1.447		1.201		1.406		1.970		1.306	
χ^2	13.40		28.61		0.60		5.30		3.53		16.13	
d.f.	8		10		4		10		6		9	
P	0.098		0.0015		0.963		0.870		0.740		0.064	

Table 22

Frequency distribution of calculated right-angle distances y for minke whales fitted to a negative exponential $g\,(y) = e^{-\lambda y}$ truncated at 0.4 nautical miles

	K27				*T11*				*V34*			
	Leg 1: VW—South		Leg 2: VE—North		Leg 1: VW—North		Leg 2: VE—South		Leg 1: VW—South		Leg 2: VE—South	
Distance interval (n. miles)	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
$0 \leq y < 0.1$	18	19.8	38	37.6	5	5.0	15	16.2	12	12.7	20	17.7
$0.1 \leq y < 0.2$	10	10.9	13	19.0	5	4.3	18	14.2	8	7.7	4	11.1
$0.2 \leq y < 0.3$	10	6.0	9	9.6	3	3.7	12	12.5	4	4.7	8	6.9
$0.3 \leq y < 0.4$	2	3.3	11	4.8	3	3.1	9	11.0	4	2.9	8	4.3
λ (n. miles^{-1})	5.942		6.840		1.557		1.274		4.974		4.675	
e	1.84		2.35		0.99		0.86		1.58		1.61	
χ^2	1.00		9.81		0.14		1.48		0.08		6.81	
d.f.	2		3		1		3		2		2	
P	0.607		0.020		0.713		0.687		0.963		0.033	

Table 23

Distribution of estimated right-angle distances for minke whales for all primary sightings, compared to the distribution of these distances for only those primary sightings where distances can be calculated on a speed × time-to-close basis ('y-calculable'). 'e' is the density conversion factor for the negative exponential truncated at 0.4 nautical miles compared to the untruncated case

	K27				*T11*				*V34*			
	Leg 1: VW—South		Leg 2: VE—North		Leg 1: VW—North		Leg 2: VE—South		Leg 1: VW—South		Leg 2: VE—South	
Distance interval (n. miles)	All Obs. (%)	y-calculable Obs. (%)	All Obs. (%)	y-calculable Obs. (%)	All Obs. (%)	y-calculable Obs. (%)	All Obs. (%)	y-calculable Obs. (%)	All Obs. (%)	y-calculable Obs. (%)	All Obs. (%)	y-calculable Obs. (%)
$0 \leqslant y < 0.1$	32 (35)	27 (34)	37 (23)	35 (23)	13 (25)	11 (24)	60 (17)	16 (11)	19 (18)	12 (23)	44 (24)	16 (15)
$0.1 \leqslant y < 0.2$	10 (11)	7 (9)	14 (9)	13 (9)	7 (13)	7 (16)	41 (11)	19 (13)	8 (8)	3 (6)	12 (7)	2 (2)
$0.2 \leqslant y < 0.3$	8 (9)	8 (10)	16 (10)	15 (10)	5 (9)	4 (9)	31 (9)	15 (11)	9 (9)	7 (13)	16 (9)	7 (7)
$0.3 \leqslant y < 0.4$	9 (10)	9 (11)	12 (8)	12 (8)	3 (6)	3 (7)	26 (7)	10 (7)	5 (5)	3 (6)	18 (10)	9 (9)
$0.4 \leqslant y < 0.5$	2 (2)	2 (3)	5 (3)	5 (3)	0 (0)	0 (0)	18 (5)	11 (8)	5 (5)	3 (6)	12 (7)	8 (8)
$0.5 \leqslant y < 0.6$	4 (4)	3 (4)	14 (9)	13 (9)	3 (6)	3 (7)	21 (6)	11 (8)	12 (12)	5 (10)	20 (11)	16 (15)
$0.6 \leqslant y < 0.7$	2 (2)	2 (3)	9 (6)	9 (6)	3 (6)	2 (4)	18 (5)	5 (4)	8 (8)	1 (2)	9 (5)	7 (7)
$0.7 \leqslant y < 0.8$	5 (5)	3 (4)	9 (6)	7 (5)	2 (4)	2 (4)	14 (4)	9 (6)	3 (3)	1 (2)	6 (3)	5 (5)
$0.8 \leqslant y < 0.9$	2 (2)	2 (3)	4 (3)	4 (3)	0 (0)	0 (0)	15 (4)	7 (5)	0 (0)	0 (0)	7 (4)	3 (3)
$0.9 \leqslant y < 1.0$	0 (0)	0 (0)	2 (1)	2 (1)	3 (6)	2 (4)	11 (3)	4 (3)	6 (6)	6 (12)	3 (2)	2 (2)
$y \geqslant 1.0$	18 (20)	17 (21)	38 (24)	38 (25)	14 (26)	11 (24)	103 (29)	36 (25)	28 (27)	11 (21)	36 (20)	30 (29)
Total	92	80	160	153	53	45	358	143	103	52	183	105
e	2.13	2.03	1.72	1.69	1.93	1.70	1.34	0.93	1.36	1.37	1.62	1.20

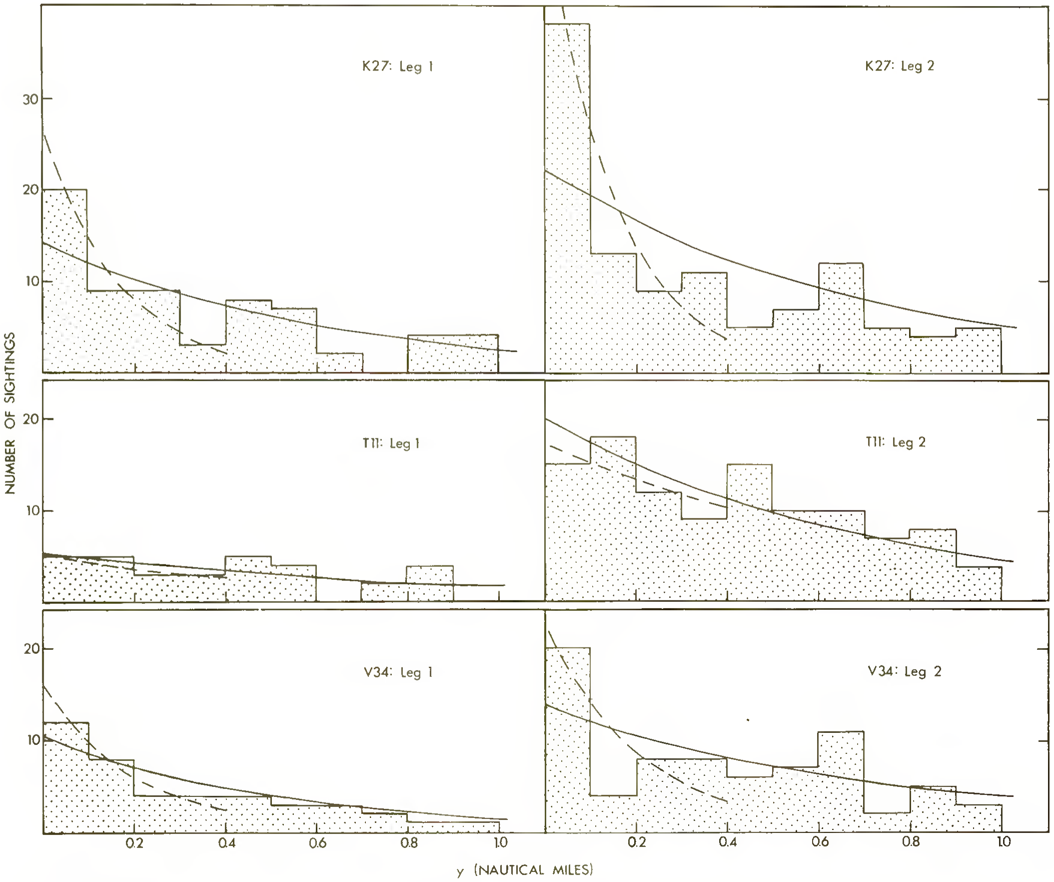

Fig. 12. Distribution of primary minke whale school sightings with perpendicular distance from the trackline (y-calculated) for y less than one nautical mile. The solid line shows the fit by an untruncated negative exponential, and the dotted line by a negative exponential truncated at 0.4 nautical miles.

the nearest second, Δt was taken to be 20 seconds to allow for errors arising from the time taken to execute a turn, and the time needed to accelerate to closure speed.

The preference for recording angles as even multiples of 5° was noted in the discussion on the angular distribution of sightings, and indicates a choice $\Delta\theta = 10°$. However aspects noted by Hiby (IWC, 1982) suggest $\Delta\theta = 20°$ may be more appropriate, and this value has been preferred, though certain results are also quoted for $\Delta\theta = 10°$.

Results are shown in Fig. 13, which is to be compared with Fig. 12 for the unsmeared case. Partial reduction of the peak near $y = 0$ is clear for both the *K 27* and *V 34* data sets.

Also shown in Fig. 13 are fits to the smeared data by a negative exponential function for g(y), both untruncated and truncated at 0.4 nautical miles, for each vessel and cruise leg. These fits are also detailed in Tables 24 and 25, where the χ^2 values indicate improved fits compared to the unsmeared case (Tables 21 and 22) in every case except one (*T 11*: leg 1—untruncated).

Table 26 lists values for the conversion factor 'e' (density estimates relative to the unsmeared untruncated negative exponential fit to g(y)). For the untruncated case the differences are of little significance (maximum −4%), but with truncation at 0.4 nautical miles smearing has a much greater effect because of greater sensitivity of the estimate to small y values (maximally −55% for the *V 34* leg 2).

In the previous section, estimated y values were used to assess 'e' values for the *T 11* because of apparent bias in this vessel's choice of sighting with which to close. Thus a smearing procedure for y-estimated was also required.

If r is the topman's estimate of the radial distance to the whale when first sighted (see Fig. 6) then

$$\begin{cases} r_{\max} = r + \dfrac{\Delta r}{2} \\ r_{\min} = \begin{cases} r - \dfrac{\Delta r}{2} & r > \dfrac{\Delta r}{2} \\ 0 & r \leqslant \dfrac{\Delta r}{2} \end{cases} \end{cases}$$

$$\begin{cases} \theta_{\max} = \theta_1 + \dfrac{\Delta\theta}{2} \\ \theta_{\min} = \theta_1 - \dfrac{\Delta\theta}{2} \end{cases}$$

$$\text{giving} \begin{cases} y\,(\max) = r_{\max} \sin \theta_{\max} \\ y\,(\min) = \begin{cases} r_{\min} \sin\theta_{\min} & \text{for } \theta_{\min} > 0 \\ r_{\max} \sin\theta_{\min} & \text{for } \theta_{\min} < 0. \end{cases} \end{cases}$$

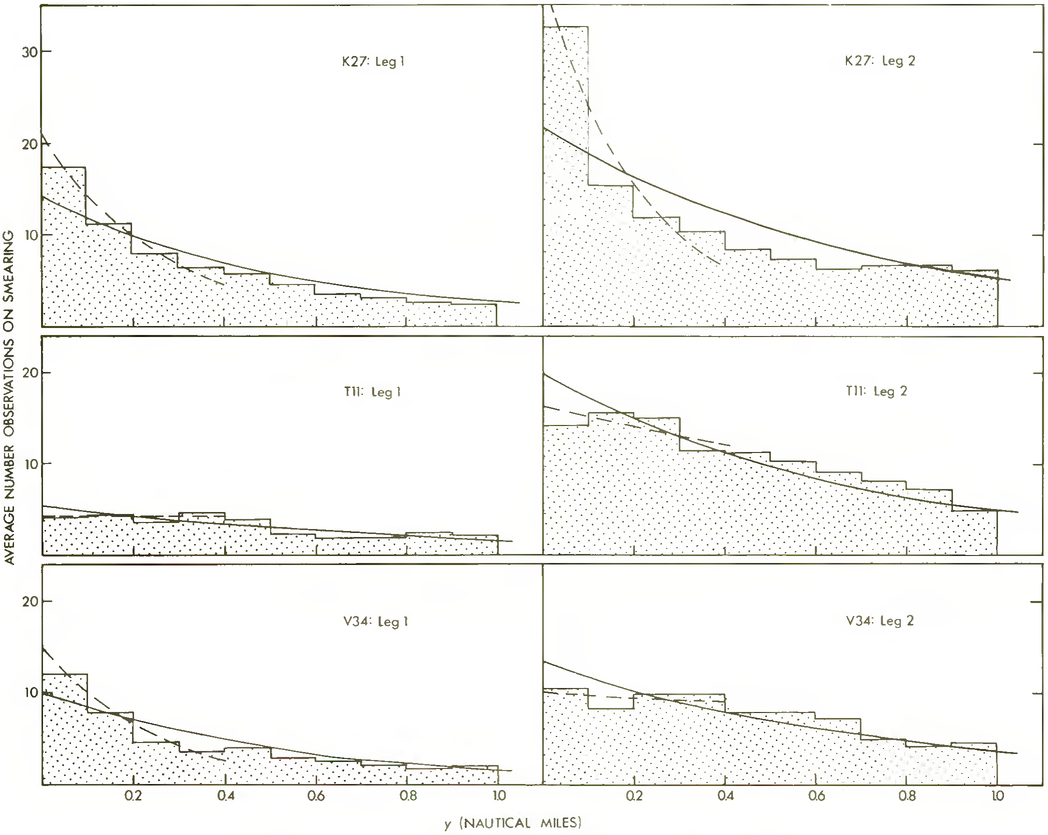

Fig. 13. As for Fig. 12, but with smeared values of y-calculated ($\Delta\theta = 20°$).

Table 24

Frequency distribution of calculated right-angle distances y for minke whales, smeared as described in the text with $\Delta\theta = 20°$ ('Obs') and fitted to an untruncated negative exponential $g(y) = e^{-\lambda y}$

	K27				*T11*				*V34*			
	Leg 1: VW—South		Leg 2: VE—North		Leg 1: VW—North		Leg 2: VE—South		Leg 1: VW—South		Leg 2: VE—South	
Distance interval (n. miles)	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.
$0 \leqslant y < 0.1$	17.4	12.8	32.8	20.1	4.3	5.0	14.2	18.5	11.9	9.1	10.5	12.4
$0.1 \leqslant y < 0.2$	11.3	10.8	15.5	17.5	4.4	4.5	15.6	16.1	7.8	7.5	8.3	10.9
$0.2 \leqslant y < 0.3$	8.0	9.1	11.9	15.2	3.7	4.0	15.1	14.0	4.7	6.2	9.8	9.6
$0.3 \leqslant y < 0.4$	6.4	7.7	10.4	13.2	4.8	3.5	11.4	12.2	3.6	5.1	9.8	8.5
$0.4 \leqslant y < 0.5$	5.8	6.4	8.4	11.4	4.0	3.1	11.3	10.6	3.9	4.2	7.9	7.5
$0.5 \leqslant y < 0.6$	4.7	5.4	7.4	9.9	2.3	2.8	10.2	9.3	3.0	3.5	7.9	6.6
$0.6 \leqslant y < 0.7$	3.6	4.6	6.4	8.6	2.1	2.5	9.1	8.1	2.6	2.9	7.3	5.8
$0.7 \leqslant y < 0.8$	3.2	3.8	6.6	7.5	2.1	2.2	8.2	7.0	2.1	2.4	5.1	5.1
$0.8 \leqslant y < 0.9$	2.7	3.2	6.6	6.5	2.4	2.0	7.3	6.1	1.8	2.0	4.3	4.5
$0.9 \leqslant y < 1.0$	2.6	2.7	6.2	5.7	2.1	1.7	5.0	5.3	2.1	1.6	4.6	4.0
$y \geqslant 1.0$	15.3	14.4	40.9	37.4	12.8	13.7	35.8	35.8	8.5	7.6	29.7	30.0
λ (n. miles^{-1})	1.726		1.408		1.188		1.384		1.927		1.253	
χ^2	2.61		12.03		1.09		1.81		1.92		1.73	
d.f.	8		10		5		10		6		9	
p	0.957		0.283		0.955		0.998		0.927		0.995	

Table 25

Frequency distribution of calculated right angle distances y for minke whales, smeared as described in the text with $\Delta\theta = 20°$ ('Obs'), and fitted to a negative exponential $g(y) = e^{-\lambda y}$ truncated at 0.4 nautical miles

	K27				*T11*				*V34*			
	Leg 1: VW—South		Leg 2: VE—North		Leg 1: VW—North		Leg 2: VE—South		Leg 1: VW—South		Leg 2: VE—South	
Distance interval (n. miles)	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.	'Obs.'	Exp.
$0 \leqslant y < 0.1$	17.4	17.4	32.8	30.6	4.3	4.3	14.2	15.8	11.9	12.1	10.5	9.9
$0.1 \leqslant y < 0.2$	11.3	12.0	15.5	19.5	4.4	4.3	15.6	14.6	7.8	7.7	8.3	9.7
$0.2 \leqslant y < 0.3$	8.0	8.2	11.9	12.4	3.7	4.3	15.1	13.5	4.7	5.0	9.8	9.5
$0.3 \leqslant y < 0.4$	6.4	5.7	10.4	7.9	4.8	4.3	11.4	12.5	3.6	3.2	9.8	9.3
λ (n. miles^{-1})	3.728		4.505		0		0.789		4.468		0.211	
e	1.46		1.72		0.79		0.82		1.46		0.73	
χ^2	0.06		1.77		0.001		0.50		0.01		0.27	
d.f.	2		3		1		3		2		2	
p	0.973		0.622		0.973		0.919		0.997		0.874	

Table 26

Conversion factors 'e' for estimates of minke whale density relative to estimates using the unsmeared untruncated negative exponential fit to g(y). The value given for $\bar{y}$(calc)/$\bar{y}$(est) would convert estimates using calculated y values to ones using estimated y values

				e					
				Untruncated			Truncated at 0.4 nautical miles		
Method y values obtained	Vessel/ Cruise leg	$\bar{y}$ nautical miles	$\bar{y}$ (calc) / $\bar{y}$ (est)	No smear	Smear: $\Delta\theta = 10°$	Smear: $\Delta\theta = 20°$	No smear	Smear: $\Delta\theta = 10°$	Smear: $\Delta\theta = 20°$
Calculated	*K27* Leg 1	0.567	—	1	0.98	0.98	1.84	1.52	1.46
	K27 Leg 2	0.691	—	1	0.98	0.97	2.35	1.92	1.72
	T11 Leg 1	0.833	—	1	0.99	0.99	0.99	0.85	0.79
	T11 Leg 2	0.711	—	1	0.99	0.98	0.86	0.80	0.82
	V34 Leg 1	0.508	—	1	0.98	0.98	1.58	1.47	1.46
	V34 Leg 2	0.766	—	1	0.97	0.96	1.61	0.99	0.73
Estimated	*K27* Leg 1	0.489	1.16	1	0.96	0.92	2.13	1.70	1.40
	K27 Leg 2	0.595	1.16	1	0.97	0.95	1.72	1.33	1.15
	T11 Leg 1	0.642	1.30	1	0.98	0.97	1.93	1.84	1.63
	T11 Leg 2	0.717	0.99	1	0.98	0.96	1.34	1.20	1.05
	V34 Leg 1	0.651	0.78	1	0.98	0.97	1.36	1.16	1.14
	V34 Leg 2	0.582	1.32	1	0.97	0.95	1.62	1.25	1.05

For the ranges of the measurement inaccuracies, $\Delta\theta$ was chosen as in the y-calculated case, i.e. $\Delta\theta = 20°$ preferred, though some additional results are shown for $\Delta\theta = 10°$. In the absence of tests of the accuracy with which the topmen estimated r, values of Δr were taken to be

$$\Delta r = \begin{cases} 0.2 \text{ for } r < 1 \text{ nautical mile} \\ 0.5 \text{ for } r \geqslant 1 \text{ nautical mile.} \end{cases}$$

(These relate in part to the accuracy requested of the topmen: the nearest tenth of a mile for distances less than one mile, and the nearest half a mile for distances greater than one mile.)

The simulated value y′ was then chosen as in the y-calculated case:

$$y' = y\,(\min) + \alpha\,[y\,(\max) - y\,(\min)]$$

Fig. 14 compares the distribution of smeared and unsmeared estimated y values. The reduction of the distribution peak near y = 0 for the smeared data is noticeable in all cases. Table 26 also lists the conversion factors 'e' for y-estimated distributions. For the untruncated case the effect is slightly larger than for y-calculated, but still relatively small (maximally − 8%). With truncation the effect again becomes more substantial (maximally − 35%).

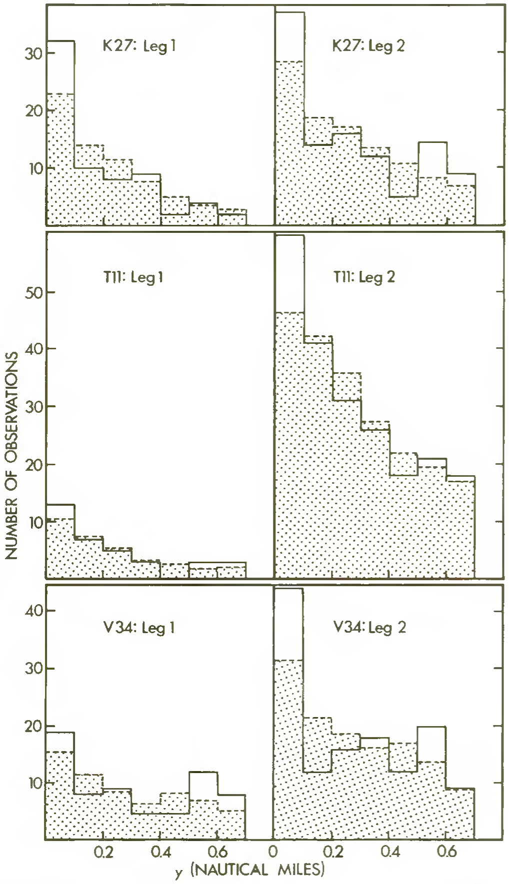

Fig. 14. Distribution of primary minke whale school sightings with perpendicular distance from the trackline (y-estimated) for y less than 0.7 nautical miles. The solid boundary corresponds to unsmeared, and the dotted boundary to smeared data.

To select an overall best estimate for 'e', the same procedure as in the previous section has been used, i.e. choosing y-calculated values for the *K 27*, but y-estimated for the *T 11*. Taking $\Delta\theta = 20°$ yields respectively 1.46, 1.72, 1.63 and 1.05, with resultant average estimate e = 1.47 (a reduction of 22% compared to the unsmeared case).

(*e*) *Proportion of whales missed on the trackline*

This factor was assessed from results of the variable speed experiments carried out during the cruise (Butterworth, Best, and Basson, 1982). A weighted average of the results for the *K 27* and *T 11* yielded an estimate for g(0), the probability of sighting a whale on the trackline:

$$g(0) = 0.72.$$

The appropriate multiplicative factor adjusting density estimates is thus

$$h = \frac{1}{g(0)} = 1.39.$$

Population estimate and discussion

Neglecting first the correction/conversion factors above, and using only data from the two Japanese vessels, the population is calculated using the equation

$$\text{Pop}' = \bar{s}N'$$

where the mean school size $\bar{s}$ = 2.19 (regression technique), and the number of schools N′ = 44,561 (contouring).

This yields a population estimate of 97,589 minke whales (Area VW: 15,810; Area VE: 81,779).

Incorporating the first three correction/conversion factors gives an estimate

$$\text{Pop} = t\ e\ m\ \text{Pop}'$$

where t = proportion takeable = 0.654 (average for all three vessels)
e = effect of the negative exponential for g(y) being truncated = 1.87
m = correction for whale movement = 0.96.

Final estimates of the exploitable populations are then:

Area VW:	18,562	(4,034)
Area VE:	96,014	(15,192)
Total	114,576	(15,718)

The bracketed figures are standard error estimates. They have been calculated by summing the squared coefficient of variation estimates for $\bar{s}$ (c.v. = 14.6%) and for N′. The coefficient of variation values used for N′ are those for the Kriging estimates for the maximum block-size used (Table 18), which are negatively biased. Hence the coefficient of variation for the total exploitable population estimate of 14% is likely to be an underestimate.

These estimates are comparable with those for Area IV (Best and Butterworth, 1980) and Area III (Butterworth, 1982b), and do not incorporate adjustments for the proportion of whales missed on the trackline (Butterworth, Best and Basson, 1982), nor an allowance for the effect of speed, time, distance and angle measurement inaccuracies on the y distribution ('smearing' correction) (Butterworth, 1982a).

If these last two adjustments are also included, the estimate becomes

$$\text{Pop}^* = t\ e'\ m\ h\ \text{Pop}'$$

where t, m and Pop′ have their previous values, but e′ now also incorporates smearing effects, and h accounts for whales missed on the trackline:

$$e' = 1.47$$
$$h = 1.39.$$

The exploitable populations are then estimated to be:

Area VW:	20,282	(4,408)
Area VE:	104,911	(16,600)
Total	125,193	(17,174)

where the standard deviation estimates have been calculated as before and are likely to be underestimates.

These population estimates do not include minke whales outside the area at the time of the survey (either to the north or in the pack ice to the south).

The Kriging calculations for Area VE together with the comparison of the *V 34* and contour daily density estimates (Fig. 9) indicate inclusion of *V 34* data would slightly decrease the school abundance estimates (by ~ 5%), but this may be a reflection of the *V 34* missing a greater proportion of whales on the trackline.

The low value of the correlation coefficient in the regression of mean school size against y suggests that use of the mean school size of all sightings with $y < 0.5$ nautical miles might be more appropriate. This would increase abundance estimates by approximately 25%.

Aspects of this abundance estimation technique most meriting further investigation appear to be:

(i) accuracy of the y-value: new features introduced into the closing procedure for this cruise (particularly recording of shortfall, and delayed turns) significantly affected estimates;

(ii) the functional form used for g(y) to obtain the effective search half-width;

(iii) the proportion takeable estimation: there have been wide variations between vessels on all three cruises to date;

(iv) obtaining a standard deviation for the population estimate: the Kriging technique holds promise in this regard;

(v) the effect of whale movement: both theoretical studies, and more data on the average swimming speed of undisturbed whales are needed;

(vi) the proportion of whales missed on the trackline: the double sightings proportion in the parallel ship experiment may provide more information on this (and item (ii)), and further variable speed experiments also deserve consideration; the possible effect of weather conditions on this proportion should be investigated (probably by hazard-rate model computer simulations, as sets of different conditions would not each be maintained sufficiently long during an experiment).

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REFERENCES

Best, P. B. and Ohsumi, S. 1980. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR) Southern minke whale assessment cruise, 1978–79. *Polar Rec.* 20 (124): 52–7.

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Butterworth, D. S. 1982. A possible basis for choosing a functional form for the distribution of sightings with right angle distance: some preliminary ideas. Paper SS/7 (published in this volume).

Butterworth, D. S. 1982a. On the functional form used for g(y) for minke whale sightings, and bias in its estimation due to measurement inaccuracies. Paper SC/Jn81/MiS18 (published in this volume).

Butterworth, D. S. 1982b. An alternative sightings estimate of the minke whale population in Area III from data from the 1979/80 assessment cruise. Paper SC/Jn81/MiS16 (published in this volume).

Butterworth, D. S., Best, P. B. and Basson, M. 1982. Results of analysis of sighting experiments during the 1980/81 Southern Hemisphere minke whale assessment cruise. Paper SC/Jn81/MiS5+13+17 (published in this volume).

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with application to zoological censuses. *Univ. Calif. Publs Statist.* 1: 131–60.

Doi, T., Kasamatsu, F. and Nakano, T. 1982. A simulation study on sighting survey of minke whales in the Antarctic. Paper SC/Jn81/MiS29 (published in this volume).

Hiby, A. R. 1982. The effect of random whale movement on density estimates obtained from whale sightings surveys. Paper SC/Jn81/MiS7 (published in this volume).

Horwood, J. W. 1981. Results from the IWC/IDCR minke marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Horwood, J. W., Best, P. B. and Ohsumi, S. 1981. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR) Southern Hemisphere minke whale assessment cruise, 1979–80. *Polar Rec.* 20(129): 565–9.

International Whaling Commission. 1982. Report of the Special Meeting on Southern Hemisphere minke whales, June 1981. Appendix 16. Report of the Sightings Subgroup (published in this volume).

Joyce, G. G. 1982. Preliminary results on blow patterns as sighting cues for the minke whale in the Antarctic. Paper SC/Jn81/MiS6 (published in this volume).

Kato, H. 1981. Trial-firing of .410 marks at a minke whale carcase on the factory ship, 1979/80 Antarctic season. *Rep. int. Whal. Commn* 31: 367–70.

Matheron, G. 1969. Le Krigeage universal. Les Cahiers du Centre de Morphologie Mathématique de Fontainebleau, Ecole Nationale Supérieure des Mines de Paris.

Robson, D. S. and Regier, H. A. 1964. Sample size in Petersen mark-recapture experiments. *Trans. Am. Fish. Soc.* 93: 215–26.

Appendix I

MINKE WHALE ASSESSMENT CRUISE WEATHER RECORD (III)

	Form No.	Vess.	DATE Yr.	DATE Mo.	DATE Day	Observ.	POSITION SHIFT Time	POSITION SHIFT Bear.	POSITION SHIFT Dist.
01	W								
	1 4	5 7	8		13	14 17	18 21	22 24	25 27
							28 31	32 34	35 37
							38 41	42 44	45 47

	Form no.	Time	POSITION Latitude		POSITION Longitude	E/W	Weather	WIND Dir.	WIND Speed	Surface temp.	Vis.	Ice	Top men	Sightability
02	W	04		S						±				
03	W	05		S						±				
04	W	06		S						±				
05	W	07		S						±				
06	W	08		S						±				
07	W	09		S						±				
08	W	10		S						±				
09	W	11		S						±				
10	W	12		S						±				
11	W	13		S						±				
12	W	14		S						±				
13	W	15		S						±				
14	W	16		S						±				
15	W	17		S						±				
16	W	18		S						±				
17	W	19		S						±				
18	W	20		S						±				
	1 4	4 5	6 7		17	18	19 20		25	26 29	30 32	33 34	35 36	37

MINKE WHALE ASSESSMENT CRUISE SEARCHING EFFORT RECORD (III)

	Form No.				Vessel			DATE Yr.		Mo.		Day		Observers				Sheet No.	
01	E																		
	1			4	5		7	8					13	14			17	18	19

	Form No.				Activity		Time				POSITION Latitude					Longitude					E/W	Course			Speed		
02	E														S												
03	E														S												
04	E														S												
05	E														S												
06	E														S												
07	E														S												
08	E														S												
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21	E														S												
22	E														S												
23	E														S												
24	E														S												
25	E														S												
	1			4	5	6	7			10	11										21	22		24	25		27

MINKE WHALE ASSESSMENT CRUISE SIGHTING RECORD (III)

	Form No.	Vessel	DATE Yr.	DATE Mo.	DATE Day	Sight No.	Type	Status	Seen by	Observer
01	S									
	1 5	6 8	9		14	15 16	17	18	19	20 23

	Sighting time	cue	Angle from course	P / S	Est. Distance	Compass heading Ship	Compass heading Whale	A → B Elapsed time	A → B Speed
A					:				:
	24 27	28	29 31	32	33 35	36 38	39 41	42 45	46 48

B			:
	49 52	53 55	56 58

	Event	B → C Elapsed time	B → C Speed	Short-fall
C			:	:
	59	60 63	64 66	67 69

POSITION	Latitude	Longitude	E / W
	S		
	70		80

	Form No.
02	S
	81 85

Estimate of School Size Highest	Estimate of School Size Lowest	Estimate of School Size Best	% Takeable	Type	No. of calves	Size Range max.	Size Range min.
86		97	98 100	101		104	109

SPECIES

%	Code	Name	Number marked
110 112	114		115 116
117 119	121		122 123
124 126	128		129 130

Total time of obs.	Closest distance	Photo	By
	:		
131 133	134 136	137	138

REMARKS—See next page.

REMARKS

☐ Pod behaviour prior to pursuit
139

☐ Pod behaviour during marking/pursuit
140

☐ Individual behaviour
141

☐ Distinctive characteristics
142

☐ Size composition of individual groups
143

☐ Associated wildlife
144

☐☐.☐ Estimated swimming speed of undisturbed whale
145 147

☐ Ice condition
148

☐ Distance of sighting from pack edge
149

MINKE WHALE ASSESSMENT CRUISE MARKING RECORD (III)

DATE		VESSEL		OBSERVERS		SHEET NO.	

Mark No.	Species	Position	Sighting-Whale no.	Range	Result	Length	Hit position	Remarks

H = Hit, PH = Possible Hit, HP = Hit protruding, M = Miss, R = Ricochet, NV = No verdict.

SC/Jn81/MiS16

An Alternative Sightings Estimate of the Minke Whale Population in Area III from Data from the 1979/80 Assessment Cruise

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ABSTRACT

Minke whale population estimates for Area IV from sightings data from the 1978/79 assessment cruise were obtained using both stratification and contouring techniques.

Horwood's stratification analysis of the 1979/80 cruise sightings data yielded an estimate of some 71,000 exploitable minkes for Area III. This paper analyses these data using the contouring technique, and obtains an estimate of some 87,000 exploitable minkes.

The discrepancies between estimates for each of the areas is discussed. This points to the need for further investigation to establish the most appropriate procedure for calculating effective search half-width.

INTRODUCTION

Two methods have been used to obtain estimates of the minke whale population in Area IV from the 1978/79 assessment cruise sightings data. Best and Butterworth (1980) used a contouring technique on daily estimates of minke school density to obtain an estimate of the total number of schools; this was then multiplied by a mean school size to obtain an abundance estimate (78,000 exploitable minkes).

Chapman (1980) utilised a different approach, stratifying both by area and school size, with uniform density being assumed within each of the two area strata. His resultant estimate was 147,000 for the total population. Multiplying by a percentage takeable figure of 82% (utilised in Best and Butterworth (1980)) yields an estimate of 121,000 exploitable minkes.

Horwood's (1981) analysis of the 1979/80 assessment cruise sightings data uses essentially Chapman's stratification approach, obtaining an estimate of 71,250 recruited minke whales for Area III.

Since the two approaches yield estimates for Area IV that differ quite substantially, it is of interest to obtain an alternative estimate from the 1979/80 data for Area III using the contouring technique, to compare this with Horwood's result.

CALCULATION METHOD

The method used for this assessment is essentially identical to that of Best and Butterworth (1980) for the 1979/80 cruise in Area IV.

Data collected on the cruise were encoded and checked by validation programs. Resultant minor changes mean that the data base is marginally different from that used by Horwood.

Number of schools

Daily mean school density estimates were calculated from the number of primary sightings on each day. The untruncated negative exponential $g(y) = e^{-\lambda y}$, where y is the perpendicular distance from the track-line, was used to estimate effective search half-width, with the parameter λ being separately estimated for each vessel for each leg of the cruise. Results are shown in Table 1; the estimates of λ were made utilising only those primary sightings for which distances could be calculated on a speed × time-to-close basis.

These density estimates were plotted at the vessel's noon position for the appropriate day, and a density contour map drawn by hand (Fig. 1). The area between successive contours was measured using a digitiser; multiplying this area by the average of the density values for the two contours concerned, and summing over all contours, yields an estimate for the total number of minke whale schools. Results are shown in Table 2; the totals are as follows:

Number of schools:	Area III W (Long. 0°–35° E)	14,466
	Area III E (Long. 35°–70° E)	10,617
	Total for Area III	25,083

Mean school size

The observed mean school size is a biased estimate of the true average as larger schools are more likely to be sighted, particularly away from the track-line. To allow for this Best and Butterworth (1980) calculated the mean school size and associated standard error for primary sightings in successive intervals of 0.1 nautical miles away from the track-line. A weighted least squares straight line was fitted to these data, with weights inversely proportional to the squared standard error of the mean, and only intervals containing at least five sightings being considered.

The results of such a regression fit to the 1979/80 data are shown in Fig. 2 and Table 3. Only primary minke sightings for which school size is confirmed and y calculable on a speed × time-to-close basis are included in the data fitted. If $\bar{s}(y)$ is the mean school size observed at distance y, the regression fit for all cruise sectors combined yields:

$$\bar{s}(y) = 2.35 + 1.07y \quad \text{(y in nautical miles)}$$

The true mean school size is then taken to be $\bar{s}(0)$ on the assumption that all schools on the track-line are seen. This yields

$$\bar{s}(0) = 2.35 \pm 0.32$$

where the error quoted refers to one standard deviation (i.e. standard error of the mean).

---

* Revised since July 1981 Meeting.

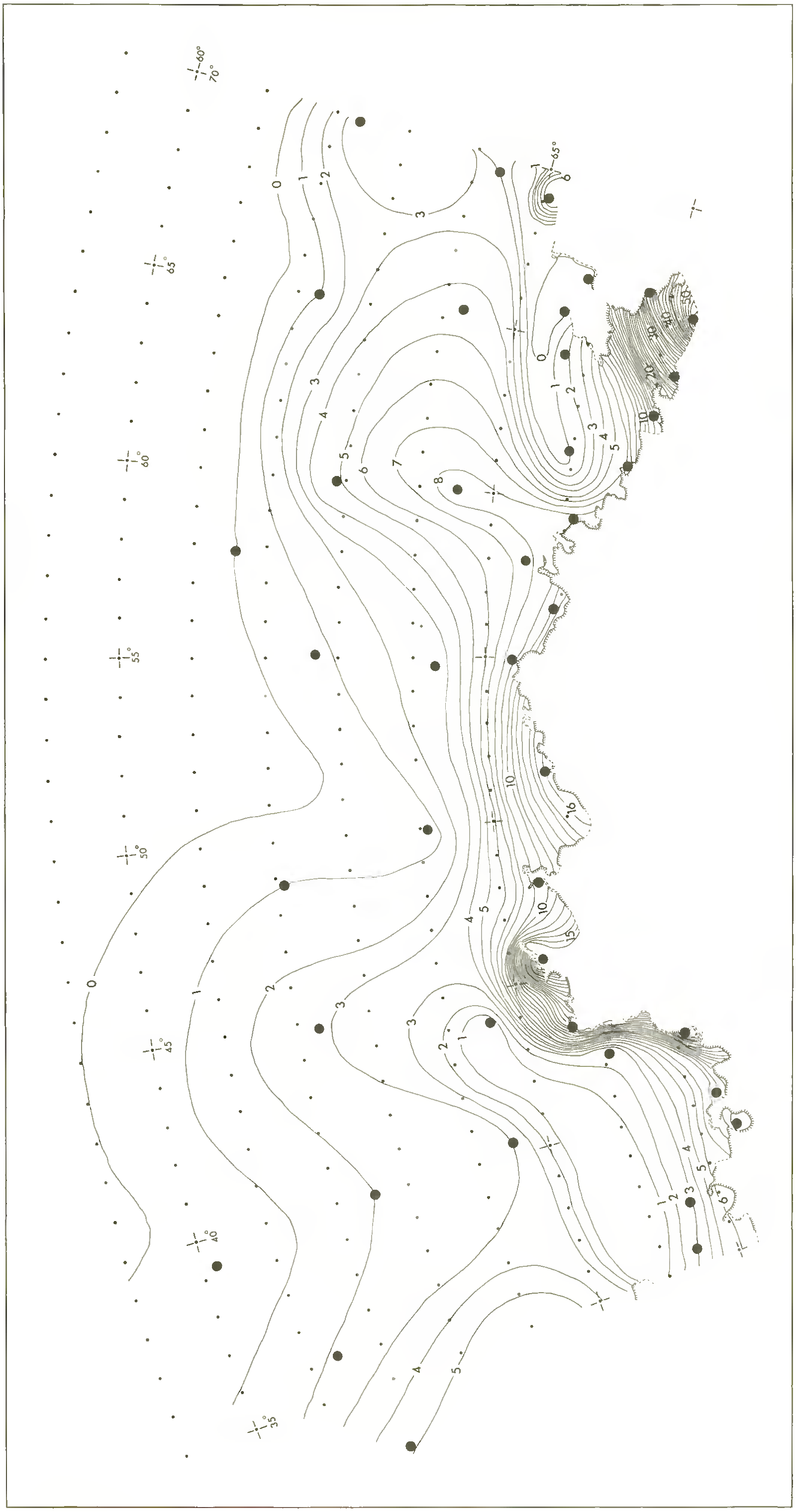

Fig. 1b. Contours of equal density of minke whales in Area III E (cruise leg 1) as for Fig. 1a.

The correlation coefficient for this fit is somewhat low ($r = +0.28$), compared to the 1978/79 data which yielded $r = +0.85$. The justification for a linear regression in this case is thus somewhat in doubt, and alternative procedures of taking the mean school size of all sightings with y less than, say, 1.0 or 0.5 nautical miles, might be argued to be more appropriate in this situation. The associated values are 4.04 and 3.55 respectively, which are less than the mean for all primary sightings of 4.13 (see Fig. 3).

The mean school size estimate is significantly affected by three 'outlier' sightings of school size greater than 50, specifically schools of size 95 ($y = 0$), 115 ($y = 0.48$) and 65 ($y = 0.87$). Omitting these observations would decrease mean school size estimates by some 20%, except that the regression fit estimate increases by some 10% to 2.62, but with correlation coefficient declining to $r = +0.04$.

Correction/Conversion factors

As in Best and Butterworth (1980) a multiplicative correction factor of 0.96 (i.e. = −4%) is used to correct for target motion.

The 1978/79 data showed an excess of observations far from the track-line compared to the predication of the negative exponential form for g(y). The 1979/80 data show a similar effect (Butterworth 1982).

Truncating the negative exponential at $y = 0.4$ nautical miles as in Best and Butterworth (1980) to offset this bias, yields correction factors for the four cruise sectors of 2.78; 1.42; 2.13; and 2.95, whose average is 2.32.

This is similar to the value of 2.06 for the 1978/79 cruise (Butterworth 1982). (This value is higher than the 1.64 quoted in Best and Butterworth (1980), as that calculation used also y-values calculated from estimated distances for

Table 1a

Estimates of minke whale density from sightings: *Kyo-Maru* 27

Date	Noon position		Primary sightings	Density Sch/Mile^2	Standard deviation	Prim. eff. naut. miles
Leg 1—Eff. search half-width 0.542 nautical miles (no. obs. 143)						
27.12.1979	61.56	33.02	9	0.049	0.017	167.7
28.12.1979	66.31	35.26	4	0.030	0.015	124.8
29.12.1979	66.37	36.57	3	0.027	0.016	102.2
30.12.1979	67.33	38.59	8	0.108	0.039	68.5
31.12.1979	67.22	40.12	9	0.084	0.029	98.2
1.1.1980	67.11	42.30	15	0.225	0.061	61.4
2.1.1980	65.42	43.27	12	0.162	0.049	68.1
3.1.1980	65.24	45.28	17	0.294	0.075	53.3
4.1.1980	65.31	48.00	9	0.096	0.033	86.4
5.1.1980	65.46	51.26	12	0.160	0.048	69.0
6.1.1980	65.24	54.48	10	0.089	0.029	103.3
7.1.1980	65.55	56.28	8	0.104	0.038	70.6
8.1.1980	65.30	57.59	6	0.075	0.031	74.1
9.1.1980	66.07	59.21	11	0.085	0.027	119.2
10.1.1980	66.48	61.13	6	0.066	0.027	84.3
11.1.1980	67.06	63.02	7	0.137	0.053	47.2
12.1.1980	67.14	64.22	13	0.279	0.081	42.9
13.1.1980	67.21	66.24	11	0.530	0.166	19.1
14.1.1980	66.42	66.57	4	0.399	0.202	9.2
15.1.1980	65.38	65.50	0	0.000	No est	3.6
16.1.1980	65.52	67.00	0	0.000	No est	41.6
Leg 2—Eff. search half-width 0.440 nautical miles (no. obs. 50)						
28.1.1980	67.06	31.21	5	0.060	0.028	94.4
29.1.1980	65.21	29.52	1	0.006	0.006	206.1
30.1.1980	64.08	25.03	6	0.048	0.021	142.0
31.1.1980	66.52	25.01	8	0.074	0.028	123.5
1.2.1980	68.05	22.12	11	0.096	0.032	129.8
2.2.1980	66.06	19.53	1	0.007	0.007	163.4
3.2.1980	64.00	18.46	0	0.000	No est	82.3
4.2.1980	65.10	15.05	2	0.013	0.009	174.4
5.2.1980	67.25	14.46	5	0.110	0.052	51.6
6.2.1980	68.01	11.55	5	0.041	0.019	137.6
7.2.1980	67.09	10.02	1	0.026	0.026	44.0
8.2.1980	65.00	9.10	1	0.006	0.007	175.0
9.2.1980	66.12	5.03	4	0.035	0.018	130.0
10.2.1980	68.06	3.28	6	0.051	0.022	133.2
11.2.1980	68.05	0.03				0.0
12.2.1980	68.01	0.07				0.0
13.2.1980	67.29	0.30	0	0.000	No est	108.4
14.2.1980	64.38	0.26	2	0.019	0.014	120.0

Note: There are a few marginal differences in this table from comparable figures in Horwood's Table 8, following encoding and validation of data from the cruise. The density standard deviation estimates quoted are calculated from an approximate expression for the coefficient of variation

$$\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

where n_1 is the number of primary sightings on the day concerned, and n_2 the number of sightings from which the effective search half-width for that cruise-leg was calculated.

Table 1b

Estimates of minke whale density from sightings: *Toshi-Maru* 11

Date	Noon position		Primary sightings	Density Sch/Mile^2	Standard deviation	Prim. eff. naut. miles
Leg 1—Eff. search half-width 0.554 nautical miles (no. obs. 59)						
27.12.1979	61.24	35.59	4	0.023	0.012	158.1
28.12.1979	60.45	39.12	1	0.005	0.005	168.0
29.12.1979	62.32	39.55	3	0.020	0.012	136.1
30.12.1979	64.31	40.18	4	0.030	0.016	118.4
31.12.1979	66.05	42.14	4	0.023	0.012	159.6
1.1.1980	64.36	44.00	1	0.007	0.007	127.0
2.1.1980	62.17	44.44	4	0.030	0.015	122.0
3.1.1980	62.05	48.46	2	0.010	0.007	174.2
4.1.1980	64.05	49.55	1	0.007	0.007	135.0
5.1.1980	64.18	54.46	4	0.027	0.014	132.0
6.1.1980	62.40	54.04	1	0.007	0.007	126.0
7.1.1980	61.35	57.55	0	0.000	No est	187.2
8.1.1980	62.35	59.56	7	0.051	0.020	125.1
9.1.1980	64.29	60.01	9	0.089	0.032	91.6
10.1.1980	65.58	61.31	2	0.011	0.008	169.2
11.1.1980	65.46	64.34	1	0.019	0.019	48.4
12.1.1980	64.15	65.20	6	0.047	0.020	116.1
13.1.1980	62.17	65.01	2	0.010	0.007	175.7
14.1.1980	62.19	69.56	5	0.037	0.017	123.1
15.1.1980	64.20	69.32	1	0.020	0.020	44.4
16.1.1980	65.06	69.08	3	0.068	0.040	40.0
Leg 2—Eff. search half-width 0.487 nautical miles (no. obs. 143)						
25.1.1980	68.47	32.47	5	0.121	0.055	42.6
26.1.1980						
27.1.1980	68.49	30.11	2	0.014	0.010	142.2
28.1.1980	69.21	27.29	11	0.240	0.075	47.0
29.1.1980	69.33	26.13	8	0.206	0.075	39.8
30.1.1980	69.56	24.39	6	0.072	0.030	85.4
31.1.1980	69.14	21.30	17	0.411	0.105	42.5
1.2.1980	68.55	19.52	12	0.337	0.101	36.6
2.2.1980	68.33	18.01	11	0.152	0.047	74.4
3.2.1980	68.18	17.55	8	0.279	0.101	29.4
4.2.1980	68.20	16.06	11	0.131	0.041	86.2
5.2.1980	69.01	12.36	3	0.032	0.019	96.5
6.2.1980	68.57	9.40	12	0.166	0.050	74.3
7.2.1980	68.19	9.31	1	0.037	0.037	27.8
8.2.1980	68.42	7.01	6	0.359	0.150	17.1
9.2.1980	68.42	5.54	5	0.196	0.089	26.2
10.2.1980	68.45	5.34	12	0.358	0.108	34.4
11.2.1980	69.27	3.39	9	0.470	0.162	19.6
12.2.1980	69.21	1.50	6	1.270	0.529	4.8
13.2.1980	69.22	0.05	9	0.130	0.045	70.8

sightings where speed × time-to-close data were not available. This paper, as Butterworth (1982), uses only sightings for which speed × time-to-close data are available, in this context.)

Percentage takeable records of confirmed minke whale school sightings during the cruise average values of 52.5% (374 schools) for T11 observations, and 79.8% (280 schools) for the K27. Horwood (1981) discusses the difference between these values; as with his estimate, an average of the two values of 66% will be used here.

(Note that no allowance has been made here for the distance measurement inaccuracy bias—'smearing' correction—discussed in Butterworth (1982).)

POPULATION ESTIMATE

Neglecting first the correction/conversion factors above, the population estimate is calculated using the equation

$$P' = \bar{s}\, N'$$

where the mean school size $\bar{s} = 2.35$ and number of schools $N' = 25{,}083$.

This yields a population estimate of 58,945 minke whales (Area III W: 33,995; Area III E: 24,950).

Incorporating the correction/conversion factors gives an estimate:

$$P = t\, e\, m\, P'$$

where t = proportion takeable = 0.66
e = effect of truncating negative exponential for $g(y) = 2.32$
m = correction for whale movement = 0.96.

The final estimate of exploitable minke whales in Area III is thus 86,646 (Area III W: 49,971; Area III E: 36,675). This compares with Horwood's estimate of 71,250 (Area III E: 43,680; Area III E: 27,570).

DISCUSSION

Approaches used in the Best and Butterworth (1980) Area IV estimate were mirrored here as closely as possible to obtain comparable estimates.

However some of these techniques do not appear as suitable for the Area III data as they might have done for Area IV. The regression method for mean school size estimation is unconvincing with its associated low correlation coefficient. Fig. 3 shows that whatever strip width about the track-line is chosen, the mean school-size of schools observed within the strip always exceeds 3, compared to the 2.35 calculated by regression. It is interesting that Horwood's analysis also corresponds to a larger overall mean school size (3.21). Chapman's Area IV analysis similarly yielded a larger overall mean school size (3.94), than the regression technique (2.64).

Using a larger value for the mean school size would further increase the discrepancy between Horwood's estimate and that of this paper. The root of this difference is the factor allowing for truncation of the negative exponential. In this analysis a large factor (2.32) for overall truncation at 0.4 nautical miles is used; Horwood truncated only for small schools in the South-East sector.

Further investigation to establish the most appropriate procedure for calculating the effective search half-width for minke whale sightings is clearly a priority, because of the considerable differences alternative calculations yield for this parameter.

The contouring estimate for Area III of this paper is greater than Horwood's stratification estimate by 22%.

For Area IV the difference was in the opposite direction with the contouring estimate being 36% smaller. A fairer comparison should however use a conversion factor for truncating the negative exponential, derived only from speed × time-to-close distance calculations as was the case for Area III; this would reduce the Area IV discrepancy to

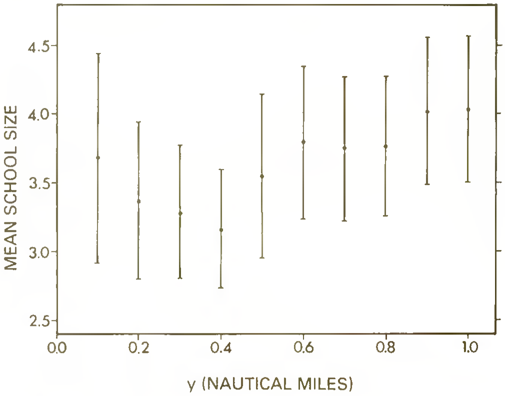

Fig. 3. Mean school sizes for all primary sightings within a distance y from the track-line, and the associated standard errors. Sightings are from all four cruise sectors combined.

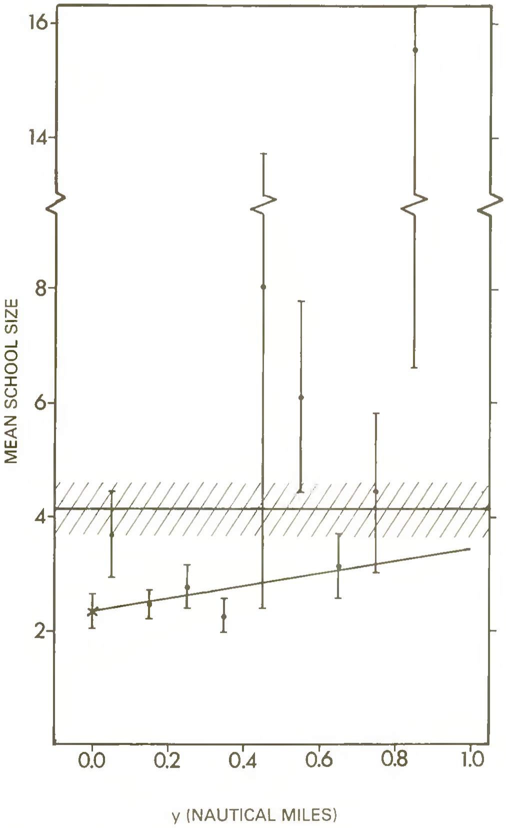

Fig. 2. Mean school sizes of minke whale schools in bands of width 0.1 nautical miles from the track-line as determined from primary sightings, for all four cruise sectors combined. The values are plotted against y, the distance of the band centre from the track-line, and the error bars represent the standard error of each mean. The horizontal band is the mean and associated standard error for all primary sightings (irrespective of their y values). The weighted least squares straight line fit is shown, with the associated extrapolated value $\bar{s}(0)$ at $y = 0$ and its standard error.

Table 2

Estimates of number of minke whale schools from area between density contours

Density interval (schools/100 mi²)	Area III W		Area III E	
	Area (mi²)	No. of schools	Area (mi²)	No. of schools
0–1	49.243	246.2	67,897	339.5
1–2	39.360	590.4	58,506	877.6
2–3	40.201	1,005.0	60,389	1,509.7
3–4	30.025	1,050.9	37,456	1,311.0
4–5	16,906	760.8	18,921	851.4
5–6	15.913	875.2	14,573	801.5
6–7	13,680	889.2	11.896	773.2
7–8	15.619	1,171.4	8,508	638.1
8–9	10.333	878.3	6.516	553.9
9–10	6,720	638.4	2,556	242.8
10–11	3.874	406.8	2,093	219.8
11–12	4.556	523.9	1,765	203.0
12–13	4,082	510.3	1,438	179.8
13–14	821	110.8	1,287	173.7
14–15	1.236	179.2	1,268	183.9
15–20	6,495	1,136.6	3,143	550.0
20–25	4.703	1,058.2	1.151	259.0
25–30	2,065	567.9	726	199.7
30–35	1.536	499.2	429	139.4
35–40	653	244.9	392	147.0
40–45	424	180.2	445	189.1
45–50			405	192.4
50–55			156	81.9
Misc.‡	2,967	942.1		
Total	271.412	14,465.9	301.916	10.617.4

‡ An estimate for three miscellaneous areas where, because of the large number of contours, individual area digitising was not practical.

Table 3

Estimates of mean school size from primary sightings of minke whales

Procedure	All primary sightings			Omission of outliers (see text)			K27 North-West Sector			T11 South-West Sector			T11 North-East Sector			K27 South-East Sector		
	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings	Value	Standard error	No. of sightings
$\bar{s}$(No y restriction)	4.13	0.46	381	3.43	0.20	378	2.27	0.29	48	5.52	1.14	134	4.54	0.48	56	3.28	0.52	143
$\bar{s}(y<1.0$ n. miles)	4.04	0.53	323	3.22	0.22	320	2.02	0.25	43	5.79	1.33	115	3.82	0.43	45	3.16	0.61	120
$\bar{s}(y<0.5$ n. miles)	3.55	0.59	255	2.74	0.16	253	1.89	0.25	36	5.55	1.52	97	3.16	0.44	31	2.20	0.16	91
$\bar{s}(y = 0)$ (Regression fit)	2.35	0.32	319	2.62	0.23	316	1.69	0.45	39	3.72	0.75	110	2.17	0.56	39	2.19	0.21	110
Equation	$\bar{s}(y) = 2.35 + 1.07y$			$\bar{s}(y) = 2.62 + 0.10y$			$\bar{s}(y) = 1.69 + 0.96y$			$\bar{s}(y) = 3.72 - 1.33y$			$\bar{s}(y) = 2.17 + 2.58y$			$\bar{s}(y) = 2.19 - 0.42y$		
Correlation coefficient	$r = +0.28$			$r = +0.04$			$r = +0.43$			$r = -0.27$			$r = +0.41$			$r = -0.24$		

19%, but still in the opposite direction to that for Area III (i.e. Best and Butterworth Area IV estimate raised to 98,000 c.f. Chapman's 121,000).

Part of the difference remaining may be attributed to the Horwood's area stratification being more conservative than that of Chapman's for Area IV. Chapman's high density stratum comprised 23% of the area considered in Area IV, while Horwood's made up only 13% of that in Area III.

If Chapman's high density stratum is reduced to the same proportion of the total area as Horwood's (13%), his estimate would drop by 12% to 107,000.

In summary then, making the adjustments discussed above, the contouring (98,000) and stratification (107,000) estimates for Area IV are not dissimilar, with the stratification slightly the higher (by 9%). This compares with Area III where the contouring (87,000) exceeds the stratification (71,000) by 22%. This remaining difference may be attributed in part to the greater negative exponential truncation correction factor used for Area III contouring estimate (2.32), compared to Area IV (2.06).

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REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise 1978/79. *Rep. int. Whal. Commn* 30: 257–283.

Butterworth, D. S. 1982. On the functional form used for g(y) for minke whale sightings, and bias in its estimation due to measurement inaccuracies. Paper SC/Jn81/MiS18 (published in this volume).

Chapman, D. G. 1980. Stratified estimate of Area IV Series B minke whale population from sightings data of assessment cruise 1978/79 and estimate of its variance. *Rep. int. Whal. Commn* 30: 100–101.

Horwood, J. W. 1981. Results from the IWC/IDCR minke marking and sightings cruise 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

SC/Jn81/MiS18

On the Functional Form Used for g(y) for Minke Whale Sightings, and Bias in its Estimation due to Measurement Inaccuracies

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ABSTRACT

On the minke whale assessment cruises, the angle of sightings from the trackline, and speed and time-to-close to sightings are recorded only at intervals of 5°, one knot, and 1 minute respectively. This procedure leads to a positive bias in density estimates, arising particularly from sightings with angle or time-to-close recorded as zero.

A simulation technique termed 'smearing' is developed to quantify this bias. Though the bias is small for the untruncated negative exponential fit to g(y), it can become substantial for the truncated case (e.g. some 20% for truncation at 0.4 nautical miles).

The bias due to these measurement inaccuracies on density estimates using the Kelker strip and generalised exponential $g(y) = e^{-\lambda y^p}$, is also investigated. The generalised exponential with $p = 0.6$ provides a much improved fit to data compared to the negative exponential ($p = 1$); the associated higher density estimates should however be considered with care, as positive bias is likely to result from the seemingly unrealistic shape of the generalised exponential near $y = 0$.

INTRODUCTION

In estimating the Area IV minke whale population from sightings data from the 1978/79 assessment cruise, Best and Butterworth (1980) used the negative exponential $g(y) = e^{-\lambda y}$ (Gates *et al.*, 1968) to represent the probability of sighting a whale school as a function of y, the right-angle distance from the track-line.

They noted however that the data showed more observations at large y than this parametrization would suggest. These observations negatively biased the estimate of λ:

$$\hat{\lambda} = \frac{n-1}{\sum_{i=1}^{n} y_i} \tag{1}$$

and hence also the population estimate:

$$\hat{N} = \frac{nA}{2L}\hat{\lambda} \tag{2}$$

(n = no. of sightings; y_i = right angle distance of i^{th} sighting from track-line).

To allow for this they 'truncated' observations, with only those for which y was less than cut-off distance 'a' being considered. An adaption of equation (1) allowing for this restriction was then used to re-estimate populations.

Best and Butterworth semi-arbitrarily chose a value of $a = 0.4$ naut. miles to calculate their revised estimates. The procedure was however not particularly satisfactory, as estimates continued to increase as the value of the cut-off 'a' was decreased, rather than stabilising as had been hoped.

This paper investigates the role played in this truncation instability by the manner in which the y_i values are calculated, and the effect on estimates of replacing the negative exponential form for g(y) by the generalised exponential (Quinn and Gallucci, 1980) $g(y) = e^{-\lambda y^p}$.

MEASUREMENT INACCURACIES

For the minke whale assessments, y has been calculated from the relation:

$$y = r \sin \theta \tag{3}$$

where r is the distance from the vessel to the whale school sighted, and θ is the angle between the direction the vessel is heading (the track-line), and the direction of the school sighted.

The angle θ is almost always recorded as a multiple of 5°. The distance r can be calculated by multiplying the vessel's speed by the time it takes to close with the whale school. The speed is generally recorded to the nearest knot, and the time to the nearest minute. Alternatively if the top-man's estimate of the distance to the school when sighted is utilised, this value for r is usually recorded to the nearest tenth of a mile for distances less than one nautical mile, or nearest half a mile for greater distances. The set of possible value for y_i is thus discrete rather than continuous.

The discrete nature of these observations can introduce a bias into the population estimate N. For example, a sighting for which θ is recorded as 0° will yield an associated estimate $y = 0$ irrespective of the value of r. However if θ is in fact measured correct only to the nearest 5°, the actual value of θ when recorded as 0° may lie anywhere between 0° and 2½°, with $y = 0$ being the lower limit of a range of possible values for y. Similarly sightings with time-to-close recorded as zero minutes, also yield $y = 0$ which is actually the lower limit of a range of possible values.

Thus, while sightings with non-zero recorded values for θ and the time-to-close will yield a y value that could be either an under- or over-estimate of the true distance, sightings where either of these is recorded as zero can only underestimate y.

One expects therefore that

$$\sum_{i=1}^{n} y_i$$

in equation (1) will be underestimated, and the population overestimated. To attempt to quantify this bias, a simulation method referred to as 'smearing' has been utilised.

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† This paper is a combination, with revisions, of unpublished documents SC/32/Mi12 (July 1980); SS/6 (Sightings Workshop, Sept. 1980); and SC/Jn81/MiS18.

THE SMEARING SIMULATION

This analysis considers only sightings for which r is calculable on a speed x time-to-close basis, with

$$y = vt \sin \theta$$

$$\text{where} \begin{cases} v = \text{vessel speed (knots)} \\ t = \text{time to close (minutes)} \end{cases}$$

In the simulation the set of y values calculated from the recorded measures of v, t and θ: $\{y_i\}$, is replaced by a simulated set $\{y_i'\}$ calculated as follows:

$$y' = v'\, t' \sin \theta' \tag{4}$$

$$\begin{cases} v' = v + \alpha_1 \Delta v \\ t' = |t + \alpha_2 \Delta t| \\ \theta' = |\theta + \alpha_3 \Delta\theta| \end{cases}$$

where $\alpha_1, \alpha_2, \alpha_3$ are numbers chosen at random according to a uniform distribution over the range $[-\frac{1}{2}, +\frac{1}{2}]$.

Values of $\Delta v = 1$ knot and $\Delta t = 1$ minute are reasonably clear choices on the basis of the recording procedure for these variables, and assuming such accuracy is achieved. A similar choice of $\Delta\theta = 5°$ would seem indicated. However the data indicate a favouring of even over odd multiples of 5° in values recorded for θ. For the 1978/79 cruise sectors the ratio of even/odd multiples were: T16(S) (95/29); T16(N) (82/17); T18(S) (107/66); T18(N) (65/14). This suggests that angle estimates are in reality not measured more accurately than the nearest 10°, so that a choice of $\Delta\theta = 10°$ seems more appropriate.

For each set $\{y_i'\}$ so generated, a value of

$$\left(\sum_{i=1}^{n} y'_i\right)^{-1}$$

is calculated; the average of this value over a large number of simulated sets is then used in equation (1) (or its adaptions) to offset the bias due to the original measurement inaccuracies.

For a typical cruise sector, averaging over 900 such simulated sets yielded a standard error of the mean

$$\text{s.e.m.} \left[\left(\sum_{i=1}^{n} y'_i\right)^{-1}\right] \lesssim 0.2\%,$$

which is not of significance. In practice, 100 sets would customarily be used.

This method of smearing has one undesirable property. Observations recorded with both $t = 0$ and $\theta = 0$ will yield:

$$y \propto |\alpha_2 \alpha_3|$$

This has a distribution that behaves as $-\ln y$, which diverges as $y \rightarrow 0$. The uniform distribution assumption for smearing t and θ values for observations recorded with $t = 0$ and $\theta = 0$, cannot therefore be exactly correct. However though this procedure thus produces an unrealistic peak in the simulated g(y) on a scale ~0.01 nautical miles, estimates with cut-off (a) values much greater than this scale are not substantially affected.

THE GENERALISED EXPONENTIAL

The generalised exponential form for g(y) may be written

$$g(y) = e^{-\lambda y^p} \tag{5}$$

For $p = 1$ this corresponds to the negative exponential. With $p < 1$ this form produces both a sharper peak at $y = 0$, and a slower fall-off with large y, than does the negative exponential; this is of interest as the data appear to show both these features.

For a fixed value of p, the maximum likelihood estimate of the parameter λ for a fit to observations with $y \leqslant a$ is given by iterative solution of the equation:

$$\hat{\lambda} = \frac{\tilde{n}}{p \sum_{i=1}^{\tilde{n}} y_i^p} \left\{ 1 - \frac{p}{\Gamma_\alpha(\frac{1}{p})} (\alpha)^{\frac{1}{p}} e^{-\alpha} \right\} \tag{6}$$

$$\text{where} \begin{cases} \alpha = \hat{\lambda} a^p \\ \Gamma_\alpha(x) = \int_0^\alpha u^{x-1}\, e^{-u}\, du \quad \text{(incomplete Gamma function).} \end{cases}$$

$$\text{and} \begin{cases} \tilde{n} = \text{no. of observations with } y_i \leqslant a \\ \Sigma \text{ extends only over observations with } y_i \leqslant a \end{cases}$$

The associated estimate of whale school density $D(= N/A)$ is given by

$$\hat{D} = \frac{\tilde{n}\, p (\hat{\lambda})^{1/p}}{2L\, \Gamma_\alpha(\frac{1}{p})} \tag{7}$$

with associated coefficient of variation given approximately by

$$[\text{c.v.}(\hat{D})]^2 \approx \frac{1}{\tilde{n}} \left[1 + \frac{1}{p} \left\{ 1 - \frac{p(\alpha)^{\frac{1}{p}} e^{-\alpha}}{\Gamma_\alpha(\frac{1}{p})} \right\}^2 \times \right.$$
$$\left. \times \left\{ 1 - \frac{p(\alpha)^{\frac{1}{p}} e^{-\alpha}}{\Gamma_\alpha(\frac{1}{p})} \left[\alpha + \frac{(\alpha)^{\frac{1}{p}} e^{-\alpha}}{\Gamma_\alpha(\frac{1}{p})} - \frac{1}{p} + 1 \right] \right\}^{-1} \right] \tag{8}$$

The smearing simulation may be carried out in similar fashion to that for the negative exponential, with

$$\sum_{i=1}^{\tilde{n}'} (y_i')^p$$

replacing

$$\sum_{i=1}^{n} y_i'$$

in the average over the simulated observation sets. Note that $\tilde{n}'$ will vary for the different sets $\{y_i'\}$; the average value $\overline{\tilde{n}'}$ is used for $\tilde{n}$ in the formulae above.

THE KELKER STRIP

This estimating procedure assumes that all schools within the cut-off distance 'a' are seen. The density estimate is

$$\hat{D} = \frac{\tilde{n}}{2\,L\,a} \qquad \text{c.v.}\,(\hat{D}) = \frac{1}{\sqrt{\tilde{n}}} \tag{9}$$

Incorporating the smearing simulation, the estimate is adjusted to:

$$D = \frac{\overline{\tilde{n}'}}{2\,L\,a} \qquad \text{c.v.}\,(\hat{D}) = \frac{1}{\sqrt{\overline{\tilde{n}'}}} \tag{10}$$

Since the data does indicate a fall-off of sightings with y, the assumption of this procedure is optimistic, and will produce negatively biased estimates, provided the appropriate smearing adjustment is made to allow for measurement inaccuracies. The larger the Kelker strip half-width 'a' chosen, the greater will be this bias.

RESULTS AND DISCUSSION

Negative Exponential ($p = 1$)
For consistency in comparison with the generalised exponential, results quoted here have utilised the maximum likelihood estimator for $\hat{\lambda}$ without allowance for bias (i.e. $(n - 1) \rightarrow n$ in equation (1)). As n is typically $\gtrsim 50$, the difference is insubstantial.

The effect of different choices for $\Delta\theta$, the assumed angular inaccuracy, is shown in Fig. 1 for the T16(N) sector of the 1978/79 cruise. Density estimates are decreased marginally for the untruncated case; as the cut-off value 'a' is decreased, differences become more substantial. This is as would be expected, because $y = 0$ observations play a proportionately greater role in

$$\sum_{i=1}^{\hat{n}} y_i$$

as the cut-off value decreases.

Also as might be expected, the larger the value chosen for $\Delta\theta$, the greater the decrease in density estimates. The results following all take $\Delta\theta = 10°$.

Table 1 compares the observed distribution of sightings with y for 16T(N), with that predicted by the untruncated negative exponential, for both original and smeared data. The smeared set shows a slightly improved fit, though neither satisfy the χ^2 test at the 1% level.

Table 1

Comparison of fits of the untruncated negative exponential ($p = 1$) and generalised exponential ($p = 0.6$) to g(y) data for the T16(N) cruise sector in 1978/79

(a) Without smearing

y nautical miles	Observed	Expected $p = 1.0$	Expected $p = 0.6$
0.00–0.10	48	27.9	44.0
0.10–0.20	13	19.4	18.3
0.20–0.30	6	13.4	10.0
0.30–0.40	6	9.3	6.0
0.40–0.50	2	6.5	3.8
0.50–0.60	5	4.5	2.5
0.60–0.70	1	3.1	1.7
0.70–0.80	1	2.2	1.2
0.80–0.90	0	1.5	0.9
0.90–1.00	1	1.0	0.6
> 1.00	8	2.3	1.9
χ^2 (4 deg. freedom) (0.40–1.00 grouped)		34.5	9.8
P		<0.0001	0.044

(b) With smearing

y nautical miles	'Observed'	Expected $p = 1.0$	Expected $p = 0.6$
0.00–0.10	46.1	26.5	37.5
0.10–0.20	13.4	18.8	17.8
0.20–0.30	6.9	13.3	10.6
0.30–0.40	5.6	9.4	6.9
0.40–0.50	4.6	6.7	4.7
0.50–0.60	2.7	4.7	3.3
0.60–0.70	1.7	3.4	2.4
0.70–0.80	1.0	2.4	1.8
0.80–0.90	0.7	1.7	1.3
0.90–1.00	1.0	1.2	1.0
> 1.00	7.4	2.9	3.7
χ^2 (4 deg. freedom)		27.7	7.8
P		0.00001	0.099

Smearing correction factors are listed in Table 2 for all sectors of the 1978/79 and 1979/80 cruises, with their averages for each Area. For the untruncated case, the decrease is small: 3% for both 1978/79 and 1979/80.

Without smearing, truncation at $a = 0.4$ nautical miles indicates a multiplicative correction factor of 2.06 for 1978/79 and a similar value of 2.32 for 1979/80. (The first differs from the 1.64 value used in Best and Butterworth (1980) due to exclusion of sightings where only top-man estimates of r were available, and a slightly different selection of primary sightings.)

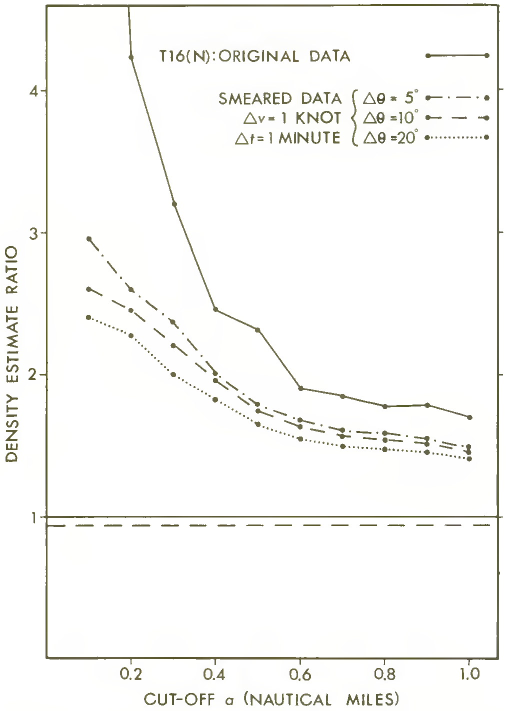

Fig. 1. Density estimates for the truncated negative exponential form for g(y) are shown as a function of the cut-off distance 'a' for the T16(N) cruise sector (1978/79) by the solid line. Estimates are relative to the untruncated negative exponential estimate. The broken lines show the effect of allowing for the bias due to measurement inaccuracies ('smearing'); the different lines correspond to different values assumed for the angle measurement inaccuracy. Horizontal lines represent the untruncated cases.

Incorporation of the smearing for this cut-off value reduces these factors to 1.71 and 1.82 respectively, i.e. a decrease of about 20%.

Calculations indicate that the contributions of the inaccuracies in v, t and θ measurements to the overall bias are effectively independent, i.e. the total correction is given within a few percent by the sum of the corrections for smearing each variable alone. Also to a good approximation these corrections are linear in the magnitude of the inaccuracy (Δv, Δt, $\Delta\theta$) for the orders of magnitude of such inaccuracies considered.

The approximate contributions of the inaccuracies to the bias are: speed negligible (a few percent); time 40%; and angle 60%.

Table 2

Comparison of density estimates for $g(y) = e^{-\lambda y^p}$ for minke whale cruises in 1978/79 and 1979/80. The standard (1) is the untruncated unsmeared negative exponential (p = 1). Figures in brackets represent coefficients of variation

Year	Cruise	Standard $p = 1$ $a = \infty$ no smear	$p = 1$ $a = \infty$ smear	$p = 1$ $a = 0.4$ n.m. no smear	$p = 1$ $a = 0.4$ n.m. smear	$p = 0.6$ $a = 0.4$ n.m. smear
78/79	T16(S)	1 (0.13)	0.97 (0.13)	1.86 (0.17)	1.59 (0.18)	2.33 (0.20)
Area IV	T16(N)	1 (0.15)	0.94 (0.15)	2.45 (0.17)	1.96 (0.18)	3.33 (0.22)
	T18(S)	1 (0.11)	0.98 (0.11)	1.63 (0.17)	1.44 (0.17)	1.93 (0.16)
	T18(N)	1 (0.16)	0.97 (0.16)	2.29 (0.21)	1.86 (0.22)	2.84 (0.26)
	Average		0.97	2.06	1.71	2.61
79/80	K27SE	1 (0.12)	0.96 (0.12)	2.78 (0.17)	1.88 (0.18)	2.68 (0.20)
Area III	K27NW	1 (0.20)	0.98 (0.20)	1.42 (0.30)	1.33 (0.30)	1.74 (0.26)
	T11NE	1 (0.19)	0.99 (0.19)	2.13 (0.29)	1.91 (0.30)	2.92 (0.34)
	T11SW	1 (0.12)	0.96 (0.12)	2.95 (0.16)	2.16 (0.17)	3.45 (0.20)
	Average		0.97	2.32	1.82	2.70
Overall average c.v.		0.15	0.15	0.21	0.21	0.23

Thus improving the accuracy of the speed measurement is of minor concern, while improving the accuracy for θ may prove difficult in practice. However if closure times could be recorded correct to the nearest half-minute rather than nearest minute, a decrease of some 20% in the bias might be expected.

Incorporation of smearing had been hoped to arrest the increase in density estimates as the cut-off value 'a' was decreased (truncation instability). However Fig. 2 shows that for only one cruise sector, T16(S) in 1978/79, does this occur. This suggests that the peak in sightings at $y = 0$ is sharper that the negative exponential parametrization can represent, and that other forms merit investigation.

Generalised exponential

For $p < 1$ the generalised exponential $g(y) = e^{-\lambda y^p}$ shows a sharper peak at $y = 0$ than does the negative exponential. Values of $p = 0.6$ and $p = 0.5$ usually provided the best fits. (It is interesting to note that Quinn and Gallucci (1980) fit a value $p = 0.71$ to shipboard porpoise survey data.) The example of T16(N) in Table 1 shows that the fit for the untruncated case with $p = 0.6$ is a considerable improvement over the negative exponential; incorporation of smearing gives further improvement.

Fig. 2 shows that density estimates for $p = 0.6$ with smearing incorporated show reasonable truncation stability for a number of cruise sectors, and for all sectors there is a distinct improvement in this respect compared to the negative exponential.

Using the generalised exponential increases density estimates. The comparison of relative densities in Table 2 indicates a conversion factor averaging 2.66 for the $p = 0.6$ case truncated at $a = 0.4$ nautical miles, where the untruncated negative exponential without smearing is used as the standard.

Thus though smearing decreases the Area IV estimate of Best and Butterworth (1980) by some 20%, taking $p = 0.6$ would increase it again by about 50%.

The coefficient of variation of the density estimate is increased for this fit compared to the negative exponential. The increase is approximately represented by:

$$\sqrt{\frac{2}{n}} \rightarrow \sqrt{\frac{(1+\frac{1}{p})}{n}} \qquad (11)$$

However the numerical value of this increase appears minimal; Table 2 indicates a rise from 0.21 to 0.23.

Though the generalised exponential does appear to provide an improved fit to the minke whale data, the density estimates it provides need to be considered with

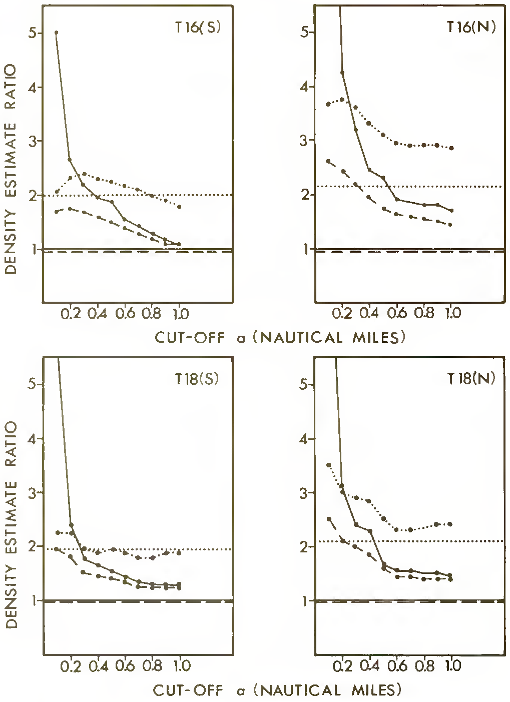

Fig. 2a. Plots of relative density estimates for fits to the generalised exponential $g(y) = e^{-\lambda y^p}$ as a function of the cut-off distance 'a' for cruise sectors of the 1978/79 minke whale assessment cruise. Estimates are relative to the untruncated unsmeared negative exponential (p = 1). Horizontal lines represent the untruncated cases. The negative exponential (p = 1) is shown by the solid line (———) without smearing incorporated, and by the dashed line (- - -) when smearing is taken into account. The dotted line (.....) corresponds to the generalised exponential fit with p = 0.6 and smearing incorporated.

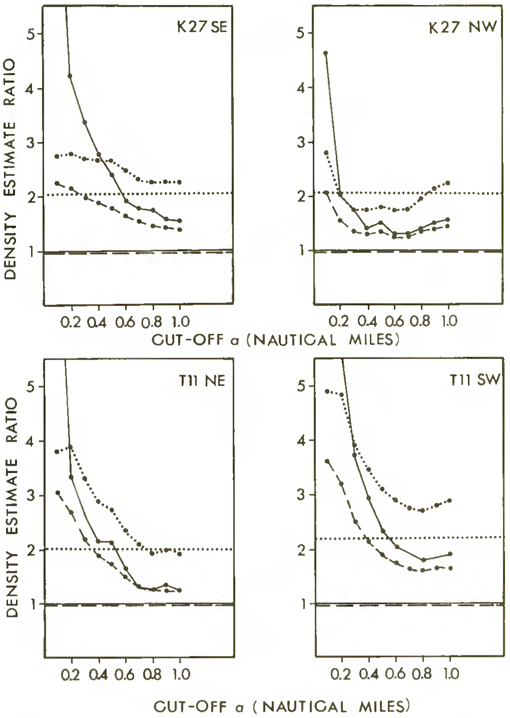

Fig. 2b. As for Fig. 2a for the cruise sectors of the 1979/80 minke whale assessment cruise.

some caution. The reason is the behaviour for $p < 1$ of this form close to $y = 0$, in particular the divergence of $g'(y)$ as $y \rightarrow 0$.

Burnham *et al.* (1980) among others argue for the shape criterion $g'(0) = 0$ for line transect models. Their reasoning is however more applicable to the $g(0) = 1$ situation; with whales it is not unlikely that some animals on the track-line would be missed, and there are some indications that this is the case (e.g. Butterworth *et al.* (1982)).

Even if $g'(0) < 0$ however, an infinite value seems implausible, so that the generalised exponential, though providing a reasonable overall fit to the data, would because of its shape be likely to give positively biased density estimates.

Hazard-rate models for $g(y)$ (e.g. Butterworth (1982a), Hayes and Buckland (1982)) can show a shoulder at $y = 0$ whose width is much less than the effective strip half-width associated with $g(y)$

$$\text{i.e.} \int_0^\infty g(y)dy$$

Again the generalised exponential may produce a reasonable overall approximation, but would be likely to provide positively biased density estimates.

The actual width of any such shoulder is crucial to the quantitative assessment of this bias. This aspect requires further investigation; in the meantime generalised exponential density estimates are probably best regarded in an upper limit context.

Since the structure of the peak at $y = 0$ in sightings is critical to density estimates, it is also important to investigate to what extent it may be a spurious effect caused by other factors. Ship seeking by the minkes could be a factor that would enhance the peak. However observations and analysis (e.g. Horwood, 1981; Butterworth *et al.*, 1982; and Leatherwood *et al.*, 1982) have found no positive indication of ship seeking.

Kelker strip

Results for $a = 0.1$ and $a = 0.2$ nautical miles are shown in Table 3, both with and without smearing being incorporated.

Even with smearing, a strip half-width of 0.1 nautical miles shows a conversion factor corresponding to an increase of some 40% over untruncated negative exponential estimates. Since the Kelker strip estimate is negatively biased, provided the data inaccuracies are adequately represented by the degree of smearing used, this suggests that the untruncated negative exponential is significantly underestimating the density.

Table 3

Comparison of density estimates for Kelker strips for minke whale cruises in 1978/79 and 1979/80. The standard (1) is the untruncated unsmeared negative exponential ($p = 1$). Figures in brackets represent coefficients of variation

		Standard	Kelker strip			
		$p = 1$	$a = 0.1$ n.m.		$a = 0.2$ n.m.	
Year	Cruise	$a = \infty$ No smear	No smear	Smear	No smear	Smear
78/79	T16(S)	1 (0.13)	1.38 (0.14)	1.25 (0.15)	0.94 (0.12)	0.93 (0.12)
Area IV	T16(N)	1 (0.15)	1.44 (0.14)	1.38 (0.15)	0.92 (0.13)	0.89 (0.13)
	T18(S)	1 (0.11)	1.35 (0.15)	1.29 (0.15)	0.97 (0.13)	0.98 (0.13)
	T18(N)	1 (0.16)	1.47 (0.19)	1.40 (0.19)	1.05 (0.16)	1.04 (0.16)
	Average		1.41	1.33	0.97	0.96
79/80	K27SE	1 (0.12)	1.85 (0.14)	1.52 (0.16)	1.26 (0.12)	1.16 (0.13)
Area III	K27NW	1 (0.20)	1.26 (0.28)	1.13 (0.28)	0.95 (0.22)	0.95 (0.22)
	T11NE	1 (0.19)	1.58 (0.25)	1.62 (0.25)	1.09 (0.21)	1.05 (0.22)
	T11SW	1 (0.12)	1.95 (0.14)	1.78 (0.14)	1.23 (0.12)	1.16 (0.13)
	Average		1.66	1.51	1.13	1.08
Overall average c.v.		0.15	0.18	0.18	0.15	0.16

SUMMARY OF CONCLUSIONS

1. Allowing for measurement inaccuracies in the calculation of y ('smearing') indicates that untruncated negative exponential estimates of density should be decreased by some 3%. For truncation at 0.4 nautical miles (cf.: Areas IV and III minke estimates in Best and Butterworth (1980) and Butterworth (1982) respectively), a decrease of about 20% is appropriate.
2. This bias could be reduced by some 20% if the time for the vessel to close with the school sighted could be measured accurate to the nearest ½-minute, rather than the nearest minute.
3. Even with smearing taken into account, the negative exponential provides an inadequate fit to the observed g(y).
4. The 'conservative' Kelker strip approach, with half-strip-width of 0.1 nautical miles, indicates untruncated negative exponential density estimates should be increased by some 40%.
5. The generalised exponential model $g(y) = e^{-\lambda y^p}$ provides a better fit to observations and improved truncation stability of density estimates, compared to the negative exponential.

   Taking p = 0.6 (which provides reasonable and in some cases optimal fits), and incorporating smearing, indicates an increase of some 20% to estimates of Best and Butterworth (1980) and Butterworth (1982) where the negative exponential is truncated at 0.4 nautical miles. However this model is likely to produce positively biased estimates because of its shape near y = 0; the likely magnitude of such bias has yet to be assessed.

The calculations upon which the above conclusions are based have assumed measurement inaccuracies are adequately represented by the specification $\Delta\theta = 10°$, $\Delta v = 1$ knot, $\Delta t = 1$ minute (see equation (4)).

ACKNOWLEDGEMENTS

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REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise 1978/79. *Rep. int. Whal. Commn* 30: 257–283.

Burnham, K. P., Anderson, D. R. and Laake, J. L. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 72: 1–202.

Butterworth, D. S. 1982. An alternative sightings estimate of the minke whale population in Area III from data from the 1979/80 assessment cruise. Paper SC/Jn81/MiS16 (published in this volume).

Butterworth, D. S. 1982a. A possible basis for choosing a functional form for the distribution of sightings with right angle distance: some preliminary ideas. Paper SS/7 (published in this volume).

Butterworth, D. S., Best, P. B. and Basson, M. 1982. Results of analysis of sightings experiments carried out during the 1980/81 Southern Hemisphere minke whale assessment cruise. Paper SC/Jn81/MiS5+13+17 (published in this volume).

Gates, C. E., Marshall, W. H. and Olson, D. P. (1968). Line transect method of estimating grouse population densities. *Biometrics* 24: 135–45.

Hayes, R. J. and Buckland, S. F. 1982. Radial distance models for the line transect method. *Biometrics* (in press).

Horwood, J. W. 1981. Results from the IWC/IDCR minke marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Leatherwood, S., Awbrey, F. T. and Thomas, J. A. 1982. Minke whale response to a transiting survey vessel. Paper SC/Jn81/MiS9 (published in this volume).

Quinn, T. J. II and Gallucci, V. F. 1980. Parametric models for line transect estimators of abundance. *Ecology* 61(2): 293–302.

SC/Jn81/MiS20

Early Changes in the Recruitment Rates of Antarctic Minke Whales Inferred from Recent Age Distributions[1]

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ABSTRACT

The steep slopes of the age compositions of Antarctic minke whale catches are regarded as indicating a gross recruitment rate in excess of natural mortality. This paper reports an effort to discover by simulation what rate of natural mortality and what early changes in r_1 recruitment rates would be necessary to account for the shape of recent age distributions. The exercise strongly indicates a value of M in the range of 0.04 – 0.06 and a severalfold increase in r_1 recruitment rates between 1930 and 1950, when blue whales were being depleted. Alternatively, the steep slopes of recent age distributions could just as well be explained by declining catchability with age or increasing natural mortality with age, of which there is some evidence in the data.

INTRODUCTION

Age composition data on minke whales were obtained at the very beginning of serious exploration in the early 1970s, and the steep slope of these age compositions was soon recognized as the result of a gross recruitment rate exceeding natural mortality, i.e. as the signature of a growing population. This was inferred first from the failure of catch per effort to decrease in the wake of several years of large catches (IWC, 1978) and later from the excess of the slope of the age distributions over any natural mortality rate that could have been balanced by reproduction before 1940, when the mean age at sexual maturity was about 14 years (IWC, 1981).

Masaki (1979) reported a decline in mean age at sexual maturity that began with the 1940 year-class and would therefore have produced some population growth before the beginning of exploitation about 1970. This decline, by itself, would have begun to affect the size of the breeding stock, and therefore the slope of subsequent age distributions, in about 1955. But the steep slope of the age distributions of the early 1970s extends at least to age 40—i.e., back to the 1930 year-class—and therefore presumably reflects some earlier change in reproductive parameters, beginning around the time pelagic whaling commenced in the Antarctic.

The purpose of this paper is to investigate the kind and size of changes in reproductive parameters, beginning in 1930 and later accompanied by the decline in age at sexual maturity, that could account for the age distributions in the early 1970s.

BASIC DATA

The basic data for this study were Japanese biological sampling data from all Antarctic Areas during the seasons 1971/72–1977/78. Most of these data refer to Areas III and IV, where most of the catches were taken, and to avoid possible complications raised by whaling operations before 1930 in Area II and by an apparent stock boundary between Areas IV and V (Wada and Numachi, 1979) only the age compositions from Areas III and IV were used.

There are a number of ways to combine these data—all the age readings can be treated as a random sample; a single key can be constructed from all the age readings and applied to the length distribution of the total catch; separate keys can be constructed for each season and the results summed; and so on. All of these procedures are defensible in the case of minke whales, and they all produce slightly different estimated age compositions for the period. For this study, a single age composition for each sex was obtained by constructing an age-length key for each area/season/sex stratum, applying the key to the corresponding length distribution to estimate an age composition, referring that age composition to the 1971/72 season, and finally summing for each sex. Thus the 14-yr-olds in the female age distribution comprised 14-yr-olds caught in 1971/72, plus 15-yr-olds caught in 1972/73, and so on. In other words, the age distributions so obtained in fact show the catch during the seasons 1971/72–1977/78 from each of the year-classes present in 1971/72.

These age distributions, for males and females, are given in Table 1 and plotted in semilog form in Fig. 1. Beginning with the age of full recruitment, which could be argued to be anywhere between about ten and about twenty years, these distributions should represent the relative abundance in 1971, at the beginning of serious exploitation, of year classes back to about 1930.

Since pelagic operations began in about 1930 in Areas III and IV, it is possible that some increase in the reproductive success of minke whales began at that time in response to a reduction in the biomass of other baleen whales, particularly blues, which have similar feeding habits (Nemoto and Kawamura, 1977). The larger year-classes resulting from higher recruitment rates in the 1930s would have begun to enter the breeding stock (on average) in 1945, since the mean age at sexual maturity was about 14 years in the 1940 year-class and presumably in earlier year-classes also. Thus between 1930 and 1945 absolute year-class strength may have also been increasing as a result of some increase in specific recruitment rates (eventual recruits per mature female), but the size and composition of the breeding stock—animals over 14 years of age—must have remained at the earlier equilibrium values until 1945.

Even with no further increase in specific recruitment rates, the size of succeeding year-classes would have increased after 1945 as the larger year-classes from the

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[1] This work was supported by the US Marine Mammal Commission.

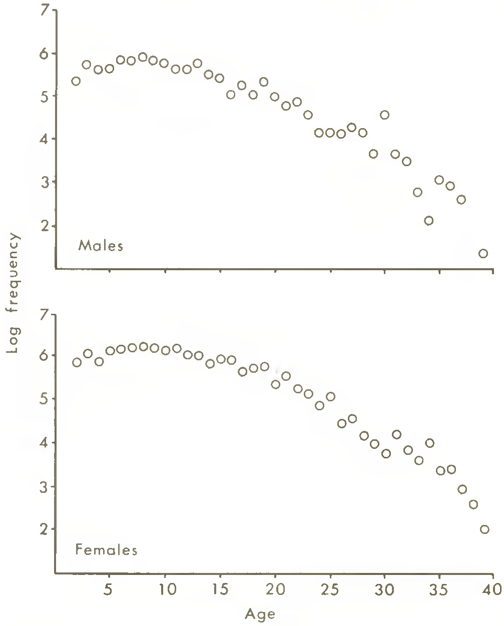

Fig. 1. Logarithmic age distributions in 1971 of Japanese catches of minke whales in Areas III and IV during seasons 1971/72–1977/78. (Data from Table 1; age groups 1- and 40+ not plotted).

1930s and early 1940s augmented the breeding stock. Beginning in about 1955, the reduction in age at maturity reported by Masaki (1979) would have added to the growth of the breeding stock. This change was a nearly linear decline in mean age at maturity with year-class, from 14 in the 1940 year-class to 6 in the 1968 year-class according to Free and Beddington's (1980) adjustment of the data for the effect of fishing mortality. Thus the first effect of the decline was in about 1955 when the 1941 year-class matured a little earlier (on average) than its predecessors, and the decline was probably complete in 1974 when the 1968 year-class matured at age 6 (on average).

The age distribution of minke whales in 1971, while not affected by fishing mortality, can therefore be expected to show several other effects, mostly transient effects, on different segments. To summarize:

(i) Ages 25–40 are the 1930–45 year-classes, whose relative abundance depends on natural mortality, plus any change in specific recruitment rates between 1930 and 1945.

(ii) Ages 15–25 are the 1945–55 year-classes, whose relative abundance depends on natural mortality, plus any further change in specific recruitment rates between 1945 and 1955, plus the growth of the breeding stock during this period as a result of improved reproductive success in the 1930s.

(iii) Ages 1–15 or so are the 1955 and later year-classes. In addition to the factors mentioned above, their relative abundance is influenced by the decline in mean age at sexual maturity which first affected the breeding stock in about 1955.

Some previous studies (e.g. Ohsumi and Masaki, 1975; Ohsumi, 1979) have treated these data as representing a stable age distribution, with a single slope that could be interpreted as representing stable values of population parameters, but this is not correct. The reduction in age at sexual maturity, for example, had hardly begun to affect the age structure of the fully recruited stock (say ages 15+) in 1971. Even with all the parameters stabilized at new values, it would take several decades with no fishing—i.e. until well into the next century—for the age distribution to reach the corresponding stable form.

The approach taken here is to regard the 1971 age distribution as a transient state and to investigate what changes in the past could account for the form in 1971 of the segments representing different groups of year-classes. Of these, the most interesting are the 1930–45 year-classes, since during that period the breeding stock was presumably constant and any increase in year-class size could only have resulted from an increase in specific recruitment rates.

In keeping with the piecewise approach, Table 2 shows the slopes of semilog regressions on many different pieces

Table 1

Estimated age composition in 1971 of Japanese catches in Areas III and IV during seasons 1971/72–1977/78. (Age group '1-' includes all animals born in 1970 and later.)

	Males[1]		Females[2]	
Age	Est. no.	Std dev.	Est. no.	Std dev
1−	408.1	31.5	673.8	39.4
2	209.5	23.7	335.0	31.9
3	307.1	30.4	407.9	34.5
4	272.5	27.8	343.5	31.8
5	279.3	28.6	435.4	34.0
6	341.9	32.0	460.4	33.2
7	332.9	29.7	477.2	34.8
8	365.5	31.7	492.4	35.0
9	336.6	29.4	477.9	35.9
10	314.0	27.1	449.7	36.2
11	275.7	26.1	473.7	33.6
12	273.3	26.3	409.8	34.5
13	314.7	32.6	403.1	30.7
14	242.0	24.5	335.6	29.2
15	221.7	23.6	372.7	30.1
16	151.1	20.1	367.5	30.6
17	186.0	21.5	281.9	27.0
18	151.1	18.2	304.6	27.9
19	204.3	26.4	316.5	30.1
20	144.1	20.3	212.1	28.1
21	116.5	18.3	252.1	25.4
22	127.6	22.9	189.9	22.1
23	94.3	15.9	169.1	20.9
24	62.0	13.1	129.5	19.3
25	62.3	12.3	160.7	21.9
26	59.7	13.3	86.4	14.5
27	70.0	15.2	96.6	16.3
28	62.0	13.1	65.3	13.0
29	38.0	9.6	53.9	12.2
30	95.4	11.5	43.9	11.2
31	37.8	10.7	67.4	15.0
32	32.1	9.7	47.5	11.4
33	15.8	6.1	37.7	10.4
34	8.3	4.9	56.3	12.3
35	21.0	7.7	30.0	9.2
36	18.5	7.6	31.3	9.2
37	13.4	6.3	19.8	8.0
38	2.2	2.1	13.9	6.2
39	3.9	2.8	7.8	4.7
40+	50.6	13.0	68.1	14.0

[1] 2,301 males aged out of 6,381 caught, 58 not keyed to age for lack of samples.

[2] 3,695 females aged out of 9,734 caught; 76 not keyed to age for lack of samples.

of the age distributions. On the whole, these values tend to increase from the lesser to the greater ages. The low values at the low end must reflect partial recruitment to some degree, and there is some evidence (discussed below) that the very high values at the high end (ages 30–39) contain an element of increasing natural mortality with age in that range. It is not certain what, if any, part of the distribution in the middle may be free of both effects, but for purposes of this paper it will be assumed that catchability and natural mortality are equal for all ages 15–35. On this assumption, the slope of that part referring to the 1930–45 year-classes is around 0.14. The 95% confidence limits on this value run from 0.09 to 0.19, but point estimates between 0.12 and 0.15 have been obtained so consistently from different ways of handling the data that the true value will be considered to be in this range.

THE SIMULATION MODEL

To investigate the effect of various combinations of parameter changes, a computer model of a minke whale stock was constructed which would show the age distribution in 1971 (or any other season) resulting from linear changes in age at sexual maturity, pregnancy rate, juvenile mortality rate or any combination. Each such trend was defined by an initial (equilibrium) value, a maximum (final) value, and the years marking the endpoints of the trend, which could be different for each parameter. More specifically:

(i) Values of the mean age at sexual maturity by year-class were taken from Free and Beddington (1980) and never varied. The standard deviation of age at sexual maturity by year-class was taken from the same source, except that a very close linear approximation was used in place of the quadratic reported. The mean and standard deviation for each year-class defined the distribution of ages at maturity that would have been observed in the absence of natural mortality. The actual mean in each run was therefore affected slightly, but only slightly, by the rate of natural mortality assumed.

Table 2

Regression estimates of Z′, and other features of the age distribution in 1971 of minke whales caught by Japanese expeditions in Areas III and IV during seasons 1971/72–1977/78.

		Males	Females	Average[1]
Slope ± 1 std dev.:				
Ages	10–19	0.074 ± 0.018	0.050 ± 0.009	0.058 ± 0.008
	15–24	0.108 ± 0.023	0.109 ± 0.014	0.109 ± 0.012
	20–29	0.126 ± 0.020	0.163 ± 0.019	0.145 ± 0.014
	25–34	0.193 ± 0.054	0.115 ± 0.030	0.143 ± 0.027
	30–39	0.314 ± 0.066	0.195 ± 0.037	0.238 ± 0.034
	10–24	0.097 ± 0.011	0.081 ± 0.008	0.090 ± 0.007
	15–29	0.113 ± 0.012	0.135 ± 0.011	0.124 ± 0.008
	20–34	0.151 ± 0.025	0.132 ± 0.014	0.139 ± 0.013
	25–39	0.214 ± 0.034	0.160 ± 0.018	0.179 ± 0.017
	10–29	0.105 ± 0.007	0.107 ± 0.008	0.106 ± 0.005
	15–34	0.131 ± 0.015	0.128 ± 0.008	0.130 ± 0.007
	20–39	0.177 ± 0.020	0.153 ± 0.011	0.162 ± 0.010
	10–34	0.119 ± 0.010	0.111 ± 0.006	0.114 ± 0.005
	15–39	0.155 ± 0.014	0.143 ± 0.007	0.147 ± 0.007
	10–39	0.139 ± 0.010	0.126 ± 0.006	0.131 ± 0.005
r_{II} values:[2]				
at age	5	0.046	0.055	0.051
	10	0.072	0.081	0.077
	15	0.108	0.107	0.108
P(40+)/P(30–39)[3]		0.204	0.192	0.198

[1] Weighted by inverse of standard deviations.

[2] e.g. at age 5 this is the number of 5 yr-olds as a proportion of those 5 and older.

[3] This is the number aged 40 and over as a proportion of the number aged 30 through 39.

(ii) While age at maturity was treated as a function of year-class, pregnancy rate and juvenile mortality rate were treated as linear functions of time (season). The maximum pregnancy rate considered was 0.86, believed to be the physiological maximum (IWC, 1981).

(iii) The adult natural mortality rate was assigned arbitrarily, and in conjunction with the initial (equilibrium) maturation schedule and pregnancy rate was used to calculate the balancing rate of juvenile mortality just before the first change began (usually 1930). This juvenile rate always applied to the first four years of life only, and if there was a trend in this parameter it was defined as a reduction by some proportion of the difference between the initial balancing rate for juveniles and the definitive rate for adults. Juvenile mortality was never allowed to be less than adult natural mortality.

(iv) Beginning with the stable age distribution implied by the balanced initial parameter values, the model computed the effects of any prescribed parameter changes on the age distribution year by year until reaching 1971 (or any other year specified). The absolute population sizes in every run were arbitrary, and no provision was made for simulating the effect of catches, the object being to predict the age distribution at the beginning rather than in the course of exploitation.

Before considering the detailed model results, it will be helpful to show the interaction of the parameter values, and particularly the effect of the adult natural mortality rate, in the simpler terms of the balance equation, which in fact approximates the equilibrium values of the more detailed model quite closely. Given a natural mortality rate M and an age at maturity of 14 years, the balancing r_I recruitment rate of six-year olds, denoted $(r_6)_{bal}$, can be found by solving:

$$(r_6)_{bal} e^{-8M}/(1 - e^{-M}) = 1$$

This recruitment rate is of course the product of half the initial pregnancy rate (to count females only), survivorship for four years at the juvenile rate, and survivorship for three years at the adult rate (one for the pregnant mother and two for the daughter). The corresponding maximum possible rate can be found by setting the pregnancy rate to 0.86 and the juvenile mortality rate to M, or:

$$(r_6)_{max} = 0.43\ e^{-7M}.$$

Table 3 shows the balancing and maximum r_6 rates for various values of adult natural mortality. Obviously at M = 0.10 there is simply no potential for increasing specific rates, while at low values of M the hypothetical potential is enormous—up to a sixteenfold increase at M = 0.02.

The import of this lies in the slope of the logarithmic 1971 age distribution referring to the 1930–45 year-classes. This slope, considered to be in the range 0.12–0.15, must be the sum of the adult natural mortality rate plus the average logarithmic increase in specific recruitment rates during that period, when the breeding stock was presumably constant. The total logarithmic increases available for distribution over that period, or any other, vary from 0 at M = 0.10, to 2.78 at M = 0.02, thus if the entire increase were applied to the 1930–45 period, the

Table 3

Balancing and maximum r_I recruitment rates at age 6 for various levels of adult natural mortality (calculated from the balance equation).

M	(r_6) bal	(r_6) max	Ratio	Log ratio
0.02	0.023	0.374	16.11	2.78
0.03	0.038	0.349	9.28	2.23
0.04	0.054	0.325	6.02	1.79
0.05	0.073	0.303	4.16	1.43
0.06	0.094	0.283	3.00	1.10
0.07	0.118	0.263	2.23	0.80
0.08	0.146	0.246	1.68	0.52
0.09	0.177	0.229	1.30	0.26
0.10	0.212	0.214	1.01	0.01

slope of the corresponding portion of the 1971 age distribution would be approximately $0.02 + 2.78/15 = 0.205$ at $M = 0.02$, or $0.06 = 1.10/15 = 0.133$ at $M = 0.06$, or $0.10 = 0.01/15 = 0.100$ at $M = 0.10$. Spreading the increase over a longer period, say 1930–50, to correspond better with the period in which blue whales were depleted, would lower these values accordingly.

The main points, of this argument and the simulation results, are:

(i) At values of M greater than about 0.06 it is impossible to reach the slope of the observed 1971 age distribution.

(ii) At $M = 0.06$ or less the 1971 slope can be generated. At somewhat lower values this can be done with the entire hypothetical increase spread over a longer period, and at very low values only a part of the hypothetical maximum increase is required.

SIMULATION RESULTS

The model's predictions agree with those based on the balance equation, although the numbers are slightly different owing to the model's split maturation schedule and time-varying juvenile mortality rate (e.g. a change in juvenile mortality in 1930 has some effect on the 1928 year-class, since all animals under age four are subjected to the same rate). Briefly stated, the model results are as follows:

(i) If only the observed change in maturation schedule is allowed (that is, if pregnancy and juvenile mortality rates maintained their initial balancing values) nothing happens, at least not to the age distribution in 1971 of animals aged 15 and older. The change in maturation schedule simply has not begun to affect that part of the age distribution, so the slope there is M, which cannot be larger than 0.10 and therefore is too small. For information, Table 4 shows the balancing juvenile mortality rates for various feasible combinations of pregnancy rate and adult mortality.

(ii) If only an increase in pregnancy rates is allowed, the effect where feasible is too small. A doubling of pregnancy rates would provide 0.07 log units of increase in recruitment rates, or about 0.045 units/year if applied to the 1930–45 period alone. This increment added to a natural mortality rate of 0.08 or 0.10 would achieve the observed slope, but at these mortality rates the initial pregnancy rate must be more than half the maximum to balance the stock in 1930. At $M = 0.06$ a doubling of pregnancy rates is feasible, but the highest slope achievable is roughly $0.06 + 0.045 = 0.105$, too low.

(iii) If the maximum increase in both pregnancy and juvenile mortality rates is allowed, but this increase is spread over the entire period 1930–70 so as to continue throughout the change in maturation schedule, the slope of the far end of the predicted 1971 age distribution is between 0.085 and 0.100 for all values of M between 0.02 and 0.10. On this time scale, and with a linear change in parameter values, the model shows that natural mortality and the corresponding recruitment rate increase have a nearly constant sum, which again is too low, even at $M = 0.02$.

(iv) If the maximum increase in both pregnancy and juvenile mortality rates is allowed, and this increase is restricted to the period 1930–45, or 1930–50, the predicted slope can be made to fall above, within, or below the observed range (0.12–0.15) by manipulating three factors in the model:

(a) the adult natural mortality rate;
(b) the period of increase;
(c) the proportion of the hypothetical maximum increase allowed to occur (e.g. with $M = 0.02$ the predicted slope is too large if the maximum increase is allowed, but within the proper range if 70% of the maximum hypothetical increased is allowed between 1930 and 1945, or 80% between 1930 and 1950).

Table 5 shows, among other things, the slopes of various pieces of the predicted age distribution for various settings of these three factors that produce 1971 age distributions in the vicinity of those observed. As expected, with M greater than 0.06 the slopes are too low, even when the entire increase occurs between 1930 and 1945. Reasonable slopes can be obtained with $M = 0.02$ or 0.03, but values of natural mortality this low seem improbable. On the whole, therefore, the results indicate a natural mortality rate in the range of 0.04–0.06 and a large increase in specific recruitment rates (three- to sixfold) between 1930 and 1950.

Table 4

Balancing juvenile mortality rates for various adult mortality rates M and pregnancy rates p.

M	0.02	0.04	0.06	0.08	0.10
p					
0.3	0.45	0.22	0.07	—	—
0.4	0.52	0.29	0.14	—	—
0.5	0.58	0.35	0.20	—	—
0.6	0.62	0.40	0.24	0.12	—
0.7	0.66	0.43	0.28	0.16	—
0.8	0.69	0.47	0.31	0.19	—
0.86	0.71	0.49	0.33	0.21	0.10

MANAGEMENT IMPLICATIONS

According to the results obtained above, the minke whale stock(s) in Areas III and IV achieved very large increases in specific recruitment rates and absolute size between 1930 and 1971. The age structure was still changing in 1971, but it is nonetheless possible to estimate various yield rates from the simulation results.

In all runs with M in the range 0.04–0.06, the value of $(r_{11}-M)$ at age 10 in 1971—more or less the actual rate of increase of the exploited part of the stock—was in the range 0.05–0.07. These are lower than the values that would ultimately be reached with no fishing. Meanwhile r_I recruitment rates would have nearly reached the limiting

Table 5

Features of simulated 1971 age distributions for various rates of natural mortality, periods of increase in gross recruitment rates, and amount of increase as a proportion of the hypothetical maximum.

Natural mortality	0.02	0.02	0.02	0.02	0.03	0.03
Period of increase	30–45	30–45	30–50	30–50	30–45	30–45
Relative increase	1	0.7	1	0.8	1	0.8
Slopes:						
Ages 15–24	0.090	0.058	0.082	0.065	0.094	0.076
20–29	0.066	0.049	0.142	0.117	0.072	0.062
25–34	0.167	0.122	0.161	0.133	0.149	0.125
30–39	0.205	0.149	0.159	0.131	0.178	0.148
15–39	0.129	0.093	0.139	0.114	0.121	0.101
20–39	0.148	0.109	0.155	0.128	0.135	0.113
25–39	0.186	0.136	0.160	0.132	0.164	0.137
r_{II} values:						
at age 5	0.119	0.080	0.121	0.093	0.119	0.098
10	0.113	0.075	0.109	0.084	0.112	0.091
15	0.096	0.066	0.095	0.076	0.097	0.080
P(40+)/P(30–39)	0.89	1.49	1.37	1.76	0.79	1.04
Population growth (1930–71)	22.82	6.61	17.91	8.17	16.23	8.10
Ultimate r_I	0.374	0.163	0.374	0.215	0.349	0.224
Ultimate r_{II} (slope)	0.150	0.096	0.150	0.112	0.150	0.120

Natural mortality	0.03	0.04	0.04	0.04	0.05
Period of increase	30–50	30–45	30–45	30–50	30–45
Relative increase	1	1	0.9	1	1
Slopes:					
Ages 15–24	0.087	0.097	0.090	0.091	0.100
20–29	0.132	0.077	0.073	0.125	0.082
25–34	0.144	0.137	0.127	0.133	0.127
30–39	0.141	0.159	0.147	0.129	0.144
15–39	0.128	0.116	0.108	0.121	0.112
20–39	0.140	0.126	0.117	0.129	0.119
25–39	0.143	0.148	0.137	0.131	0.136
r_{II} values:					
at age 5	0.121	0.120	0.111	0.121	0.120
10	0.110	0.112	0.103	0.110	0.112
15	0.096	0.098	0.091	0.097	0.099
P(40+)/P(30–39)	1.11	0.73	0.81	0.95	0.68
Population growth (1930–71)	13.26	11.49	8.61	9.72	8.12
Ultimate r_I	0.349	0.325	0.272	0.325	0.303
Ultimate r_{II}	0.150	0.150	0.137	0.150	0.150

Natural mortality	0.05	0.06	0.07	0.08	Observed (Table 2)
Period of increase	30–50	30–45	30–45	30–45	
Relative increase	1	1	1	1	
Slopes:					
Ages 15–24	0.095	0.102	0.103	0.104	0.109
20–29	0.119	0.086	0.090	0.094	0.145
25–34	0.124	0.120	0.114	0.109	0.143
30–39	0.121	0.133	0.123	0.114	0.238
15–39	0.116	0.109	0.107	0.105	0.147
20–39	0.122	0.114	0.110	0.106	0.162
25–39	0.122	0.126	0.118	0.112	0.179
r_{II} values:					
at age 5	0.120	0.120	0.120	0.120	0.051
10	0.110	0.111	0.111	0.111	0.077
15	0.098	0.099	0.099	0.100	0.108
P(40+)/P(30–39)	0.85	0.66	0.63	0.61	0.198
Population growth (1930–71)	7.09	5.72	4.02	2.83	—
Ultimate r_I	0.303	0.283	0.263	0.246	—
Ultimate r_{II}	0.150	0.150	0.150	0.150	—

value, which is large in every case and implies values in the range 0.24–0.30 for $(r_I–M)$ at age 6, which is the potential rate of net increase, or potential yield, of the breeding stock. The large difference in these two net recruitment rates—$(r_{II}–M)$ and $(r_I–M)$—results primarily from the heavy discounting of r_I rates that occurs in a growing population between the time a year-class is born and the time it recruits.

To bring these results forward to the present it is necessary to account in some way for the catches taken in the 1970s. In about 1979 the exploited stock size in each Area was estimated to be about 75,000 (IWC, 1981), and before that the average total catch since 1971 (inclusive) had been 1,827 per year in Area III and 2,353 per year in Area IV. With these figures, the 1971 stock sizes and 1979 r_{II} recruitment rates can be estimated if one simply assumes that year-class strength (at age 10) continued to increase in the interim at the 1971 rate of $(r_{II}–M)$. Specifically, letting N and R represent exploited stock size and absolute recruitment to it in a given year, and $\bar{C}$ the average annual catch:

$$N_{72} = (N_{71} + R_{71} - \bar{C})e^{-M}$$

$$N_{73} = (N_{72} + R_{72} - \bar{C})e^{-M}$$

and so on. With $R_{71} = r_{II}N_{71}$, then $R_{72} = R_{71}e^{(r_{II}-M)}$, and so on where r_{II} refers to the value in 1971, one eventually obtains the expression

$$N_{79} = N_{71}e^{8(r_{II}-M)} - \bar{C}\,e^{-M}(1 - e^{-8M})/(1-e^{-M})$$

which can then be compared with a corresponding 1979 recruitment of $r_{II}N_{71}e^{8(r_{II}-M)}$.

Table 6 shows results of these rough calculations for various natural mortality rates (and the corresponding 1971 r_{II} value at age 10 from Table 5) and average catch levels of 1,500 and 2,500, which bracket the Area III and Area IV levels. For natural mortality rates in the range 0.04–0.06, the effect of catches is to raise r_{II} values from 0.05–0.07 in 1971 to 0.06–0.10 in 1979—not much of an effect.

Table 6

Approximate 1971 exploited stock size N_{71} and corresponding 1979 r_{II} recruitment rates, given an exploited stock of 75,000 in 1979 and average catches $\bar{C}$ of 1,500 and 2,500.

		$\bar{C} = 1,500$		$\bar{C} = 2,500$	
M	r_{II} (1971)	N_{71} ('000)	r_{II} (1979)	N_{71} ('000)	r_{II} (1979)
0.02	0.09	49	0.10	53	0.11
0.03	0.10	49	0.11	53	0.12
0.04	0.11	49	0.13	53	0.14
0.05	0.11	52	0.12	56	0.13
0.06	0.11	57	0.12	61	0.13
0.07	0.11	61	0.12	65	0.13
0.08	0.11	66	0.12	70	0.13

The reason for this inertia in r_{II} recruitment is simply the momentum of population growth. In effect, slowing or halting the growth of the breeding stock by fishing tends to elevate the r_{II} values, which according to the model are large. The result is that within limits, the value of $(r_{II}–M)$ rises to offset fishing mortality, which by 1979 was not very large.

If the aim of management were to take the replacement yield year after year from a stock that had been growing, the fishing mortality rate (and the absolute catch in proportion) would have to be increased year by year to match the growth of $(r_{II}–M)$ from current values to the level of $(r_I–M)$. In the case of the minke whale stocks in Areas III and IV, always according to the model calculations, that would mean harvesting at a rate of 6–10% now, steadily rising to 24–30% over the course of half a dozen years.

DISCUSSION

There is nothing unusual in the model used here, which shows that a fairly low natural mortality rate and a very large increase in recruitment rates is required to achieve both a balanced stock in 1930 and the observed 1971 age distribution. Basically all that was assumed was that natural mortality and catchability were equal from age 15 to age 35 in the 1970s.

These assumptions are open to question, however. The most suspicious feature of the data in this regard is the scarcity of animals aged 40 years and older. In Tables 2 and 5 the abundance of these oldest animals relative to the group aged 30–39 years is shown by the proportion 'P(40+)/P(30–39)'. According to the simulations, with M in the range of 0.04–0.06, this proportion in 1971 should have been in the range of 0.66–0.95. In the observed age distributions it is only 0.20, and the oldest animal in all the age data was only 47. What this suggests, of course, is older animals disappearing from the stock at an accelerating rate rather than younger animals recruiting to it at an accelerating rate. The cause of an increasing apparent loss rate among the older groups could be a progressive bias in age determinations, a real increase in natural mortality with age[1], or a decline in catchability with age, as Christensen and Rørvik (1980) detected among North Atlantic minkes.

The relative abundance of successive year-classes in the age composition of a catch depends on their relative strengths at recruitment, fishing mortality at that time, natural mortality at their age when caught, and any differences in catchability. Some simplifying assumptions about these factors have to be made in order to infer anything from an age composition, and in the case of Antarctic minke whales the usual simplifying assumptions lead to the extremely sanguine conclusions reported above. At the other extreme one could dismiss the steep slopes of the 1971 age distributions as consequences of age-specific schedules of catchability or natural mortality alone. Most likely the age distributions reflect both some early increase in recruitment rates and some age-specific effects, but there is no way to distinguish their contributions.

REFERENCES

Christensen, I. and Rørvik, C. J. 1980. Availability of minke whales in the Barents Sea and adjacent waters. *Rep. int. Whal. Commn* 31: 259–62.

Free, C. A. and Beddington, J. R. 1980. A technique for estimating mean and variance of the age at sexual maturity for data obtained from the transition phase of ear plug laminae. *Rep. int Whal. Commn* 30: 375–8.

International Whaling Commission. 1978. Report of the Scientific Committee. *Rep. int. Whal. Commn* 28: 54–7.

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[1] Chapman (this volume, pp. xxx–xx) has fitted linear increase in natural mortality with age to the data reported here for age groups 20–39 and found that it implies a value of 0.217 for 'P(40+)/P(30–39)', very close to that observed.

International Whaling Commission. 1981. Report of the Minke Whale Sub-committee. *Rep. int. Whal. Commn.* 31: 103–21.

Masaki, R. 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 375–96.

Nemoto, T. and Kawamura. A. 1977. Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. *Rep. int. Whal. Commn* (special issue 1): 80–87.

Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 407–20.

Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish Res. Bd Canada* 32: 995–1,004.

Wada, S. and Numachi, K. 1979. External and biochemical characters as an approach to stock identification for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 421–32.

SC/Jn81/MiS21

Estimation of the Population Size of Minke Whales in Areas III and IV in 1980/81 Using a Mark Recapture Method

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ABSTRACT

Although no marking was carried out in Areas III and IV in the 1980/81 season, the calculation of the survivors of whales marked in earlier seasons enables us to estimate the population size using a mark recapture method. The resultant population estimates in Areas III and IV are as follows: Area III: 200,555; Area IV: 126,945; Area (III + IV): 318,911.

INTRODUCTION

Japan has marked minke whales under the International Whale Marking Scheme in the Antarctic since the 1975/76 season, and a large number of minke whales have been marked in the Antarctic since the start of IDCR minke whale assessment cruises in 1978/79. As a result, the number of recaptured animals has increased in recent years, thereby increasing the reliability of population assessments using mark recapture methods.

Best and Butterworth (1980) estimated the population size of minke whales in Area IV using a mark recapture method, and discussed the assumptions inherent in the method. The assumption that 'all marks are reported on recovery in the second sample' seems more realistic as a result of deck trials carried out on the Japanese factory ship *Nisshin Maru No. 3* since 1979/80 (Kato and Miyashita, 1982).

In this paper I have used the Chapman single recapture method (after Best and Butterworth, 1980) to estimate the total population sizes in Areas III and IV.

MATERIALS AND METHODS

Table 1 shows the number of minke whales in Areas III and IV marked by Japanese scouting boats and the IDCR/minke whale assessment cruises. Most of the whales have been marked on IDCR cruises: Area III, 91.6%; Area IV, 96.7%. No marking has been carried out in these Areas since the IDCR cruises. Catches are given in Table 2 and recaptures in Table 3.

Table 1

Number of marked whales in Areas III and IV by Japanese scouting boats and IDCR projects

Season	Area III	Area IV
1975/76	16	0
1976/77	24	2
1977/78	22	18
1978/79	2	732[1]
1979/80	703[2]	0
1980/81	0	0
Total	767	752

[1] 725 on the IDCR cruise.
[2] 703 on the IDCR cruise.

Table 2

Catch of minke whales in Areas III and IV in 1980/81

Fleet	Area III	Area IV	Total
Japan	619	1,193	1,812
USSR	618	1,193	1,811
Total	1,237	2,386	3,623

Of the 22 recaptured whales, 3 were recaptured in different Areas to those in which they were marked. In this paper I have considered that these whales belong to the stock from the Area of their recapture.

The efficiency of mark-recovery reporting is assumed to be 100% on the Japanese factory ship (Best and Butterworth, 1980; Kato and Miyashita, 1982), and 70% on the Soviet factory ship. The Soviet figure is based on personal information from the International Observer to the Soviet fleet.

The population sizes are calculated by the following equation (Best and Butterworth, 1980):

$$N = \frac{(n + 1)\ (c + 1)}{m + 1} - 1 \qquad (1)$$

where N = estimated population size,
n = number of whales marked,
c = number of whales caught,
m = number of marked whales in c.

I consider n as the number of whales alive at the beginning of the 1980/81 season, since marking was not carried out in Areas III and IV in that season. The variance of N is shown by Seber (1973) to be as follows;

$$V = \frac{(n + 1)(c + 1)(n - m)(c - m)}{(m + 1)^2\,(m + 2)} \qquad (2)$$

The marked whales alive at the beginning of season i can be calculated by the following equation:

$$A_i = (A_{i-1} - m_{i-1})\, e^{-M} + n_i \times 0.95 \qquad (3)$$

where A_i = marked whales which are alive at the beginning of season i,
m_i = number of marked whales caught in season i,
n_i = number of whales marked at the beginning of season i,
M = natural mortality rate.

Table 3

Recapture of marked minke whales in Areas III and IV from 1976/77 to 1980/81. * These whales marked and recaptured in different Areas.

Mark no.	Date marked	Date recovered	Position marked	Position recovered	Fleet
32344	17 Feb. 77	18 Feb. 77	67°02′S, 61°06′E	66°48′S, 59°41′E	Japan
34130	12 Jan. 79	30 Jan. 79	68°05′S, 73°56′E	67°46′S, 74°01′E	Japan
37007	1 Feb. 79	19 Feb. 79	64°35′S, 123°11′E	64°51′S, 111°18′E	Japan
37008	1 Feb. 79	19 Feb. 79	64°35′S, 123°11′E	64°48′S, 111°01′E	Japan
37010	1 Feb. 79	19 Feb. 79	64°35′S, 123°11′E	64°51′S, 111°18′E	Japan
33896*	6 Feb. 79	25 Feb. 79	65°02′S, 130°18′E	65°18′S, 127°52′E	Japan
37169	5 Feb. 79	27 Dec. 79	65°06′S, 128°47′E	65°03′S, 89°27′E	Japan
26260 27968 }	31 Dec. 78	19 Jan. 80	63°33′S, 95°51′E	64°22′S, 88°42′E	Japan
34390	5 Jan. 79	8 Jan. 80	65°34′S, 85°04′E	65°51′S, 85°00′E	Japan
34559*	13 Jan. 79	27 Feb. 80	64°01′S, 71°30′E	69°11′S, 03°56′E	Japan
34576	14 Jan. 79	5 Mar. 79	64°45′S, 70°18′E	66°55′S, 71°27′E	USSR
35170	9 Jan. 80	16 Dec. 80	64°12′S, 60°29′E	63°21′S, 60°50′E	Japan
34102*	14 Jan. 79	19 Dec. 80	67°17′S, 70°55′E	63°57′S, 59°41′E	Japan
31461	29 Jan. 79	5 Jan. 81	63°49′S, 116°40′E	63°22′S, 94°58′E	Japan
31466	29 Jan. 79	5 Jan. 81	63°49′S, 116°40′E	63°22′S, 94°58′E	Japan
35722	6 Feb. 80	9 Dec. 80	68°52′S, 11°16′E	62° S, 56° E	USSR
33975	22 Jan. 79	4 Jan. 81	62°43′S, 104°52′E	64° S, 81° E	USSR
38820	13 Jan. 80	12 Jan. 81	67°06′S, 66°46′E	67° S, 73° E	USSR
34266	11 Jan. 79	14 Jan. 81	67°41′S, 75°10′E	67° S, 74° E	USSR
38822	13 Jan. 80	19 Jan. 81	67°07′S, 66°51′E	68° S, 77° E	USSR
34216	12 Jan. 79	19 Jan. 81	68°04′S, 73°56′E	68° S, 77° E	USSR
32985	12 Feb. 78	26 Jan. 81	67°41′S, 75°45′E	68° S, 73° E	USSR

Table 4

Number of marked minke whales alive at the beginning of each season

Season	Area III	Area IV	Total
1976/77	36	1	15
1977/78	51	17	48
1978/79	47	710	771
1979/80	709	644	1,373
1980/81	647	584	1,231

It is assumed in this paper that M is 0.09 (IWC, 1980), and that the marking mortality rate is 5% (Best and Butterworth, 1980). A_i values are shown in Table 4.

RESULTS

The number of marked whales in the catch in the 1980/81 season is estimated to be:

Area III: 3
Area IV: 10 (= 2 + 6/0.7)
Area (III + IV): 13

The resultant population estimates are:

Area III: N = 200,555 SD = ± 89,700
Area IV: N = 126,945 SD = ± 28,310
Area (III + IV): N = 318,911 SD = ± 81,715

DISCUSSION

The Minke Whale Sub-Committee in 1980 (IWC, 1981) estimated the total population sizes of minke whales in Areas III and IV in 1979/80 to be:

Area III: 91,800 ± 10,400 by sighting
Area IV: 147,000 ± 13,700 by sighting
" 95,000 ± 30,000 by mark recovery
" 29,300 by population model

The low value obtained by the population model for Area IV is shown to be unrealistic by the result presented in this paper. On the other hand the estimates obtained from marking and sightings last year concur with the present results. Last year's sighting estimate for Area III, appears to be an underestimate when compared to the result found here. The marking result for Areas III and IV combined is very similar to the sum of the population estimate for Areas III and IV, which suggests that some reliability can be placed on the use of mark recapture methods in population assessment.

REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

International Whaling Commission. 1981. Report of the Minke Whale Sub-Committee. *Rep. int. Whal. Commn* 31: 103–21.

Kato, H. and Miyashita, T. 1982. Summary of the experiments on mark recovery efficiency on the Japanese factory ship. Paper SC/Jn81/MiS23 (published in this volume).

Seber, G. A. F. 1973. *The Estimation of Animal Abundance and Related Parameters*. Griffin, London, 506 pp.

penetrate inside and had to operate outside. Under these circumstances there was a considerably lower female sex ratio in the catch: 20.0%, less than half the average figure (49.2%) in this Area (Shimadzu, 1982).

Table 1

Summarized effort data for the Antarctic minke whaling by the Japanese expeditions in 1978/79–1980/81

Season	1978/79	1979/80	1980/81
Boats	4	4	4
CDW	302	408	403
Catch total	2,733*	3,279	3,120*
Male	1,097	1,952	1,472
Female	1,635	1,327	1,647
Catch per day	9.05	8.04	7.74
Time per boat per day			
CSW Searching	3.32	6.30	5.35
Confirming	1.49	1.11	1.08
Chasing	3.41	3.01	2.53
Handling	1.92	1.49	1.28
Towing	1.88	1.17	1.69
Resting	11.93	10.93	11.73
Time per whale caught			
CSW Searching	0.37	0.78	0.69
Confirming	0.16	0.14	0.14
Chasing	0.38	0.37	0.33
Handling	0.21	0.19	0.17
Towing	0.21	0.15	0.22
Resting	1.32	1.36	1.56

* Includes one whale caught but lost.
Resting time includes stop catch hours and other time losses.

Nissin Maru No. 3 reached her Area I limit (450 whales) on 13 March and finished operations for the 1980/81 season. No operations were conducted in Area II since the accumulated catch under the 5% allowance system for the other Areas had already reached the total quota value of 3,120 whales for the season.

TIME BUDGET DATA

Catch and effort data reported by operating catcher boats have been compiled in the same format explained by Ohsumi and Shimadzu (1981). The original report forms were completed on board the catcher boats for every event which took place during whaling activities.

Summarised results are shown in Table 1 together with data from the two previous seasons. In the 1979/80 season, CDW increased by about 30% of the previous season due to the increased quota and the extended operating area (Shimadzu and Kasamatsu, 1981). In general the CSW per whale caught also doubled in this season, mainly due to bad weather conditions. In 1980/81 the CDW remained at the same level and the CSW per whale caught decreased by about 10% from the previous season despite much extended operating coverage. Other fractions of time budget such as handling, chasing, and resting per whale caught remained at almost the same level during these three years except the towing time in 1979/80 season.

REFERENCES

Ohsumi, S. and Shimadzu, Y. 1981. Catch and effort statistics for minke whaling: Japanese expeditions in the Antarctic, 1971/72–1979/80. *Rep. int. Whal. Commn* 31: 363–6.

Shimadzu, Y. 1980. Basis of fishing effort for minke whaling in the Antarctic. *Rep. int. Whal. Commn* 30: 425–33.

Shimadzu, Y. and Kasamatsu, F. 1981. Operating pattern of Japanese whaling expeditions engaged in minke whaling in the Antarctic. *Rep. int. Whal. Commn* 31: 349–55.

Shimadzu, Y. 1981. Unbalanced sex ratio of the minke whale catch and its effect on management. Paper SC/Jn81/MiS24 (published in this volume).

The authors will be pleased to supply the following tabulations on request: compiled catch and effort statistics for minke whaling by 10° square by day and with weather conditions for 1980/81 season, and a list of amended data from Ohsumi and Shimadzu (1981) for seasons 1971/72–1979/80.

A final version of the catch and effort data from 1971/72 to 1979/80 in a computer file compiled from original reporting forms will be available at next year's meeting.

SC/Jn81/MiS23

Summary of the Experiments on .410 Mark Recovery Efficiency on the Japanese Factory Ship

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Since the 1978/79 Antarctic whaling season, large scale, systematic marking and sighting cruises for minke whales have been carried out by the IWC as part of the IDCR programme (Best and Ohsumi, 1980; Best and Butterworth, 1980; Horwood, 1981; Horwood, Best and Ohsumi, 1981; Butterworth and Best, 1982). One of the aims is the application of a mark recapture method to estimate population size for which the mark recovery efficiency on the factory ship is an important factor. In the first IDCR/Antarctic minke whale assessment cruise in the 1978/79 season, a total of 19 valid experiments were carried out to try to estimate mark recovery efficiency on the Japanese factory ship, *Nisshin Maru No. 3.* In addition to the above experiments a total of 32 marks were fired at whale carcases as they were towed alongside operational catcher boats. These results were reported by Best and Butterworth (1980) and are reproduced in our Table 1a–c.

In the 1979/80 season similar experiments were carried out using 18 marks (Table 2). However, relatively few 'pot' trials were carried out, and the necessity to confirm recovery efficiency in the pots was pointed out. Therefore six pot trials were carried out by Miyashita on the factory ship in the 1980/81 Antarctic season (Table 3).

Of the experiments carried out between 1978/79 and 1980/81, 45 comprised deck trials and 32 catcher boat trials. All valid marks were recovered on the Japanese factory ship. Therefore it is reasonable to assume 100.0% recovery efficiency on the Japanese factory ship. Such a high value may be due to the careful treatment of the whale carcase during processing to obtain better quality products and the use of a metal detector in checking all frozen foods.

It is also important to be able to discover from which whale a mark was recovered, to determine the associated biological data of the recaptured animal. The frequency of correct identification of an individual at each stage in the processing is given in Table 4 and as one might expect the most successful stage is during flensing.

Table 1a

Results of deck trials on *Nisshin Maru* No. 3 in 1978/79 (Best and Butterworth, 1980)

Trial no.	Date	Mark	Where placed		Platform no.	Length (m)	Sex	Date found	Where found	Tissue	Platform no.
			Tissue	Position							
1	24.1	27514	Meat	7	1564	7.0	F	24.1	Panning	Ventral meat	1562–1564
2	25.1	27512	Pot no. 10	—	—	—	—	15.2	Pot no. 10	—	— —
3	25.1	27517	Meat	2	1580	8.5	M	25.1	Panning	Dorsal meat	1580 —
4	26.1	27519	Blubber	2/6	1614	7.8	M	26.1	Fat-skinning	Blubber dorsal	— —
5	26.1	27515	Meat	8	1622	9.0	F	15.2	Pot no. 10	—	— —
6	26.1	27514	Pot no. 7	—	—	—	—	31.1	Pot no. 7	—	— —
7	27.1	27518	Meat	6	1662	9.3	F	27.1	Meat-cutting	Dorsal meat	1662–1663
8	27.1	27520	Blubber	2/6	1678	8.5	M	27.1	Flensing	Blubber	1674 —
9	5.2	34030	Pot no. 8	—	—	—	—	8.2	Pot no. 8	—	— —
10	5.2	27513	Blubber	2/6	1915	8.0	F	15.2	Pot no. 10	—	— —
11	6.2	34402	Pot no. 7	—	—	—	—	7.2	Pot no. 7	—	— —
12	8.2	27516	Blubber	2	2012	8.4	M	8.2	Fat-skinning	Blubber	— —
13	10.2	28003	Meat	1	2074	8.4	M	10.2	Meat-cutting	Neck meat	2074–2075
†14	21.2	34326	Pot no. 8	—	—	—	—	—	—	—	— —
15	22.2	34062	Blubber	1	2448	7.7	M	23.2	Fat-skinning	Blubber	2413–2448
16	24.2	34366	Meat	3	2520	8.4	F	25.2	Lemming	Bone and meat	2480–2520
17	25.2	28013	Blubber	3	2569	8.1	M	26.2	Fat-skinning	Blubber	2521–2570
18	26.2	28000	Blubber	1	2600	8.1	M	27.2	Fat-skinning	Blubber	2571–2602
19	27.2	34055	Meat	2	2642	8.3	F	27.2	Panning	Dorsal meat	2605–2638
20	28.3	34401	Blubber	7	2680	8.8	F	1.3	Fat-skinning	Blubber	2643–2682
†21	3.3	28010	Pot no. 10	—	—	—	—	3.11	Pot no. 10	—	— —

† Invalid

Table 1b

Result of catcher trials on *Kyo Maru* No. 1 in 1979/80 (Best and Butterworth, 1980).

Date	Time fired	Mark no.	Whale no.	Result	Position of whale	Position of marksman	Range (m)	Est. angle	Struck whales's body	Dry or wet	P.m. time (mins.)	Est. body length (m)	Platform no.	Length/sex/ blubber thickness (cm)
29.1.79	0820	34352	3–2	H	Towing	Stbd wing	6.75	80°	RD2	D	125	8.6–8.7	1732	9.6 m ♀ 5.8
	0821	27998	3–1	H	,,	Stbd wing	6.75	80°	RD2	D	179	8.3	1723	8.2 m ♀ 4.5
	0822	28011	3–1	H	,,	Stbd wing	6.75	80°	RD2	D	180	8.3	1723	8.2 m ♀ 4.5
	1241	34042	3–9	H	,,	Port wing	6.60	80°	LD1	D	6	8.0	1740	8.2 m ♀ 4.0
30.1.79	0625	28003	3–2	H	Towing	Stbd deck	1.50	70°	LD1	D	40	8.5	1763	8.7 m ♀ 4.3
	0837	34383	3–8	H	,,	Stbd deck	1.50	80°	LD3	D	27	8.3–8.5	1756	8.0 m ♂ 4.0
	0841	34365	3–6	H	,,	Port deck	1.50	80°	RD1	D	66	8.4–8.5	1761	8.5 m ♀ 5.0
2.2.79	1430	34054	3–1	PH	Towing	Port wing	6.75	85°	LD2	D	90	8.3–8.5	1800	8.2 m ♀ 3.7
	1431	34402	3–1	H	,,	Port wing	6.85	80°	LD1	D	91	8.3–8.5	1800	8.2 m ♀ 3.7
	1708	34325	3–3	PH	,,	Stbd wing	6.90	85°	LD1	W†	111	8.5	1806	7.9 m ♂ 3.4
	1709	34393	3–4	H	,,	Stbd deck	2.50	45°	RD2	D	74	—	1805	8.3 m ♀ 4.0
	2037	34030	3–7	HP	,,	Port wing	6.80	80–85°	LD1	D	72	8.8–9.0	1817	8.6 m ♀ 3.6
3.2.79	0955	34400	3–3	H	Towing	Port deck	1.50	60°	RD2	D	30	9.0	1831	9.0 m ♀ 7.0
	0956	34061	3–1	H	,,	Port deck	2.00	50°	LD1	D	186	9.0	1833	8.5 m ♀ 4.5
	1240	34411	3–9	H	,,	Stbd wing	6.70	85°	RD1	D	29	8.9–9.0	1857	8.5 m ♀ 4.2
	1241	34336	3–7	H	,,	Stbd wing	6.80	80°	RD2	D	76	(28 ft)	1854	9.0 m ♀ 4.1
	1244	34025	3–6	H	,,	Port deck	2.50	60°	RD2	D	98	(28 ft)	1847	7.7 m ♂ 4.8
4.2.79	0620	34117	3–1	H	Towing	Stbd wing	6.70	80°	RD1	D	25	8.0	1866	8.4 m ♀ 4.0
	1025	34341	3–4	H	,,	Port deck	1.50	60°	LD1	D	—	8.5	1878	8.4 m ♀ 5.6
	1026	34032	3–5	H	,,	Port deck	1.50	60°	LD1	D	—	8.5	1879	8.5 m ♀ 4.7
9.2.79	1326	34035	3–9	H	Towing	Stbd wing	7.75	85°	RD1	D	61	—	2041	8.6 m ♀ 5.6
	1328	34413	3–8	H	,,	Stbd wing	7.60	80°	RD1	D	85	—	2042	9.2 m ♀ 4.8
	1332	34397	3–10	H	,,	End of catwalk	7.85	70°	RC2	D	40	—	2049	7.8 m ♀ 4.4
10.2.79	0924	34119	3–1	H	Towing	Port wing	*c.* 7 m	70°	LD2	D¹	168	8.5	2069	8.9 m ♀ 4.0
	0925	34403	3–2	H	,,	Port wing	*c.* 7 m	70°	LD2	D	132	8.7	2065	8.3 m ♂ 4.0
	1449	34392	3–5	H	,,	Port wing, upper bridge	9.75	70°	LD2	D	72	9.0	2075	8.8 m ♀ 5.6
11.2.79	0855	34024	3–3	H	Towing	Port wing	7.25	75°	LD2	D	71	8.3	2096	8.1 m ♂ 4.1
	1401	34342	3–8	H	,,	Port wing	7.25	70°	LD2	D	127	9.0	2126	7.9 m ♂ 4.0
	1403	34353	3–10	H	,,	End of catwalk	8.25	60°	RD1	D	15	9.2	2116	8.5 m ♂ 5.0
	1404	34028	3–10	H	,,	End of catwalk	8.25	70°	RD2	D	16	9.2	2116	8.5 m ♂ 5.0
*12.2.79	1247	34045	3–1	H	Towing	Stbd wing	6.85	70°	RD2	D	374	8.3	2138	8.2 m ♂ 3.4
	1248	34339	3–4	H	,,	End of catwalk	7.65	70°	RD2	D	107	8.3	2140	8.3 m ♂ 2.5

* In this trial pieces of cartridge wadding found in blubber.
† Est. 3–5 cm deep.
¹ Through spray.

REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Best, P. B. and Ohsumi, S. 1980. International Whaling Commission/ International Decade of Cetacean Research (IWC/IDCR). Southern minke whale assessment cruise, 1978–79. *Polar Rec.* 20 (124): 52–7.

Butterworth, D. S. and Best, P. B. 1982. Report of the Southern Hemisphere minke whale assessment cruise, 1980/81. Paper SC/Jn81/MiS14+15+19 (published in this volume).

Horwood, J. W. 1981. Results from the IWC/IDCR minke whale marking and sighting cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Horwood, J. W., Best, P. B. and Ohsumi, S. 1981. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR) Southern Hemisphere minke whale assessment cruise, 1979/80. *Polar Rec.* 20 (129): 565–9.

Table 1c

Recoveries from catcher trials in 1979/80 (Best and Butterworth, 1980).

Mark no.	Date found	Where found	Tissue	Platform nos.	Remarks
34352	29.1	Meat-cutting	Ventral meat	1740	
*27998	29.1	Flensing	Dorsal meat	1723	Butt end of mark visible through fascia
*28011	29.1	Flensing	Blubber/dorsal meat	1723	Partly embedded in meat and partly in blubber
*34042	29.1	Panning	Ventral meat	1732	
28003	31.1	Meat-cutting	Dorsal meat	1747–1782	
34383	31.1	Metal-detector	Dorsal meat	1747–1782	
*34365	30/31.1	Panning	Dorsal meat	1747–1782	Mark without head: separate head found in whale 1761 by flenser in back meat by vertebral column
34054	2.2	Flensing	Dorsal meat	1800	Head found in blubber while blubber skinning
34402	2.2	Meat-cutting	Dorsal meat	1800	
34325	2.2	Panning	Dorsal meat	1808	
*34393	2.2	Lemming	Ventral meat	1805	Extreme anterior end of muscle inside thorax
34030	2.2	Meat-cutting	Ventral meat	1817	
*34400	3.2	Flensing	Dorsal meat	1831	
34061	3.2	Flensing	Thorax	1833	Loose inside rib-cage
34411	3.2	Meat-cutting	Dorsal meat	1856–1857	Head separate but adjacent to mark
34336	3.2	Panning	Dorsal meat	—	
34025	3.2	Panning	Ventral meat	1847	
34117	4.2	Panning	Dorsal meat	1866–1867	
34341	5.2	Panning	Ventral meat	—	
*34032	5.2	Panning	Ventral meat	—	Head separate but adjacent to mark
34035	10.2	Meat-cutting	Neck meat	2050–2061	
34413	10.2	Meat-cutting	Dorsal meat	2050–2061	
34397	9.2	Flensing	Dorsal meat	2049	Near vertebra
34119	10.2	Panning	Dorsal meat	2062–2072	
34403	10.2	Meat-cutting	Dorsal meat	—	
34392	10.2	Flensing	Ventral meat	2075	
34024	11.2	Flensing	Dorsal meat	2096	Between meat and bone
34342	11.2	Flensing	Dorsal meat	2126	Between meat and bone
34353	11.2	Panning	Dorsal meat	—	
34028	11.2	Flensing	Blubber	2116	Head protruding inside blubber
34045	12.2	Meat-cutting	Dorsal meat	—	
34339	12.2	Flensing	Loose	—	Loose on deck

* In these whales pieces of cartridge wadding found in blubber.

Table 2

Results of deck trials on *Nisshin Maru No. 3* in 1979/80

Trial no.	Date	Mark	Where placed		Platform no.	Length (m)	Sex	Date found	Where found	Tissue	Platform no.
			Tissue	Position							
1	26.1	35308	Meat	3	1980	8.4	M	26.1	Panning	Tail meat	1980 —
2	26.1	35313	Pot no. 9	—	—	—	—	4.3	Pot no. 9	—	2014–3279
3	29.1	35318	Pot no. 9	—	—	—	—	18.3	Pot no. 9	—	1–3279
4	30.1	35316	Meat	2	2096	8.7	M	30.1	Flensing	Dorsal meat	2096 —
5	1.2	35321	Blubber	15	2160	8.0	F	1.2	Flensing	Ventral meat	2160 —
6	1.2	35317	Pot no. 10	—	—	—	—	4.3	Pot no. 10	—	2027–3279
7	4.2	35307	Meat	6	2271	8.8	F	4.2	Meat-cutting	Dorsal meat	2271 —
8	6.2	35322	Meat	3	2361	8.9	F	6.2	Meat-cutting	Ventral meat	2361 —
9	9.2	35286	Meat	1	2465	9.5	F	9.2	Meat-cutting	Ventral meat	2465 —
10	12.2	35291	Pot no. 9	—	—	—	—	4.3	Pot no. 9	—	2014–3279
11	17.2	35287	Blubber	6	2766	9.3	M	17.2	Flensing	Dorsal blubber	2766 —
12	18.2	35312	Blubber	11	2810	10.1	F	18.2	Meat-cutting	Ventral groove	2810 —
13	21.2	35306	Pot no. 9	—	—	—	—	18.3	Pot no. 9	—	1–3279
14	22.2	35298	Meat	5	2970	9.2	F	22.2	Meat-cutting	Dorsal meat	2969 —
15	22.2	35288	Meat	3	2974	7.9	M	22.2	Meat-cutting	Dorsal meat	2974 —
16	26.2	35304	Meat	4	3107	8.0	M	26.2	Flensing	Dorsal meat	3107 —
17	29.2	38863	Blubber	3	3257	8.6	M	29.2	Flensing	Dorsal blubber	3257 — *
18	1.3	35305	Pot no. 10	—	—	—	—	1.3	Pot no. 10	—	3264–3279

* Mark inserted in bore of dorsal fin on catcher boat.

Table 3

Results of deck trials on *Nisshin Maru No. 3* in 1980/81

Trial no.	Date	Mark	Where placed	Date found	Platform no.
1	22.12	34055	Pot no. 10	2.2	1–2173
2	30.12	27519	Pot no. 9	5.2	1–2247
3	11.1	34393	Pot no. 9	26.3	1–3120
4	24.1	27519	Pot no. 10	16.3	1–3120
5	2.2	28003	Pot no. 9	16.3	1–3120
6	23.2	34366	Potno. 10	26.3	1–3120

Table 4

The frequency of correlating recovered mark and whales (data from Best and Butterworth, 1980 and the present study).

Place found	Identified	Unidentified
Flensing	15 (88.2%)	2 (11.8%)
Meat-cutting	7 (41.2%)	10 (58.8%)
Panning	2 (14.3%)	12 (85.7%)
Fat-skimming	0 (0%)	6 (100%)
Lemming	0 (0%)	2 (100%)
Pot	0 (0%)	18 (100%)
Metal detector	0 (0%)	1 (100%)
Total	24	51

SC/Jn81/MiS24

The Unbalanced Sex Ratio in the Minke Whale Catch and Its Effect on Management

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ABSTRACT

The catches and sex ratio in the catch of the Antarctic minke whale are given by Area and by year. The present total quota system based on the female RY is shown to have an ambivalent effect. A block quota system is proposed.

CATCH AND SEX RATIO BY AREA

From the beginning of extensive exploitation of minke whales in the Antarctic a predominance of females in the catch has been noted. The accumulated catch figures for minke whales from the 1971/72–1980/81 seasons are 27,569 males and 41,477 females, i.e. 60.1% females in the catch as a whole. Catches by Area, by country and by year are given in Table 1 and illustrated in Fig. 1. About one third of these catches were taken in Area IV. In Areas II and III the catch exceeds 10,000. In Area VI however, the catch is as small as 1,412.

When looking at minke whale stock assessments, Ohsumi (1979) showed a seasonal migration pattern by sex and Shimadzu (1980) estimated a correction factor for CPUE to account for seasonality. Analysing catch data by Japanese expeditions, Kasamatsu and Ohsumi (1981) showed a latitudinal distribution pattern by sex. The proportion of females increases in the higher latitudinal waters and the females may penetrate inside the pack ice. The sex ratio in the catch related to those factors, ranges from 23.1% to 89.7% when examined by Area and by year; yearly variation is also considerably wide (Shimadzu and Kasamatsu, 1981).

The imbalance in the sex ratio in the catch has been noted and discussed by the Scientific Committee in relation to the management of this species for some time, and a new system to recommend a quota which would ensure that the female replacement yield (RY) was not exceeded was adopted at the 30th meeting (IWC, 1979, p. 45). Three years experience has been accumulated since then and this seems an opportune moment to examine the matter.

INTRODUCTION OF A TOTAL QUOTA SYSTEM

Before its 30th meeting in Cambridge in June 1978 (IWC, 1979) the Scientific Committee recommended quotas for minke whales by Area without regard to sex. During that meeting some members expressed their concern over the possible effect on reproduction and thus on future population size of continuing to catch more females. The minke whale sub-committee had recommended catch limits by Area only, although it 'noted that it would be more appropriate to base calculations of sustainable and replacement yields on estimates of the numbers of females than of both sexes combined. The difference may be important when the removals of the two sexes have differed greatly. . . . The Committee has not, however, been able to make such calculations in the time available.' (IWC, 1979, p. 79).

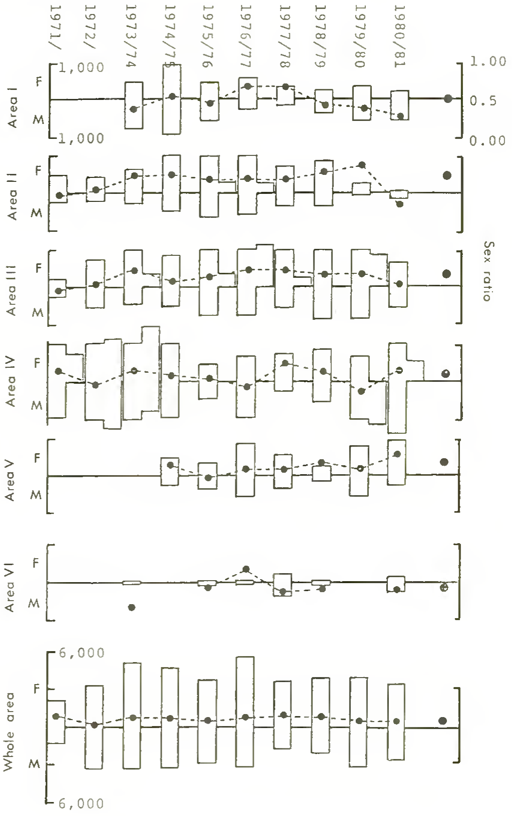

Fig. 1. Catch and sex ratio of minke whales caught in the Southern Hemisphere.

However, in London, Holt and Grenfell (1979) presented results of work carried out after adjournment of the Committee in Cambridge on RY estimation by sex. Using the sub-committee's agreed estimates they calculated a projected time series of population size by sex. From these results they stressed the need to set quotas by sex to avoid the likelihood of a further decline in the number of females.

The Committee noted these results after reconvening in London and in its report explained that a continuing high proportion of females in the catch might have an adverse effect on the population in some Areas, if it meant that the female RY was exceeded. It suggested that the Commission should examine various ways of reducing the risk of an excessive take of females, e.g. by regulation by sex (which is impossible for industry as males and females cannot be distinguished at sea) or by halting catches when the female RY was reached or by setting a total quota by Area equal to 'the female RY plus a proportion of the female RY equal to the expected proportion of males to females in the catch'.

At that time Ohsumi and Shimadzu (IWC, 1979, p. 45) explained their reservations about the hasty adoption of such a system, the first time management by sex had been proposed for baleen whales which would probably mean that whaling strategies would have to change and that the male catch may always be short of the male RY. In particular they stressed that the effects of any possible excess catch of females would not be apparent for 7–8 years and that there was thus time for further work to be carried out.

The Commission adopted the last option of the Scientific Committee (see above) and since then the Committee has recommended minke whale catch limits on that basis.

Table 1

Catch of minke whales in the Southern Hemisphere, 1971/72 to 1980/81 (Data from International Whaling Statistics)

		Japan			USSR			Brazil			S. Africa			Total			Sex ratio
Season	Area	M	F	To.	M	F	To.	M	F	To.	M	F	To.	M	F	To.	F/To.
1971/72	I													—	—	—	—
	II							233	469	702				233	469	702	0.668
	III	170	184	354							93	42	135	263	226	489	0.462
	IV	930	1,728	2.659*										930	1,728	2,659*	0.650
	V													—	—	—	—
	VI													—	—	—	—
	To.	1,100	1,912	3,013*				233	469	702	93	42	135	1,426	2,423	3,850*	0.629
72/73	I													—	—	—	—
	II							210	440	650				210	440	650	0.677
	III				490	697	1,187				125	48	173	615	745	1,360	0.548
	IV	1,116	975	2,092*	1,294	1,172	2,466							2,410	2,147	4,558*	0.471
	V													—	—	—	—
	VI													—	—	—	—
	To.	1,116	975	2,092*	1.784	1.869	3.653	210	440	650	125	48	173	3,235	3,332	6,568*	0.507
73/74	I				765	492	1,257							765	492	1,257	0.391
	II	25	138	163	7	6	13	247	514	761				279	658	937	0.702
	III	320	1,174	1,494	71	133	204				69	46	115	460	1,353	1,813	0.746
	IV	761	1.282	2,043	1.000	1,526	2,526							1,761	2,808	4,569	0.615
	V													—	—	—	—
	VI	10	3	13										10	3	13	0.231
	To.	1,116	2,597	3,717	1.843	2.157	4.000	247	514	761	69	46	115	3,275	5,314	8,589	0.617
74/75	I				932	938	1,870							932	938	1,870	0.502
	II	74	726	800	5	1	6	381	657	1,038				460	1,384	1,844	0.751
	III	554	805	1,359							83	27	110	637	832	1,469	0.566
	IV	430	410	841*	477	913	1390							907	1,323	2,231*	0.593
	V	189	311	500	69	165	234							258	476	734	0.649
	VI													—	—	—	—
	To.	1,247	2,252	3,500*	1,483	2,017	3,500	381	657	1,038	83	27	110	3,194	4,953	8,148*	0.608
75/76	I	338	239	577	231	237	468							569	476	1,045	0.456
	II	159	246	405	215	544	759	278	498	776				652	1,288	1,940	0.664
	III	417	604	1,021	376	757	1.133							793	1,361	2,154	0.632
	IV	198	237	435	231	215	446							429	452	881	0.513
	V	260	160	420	57	154	211							317	314	631	0.498
	VI	92	67	159										92	67	159	0.421
	To.	1,464	1,553	3,017	1.110	1.907	3.017	278	498	776				2,852	3.958	6.810	0.581
76/77	I	145	311	456	149	338	487							294	649	943	0.688
	II				236	629	865	329	665	994				565	1,294	1,859	0.696
	III	446	939	1,385	314	1,177	1,491							760	2,116	2,876	0.736
	IV	521	429	950	399	251	650							920	680	1,600	0.425
	V	515	495	1,010	82	375	457							597	870	1,467	0.593
	VI	51	98	149										51	98	149	0.658
	To.	1,678	2,272	3.950	1.180	2.770	3.950	329	665	994				3,187	5,707	8,894	0.642
77/78	I				147	316	463							147	316	463	0.683
	II				110	252	362	225	463	688				335	715	1,050	0.681
	III	398	614	1.012	133	656	789							531	1,270	1,801	0.705
	IV	128	353	481	123	359	482							251	712	963	0.739
	V	330	338	668	27	189	216							357	527	884	0.596
	VI	156	83	239	169	119	288							325	202	527	0.383
	To.	1,012	1,388	2.400	709	1,891	2,600	225	463	688				1,946	3,742	5,688	0.658

Table 1—*continued.*

		Japan			USSR			Brazil			S. Africa			Total			Sex ratio
Season	Area	M	F	To.	M	F	To.	M	F	To.	M	F	To.	M	F	To.	F/To.
78/79	I				364	289	653							364	289	653	0.443
	II				87	310	397	241	497	738				328	807	1,135	0.711
	III	642	958	1,600	215	681	896							857	1,639	2,496	0.657
	IV	386	573	960*	126	285	411							512	858	1,371*	0.626
	V	69	104	173	73	168	241							142	272	414	0.657
	VI				79	56	135							79	56	135	0.415
	To.	1,097	1,635	2,733*	944	1,789	2,733	241	497	738				2,282	3,921	6,204*	0.632
79/80	I				576	368	944							576	368	944	0.390
	II				31	270	301	315	587	902				346	857	1,203	0.712
	III	521	732	1,253	307	1,148	1,455							828	1,880	2,708	0.694
	IV	1,048	482	1,530	129	202	331							1,177	684	1,861	0.368
	V	383	113	496	161	687	848							544	800	1,344	0.595
	VI													—	—	—	—
	To.	1,952	1,327	3,279	1,204	2,675	3,879	315	587	902				3,471	4,589	8,060	0.569
80/81	I	359	90	450*	197	121	318							556	211	768*	0.275
	II				115	57	172	No information						115	57	172	0.331
	III	327	292	619	275	343	618							602	635	1,237	0.513
	IV	529	664	1,193	352	841	1,193							881	1,505	2,386	0.631
	V	139	486	625	156	467	623							295	953	1,248	0.764
	VI	118	115	233	134	62	196							252	177	429	0.413
	To.	1,472	1,647	3,120*	1,229	1,891	3,120							2,701	3,538	6,240*	0.567
Total	I	842	640	1,483*	3,361	3,099	6,460							4,203	3,739	7,943*	0.471
	II	258	1,110	1,368	806	2,069	2,875	2,459	4,790	7,249				3,523	7,969	11,492	0.693
	III	3,795	6,302	10,097	2,181	5,592	7,773				370	163	533	6,346	12,057	18,403	0.655
	IV	6,047	7,133	13,184****	4,131	5,764	9,895							10,178	12,897	23,079****	0.559
	V	1,885	2,007	3,892	625	2,205	2,830							2,510	4,212	6,722	0.627
	VI	427	366	793	382	237	619							809	603	1,412	0.427
	To.	13,254	17,558	30,817	11,486	18,966	30,452	2,459	4,790	7,249	370	163	533	27,569	41,477	69,046*****	0.601

Number lost: * = 1, ** = 2, etc.

VALIDITY OF THE SCIENTIFIC BASE AND AN EVALUATION OF THE EFFECT

Within the history of Antarctic minke whale population estimation a great deal of discussion has been centred on the Area IV population where exploitation has been carried out at a level sufficient to provide adequate data for successive years. Up to the 31st meeting of the Committee in 1979 (IWC, 1980) the population estimate for Area IV was used as a standard for extrapolation to other Areas based on some relative index of abundance.

The adopted estimates for the Area IV population at the last five annual meetings are shown in Table 2.

Table 2

Adopted population estimates for Area IV (in thousands)

IWC 32	IWC 31	IWC 30	IWC 29	IWC 28
78.7	39.8	16.4	25.0	26.8

Although these estimates do not carry the same weight for consideration, it is quite clear that the estimate at the 30th meeting, when the new system was introduced, was extremely low. Therefore the estimated effect of an unbalanced sex ratio in the catch would be magnified. We now have better population estimates with which to review the new system.

First I examine the effect of this new system given the latest three season's results, i.e. since the system has been in operation.

Table 3 shows catches by sex, by Area, RY estimates by sex and the total quota recommended by the Committee..

In Table 3, 30 cases are available for examination: Area I to VI for 1978/79 and 1979/80 and Areas III, IV and VI for 1980/81. Of these 30 cases, the catch of females exceeded the estimated RY in 5 cases and the catch of males exceeded the RY in one case. In the remaining 24 cases (14 males, 10 females) the catches were less than the estimated RY. For the whole Antarctic, the total male catch was lower than the estimated RY in the two seasons (by 831 and 1,860) where comparison could be made, while for the females the catch was higher (by 133) in 1978/79 and lower (by 1,191) in 1979/80.

Table 4 shows the sex ratio in the catch for two periods: 1971/72–1977/78, when there was no attempt at management by sex; and 1978/79–1980/81, after the implementation of the new system. The overall proportion of females in the catch is slightly better (0.588 vs 0.606) in the latter period. Looking at the situation by Area in five Areas (I, II, III, IV, VI) the proportion of females in the catch was reduced, while in Area V it increased.

Thus the introduction of the new system to ensure that the female RY is not exceeded has resulted in a slight improvement in the sex ratio *in the catch*. However, it has also resulted in a shortfall between the catch and the estimated RY of 2,791 males and 1,058 females in seasons 1978/79 and 1979/80, with the effect of actually exacerbating the imbalance in the sex ratio *in the population*, and thereby reducing the male RY.

Table 3

The adopted total quota and the estimated RY by sex compared with the actual catch in the 1978/79–1980/81 seasons.

	Area I		Area II		Area III		Area IV		Area V		Area VI		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
(1978/79 season)														
Total quota	738		1,272		2,510		1,389		563		371		6,221	
RY	311	345	637	789	1,234	1,493	627	713	253	301	151	147	3,213	3,788
Catch	364	289	328	807	857	1,639	512	858	142	272	79	56	2,282	3,921
RY-catch	−53	56	309	−18	377	−146	115	−145	111	29	72	91	931	−133
(1979/80 season)														
Total quota	964		1,245		2,471		1,857		1,322		243		8,102	
RY	634	691	819	890	1,626	1,760	1,222	1,325	870	941	160	173	5,331	5,780
Catch	576	368	31*	270*	828	1,880	1,177	684	544	800	0	0	3,156*	4,002*
RY-catch	58	323			798	−120	45	641	326	141	160	173		
(1980/81 season)														
Total quota	(867)		(1,120)		1,178		2,272		(1,190)		445		(7,072)	
RY	N.R.		N.R.		759	775	1,374	1,495	N.R.		297	293		
Catch	556	211	115*	57*	602	635	881	1,505	295	953	252	177	2,701*	3,538*
RY-catch					157	140	493	−10						

Note * Figures not including Brazilian catch.
The ‘total quota’ is described in the text. The Scientific Committee made no recommendations (N.R.) for Areas I, II and V for the 1980/81 season. The quotas set by the Commission are shown in parentheses.
RYs are estimated by sex and recommended as one of alternatives to take.

MEASURING THE EFFECT OF IMBALANCED REMOVALS ON THE POPULATION

The minke whale, like the other baleen whales, is considered to be monogamous. In the Antarctic this species is thought to have already been achieving the biological maximum rate of reproduction before the start of substantial takes in the 1971/72 season, so that no increasing trends in pregnancy rate have been detected during the ten years of exploitation. Thus the reduction in recruitment is proportional to the reduction of females, provided that other biological parameters such as the natural mortality coefficient of juveniles stays at the same level. A possible reduction of recruitment is to be accounted for half of the excess of males by year. The estimates of recruitment by year are given using the BALEEN program.

The ‘surviving imbalance’ in the sex ratio in the population was calculated: if the imbalance in the population in a season, i, caused by a catch (C_f or C_m) to u_i,

$$u_i = C_{f,i} - C_{m,i}$$

and to find the accumulated effect to the middle of the 1980/81 season ‘surviving imbalance’, U, is given by

$$U = \sum_i u_i \, e^{-M(10-i)}$$

where subscript i denotes the season (i = 1 for 1971/72, . . . i = 10 for 1980/81). The results are shown in Table 5.

Table 4

Catch and sex ratio before and after introduction of the new system

Area	1971/72–1977/78 Catch Male	Female	Sex ratio	1978/79–1980/81 Catch Male	Female	Sex ratio
I	2,707	2,871	0.515	1,496	868	0.367
II	2,734	6,248	0.696	789	1,721	0.686
III	4,059	7,903	0.661	2,287	4,154	0.645
IV	7,608	9,850	0.564	2,570	3,047	0.542
V	1,529	2,187	0.588	981	2,025	0.674
VI	478	370	0.436	331	233	0.413
Total	19,115	29,429	0.606	8,454	12,048	0.588

Table 5

‘Surviving imbalance’ by Area. A positive value shows a shortage of females

Area	I	II	III	IV	V	VI	Total
Number	−422	2,722	4,156	1,689	1,446	−175	9,416

The estimated ‘surviving imbalance’ up to 1980/81 shows a shortage of females (i.e. excess of males) in Areas II, III, IV and V and an excess of females in Areas I and VI.

These imbalances must then be evaluated with respect to total population size. Population sizes estimated by the BALEEN program are available for Areas III, IV and VI (IWC, 1981). These have been adjusted in Table 6 to mid-season values by deducting half the 1980/81 catch.

Table 6

Calculated imbalance in the population based on BALEEN estimates

Area	Recruited population Male	Female	Catch Male	Female	Difference Male-female
III	39,065	35,616	327	292	3,449
IV	40,136	30,436	529	664	1,700
VI	13,076	13,185	118	115	−109

Comparison of these values with those in Table 5, shows that in Area IV there is close agreement, a small difference for Area VI and disagreement for Area III. This may suggest some validity in the population estimates and recruitment in the time series for Area IV. However to return to the evaluation of the imbalances noted in Table 5, they seem small when compared to population sizes. The excess of males in the total recruited male population for these Areas are 8.8%, 4.2% and −0.8%.

Another factor which must be discussed is the probability that the foetal sex ratio is not 1:1 which would, if in favour of females, lessen the effect of an excess of females in the catch. Of the 10,737 foetuses examined from females taken by Japanese expeditions from 1971/72 to 1980/81, 5,043 were males (47.0%) and 5,694 were females (53.0%). This imbalance in the foetal sex ratio was found to be statistically significant by Kato (1982), but as stated by the author this was for all Areas combined; by Area the values varied from 44.7% to 53.8%. It also comprised small foetuses only and the ratio at birth is of course unknown. Although this phenomenon has been observed and reported previously (Ohsumi and Masaki, 1975; Masaki, 1979) the sex ratio has been treated as 1:1 as in other baleen whales.

Although mortality rate might be linked with this difference by sex, the natural mortality coefficient of the minke whale has been estimated for both sexes to be 0.09 (IWC, 1981, p. 104).

A simplistic approach reveals that a difference of roughly 6% in the sex ratio at birth would be sufficient to cancel out the accumulated difference between males and females in the catch. Bearing in mind the points raised in this section and given that the present rate of exploitation is less than 2% (Table 6), the effect of an imbalance in the sex ratio in the catch on the population as a whole seems to be slight.

REVISION OF MANAGEMENT

According to the BALEEN estimates at the 32nd annual meeting (IWC, 1981), the populations of minke whales in the Antarctic are stabilising in Area III, and increasing in Areas IV and VI. In addition it is possible that they may be approaching the maximum population size which the environment can support. This is partially supported by an observed increasing trend of age at sexual maturity (Kato, 1982). When this has been confirmed the concept and present system of minke whale population management should be changed.

However, until this time, an interim measure which attempts to adjust the albeit small imbalance in the sex ratio in the population, e.g. a block quota system (similar to those implemented for minke whales of the Okhotsk Sea – West Pacific stock, the Sea of Japan – Yellow Sea – East China Sea stock and the West Greenland stock, as well as for sei whales of the Denmark – Iceland stock), could be introduced.

Minke whales exhibit behavioural segregation by sex, in time and geographical area (Kasamatsu and Ohsumi, 1981). As the whaling grounds, and hence the sex ratio in the catch may fluctuate with meteorological conditions, e.g. in Area II in 1980/81 (Shimadzu and Kasamatsu, 1982), a block quota system is highly commendable not only to safeguard the whale population but also to allow efficient whaling operations. Continuation of the present system may not be effective in improving the sex ratio in the population.

REFERENCES

Holt, S. J. and Grenfell, B. 1979. Note on Southern Hemisphere minke whale stocks and quotas. *Rep. int. Whal. Commn* 29: 81–3.

Kasamatsu, F. and Ohsumi, S. 1981. Distribution pattern of the minke whales in the Antarctic with special reference to the sex ratio. *Rep. int. Whal. Commn* 31: 345–8.

Kato, H. 1982. Some biological parameters for the Antarctic minke whale from the 1971/72 to 1979/80 seasons. Paper SC/Jn81/MiS32 (published in this volume).

Masaki, Y. 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 375–95.

Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish. Res. Bd Can.* 32: 995–1,004

Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 407–20.

Shimadzu, Y. 1980. Basis of fishing effort for minke whaling in the Antarctic. *Rep. int. Whal. Commn* 30: 425–33.

Shimadzu, Y. and Kasamatsu, F. 1982. Operating pattern and time budget data for the Antarctic minke whaling by Japanese expedition in 1980/81 season. Paper SC/Jn81/MiS22 (published in this volume).

Table 1

Sightings distance and number of minke whales sighted (incl. secondary) by *Shonanmaru No. 2* in Area I in 1980/81

5° square	Sighting distance (mile)	Whales sighted	Area (mile^2)
BN 33W	30	0	42,302
33E	105	0	"
0W	46	2	"
0E	506	132	36,505
BS 31W	268	49	34,717
31E	215	113	"
32W	357	82	"
32E	166	73	"
33W	320	39	"
33E	284	14	"
34W	119	10	33,957
34E	170	7	33,194
35W	209	48	30,904
35E	30	3	24,089
0W	442	9	12,133
Total	3267	581	445,990

ESTIMATION OF POPULATION SIZE USING SIGHTINGS DATA

Materials

The track line of the scouting boat *Shonanmaru No. 2* in 1980/81 is shown in Fig. 1. The boat usually sailed along the pack ice edge but moved to the north once in each 10° of longitude and scouted the offshore regions. The boat recorded the angle of a school from the boat's track, the radial distance from the boat to the school, the school size, the time of finding the school, the estimated body lengths and the weather and sea conditions. The distance searched and the number of minke whales sighted in each 5° square are shown in Table 1. Total distance searched in the waters south of 65°S was 3,267 nautical miles, and 581 minke whales were sighted.

Japan also conducted sightings in Area I with scouting boats during the years 1973/74 to 1979/80, and those results in the waters south of 40°S are shown by 10° square in Tables 2 and 3. Two Japanese fleets engaged in whaling in Area I in the 1975/76 season, hence the long searching distance in that season.

Table 2

Sightings distance (miles) covered by Japanese scouting vessels in Area I from 1973/74 to 1980/81

10° square	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	Total
A31	—	352	1,675	1,270	—	57	149	—	3,503
32	—	197	470	50	323	—	11	—	1,051
33	—	385	—	1,980	171	—	—	50	2,586
34	—	—	762	611	—	—	—	268	1,641
35	—	—	1,330	165	—	—	—	—	1,495
0	—	—	1,448	50	—	—	—	218	1,716
B31	—	378	2,851	445	315	79	—	483	4,551
32	—	203	1,435	—	—	—	—	523	2,161
33	—	355	1,838	165	—	—	—	739	3,097
34	237	—	816	324	—	—	—	289	1,666
35	420	—	2,842	380	—	—	—	239	3,881
0	559	—	1,911	—	—	—	—	994	3,464
D31	—	—	—	—	176	—	—	—	176
32	—	—	—	—	203	—	247	—	450
33	—	—	—	—	—	—	162	—	162
34	—	—	1,832	—	—	—	180	95	2,107
35	—	—	194	—	—	—	—	216	410
Total	1,216	1,870	19,404	5,440	1,188	136	749	4,114	34,117

Table 3

Number of minke whales sighted, area and index of abundance. Japanese scouting vessels from 1973/74 to 1980/81

10° square	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	Total	Area (mile^2)	Index of abundance
A31	—	0	0	0	—	0	0	—	0	207,416	0
32	—	0	0	0	4	—	0	—	4	"	789
33	—	3	—	8	0	—	—	0	11	"	882
34	—	—	0	0	—	—	—	1	1	"	126
35	—	—	1	0	—	—	—	—	1	173,332	116
0	—	—	7	0	—	—	—	0	7	187,586	774
B31	—	—	85	18	28	0	—	162	293	154,038	9,917
32	—	—	36	0	—	—	—	155	191	"	13,615
33	—	—	37	0	0	—	—	53	90	"	4,476
34	158	—	30	4	—	—	—	17	209	"	19,324
35	179	—	71	12	—	—	—	51	313	139,597	11,258
0	45	—	79	—	—	—	—	143	267	91,843	7,009
D31	—	—	—	—	5	—	—	—	5	255,114	7,248
32	—	—	—	—	3	—	0	—	3	"	1,701
33	—	—	—	—	—	—	0	—	0	"	0
34	—	—	0	—	—	—	0	0	0	"	0
35	—	—	0	—	—	—	—	2	2	160,000	780
Total	382	3	346	42	40	0	0	584	1,397		78,265

Table 4

Angle from the track line and radial distance of minke whale schools sighted by *Shonanmaru No. 2* in Area I in 1980/81

Angle (°)	Radial distance (mile)									
	0.0–	0.5–	1.0–	1.5–	2.0–	2.5–	3.0–	3.5–	4.0–	Total
A. Near the pack ice edge – Small school										
0	1	7	5	3	5	2	—	—	1	24
10	1	2	3	5	3	1	—	—	—	15
20	3	4	2	3	3	—	—	—	—	15
30	—	—	3	5	1	1	—	—	2	12
40	—	1	2	1	3	—	—	—	—	7
50	1	5	1	1	—	—	—	—	—	8
60	1	2	1	2	1	—	—	—	—	7
70	2	5	2	1	1	—	—	—	—	11
80	—	—	1	—	—	—	—	—	—	1
90	1	1	—	1	1	—	—	—	—	4
Total	10	27	20	22	18	4	0	0	3	104
B. Near the pack ice edge – Large school										
0	—	1	—	2	2	—	—	—	1	6
10	—	—	2	—	3	—	—	—	—	5
20	—	1	—	—	—	—	1	—	—	2
30	—	1	—	2	—	1	1	—	—	5
40	—	—	—	2	—	—	—	—	—	2
50	—	1	—	—	1	—	—	—	—	2
60	—	—	—	—	1	—	—	—	—	1
70	—	—	1	—	—	—	—	—	—	1
80	—	1	—	1	—	—	—	—	—	2
90	—	—	—	—	1	—	—	—	—	1
Total	0	5	3	7	8	1	2	0	1	27
C. Offshore – Small school										
0	—	2	2	—	—					4
10	1	3	—	1	—					5
20	—	2	1	—	1					4
30	1	2	—	—	—					3
40	1	2	2	1	1					7
50	—	1	1	—	—					2
60	—	1	—	1	—					2
70	1	2	—	—	—					3
80	—	1	1	—	2					4
Total	4	16	7	3	4					34

Table 4—*continued.*

D Offshore—Large school

Angle (°)	Radial distance (mile)				
	0.0–	0.5–	1.0–	5.0–	Total
0	—	1	—	—	1
10	—	—	1	—	1
20	—	—	2	—	2
30	—	—	—	1	1
40	—	1	1	—	2
50	—	—	—	—	0
60	—	1	—	—	1
70	—	—	1	—	1
Total	0	3	5	1	9

According to Doi (1974), number of whales in a sub-area is shown by the following formula:

$$Y = \frac{A}{2x_1L} \cdot \frac{n}{P} \qquad (1)$$

where, Y: number of whales in sub-area A,
A: size of sub-area,
x_1: sighting width,
L: distance searched,
n: number of whales sighted,
P: real rate of sighting.

The real rate of sighting is obtained by the following equation;

$$P = \bar{P} \times Kw \qquad (2)$$

where, $\bar{P}$ is a modified average rate of sighting, and Kw a correction factor.

$\bar{P}$ is calculated from the number of whale schools sighted at each right-angle distance class. Kw is obtained from the blowing time and number of observers. I apply two values of the correction factor: 0.782 as the average of the angular velocity of two observers, and 0.967 of four observers taken from Doi (1982).[1]

Table 4 shows the relationship between the angle a school was sighted from the track line and the radial distance. In this paper I have stratified the minke whales sighted by school size (small: 1–3 whales; large: 4 or more whales) and by area (near pack ice edge and off-shore: separating contour 30 n. miles from pack ice edge).

Usual line-transect theory (Seber, 1973) assumes that all whales on the track-line can be seen by the observers, and that the probability of a whale being sighted is given a simple function g(y) such that g(0) is equal to one. For example, Seber (1973) introduced g(y) which was reported by Gates *et al.* (1968), namely $g(y) = \exp(-\lambda y)$.

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[1] In the original paper to the meeting I used the values given in Table 16–3 of Doi (1974): Kw = 0.344 for 2 topmen and 0.566 for 4 topmen.

According to this simple untruncated model the estimated number of minke whales can be written as follows:

$$Y = \frac{A}{2L} \cdot \frac{n(n-1)}{\Sigma y_i} \cdot S \qquad (3)$$

where y_i is the class mark of the i-th distance interval. However, using computer simulation, Doi *et al.* (1982) found that all whales on the track-line will not always be found by an observer, so I have corrected results from the usual line transect method by a correction factor, C, obtained by Doi *et al.* (1982) of 0.782 when there are two observers and the angular velocity of the eye-scanning of an observer is 2.7 °/sec. Thus equation (3) can be converted to the following equation (4):

$$Y = \frac{A}{2L} \cdot \frac{n(n-1)}{\Sigma y_i} \cdot S \cdot \frac{1}{C} \qquad (4)$$

This is a simplistic approach to the correction problem which really needs a more detailed theoretical examination with respect to line transect theory.

Best and Butterworth (1980) showed that a truncated model reduces a bias to underestimate the population size inherent in equation (3). The formula they used is:

$$Y = \frac{A}{2L} \cdot \frac{n^1(n^1-1)}{\Sigma^1 y} \cdot \frac{1 - \exp(-\hat{\lambda} a) - a\hat{\lambda}\exp(-\hat{\lambda} a)}{[1 - \exp(-\hat{\lambda} a)]^2} \qquad (5)$$

where n^1 and $\Sigma^1 y$ refer to whales sighted within a distance 'a'.

And $\hat{\lambda}$ can be obtained by iteration for 'a' of the following equation:

$$\hat{\lambda} = (n-1)[1 - \exp(-\hat{\lambda} a) - a\exp(-\hat{\lambda} a)]/(\Sigma^1 y)[1 - \exp(-\hat{\lambda} a)] \qquad (6)$$

This method still assumes that all whales on the track-line can be seen, and so I have again used the correction factor C. Shimadzu (1982) kindly reanalysed these data using a stratified analysis at the Special Meeting.

Results

The number of schools sighted, the mean school size and its variance, the number of nautical miles searched and the area (n. mile²) are shown in Table 5. The mean school size was obtained from Table 6; the size of the areas was calculated by F. Kasamatsu and the frequency distribution of the right-angle distance of schools sighted (Table 7) is calculated from Table 4. Fig. 2 shows the frequency distribution of the right-angle distance of minke whale schools sighted, from which the modified average rates of sighting (P) are calculated and shown in Table 8 for each stratum.

Table 5

Mean school size, miles searched and Area covered by *Shonanmaru No. 2* in Area I in 1980/81

	Near pack ice edge		Offshore	
	Small	Large	Small	Large
Nos. of schools (n)	104	27	34	9
Mean school size (S)	1.60	9.50	1.52	6.56
Variance (S)	0.607	42.900	0.508	10.528
Miles searched (L)	2,212	2,212	1,055	1,055
Area (A) (miles²)	69,172	69,172	289,848	289,848

Table 6

School sizes of minke whales in Area I

School size	Near pack ice edge			Offshore		
	a < 0.7	0.7 ≤ a	Total	a < 0.7	0.7 ≤ a	Total
A. Small schools						
1	46	15	61	18	2	20
2	15	10	25	6	2	8
3	13	5	18	2	4	6
Total	74	30	104	26	8	34
B. Large schools						
4	3	—	3	3	—	3
5	2	2	4	1	—	1
6	5	1	6	2	1	3
7	1	3	4	1	—	1
8	—	1	1	—	—	0
9	—	—	0	1	—	1
12	—	1	1	—	—	0
13	—	1	1	—	—	0
14	1	1	2	—	—	0
15	1	—	1	—	—	0
19	1	—	1	—	—	0
20	—	1	1	—	—	0
23	1	—	1	—	—	0
30	1	—	1	—	—	0
Total	16	11	27	8	1	9

a = right angle distance; 0.7 = cut off value (miles) for truncated model.

Table 8

Parameters for estimation of minke whale population in Area I by Doi's model

	Near pack ice edge		Offshore	
	Small school	Large school	Small school	Large school
Maximum width of sighting distance (x_1)	3.3	4.5	3.8	3.1
Modified average rate of sighting ($\hat{P}$)	0.3739	0.2284	0.1805	0.2289
Real rate of sighting (P)				
$K_w = 0.782$	0.292	0.179	0.141	0.179
$K_w = 0.967$	0.362	0.221	0.175	0.221

Table 9

Mean sighting distance for estimation of minke whale population in Area I: untruncated model

	Near pack ice edge		Offshore	
	Small school	Large school	Small school	Large school
Mean sighting distance ($\bar{y}$)	0.53	0.67	0.47	0.66

Using the parameters in Tables 5 and 8, the abundance of minke whales in the waters south of 65°S of Area I can be estimated from Doi's model. The results are those of Tillman (1982) who kindly reanalysed the data using Doi's latest (1982) Kw values.

Stock assessment using the untruncated model needs information on the mean sighting distance, and those values are shown in Table 9. Using this parameter and the data in Table 5, the population is estimated to be 45,833.

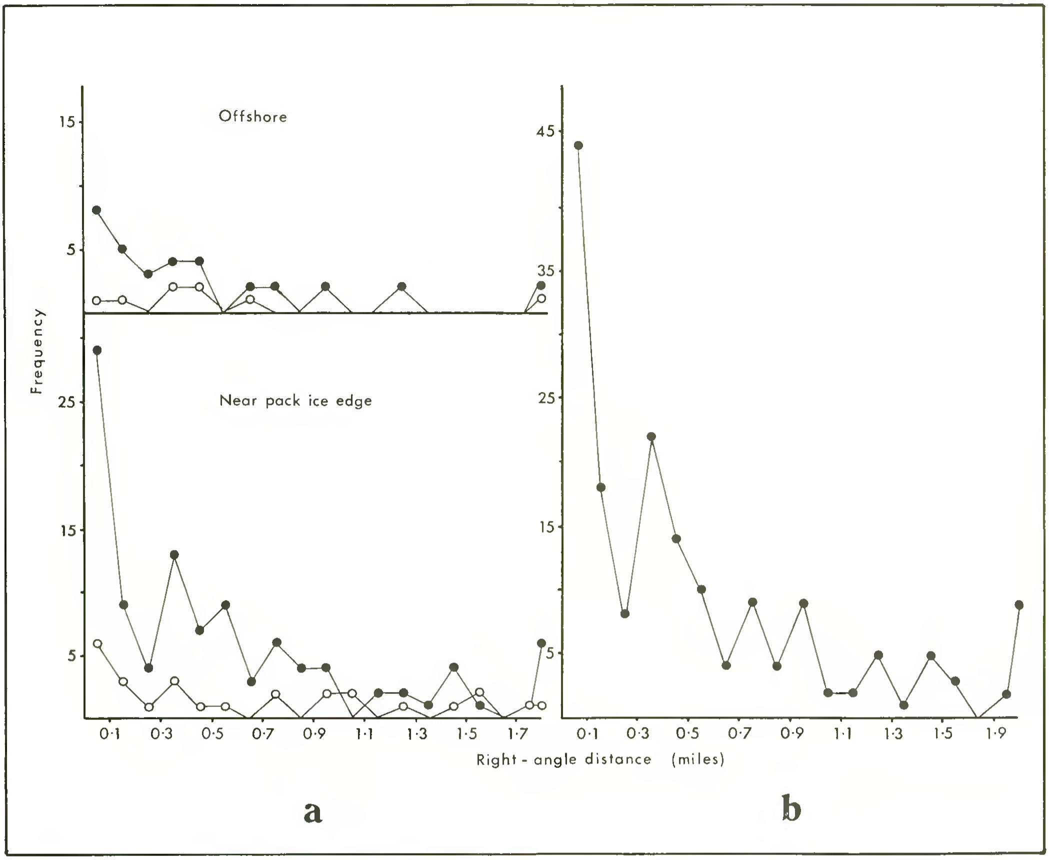

Fig. 2. (a) Frequency distribution of right-angle distance of minke whale schools sighted by *Shonanmaru No. 2* for each stratum (● = small and ○ = large schools). (b) Frequency distribution of right-angle distance of minke whale schools sighted by *Shonanmaru No. 2.*

Table 7

Frequency distribution of right-angle distance and fitting negative exponential curve

Distance (mile)	Near pack ice edge				Offshore			
	Small school		Large school		Small school		Large school	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
0.00–	29	11.0	6	2.4	8	4.5	1	1.1
0.10–	9	9.8	3	2.3	5	4.2	1	1.1
0.20–	4	8.7	1	2.2	3	4.0	7[3]	5.4
0.30–	13	7.8	3	2.1	4	3.7		
0.40–	7	6.9	1	2.0	4	3.5		
0.50–	9	6.1	1	1.9	10[2]	12.0		
0.60–	3	5.5	12[1]	11.7				
0.70–	6	4.9						
0.80–	4	4.3						
0.90–	4	3.8						
1.0	16	16.0						
Chi square	38.32		7.59		3.55		4.92	
df	10		6		5		2	

[1] refers to distance >0.60 mile. [2] refers to distance >0.50 mile. [3] refers to distance >0.20 mile.

In the case of the truncated model further information on n,y,S and $\hat{\lambda}$ is needed and those values are shown in Table 10. Using this model the abundance of minke whales is calculated to be 52,088.

Shimadzu (1982) estimated the Area I population to be 44,106.

Table 10

Parameters for estimation of minke whale population in Area I: truncated model

	Near pack ice edge		Offshore	
	Small school	Large school	Small school	Large school
Nos. of school sighted (n)	74	16	26	8
Mean school size (S)	1.55	10.00	1.38	5.63
Mean sighting distance ($\bar{y}$)	0.25	0.20	0.25	0.33
$\hat{\lambda}$	2.231	3.187	1.860	2.476

The sightings data which have been collected by Japanese scouting boats since 1973/74 can be used in Doi's technique to estimate the population size of minke whales in the waters south of 40°S of Area I by converting equation (1) to the following equation:

$$Y = \frac{1}{2Px_1} \cdot \frac{nA}{L} = \frac{1}{2Px_1} \cdot I \qquad (7)$$

where I is the index of abundance.

The value of I is shown in Table 3. P and x_1 are obtained from the total sightings data in 1980/81. The modified average rate of sighting ($\bar{P}$) from the total data is 0.2123 and maximum sighting width (x_1) is 2.7 n. miles. The resultant minke whale population abundance in the waters south of 40°S is shown in Table 13.

ESTIMATION OF POPULATION SIZE USING MARKING DATA

Materials

Shonanmaru No. 2 marked minke whales using .410 Discovery marks in Area I in 1980/81 (Table 11). Table 12 shows the number of minke whales marked and the Japanese and Soviet catch in Area I.

Table 11

Marking results for the *Shonanmaru No. 2* in Area I in 1980/81

Total no. of fired	Verdict					
	H	HP	PH	NV	R	M
327	151*	2	5	4	1	164

* Including 17 double hits.
H: Hit, HP: Hit protruding, PH: Possible Hit, NV: No verdict, R: Ricochet, M: Misfire.

Table 12

Number of minke whales marked by *Shonanmaru No. 2* and the catch by Japan & USSR in Area I Series B in 1980/81 by 5° square

5° square	No. of whales marked	Catch	
		Japan	USSR
BN 0E	26	—	—
BS 31W	7	—	—
31E	18	57	—
32W	18	18	—
32E	27	—	—
33W	18	3	—
33E	5	—	—
34W	3	146	—
34E	2	51	—
35W	5	32	—
35E	3	12	140
0W	2	—	158
Total	134	319	298

Methods

Dr S. Tanaka (pers. commn.) kindly suggested to me a method of estimating the population size from marking data when no marks are recovered:

$$\left(1 - \frac{S}{N}\right)^c \leq \alpha \qquad (8)$$

where S: the number of marked whales at the beginning of that season,
c: the catch,
N: the population size in that area,
α: significant level.

From this equation $\hat{N}$ (estimated value of N) can be given as:

$$\hat{N} \geq \frac{S}{1 - \alpha^{1/c}} \qquad (9)$$

Results[1]

$\hat{N}$ is calculated in the case of $\alpha = 0.05$ and 0.10, and the results are as follows:

$\hat{N} \geq 36{,}940 \qquad \alpha = 0.05$
$\hat{N} \geq 48{,}039 \qquad \alpha = 0.10$

DISCUSSION AND CONCLUSION

All of the present results are summarised in Table 13. The result of Doi's model is similar to that of the line-transect methods. The mark recapture results also overlap with the sightings results. From this Table I conclude that the minimum population size in the waters south of 65°S in Area I is about 35,000.

In this paper the area has been classified after Horwood (1981) and the school size classified after Chapman (1980). Using this classification, there are few schools sighted in some of the strata, especially in the 'offshore-large school' category. I did not examine how much effect this classification has on the population assessment.

The percentage of the exploitable population was assumed to be 80.7% by the IWC minke whale subcommittee in 1980. In this paper from the distribution of estimated lengths of minke whales sighted in the water south of 65°S in Area I by *Shonanmaru No. 2* in 1980/81, it is assumed that 80.2% of the total population are recruited (Table 14).

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[1] During the Special Meeting the data were re-analysed using revised catch data and the method described by Horwood (1981): $\hat{N} < 26{,}457$, $\alpha = 0.05$; $\hat{N} < 34{,}406$, $\alpha = 0.01$.

Table 13

Results of minke population estimation in Antarctic Area I by several methods

Data source	Area	Methods	Results	Note
1973/74–80/81	South of 40°	Doi's model	87,301	Kw = 0.782
			70,599	Kw = 0.967
1980/81	South of 65°	Doi's model[1]	35,545	Kw = 0.782
			28,725	Kw = 0.967
1980/81	South of 65°	Non-truncated	45,388	
1980/81	South of 65°	Truncated	52,088	
1980/81	South of 65°	Stratified[2]	44,106	
1980/81	South of 65°	Marking	36,940	α = 0.05
			48,039	α = 0.10
1980/81	South of 65°	Marking[3]	26,457	α = 0.05
			34,406	α = 0.01

[1] From Tillman (1982). [2] From Shimadzu (1982). [3] From IWC (1982b).

Thus the minimum exploitable population is about 28,000. The sub-committee estimated the exploitable population in Area I to be 20,700 in 1980 (IWC, 1980a).

The total population in the waters south of 40°S in Area I is estimated to be at least 70,000 and if it is assumed that 80.2% of the total population is exploitable, the exploitable population size is at least 56,140 south of 40°S in Area I.

Table 14

Frequency distribution of estimated lengths of minke whale sighted by *Shonanmaru No. 2* in the waters south of 65°S in Area I

Length (ft)	Whales sighted	
18	1	
20	3	
21	2	
24	12	
25	17	
26	80	
27	218	80.2%
28	195	
29	47	
30	6	
Total	581	

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REFERENCES

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/9. *Rep. int. Whal. Commn* 30: 257–83.

Chapman, D. G. 1980. Stratified estimate of Area IV series B minke whale population from sightings data of assessment cruise 1978/79 and estimate of its variance. *Rep. int. Whal. Commn* 30. 100–1

Doi, T. 1974. Further development of whale sighting theory. pp. 359–68. *In:* W. E. Schevill (ed.) *The Whale Problem: A Status Report,* Harvard University Press, Cambridge, 419 pp.

Doi, T., Kasamatsu, F. and Nakano, T. 1982. A simulation study on sightings survey of minke whales in the Antarctic. Paper SC/33/MiS29 (published in this volume).

Gates, C. E., Marshall, W. H. and Olson, D. P. 1968. Line transect method of estimating grouse population densities. *Biometrics* 24: 135–45.

Horwood, J. W. 1981. Results from the IWC/IDCR minke marking and sightings cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Horwood, J. W. and Breiwick, J. M. 1981. A note on Doc. SC/32/Mi16-sightings Area VI. *Rep. int. Whal. Commn* 31: 116.

International Whaling Commission. 1981. Report of the minke whale sub-committee. *Rep. int. Whal. Commn* 31: 103–21

International Whaling Commission. 1982a. Report of the Workshop of the Design of Sightings Surveys (published in this volume).

International Whaling Commission. 1982b. Report of the Special Meeting on Southern Hemisphere Minke Whales (published in this volume).

Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 407–20.

Ohsumi, S. 1981. Estimation of population size of the minke whale in the Antarctic Area VI by means of whale sightings. *Rep. int. Whal. Commn* 31: 323–26.

Seber, G. A. F. 1973. *The Estimation of Animal Abundance and Related Parameters.* Griffin, London, 506 pp.

Shimadzu, Y. 1982. Revised estimates of abundance of minke whales in Area I by stratified analysis of sightings data. Appendix 18 of the Report of the Special Meeting on Southern Hemisphere Minke Whales (published in this volume).

Tillman, M. F. 1982. Reanalysis of Area I sighting data by means of revised Doi model. Appendix 17 of the Report of the Special Meeting on Southern Hemisphere Minke Whales (published in this volume).

SC/Jn81/MiS29

A Simulation Study on Sighting Survey of Minke Whales in the Antarctic

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ABSTRACT

Diving (T) and blowing (τ) times for minke whales were estimated from observations carried out by *Kyo-Maru No. 27* and *Toshi-Maru No. 11* in 1980/81 to be: $T = 2$ min, $\tau = 2.3$ sec.
Analysis of videotapes of topmen behaviour on the *Kyo-Maru No. 27* revealed the angular scanning velocity, w, to be 2.7°/sec.
The human physiological discrimination function G can be expressed as $G(r,w) = e^{-0.0564\ wr^2}$ where r is the radius in miles.
Computer simulations of the sighting process under various conditions were carried out. The results of the simulation for $w = 2.7°$/sec are as follows:

Topmen	Sighting rate P	Correction factor Kw
1	0.155	0.628
2	0.217	0.782
4	0.281	0.967

The changes in P and Kw with the number of topmen and the angular velocity are examined.

INTRODUCTION

For the many whale species currently protected, analysis of sightings data is the only method of obtaining population estimates.

Even for those stocks upon which hunting is allowed, the stock assessment techniques used by the IWC Scientific Committee do not provide completely reliable estimates for several reasons, e.g. lack of data due to the small quota size, imperfect temporal and spatial standardization of fishing effort, uncertainties in estimates of the biological parameters. This may result in widely differing estimates for the same areas in successive years so that people often feel that the results are not scientifically reliable. Although in recent years techniques have been developed (e.g. Doi *et al.*, 1980; Beddington and Cooke, 1981) which do not require effort data, considerable uncertainty remains due to a lack of biological information on such factors as pregnancy rates, maturity and age compositions. Sightings methods are thus of great importance in population estimates of commercial as well as protected species.

Doi (1971; 1974) developed a sighting model and estimated the rate of sighting for each species from which population sizes may be estimated from sightings survey data. This method has since been used in several studies (e.g. Ohsumi, 1982; Ohsumi and Yamamaru, 1982).

In the Doi sighting theory, the probability of sighting on the trackline is not equal to 1, as whales may be missed due to the scanning of the topmen using binoculars with a 70° visual angle. Other authors (e.g. Best and Butterworth, 1980 and Horwood, 1981) assumed the probability of sighting on the trackline to be 1. It is thus extremely important to quantify the probability of sighting on the trackline. A Workshop on the Design of Sightings Surveys was held in Seattle in 1980 (IWC, 1982). Many topics were reviewed and discussed and common understanding obtained on several matters but no new unified mathematical model was established. However, it was agreed that the problem of the probability of sighting on the trackline can be solved by the following three approaches:

(a) Development of theoretical models.
(b) Experimental methods.
(c) Computer simulation.

Of the above three approaches, method (b) is inductive but methods (a) and (c) are deductive. There are practical problems associated with method (b) as a comprehensive experimental cruise may require for example, the simultaneous use of several scouting boats with different types of crow's nests and aircraft. On the other hand, there are also problems associated with deductive methods involving biological parameters, movements of scouting boats and the behaviour of topmen, which have not yet been clarified.

This report is based principally upon Doi's model, and examines sighting rates within a survey area and the probability of sighting along the trackline.

RESULTS OBTAINED FROM DOI'S MODEL

The sighting of whales depends on the following three elements:

(a) The physiology and behaviour of whales:
    diving times, blowing times, school and group sizes, reaction to boats.
(b) Scouting boat operations:
    speed, height of eye of topman, range of observation, sighting sector.
(c) Eye movements of observers:
    physiological discrimination, visual angle of binoculars, angular velocity of scanning.

Fig. 1 illustrates the factors involved in Doi's model with respect to the above elements. From this procedure, Doi (1971, 1974) estimated the rate of sighting and a correction factor, Kw (equivalent to the probability of sighting along the trackline). The results are shown in Table 1, along with several related parameters.

Whales are not always seen on the trackline, only a certain proportion, Kw, as topmen may miss whales due to eye scanning (angular velocity w) within the angle of the sighting sector, using binoculars with a p degree visual angle.

In calculating the rate of sighting, factors concerning the visual capabilities of the topmen and the missing of whales due to eye scanning had to be introduced. The values and formulation chosen were based on experimental data or are simplified in the model and may therefore include some degree of error or bias. In order to examine this, a simulation analysis was carried out.

The 1980/81 IDCR cruise was directed at minke whales in Area V. One of the authors (F. K.) was on board *Kyo-Maru No. 27* and collected data not only on the whales themselves but also on the activity of the topmen. Similar data were collected on the *Toshi-Maru No. 11*. All the available data were used in this report.

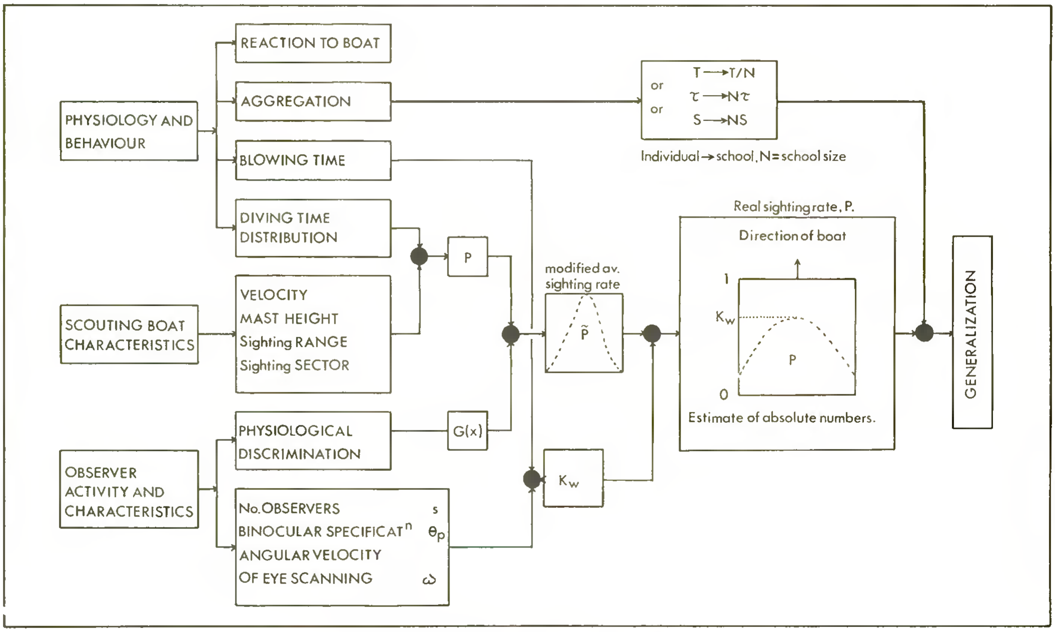

Fig. 1. Schematic diagram of Doi's sighting theory.

Table 1

Rates of sighting estimated from Doi's sighting theory

Species	Diving time (m) T	Blowing time (s) t	Angular velocity w°/sec	Number of topman s	Correction factor Kw	Sighting rate P
Blue whale	5.67	5.08	5–10	2–4	0.568	0.141
Fin whale	4.87	4.57	5–10	2–4	0.540	0.211
Sei whale	4.21	3.66	5–10	2–4	0.484	0.197
Minke whale	1.30	3.23	5–10	2–4	0.455	0.112
Pigmy blue	9.70					
Right whale	3.70	3.56	5–10	2–4	0.474	0.221
Humpback whale	8.13					
Sperm whale	8.56	2.72	5–10	2–4	0.420	0.138

Notes: Visual angle binoculars 7°; velocity of scouting boat 12 knots; range of sighting 6.4 miles; sighting sector angle 100°.

DIVING TIME OF MINKE WHALES

When an observer sights a whale, the vessel chases it. An observer can count how many times it dives and can measure the time between successive blows and estimate the diving time. Minke whales tend to aggregate and in such cases the apparent diving time will be less than in the case of individual whales, as individuals cannot be identified within the group. Table 2 shows the average diving time calculated for various group sizes. As suggested above, the mean diving time of whales in a group is smaller than that for single animals, and so the true diving time should be estimated from the data for individuals. The mean diving time of individual whales is 1 minute 56 seconds (Table 2). It is therefore concluded that the average diving time T of minke whales is about 2 minutes (i.e. for the diving cycle in which blowing time is included).

Table 2

Diving time of minke whales

Aggregation	Cases	Total number of dives	Total diving time		Mean diving time
			minutes	seconds	m s
1 whale	5	45	86	43	1 56
2–3 whales	5	142	91	39	1 26
4+ whales	2	120	19	11	1 31

Table 3

Blowing time of minke whales

Aggregation	Cases	Total blowing time	Mean blowing time
		seconds	seconds
1 whale	53	101.9	1.95
More than 2 whales	60	159.6	2.7
Total	113	261.5	2.3

BLOWING TIME OF MINKE WHALES

Observation of the blowing time (τ) is more difficult than the diving time because it is very short and the blow itself is small. Table 3 and Fig. 2 show the results from *Kyo-Maru No. 27* and *Toshi-Maru No. 11*. An average value of:

$$\tau = 2.3 \text{ seconds}$$

is found and used in the simulation analysis. As the diving time includes the blowing time, the net diving time used was 117.7 sec ($T - \tau$).

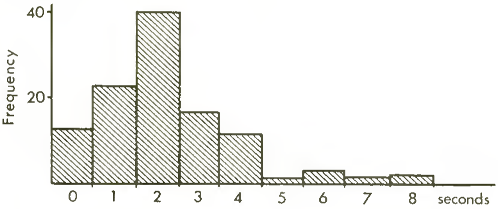

Fig. 2. Blow times of minke whales.

SCANNING ANGULAR VELOCITY

To turn from the behaviour of the whales to the behaviour of the observer, the visual range, the scanning pattern and the characteristics of the binoculars are the vital parameters. Doi (1971; 1974) found that the sighting sector has a radius of 6.4 miles with an angle of 100°, that the angular scanning velocity was 5°–10°/sec and that the visual angle of the binoculars was 7°.

The angular scanning velocity w was examined in the 1980/81 survey, by installing a remote controlled video camera above the crow's nest in *Kyo-Maru No. 27;* the topmen did not know when the camera was operating. After the cruise the turning angles of binocular movements were measured along with the elapsed time from which the angular velocity was easily calculated.

The records of 5 topmen were analysed. Usually 2 topmen are in the crow's nest, but in the morning and in the evening only 1 topman works. The results are summarised in Table 4, both by identification of topman and by number of topmen on crow's nest.

Table 4

Angular velocity of eye scanning

	In case of 2 topmen						In case of 1 topman	
I.D. No. of topman	1	2	3	4	5	Average	2	5
Northern Leg	1.79	4.66	1.60	5.01	1.64		4.66	2.32
,,	1.71	3.50	1.80	4.68	2.48		—	—
,,	2.52	4.18	2.04	3.86	1.33		—	—
,,	1.68	3.83	2.15	3.76	1.60		—	—
,,	1.80	3.45	2.35	3.79	1.24		—	—
,,	1.09	4.08	2.80	3.51	2.07		—	—
,,	1.20	—	—	2.11	1.38		—	—
,,	2.17	—	—	—	—		—	—
Average	1.70	3.96	2.15	3.94	1.56	2.62°/second	4.66	2.32
Southern Leg	2.14	2.35	2.13	4.47	1.33		—	2.65
,,	2.22	3.95	2.02	4.62	1.35		—	—
,,	2.79	2.74	2.23	3.93	2.20		—	—
,,	2.86	—	—	4.27	1.73		—	—
,,	3.15	—	—	3.69	—		—	—
,,	—	—	—	3.27	—		—	—
,,	—	—	—	3.51	—		—	
Average	2.63	2.78	2.11	3.83	1.66	2.71°/second	—	2.65
Total average	2.13	3.66	2.13	3.87	1.61	2.67°/second	4.66	2.51

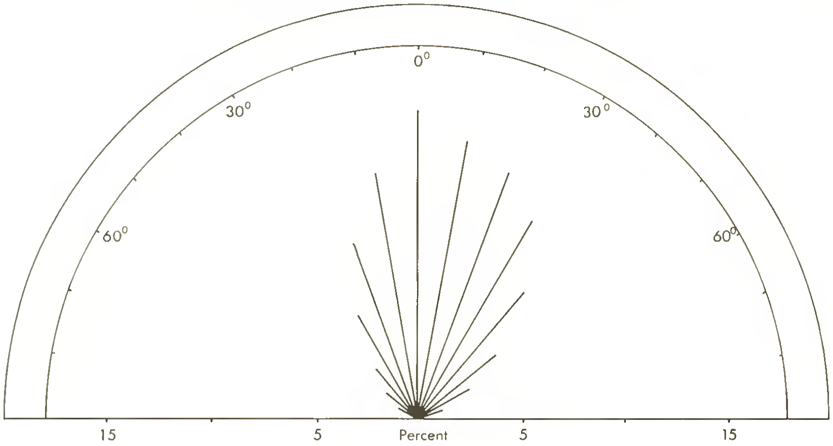

Fig. 3. Frequency of scanning (by angle): two topmen.

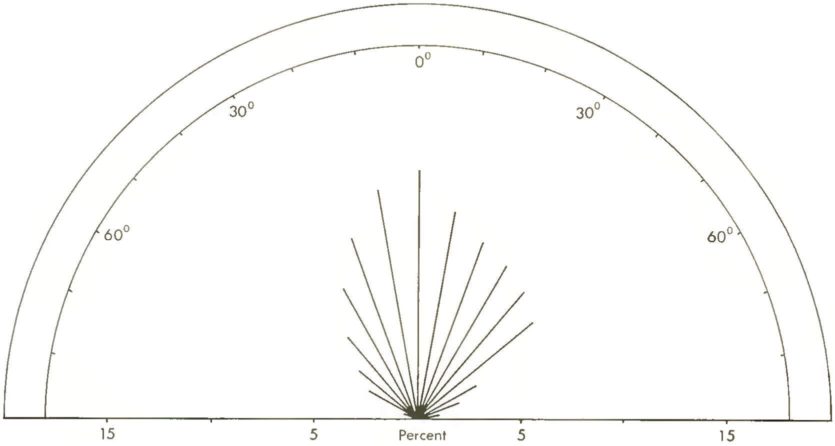

Fig. 4. Frequency of scanning (by angle): one topman.

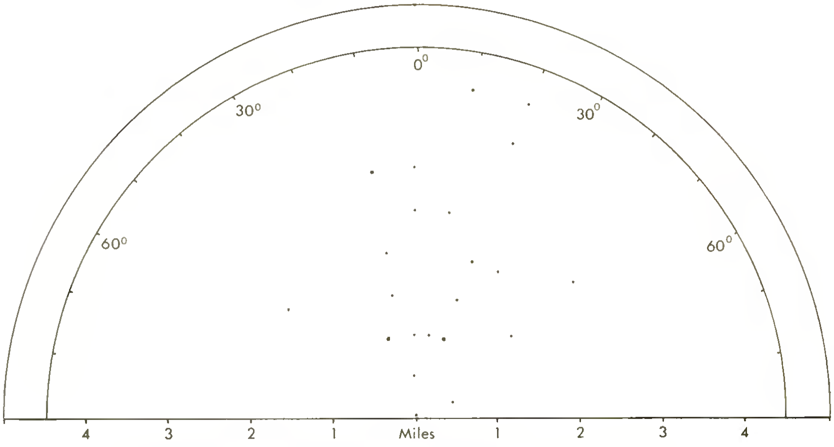

Fig. 5. Position of whales sighted by topman on board the *Kyo-Maru No. 27.*

Table 5

Polar coordinates of minke whales sighted by topmen on board *Kyo-Maru No. 27*

r θ	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	Sum	%
120													
110													
100													
90	1											1	3.4
80													
70													
60													
50					1							1	3.4
40													
30													
20			2									2	6.9
10				1	1		2					4	13.8
0		1	1			1	1				1	5	17.2
10	1		2			1			1			5	17.2
20			2	1	2			1	1			7	24.1
30					1							1	3.4
40													
50				1		1						2	6.9
60													
70		1										1	3.4
80													
90													
100													
110													
120													
Sum	2	2	7	3	5	3	3	1	2		1	29	
%	6.9	6.9	24.1	10.3	17.2	10.3	10.3	3.4	6.9		3.4	100.0	

Table 6

Polar coordinates of minke whales sighted by topman on board *Toshi-Maru No. 11*

r θ	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	Sum	%
120													
110													
100				1								1	0.5
90			2									2	1.1
80			1									1	0.5
70			2	4			1					7	3.7
60			2	1	1	1	2		1			8	4.2
50	1	1	1	1	3		1	1			1	10	5.3
40		1	2	1	2	2	1		2			11	5.8
30			1	1	3	2	3		2			12	6.3
20	1	1	3	4	3	1	1	1	1			16	8.4
10			5	4	3	4			1	1		18	9.5
0		4	6	10	4	5	3	1	2	1		36	18.9
10	1	5	7	6	5		2			1	1	28	14.7
20		1	3	3	1	4	2		2			16	8.4
30	3		1	3	5		1		1			14	7.4
40	1	2		1		2						6	3.2
50													
60				1								1	0.5
70							1					1	0.5
80			1			1						2	1.1
90													
100													
110													
120													
Sum	7	15	37	41	30	22	18	3	12	3	2	190	100.0
%	3.7	7.9	19.5	21.6	15.8	11.6	9.5	1.6	6.3	1.6	1.1	100.0	

SIMULATION TECHNIQUE

Those factors necessary for a simulation model of sighting have been discussed in the earlier sections. If the blow of a whale appears within the visual angle of the binoculars which are moving with a given angular velocity, the whale becomes sightable. However, 'sighted' or 'not sighted' is statistically determined by the discrimination function G. This is the mechanism of sighting which should be reproduced by any simulation process.

The following conditions and controls were used in the simulation:

1. *Generation of whales*

The y-axis is the trackline of the scouting vessel and the x-axis is the right angle distance. The positions of whales (x,y) are generated by uniform random numbers.

2. *Diving and blowing time*

The diving cycle is 2 minutes. The blowing time is 2.3 seconds. The net diving time is 117.7 seconds. Starting times of blows are also uniformly randomized.

3. *Temporal and special dimensions*

Vessel speed: 12 knots
Observation period: 10 hours per day
Cruise track: 120 miles per day
Sightable range: 6 mile radius
Angle of sighting sector: 101.5°
Range of right angle distance: 9.29 miles
Sweep area per day: 1,114.8 square mile
Number of whales generated within sweep area: 1,000

4. *Sighting range*

The heights of the topman's eyes above sea level are 17.5 m in the *Kyo-Maru No. 27* and 16.7 m in the *Toshi-Maru No. 11*. The sightings range is theoretically 2.07 H, where H is height of eye level. Thus the calculated range is about 8 miles. In practice, however, as shown in Tables 5 and 6, and Figs 5 and 6, the range is 6 miles.

5. *Number of observers*

Simulations were carried out for 1, 2 and 4 persons as topmen. For most of the time there are two topmen in the crow's nest (although as we have said in the early morning and late evening there is usually only one topman). Sometimes officers on the upper bridge sight whales. Four topmen is considered to be the maximum.

6. *Characteristics of binoculars and scanning angular velocity*

Visual angle of binoculars = 7°
Scanning angular velocity = 2.7°/sec.

Besides the above values obtained from cruise data, 7 different situations (w = 1, 1.5, 2, 3, 3.5, 4, 4.5°/sec) were used in order to examine how the rate of sighting varies with the angular velocity.

7. *Iterations of simulation in one case*

Simulation runs were carried out 5 times in each case. Then average values of the sighting rate and the correction factor were obtained for each case, along with the standard deviations.

8. *Simulation time interval scaling*

The increment in the time interval was 1 second.

9. *Movement of target*

Generated whales do not move or react to vessels.

10. *Sighting mechanism*

(i) If a blow is found in the visual angle of binoculars, this target is entered to the latently sightable phase.
(ii) Whether the target in the latently sightable phase is sighted or not, it is determined by the probability from the physiological discrimination function.
(iii) The target which has been 'sighted' disappears at once from the spatial and temporal dimensions. The same target cannot be sighted again.

RESULTS OF SIMULATION

The computer simulation process is shown in the flow chart of Fig. 8. An example of computer output is presented in Fig. 9 (positions sighted), Fig. 10 (targets generated and sighted by right angle distance), Fig. 11 (rate of sighting by right angle distance) and Fig. 12 (targets sighted by radius), where the number of topmen, s, is 2 with a scanning angular velocity, w, of 2.7°/sec.

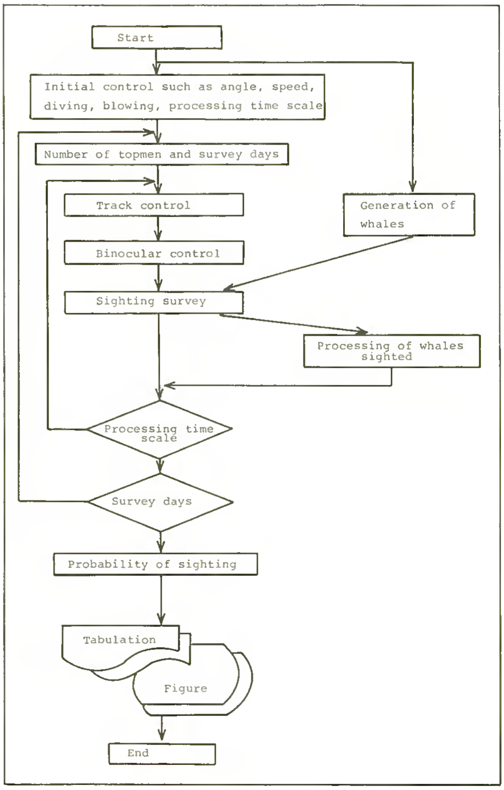

Fig. 8. Flow chart of sighting simulation.

Results of simulations with different numbers of observers and angular velocities are summarised in Table 8 (sighting rate P) and Table 9 (correction factor Kw).

Table 7

Number of whales sighted along the trackline

	Radius					(mile)					
	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Whales sighted	0	5	7	10	4	6	4	1	2	1	1
Accumulated number	41	41	36	29	19	15	9	5	4	2	1

Table 8

Rate of sighting related to number of topmen and angular velocity w

	Angular velocity W°/sec %							
Number of topmen	1	1.5	2	2.7	3	3.5	4	4.5
1	24.1 (1.5)	15.2 (1.6)	17.4 (1.0)	15.5 (1.3)	12.6 (0.9)	13.9 (1.2)	12.5 (1.2)	12.0 (1.5)
2	34.4 (2.0)	24.1 (1.5)	24.9 (1.0)	21.7 (0.7)	19.7 (0.6)	18.9 (1.4)	19.1 (0.9)	17.6 (1.8)
4	44.3 (2.3)	31.7 (1.5)	32.9 (1.1)	28.1 (1.2)	23.9 (1.0)	25.1 (1.0)	24.4 (0.9)	20.9 (1.5)

Note: standard deviation in parentheses.

Table 9

Correction factor Kw (probability of sighting along trackline related to number of topmen and angular velocity w)

	Angular velocity W°/sec %							
Number of topmen	1	1.5	2	2.7	3	3.5	4	4.5
1	71.8 (9.4)	60.7 (11.0)	63.2 (6.0)	62.7 (8.7)	64.5 (8.9)	58.9 (8.2)	39.6 (9.0)	66.6 (5.4)
2	90.3 (6.6)	83.2 (7.2)	77.5 (4.7)	78.2 (9.2)	83.5 (7.9)	73.2 (6.3)	64.5 (7.3)	86.1 (8.4)
4	96.6 (3.3)	93.9 (2.8)	94.5 (3.8)	96.7 (2.3)	92.3 (1.4)	94.5 (2.2)	92.6 (2.9)	94.3 (4.3)

Note: standard deviation in parentheses.

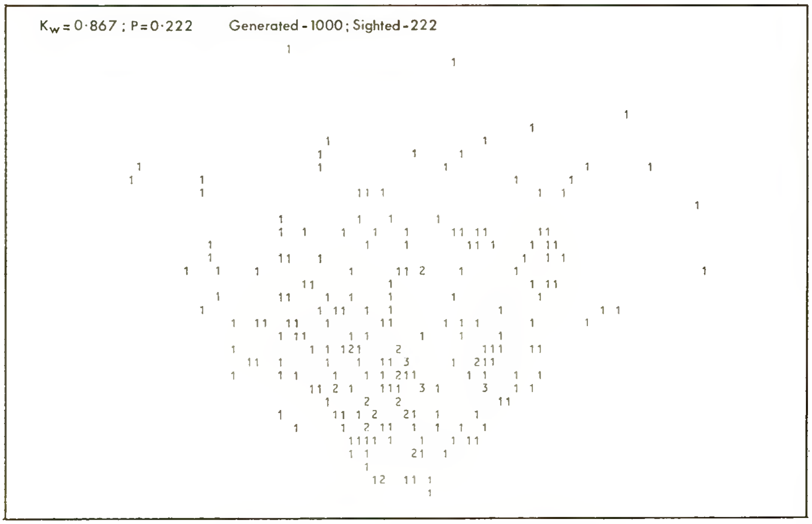

Fig. 9. Example of simulated sighting positions (w = 2.7°/s).

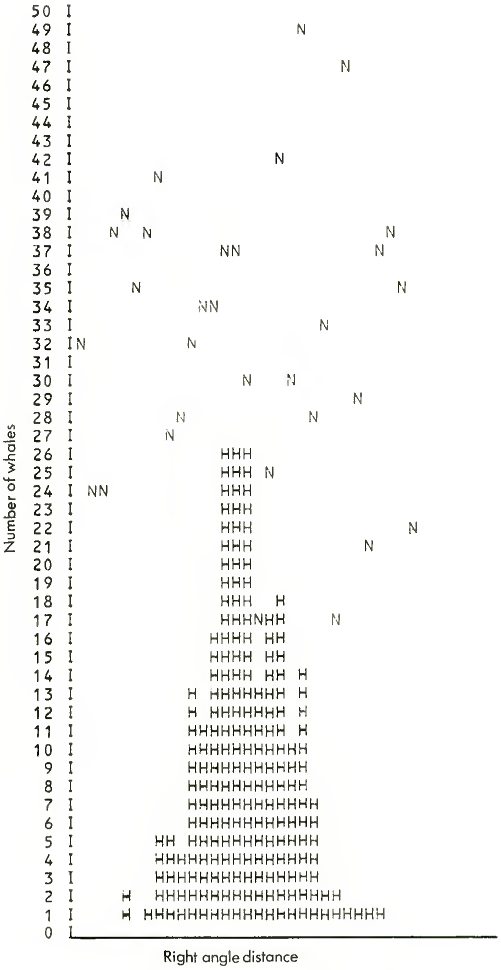

Fig. 10. Number of whales generated (N) and sighted (H) in a simulation example (right angle distance, w = 2.7°/s).

Isopleth diagrams of P and Kw are presented in Fig. 13 and Fig. 14. The abcissa is w and the ordinate the number of topmen, s. Precise values for P and Kw are not used but their standard deviations as shown in Tables 8 and 9, from which errors are found (approximately 5% coefficient of variance). The contour lines in Figs 13 and 14 are drawn by smoothing. These figures are useful and convenient for estimating approximate values of P and Kw under any combined conditions s and w. In addition, the most efficient combination of s and w can be found.

In the current Antarctic cruises the usual sighting conditions are:

$$s = 2 \text{ topmen},\ w = 2°/\text{sec}$$

Under these actual conditions the values of P and Kw are:

$$P = 0.217,\ Kw = 0.782$$

as indicated in Table 8 and Table 9.

The estimates from Doi's earlier papers under these conditions (Table 1) are P = 0.112 and Kw = 0.455. These are smaller than the present estimates. This can be attributed to changes in the fishery. Ten years ago the preferred species was the fin whale, followed by the sei whale, both larger than the minke whales currently exploited. Accordingly the sighting range, angular velocity and physiological discrimination were quite different.

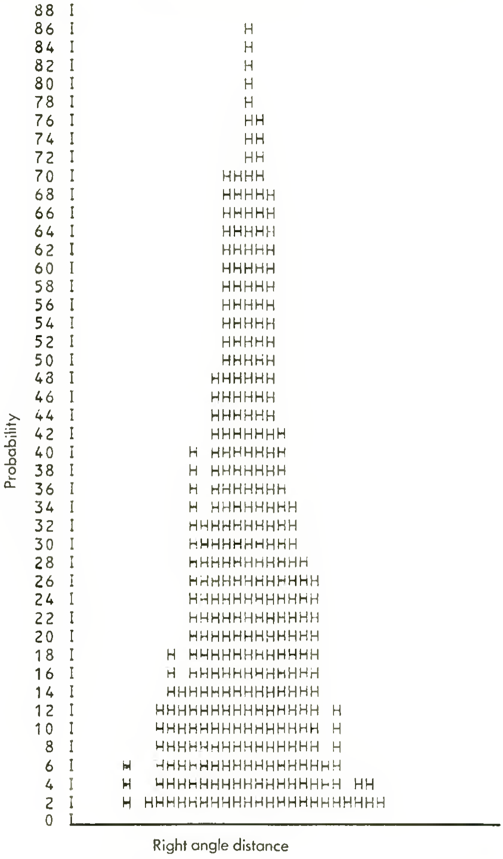

Fig. 11. Probability of sighting in a simulation example (right angle distance, w = 2.7°/s).

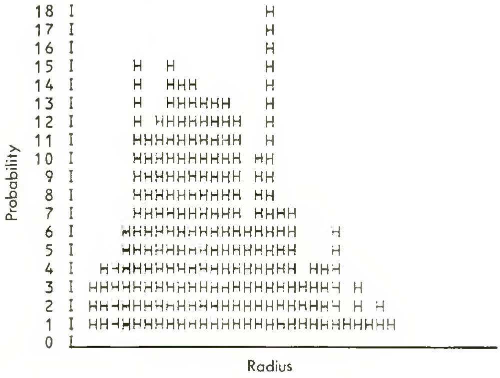

Fig. 12. Probability of sighting in a simulation example (radius, w = 2.7°/s).

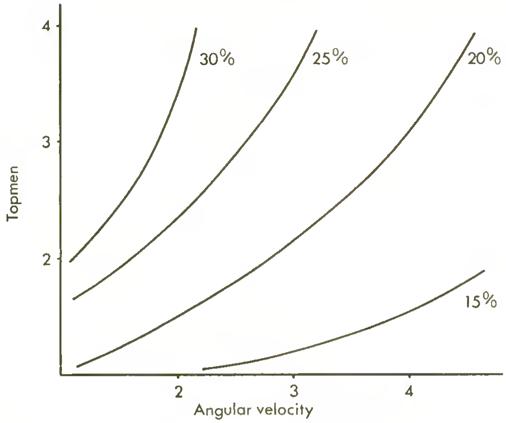

Fig. 13. Isopleth diagram of sighting rate related to number of topmen and angular velocity.

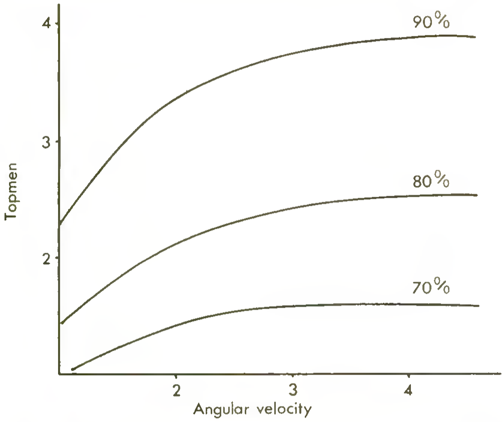

Fig. 14. (single column × 7 cm) Isopleth diagram of correction factor (probability of sighting along trackline) related to the number of topmen and angular velocity.

FUTURE WORK

Several problems remain unsolved and require further study.

(a) Although the eye movement of the topmen is not uniform, i.e. the turning angle varies with each scan and the topmen search more frequently towards the trackline, this was not taken into account in our simulation. This is not thought to greatly affect the estimates of sighting rate however.

(b) The effect of the tendency of minke whales to aggregate is an important problem to be examined in the near future.

(c) The reaction of animals to a vessel may be a decisive element in a sightings survey. This needs to be included in the simulation process and will also allow the extension of the method to other species.

REFERENCES

Beddington, J. R. and Cooke, J. G. 1981. Development of an assessment technique for male sperm whales based on the use of length data from the catches, with special reference to the Northwest Pacific stock. *Rep. int. Whal. Commn* 31: 747–60.

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Butterworth, D. S. 1980. An investigation of possible bias introduced into sightings estimates of the minke whale population by the method used for right-angle distance calculation. A brief preliminary report. Paper SC/32/Mi12 presented to the IWC Scientific Committee, July, 1980.

Doi, T. 1971. Further development of sighting theory on whales. *Bull. Tokai Reg. Fish. Res. Lab.* 68: 1–22.

Doi, T. 1974. Further development of whale sighting theory. pp. 359–68. In: W. E. Schevill (ed.), *The Whale Problem: a status report*. Harvard Univ. Press, Cambridge, Mass. 419 pp.

Doi, T. 1979. Theoretical aspects analysed by introducing age specific availability into population analysis of minke whales in the Antarctic. *Rep. int. Whal. Commn* 29: 439–46.

Horwood, J. W. 1981. Results from the IWC/IDCR minke whale marking and sighting cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Ohsumi, S. 1981. Estimation of population size of the fin whale in the Antarctic Area IV by whale sightings. *Rep. int. Whal. Commn* 31: 403–6.

Ohsumi, S. and Yamamaru, K. 1980. A review of the Japanese whale sightings system. Paper SS/17 (published in this volume).

Table 1

Sighting records of minke whales from the ice-breaker *Fuji* in pelagic waters off the coast of Enderby Land in December 1979
(* larger whale species)

Position	Time (L.T.)	Date	No. whales sighted	Angle	Estimated distance from whale (m)	Distance (n. mile)
A 63°–19.0′S,69°–46.2′E	1300	Dec. 24				
	1330	,,	3, 3, 3	L 30°–90°	1,000	209.0
	1550	,,	1	R 30°	,,	
	1630	,,	4	H	150	
	1835	,,	2	R 60°	300	
	2230	,,	1, 2	R 15°, H	800	
	0330	Dec. 25	1, 2	L 80°	600, 1,000	
	0530	,,	2	R 80°	1,000	
	0550	,,	2	R 70°	2,000	
	0555	,,	2, 2	R 30°, L 30°	400, 600	
	0610	,,	7	R 30°	5,000	
	0615	,,	20	L 30°	3,000	
B 63°–54.0′S, 61°–59.7′E	0800	,,				
C 63°–52.4′S,61°–41.2′E	1700	,,				
	1730	,,	*3	L 30°	1,500	142.9
	1750	,,	*3	H	100	
	1850	,,	3	H	200	
	1915	,,	30	L 45°	10,000	
	,,	,,	3	H	3,000	
	,,	,,	3	H	5,000	
	,,	,,	30	H	7,000	
	1930	,,	3	L 90°	500	
	1940	,,	8, 6	L 15°, 50°	5,000	
	1945	,,	1, 1	L 50°	3,000	
	2030	,,	2	L 50°	3,000	
	0300	Dec. 26	1	R 15°	4,000	
	0310	,,	1	L 90°	1,000	
	0335	,,	2	R 30°	1,000	
	0340	,,	1, 1	R 15°, L 60°	3,000, 800	
	0350	Dec. 26	2, 1	L 60°, 15°	800, 1,000	
	,,	,,	2	L 70°	1,500	
	0400	,,	*5, 5	R 45°, L 90°	4,000	
	0520	,,	1	R 50°	100	
	0525	,,	1	R 10°	1,000	
	0528	,,	1	R 20°	800	
D 64°–20.0′S, 55°–58.8′E	0800	,,				
E 64°–23.0′S, 55°–26.6′E	1800	,,				
	1800	,,	1, 1	R 30°, H	500, 2,500	206.6
	1900	,,	2	L 30°	1,000	
	2000	,,	1, 1	L 30°, 45°	1,000, 2,000	
	2045	,,	2	R 40°	6,000	
	2100	,,	1	L 30°	1,500	
	2105	,,	1	H	200	
	2140	,,	1	R 30°	5,000	
	2200	,,	5	L 45°	3,000	
	2240	,,	3	R 60°	4,000	
	2255	,,	3, 3	R 30°, L 30°	4,000, 3,000	
	,,	,,	3	H	2,000	
	2310	,,	6	L 15°	4,000	
	2315	,,	2	R 30°	2,000	
	2335	,,	2	L 20°	1,000	
	0230	Dec. 27	5	L 10°	1,000	
	0320	,,	1	H	500	
	0640	,,	2	R 30°	1,500	
	0740	,,	2	L 30°	1,000	
F 65°–48.3′S, 48°–15.8′E	1300					
F 65°–44.5′S, 48°–15.7′E	1200	Dec. 28				
	1508	,,	1	L 40°	—	43.6
	1740	,,	10	L 20°	—	
G 65°–20.0′S, 47°–17.0′E	1800	,,				
H 66°–36.2′S, 42°–08.1′E	1500	Dec. 29				
	1545	,,	1	H	500	39.7
I 67°–13.0′S, 41°–33.0′E	1900	,,				
	1443	Dec. 30	2	L 70°	500	97.4
J 68°–35.0′S, 39°–27.1′E	1600	,,				
			227			739.2

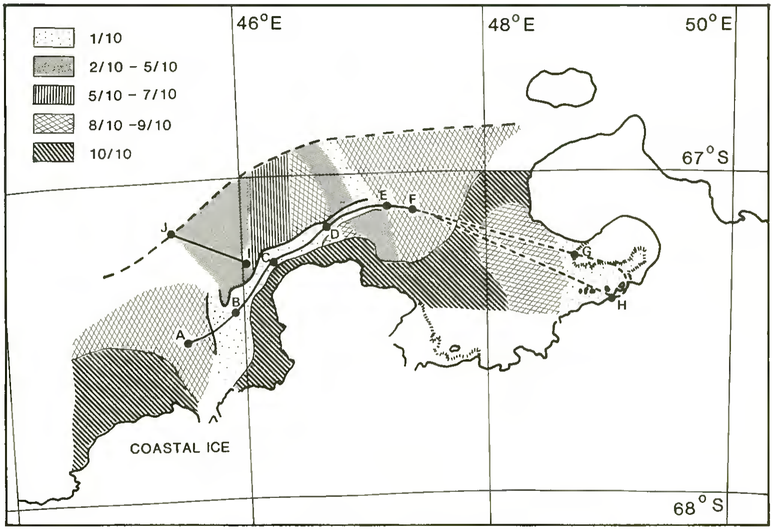

Fig. 2. Sighting cruise track, 1981, and pack ice distribution.

Table 2

Sighting records of minke whales from the ice-breaker *Fuji* (and its helicopter*) in the pack ice area off Enderby land in February 1981.

Position	Time (L.T.)	Date	No. whales	Distance (n. mile)
A 67°–30.1′S, 45°–32.0′E	1200	Feb. 17		
	1250	,,	1	11.4
	1254	,,	3	
B 67°–25.5′S, 45°–53.4′E	1300	,,		
	1301	,,	1, 1	9.9
	1303	,,	20	
	1307	,,	1	
	1317	,,	3	
	1322	,,	3	
	1333	,,	3	
	1338	,,	8	
	1340	,,	2	
	1350	,,	3	
C 67°–16.5′S, 45°–14.6′E	1400	,,		
	1408	,,	3	11.9
	1409	,,	1, 20+	
	1421	,,	30+	
	1430	,,	1	
	1432	,,	2	
	1445	,,	5	
D 67°–10.2′S, 46°–40.8′E	1500	,,		
	1505		3	12.0
	1515	,,	1	
	1525	,,	2	
E 67°–06.7′S, 47°–10.3′E	1600	,,	4	
	—	,,	0	5.6
F 67°–07.6′S, 47°–24.4′E	1700	,,		
F 67°–07.6′S, 47°–24.4′E	1715	,,		
*	1731	,,	1	31.0
G 67°–17.5′S, 47°–22.0′E	1733	,,		
H 67°–22.0′S, 47°–30.1′E	1751	,,		
	1801	,,	1	40.0
	1811	,,	1	
F 67°–07.6′S, 47°–24.4′E	1815	,,		
I 67°–09.6′S, 47°–30.5′E	1300	Feb. 19		
	1328	,,	1	23.4
	1331	,,	1	
	1441	,,	1	
	1456	,,	7	
	1500	,,	2	
H 67°–09.0′S,45°–36.0′E	1500	,,		
			136	145.7

Table 3

Density, represented as the number of whales sighted per n. mile

Section	N. whales sighted	Track distance	Density	Ice condition
		Sighting cruise 1979		
A–B	57	209.0	0.27	open water
C–D	108	142.9	0.76	''
E–F	48	206.6	0.23	''
F–G	11	43.6	0.25	pack ice 1/10–5/10
H–I	1	39.7	0.03	open water
I–J	2	97.4	0.02	pack ice 9/10–10/10
	227	739.2	0.31	
		Sighting cruise 1981		
A–F	121	45.5	2.66	pack ice 1/10
F–G	1	31.0	0.03	'' 8/10–10/10
H–F	2	40.0	0.05	'' ''
I–J	12	23.4	0.51	'' 7/10–10/10
	136	139.9	0.97	

Table 4

Density differences between open water areas and pack ice areas

	N. whales sighted	Track distance	Density
Open water	214	598.2	0.36
Pack ice 1/10–5/10	132	89.1	1.48
'' 6/10–10/10	17	191.8	0.09
	363	879.1	0.42

1979 Cruise

The average density for the first sighting cruise was 0.31 nm which appears to be relatively high compared with other results (e.g. Ohsumi *et al.*, 1970; Kato, pers. comm.). The highest density (0.76) was found in section C-D, mainly due to the sighting of a large school, the lowest density (0.02) was found in section I-J in the pack ice area, although it is not known if the pack ice was the reason for the low density.

1981 Cruise

On the second cruise, all sightings effort was made in the pack ice or coastal ice areas. Despite the high average value (0.97), the density varied greatly between sections especially in comparison with the 1979 results. The highest density was found in section A-F, and the lowest in section F-G. According to Taylor (1957), Antarctic minke whales are found in open waters within the ice. This suggests that the density may vary with the ice condition. In this study information on ice conditions was obtained from satellite data (NOAA-6), helicopter survey data and visual data from the ship. From these data, ice conditions were classified into ten groups based on the degree of ice coverage (Fig. 1). Table 4 shows the density variation with ice conditions. This clearly shows that whales are most common in 1/10–5/10 ice condition areas, 4.1 times and 16.4 times as common as in open water (pelagic) areas and 6/10–10/10 ice condition areas respectively. This suggests that the minke whales prefer the open waters within the ice, e.g. leads or pools, to the heavily ice covered areas. In heavy ice conditions, it seems to be difficult for the minke whales to breathe, as in such areas we observed on several occasions, minke whales thrusting their heads out of tiny ice openings in an unusual 'standing' position.

The highest density was found in section A-F, an ice lead area which had developed between the permanent coastal ice and the yearly pack ice. These leads usually develop around the coastal ice margin as the season advances and the pack ice retreats with the Antarctic Circumpolar easterly wind or the Antarctic coastal currents. We do not know whether the minke whales are found in such leads all around Antarctica, but members of the Japanese Antarctic Expedition say that the whales are usually found in the 'Ohtone-lead' which *Fuji* often passes through. It is also uncertain when the minke whales begin to penetrate into the pack ice areas. The leads began to develop from November in the Lützow-Holm Bay area in 1980 (NOAA-6 data). In that year a seal aerial census was undertaken in Lützow-Holm Bay and adjacent areas from the end of September to the end of December. During this survey, based at the station at 69°10′S, 38°45′E, the first minke whale was sighted on 28 December far to the south of the pack ice edge (about 90 nm and 60 nm from the pack ice and coastal ice edges respectively). This suggests that minke whales are not found in lead areas in the high latitudes before early summer. I believe that minke whales probably steadily penetrate into the pack ice area with the advance of summer and the melting of the ice, and that high densities occur in the lead or pool areas within the ice.

SCHOOL SIZE

In this study, school size was also recorded. Ohsumi *et al.*, (1970) reported that larger schools were found between 50°–60°S than between 40°–50°S. According to Best and Butterworth (1980), the larger schools were sighted between 60°S–68°S with a maximum school size of 60 individuals. The school size results from this study are

Table 5

School size of minke whales sighted in pelagic water and pack ice areas

	Number of individuals in school												
	1	2	3	4	5	6	7	8	9	10	20	30	Average
Pelagic water	21	15	11	1	2	2	1	1	0	0	1	2	3.9
Ice condition 1/10–5/10	8	3	7	1	1	0	0	1	0	1	2	1	5.3
Ice condition 6/10–10/10	6	2	0	0	0	0	1	0	0	0	0	0	1.9

shown in Table 5. Average school size is largest under 1/10–5/10 ice conditions and smallest under 6/10–10/10 conditions. All minke whales sighted in latter areas were solitary apart from one school (comprising 7 individuals) sighted in a pool in an 8/10 area. As already mentioned, if minke whales prefer leads or pools in the pack ice area, one might expect larger schools there. School sizes in this study are not as large as those reported by Best and Butterworth but as no confirming was carried out the estimates of school size will be lower than the actual values (H. Kato, pers. comm.).

The school size may also change with the feeding grounds, although the relationship (if any) between school size and krill density is unknown, but it seems possible that this factor, as well as the ice conditions, may affect the school size of minke whales.

ACKNOWLEDGEMENTS

My sincere thanks are due to all crew of ice-breaker *Fuji* for their kind help in sightings. In particular Captain S. Nei and S. Hisamatsu, ship's officer, offered me navigation information and other help. I also thank Professor S. Kawaguchi, the deputy leader of 21st Japanese Antarctic Research Expedition for his advice.

REFERENCES

Best, P. and Butterworth, D. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978/79. *Rep. int. Whal. Commn* 30: 257–83.

Kasuya, T. and Ichihara, T. 1965. Some information on minke whales from the Antarctic. *Sci. Rep. Whales Res. Inst., Tokyo* 19: 37–43.

Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 22: 75–125.

Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish. Res. Bd Can.* 32(7): 995–1,004

Taylor, R. H. F. 1957. An unusual record of three species of whales being restricted to pools in Antarctic sea-ice. *Proc. Zool. Soc., Lond.* 129: 325–31.

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Some Biological Parameters for the Antarctic Minke Whale

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ABSTRACT

Biological material and data collected by Japanese operations in the Antarctic between 1971/72 and 1979/80 are examined. Body length, age at 50% sexual maturity, pregnancy rate, ovulation rate, total mortality coefficient, foetal sex ratio and litter size are estimated by year and Area. The average body length for the whole period is 27.06 ft for males and 28.10 ft for females. In most Areas a slight increase in average body length over the period is observed, but there is no trend in the average body length of mature whales. Animals were aged by examination of ear plugs. The sexual maturity (t_m) of females is estimated at 6.5 for the whole Antarctic for the whole period; a slight increasing trend in (t_m) of year classes with time is seen in Areas III and IV and the whole Antarctic, the latter being statistically significant. The apparent pregnancy rate is estimated at 88.8% of mature females for the whole Antarctic for the whole period. No yearly trends are observed. The ovulation is estimated to be almost the same (0.883 per year) for the same area and period. The total mortality coefficient (Z) is examined using two methods, (1) involving regression analysis and (2) involving an assumption of an exponential age distribution. The Z values from both approaches are similar, 0.139–0.148 for males and 0.149–153 for females (whole Antarctic, full time series). The percentage of male foetuses is estimated to be 47% and the average litter size 1.006 with no trend by year or Area.

INTRODUCTION

The minke whale (*Balaenoptera acutorostrata*) is now the only whale species allowed to be taken by pelagic whaling: it is currently taken by a Japanese and a Soviet expedition in the Antarctic. Because of its importance much attention has been devoted to this species in recent years and a large scale marking and sightings programme has been developed under the auspices of the International Whaling Commission's 'International Decade of Cetacean Research' (Best and Ohsumi, 1980; Best and Butterworth, 1980; Horwood, 1981; Horwood, Best and Ohsumi, 1981; Best, 1982a).

The study of biological parameters is also important with respect to both the estimation of population size and an understanding of the dynamics of the stock. For example changes in age at sexual maturity and pregnancy rate have been associated with changes in the population size of certain species (e.g. fin whales—Lockyer, 1972; Gambell, 1973; and sei whales—Gambell, 1968; 1973).

Although full scale exploitation of the minke whale in the Antarctic did not begin until 1971/72, two preliminary expeditions had been carried out by Japanese fleets in 1967/68 and 1968/69. These provided basic biological information for this species in the Antarctic (Ohsumi, Masaki and Kawamura, 1970) and Ohsumi and Masaki (1971) used data from these expeditions in an attempt to construct a model of the population. Since then biological samples have been collected from the catch each year and several authors (e.g. Masaki, 1973; Ohsumi and Masaki, 1975) have reported on biological parameters. Masaki (1979) examined the yearly variation in biological parameters for the period 1967/68 and 1971/72–1976/77: no trends were apparent. However he found that the age at sexual maturity had decreased from the 1940s–1960s year classes. This paper examines some biological parameters and their changes for the seasons 1971/72–1979/80. There has been considerable discussion over the stock division for the Southern Hemisphere minke whales in recent years (e.g. IWC, 1981; 1982). In this paper I have used the traditional IWC baleen whale Areas (this volume p. 948).

AVERAGE BODY LENGTH

Since 1971/72, 13,254 males and 17,558 females have been taken by Japanese pelagic whaling in the Antarctic. The average body lengths for the nine seasons up to 1979/80 are 27.06 ft (males) and 28.10 ft (females).

Yearly changes

Fig. 1 shows the yearly changes in the average body length of the total catch (bl_t) and mature catch (bl_m) by sex and Area. The sample size is small in Areas I, II and IV due to the operational strategy of the fleet. Although slightly increasing trends are seen in females bl_t in Areas III and IV, only for the Antarctic as a whole is the trend significant ($t_{cal} = 4.653 > t(7,0.05) = 2.365$). No such trends are found for female bl_m suggesting that the increasing trend in bl_t is only apparent and due to the increasing proportion of mature females in the catch. The male bl_t and bl_m values are very similar due to the high proportion of mature animals in the catch.

The small increase in bl_t for both sexes is probably the result of the efforts of the industry to take as large whales as possible within the limited catch quota rather than being a biological phenomenon.

Monthly changes

Monthly changes in bl_m and bl_t by Area and sex are shown in Fig. 2. The sample size is small in all Areas in March. Apart from Area V there appears to be an increasing trend in bl_t from November to February in all Areas, statistically significant for females in Area IV ($t_{cal} = 6.060 > t(2,0.05) = 4.303$).

The trends in bl_m and bl_t for females are again dependent on the proportion of mature females in the catch (Table 1) which increases with month in most Areas. By contrast the proportion of mature males remains consistently high throughout the season. To summarise, most of the males found in the Antarctic whaling grounds are mature, whereas the mature females do not arrive until later in the season, supporting the views of Ohsumi *et al.* (1970),

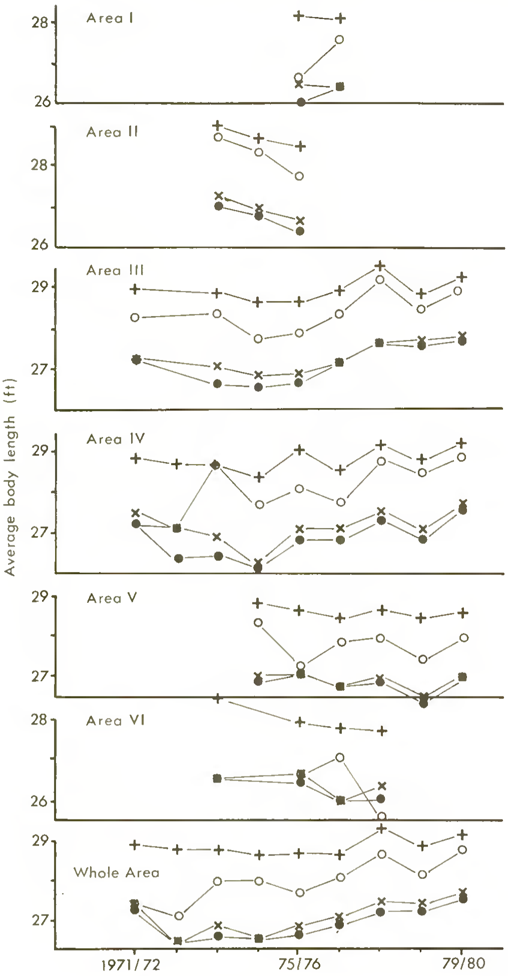

Fig. 1. Yearly changes in average body length of the Antarctic minke whale for each Area (1971/72 to 1979/80 seasons) ●——●: average body length total males; ×——×: average body length mature males; ○——○: average body length total females; +——+: average body length mature females.

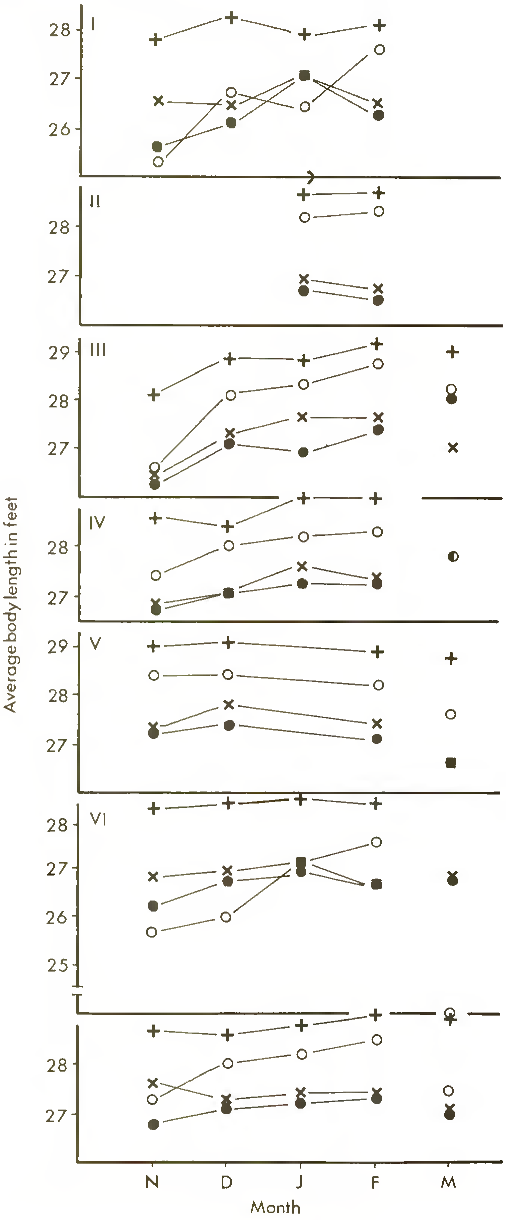

Fig. 2. Monthly change in average body length in Antarctic minke whales (1971/72 and 1979/80 seasons). (Symbols as for Fig. 1.)

Ohsumi and Masaki (1975), Masaki (1979) and Kasamatsu and Ohsumi (1981), that sexual segregation occurs in these whaling grounds.

AGE AT SEXUAL MATURITY

The ideal way to determine sexual maturity in cetaceans is to either examine the ovaries for the presence of at least one corpus luteum or albicans or to histologically examine testis tissue samples. The practical problem in the latter is the amount of time it would take to examine the vast number of samples collected. In this paper I have assumed that whales with a larger testis weight of 0.4 kg or more are mature, after Ohsumi *et al.* (1970) and Masaki (pers. comm.), while remembering that work by Best (1982) and da Rocha (1982) suggests that this value may be too small.

The ages of 5,473 males and 7,468 females caught between 1971/72 and 1979/80 for which maturity had been determined were obtained from ear plug readings. I have assumed that maturity against age is represented by a sigmoid curve and in this study determined the age at which 50% animals were mature by fitting the logistic curve. The goodness of fit between observed and expected values was determined using χ^2 test. The estimated ages at sexual maturity by Area and for all Areas are shown in Figs 4 and 5.

Table 1

Monthly changes in maturity rate and average body length of total catch in each Area 1971/72 and 1979/80

	Area I		Area II		Area III		Area IV		Area V		Area VI		Total	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
November														
M. Rate	81.8	60.7	—	—	93.0	50.4	92.9	69.1	97.4	80.9	86.6	42.5	94.1	71.1
Ave. B.L.	25.6	25.3	—	—	26.3	26.6	26.7	27.4	27.2	28.4	26.2	25.7	26.8	27.3
December														
M. Rate	92.1	57.9	—	—	94.1	80.2	91.0	78.1	97.8	83.3	95.1	50.0	92.8	78.2
Ave. B.L.	26.1	26.7	—	—	27.1	28.1	27.1	28.0	27.4	28.4	26.7	26.0	27.1	28.0
January														
M. Rate	100	53.3	94.4	86.0	92.9	82.5	91.9	78.9	—	—	90.2	57.6	92.3	81.0
Ave. B.L.	27.0	26.4	26.7	28.2	27.0	28.3	27.3	28.2	—	—	26.9	27.1	27.2	28.2
Feburary														
M. Rate	94.4	80.7	92.3	86.7	97.1	86.8	96.5	80.8	92.6	78.4	100	78.8	96.5	85.1
Ave. B.L.	26.3	27.6	26.5	28.3	27.4	28.7	27.3	28.3	27.1	28.2	26.6	27.5	27.3	28.5
March														
M. Rate	—	—	—	—	100	60.0	100	100	97.5	70.0	100	0.0	98.5	67.8
Ave. B.L.	—	—	—	—	28.0	28.2	27.8	27.8	26.6	27.6	26.8	22.0	27.0	27.5

Table 2

Yearly and areal changes in age at 50% sexual maturity in females

	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	Total
Area I										
Age	—	—	—	—	—	8.00	—	—	—	7.53
Range	—	—	—	—	—	7–10	—	—	—	7–10
Area II										
Age	—	—	—	5.43	—	—	—	—	—	5.12*
Range	—	—	—	6–8	—	—	—	—	—	3–11
Area III										
Age	—	—	3.68	7.14*	5.50	6.14	—	6.17	6.42	6.18*
Range	—	—	4–9	5–11	5–8	4–10	—	4–10	3–9	2–11
Area IV										
Age	5.51*	6.76	6.17	7.38	—	7.31	6.84	7.46	6.57*	6.63*
Range	5–9	6–10	2–11	7–13	—	4–8	4–8	3–11	4–10	2–10
Area V										
Age	—	—	—	—	6.77	5.50	—	—	5.57	5.97*
Range	—	—	—	—	6–8	4–13	—	—	5–10	3–11
Area VI										
Age	—	—	—	—	—	—	—	—	—	—
Range	—	—	—	—	—	—	—	—	—	—
Total										
Age	5.10	6.76	6.04	6.66*	6.29*	6.58*	7.00*	7.01	6.44	6.52*
Range	3–9	6–10	3–11	4–11	4–10	4–11	5–11	3–10	3–9	3–11

* Statistical significant (χ^2 test, p: 0.05)

Males

In most Areas (all except Area IV) there were insufficient immatures in the catch to fit the logistic curve. In Area IV, the age at maturity was estimated to be 2.5 years (significant at $p=0.05$) and for all Areas combined (although of course dominated by the Area IV sample) it was estimated to be 2.4 years (not significant at $p=0.05$). However as Masaki (1979) also noted this seems to be too low in comparison to the females and to other baleen whale species. This may be due to:

(i) a bias in the male samples due to a concentration of mature animals on the whaling grounds;

(ii) a bias in the male samples due to selection for larger animals by the whalers (Masaki, 1979);

(iii) an incorrect criterion for maturity—for example the epidiymis should be examined—and see Best (1982b).

Best (1982b) examined minke whales landed at Durban and estimated t_m to be between five and eight years although the sample size was small. This may be due to (i) above but it must be remembered that the exact relationship between animals found in high and low latitudes remains uncertain.

To conclude, further work is required before a satisfactory direct estimate of male age at sexual maturity, particularly taking into account latitudinal variation, can be made.

Females

Female t_m could be estimated for all areas except VI and the goodness of fit was significant for all except Area I (Fig. 3). The t_m for all Areas combined (Fig. 4) was estimated at 6.5 years ($\chi^2_{cal} = 1.472 < \chi^2\,(5,0.05) = 11.07$). The estimates from Areas III (6.2) and IV (6.6) are considered to be the most reliable due to the large sample size and length of the time series. It seems likely that the values for other Areas would approach this range if more data had been available.

The yearly change in t_m by Area is shown in Table 2 although there were of course sample size problems and only in Areas III and IV could estimates be obtained for most of the seasons. The apparent slight increase in t_m with time was only statistically significant for all Areas combined ($t_{cal} = 3.164 > t(7,0.05) = 2.365$).

However to satisfactorily examine yearly changes in age at sexual maturity the fact that the age composition in any one season is composed of different year classes must be taken into consideration. One method of estimating age at sexual maturity is by examination of the transition phase of the ear plug (Lockyer, 1972; 1979). Masaki (1979) used this technique and found a decline in age at sexual maturity from the 1940s (14 years) to the 1960s (6 years). In this section I want to examine the yearly changes in the past decade. However, in this case the transition phase approach is not applicable as the transition layer is not clear in younger animals.

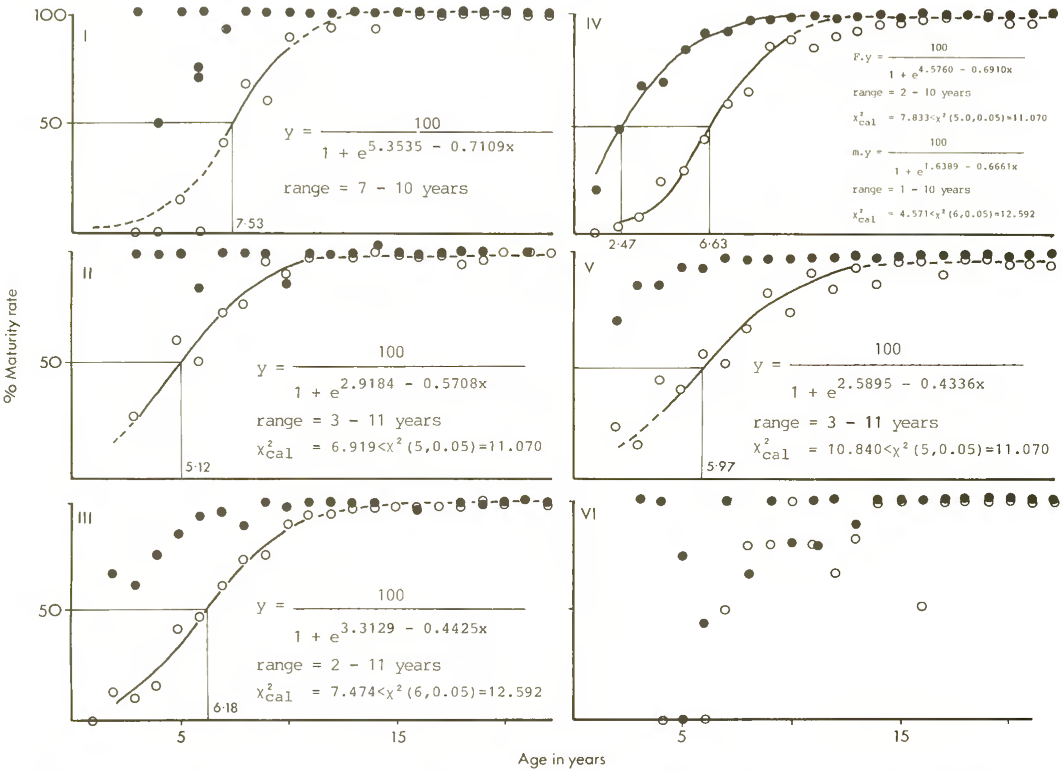

Fig. 3. Age at sexual maturity for the Antarctic minke whale in each Area estimated by logistic curve (1971/72 and 1979/80 seasons). ●——●: male; ○——○: female; Y: maturity rate (%); X: age in years.

Thus it appears that t_m may have increased from the 1965–1972 year classes but there are too few data to examine this by Area. This suggests that the decline shown by Masaki (1979) for the 1940s–1960s had reached its minimum. After the 1965 year class then t_m for females should be regarded as increasing slowly. This in turn suggests that the expanding minke whale population may have reached capacity but more data need to be collected and examined before this point can be investigated carefully.

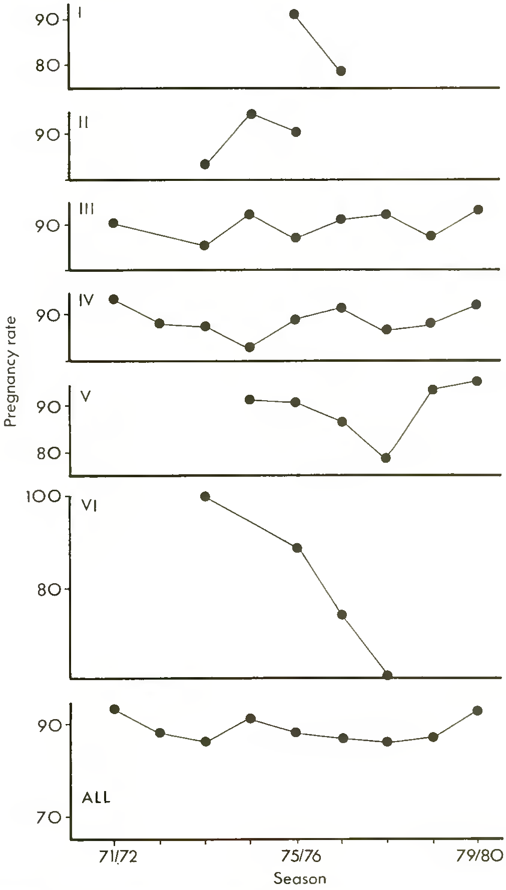

Fig. 7. Yearly changes in apparent pregnancy rate for the Antarctic minke whale in each Area (1971/72 to 1979/80 seasons).

PREGNANCY RATE

Apparent pregnancy rate

The apparent pregnancy rate, P′, is the percentage of pregnant to sexually mature animals in the catch. It does not include ovulating females with corpus luteum but no foetus. The average P′ values for the period 1971/72–1979/80 were:

Area I	82.1%	Area IV	89.6%
Area II	91.6%	Area V	86.7%
Area III	89.2%	Area VI	89.0%

The value for the whole Antarctic was 88.8%. These values are similar to those of Ohsumi and Masaki (1975) and Masaki (1979).

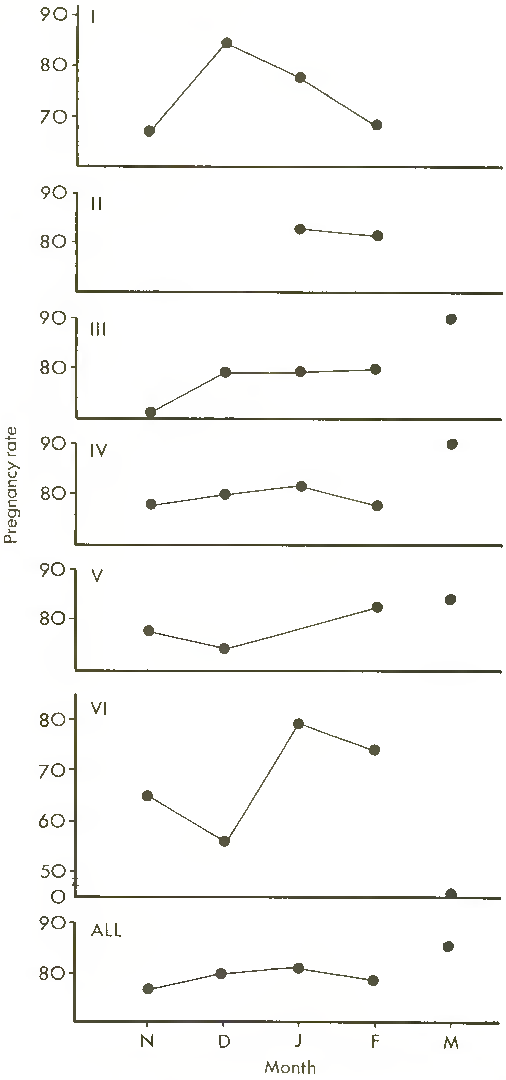

Fig. 8. Monthly changes in apparent pregnancy rate for the Antarctic minke whale (1971/72 and 1979/80 seasons).

Yearly changes in P′ by Area are shown in Fig. 7. No trends can be seen in Areas III, IV and V. In the other Areas there are too few data to examine trends. The apparent decline in Area VI is due to the small sample size and biased samples in 1976/77 and 1977/78. No trend is observed when the data for all Areas are combined.

Monthly changes in P′ by Area are shown in Fig. 8. Whaling is mainly carried out in December, January and February and as sample sizes are very small in November–January, further analysis involving shorter time periods needs to be carried out.

Ovulation rate

A plot of corpora count against age is given in Fig. 9, for Area IV from which there are the most data. As has been found in other mysticetes, there is considerable scatter. If it can be assumed that the older animals in the sample

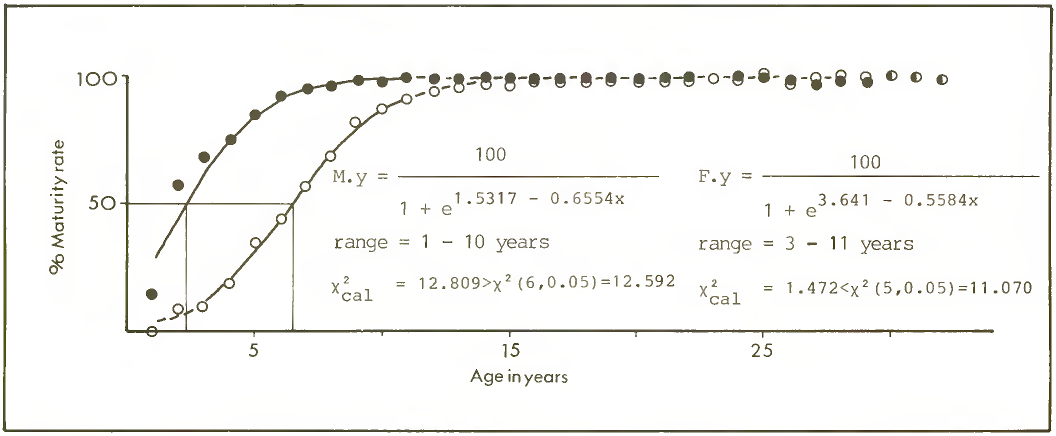

Fig. 4. Age at sexual maturity for the Antarctic minke whale estimated by logistic curve for the whole area. (1971/72 and 1979/80 seasons). (Symbols as for Fig. 3).

Table 3

Age at 50% of sexual maturity of the female Antarctic minke whale from the 1965 to 1972 year classes

Year class	1965	1966	1967	1968	1969	1970	1971	1972
Area III								
Age	—	—	6.30	7.34	5.46	—	5.80	—
Range	—	—	(6–9)	6–11	4–9	—	5–8	—
Area IV								
Age	3.72	6.82	—	—	7.10	6.78	—	6.14
Range	6–10	5–8	—	—	5–10	6–9	—	4–7
Area III + IV								
Age	6.08*	6.33	6.19	6.70	6.33	—	6.55	6.67
Range	(7–10)	(5–10)	(6–12)	(3–11)	(4–10)	—	5–8	4–7
Whole Area								
Age	5.40*	5.96	5.62*	6.64	6.15*	6.84*	6.38	6.55
Range	6–11	5–13	6–12	3–11	4–10	3–9	3–8	4–7

* Statistical significant (χ^2 test, ρ: 0.05)

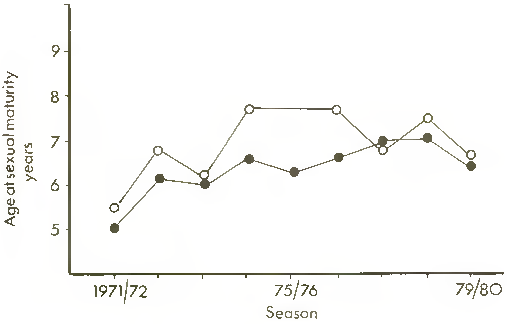

Fig. 5. Yearly changes in female age at 50% sexual maturity for Area IV (○) and the whole area (●).

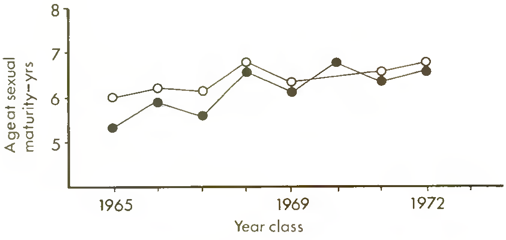

Fig. 6. Yearly changes in female age at 50% sexual maturity obtained from logistic curve in Areas III and IV (○) and the whole area (●) for 1965 to 1972 year classes.

Data for Areas III, IV, III + IV and for the whole Antarctic by year were re-examined by finding the year of birth and tables relating to maturity rate and age constructed. The data were then treated as before i.e. by fitting to a logistic curve. The estimated t_m by sex and year class are shown in Table 3 but for Areas III and IV separately the sample size was too small. Results were obtained for Areas III and IV and the whole Antarctic for the year classes 1965–72 (Fig. 6). In both cases an increasing trend was apparent, but only in the whole Antarctic was this significant. The regression of t_m (y) against year class (x) was:

$$y = 0.158x + 5.479 \ (r = 0.767).$$

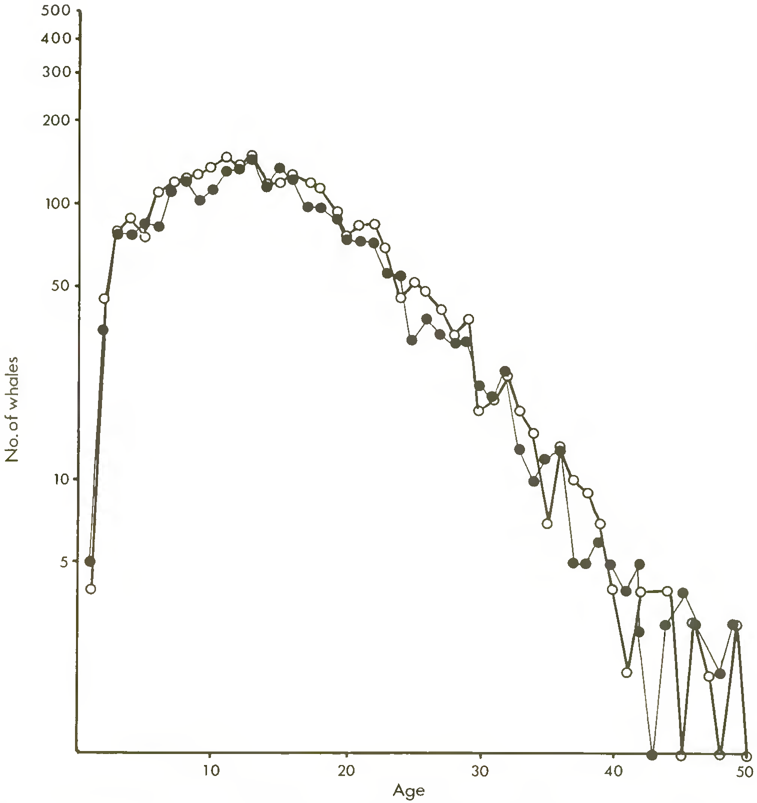

Fig. 11. Age composition for Antarctic minke whales in Area IV (1971/72 and 1979/80 seasons). ○——○: females; ●——●: males.

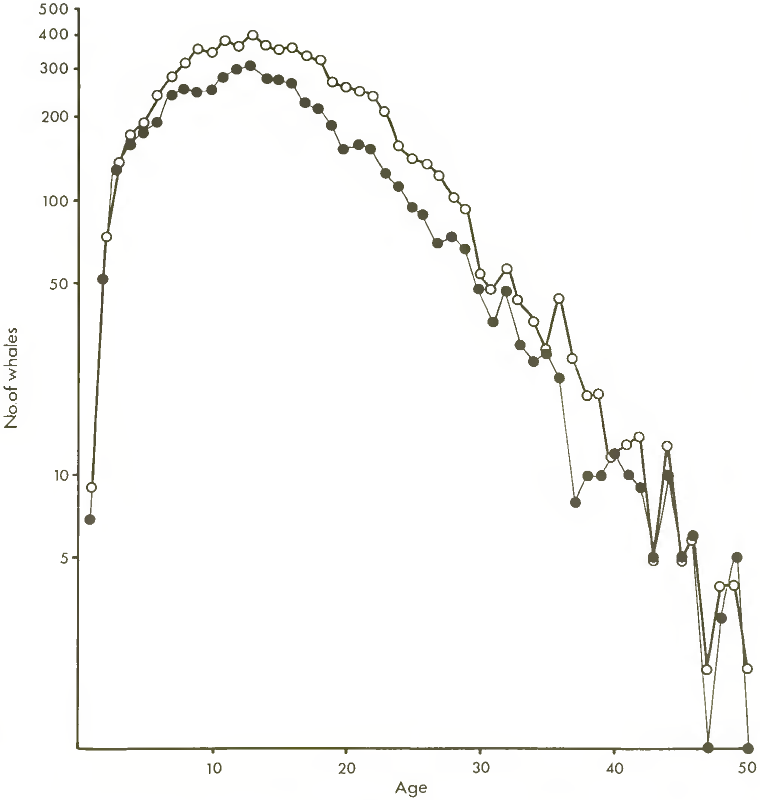

Fig. 12. Age composition for Antarctic minke whales, whole Area (1971/72 and 1979/80 seasons). ○——○: females; ●——●: males.

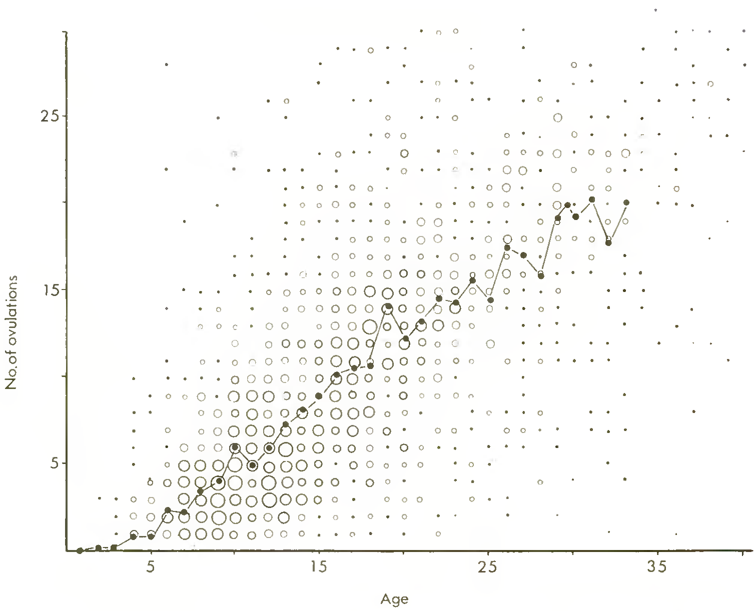

Fig. 9. Distribution of accumulated corpora in ovaries of the Antarctic minke whale (1971/72 and 1979/80 seasons). ●——●: mean number of corpora at each age.

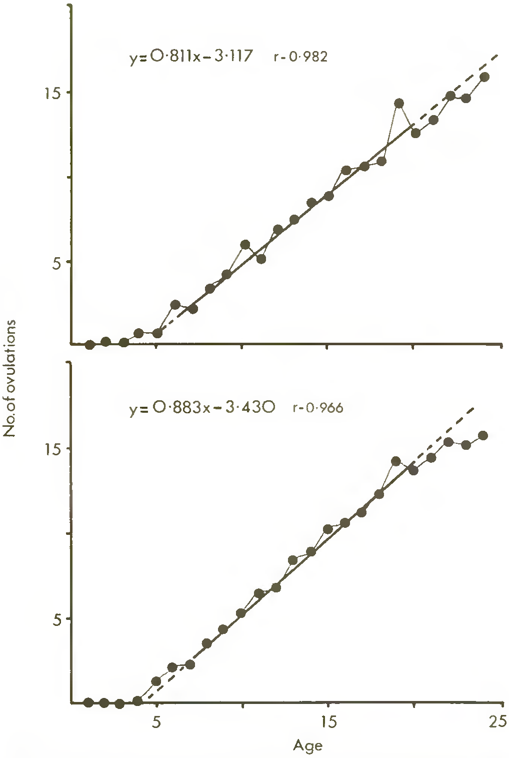

Fig. 10. Mean number of corpora relative to age in Area IV (above) and the whole area (below) (1971/72 and 1979/80 seasons) ●——●: mean number of corpora at each age.

matured at later ages, then a reasonable age range must be chosen if the annual ovulation rate is to be estimated. Looking at the plot there appears to be a refraction point at about 20 years, and as t_m has been estimated at 6.5 years I have used the age range 6–20 years to examine the ovulation rate. A regression of mean number of ovulations (y) against age (x) for the Area IV data in the 6–20 year age range (Fig. 10) gave

$$y = 0.811x - 3.117 \ (r = 0.982)$$

and for all Areas combined (Fig. 10) gave

$$y = 0.883x - 3.430 \ (r = 0.996)$$

The ovulation rates (gradients) obtained are higher than those of Ohsumi *et al.* (1970) and similar to those of Ohsumi and Masaki (1975) and Masaki (1979). They are also very similar to the P′ values estimated above.

True pregnancy rate, P

It is difficult to estimate P for the Antarctic minke whale as samples are only taken in the high latitudes, and there is the likelihood that sexual segregation occurs. Gambell (1968) found that P in the Antarctic sei whale was almost equal to the annual ovulation rate and it may be that this is also true for the minke whale. However, Best (1982b) estimated P for minke whales off Durban to be 78.4% from the proportion of non-lactating animals in the population.

TOTAL MORTALITY COEFFICIENT, Z

Two approaches were used to obtain Z from the age distributions in the catch. The data were examined by Area for all seasons combined. Figs 11 and 12 show the age distributions for Area IV and for all Areas combined, where most of the data have been accumulated, and may be considered as typical distributions for the Antarctic minke whale.

Table 4

Yearly and Areal changes in the total mortality coefficient (Z) using of approach (1)

	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	Total
Area I										
M. Interval					10–28					13–29
Z	—	—	—	—	0.105	—	—	—	—	0.092
(r)					(0.893)					(0.853)
F. Interval										
Z	—	—	—	—	—	—	—	—	—	—
(r)										
Area II										
M. Interval										
Z	—	—	—	—	—	—	—	—	—	—
(r)										
F. Interval				10–33						15–29
Z	—	—	—	0.119	—	—	—	—	—	0.134
(r)				(0.917)						(0.939)
Area III										
M. Interval				9–32		16–33	13–36	13–34	12–35	18–36
Z	—	—	—	0.117	—	0.092	0.097	0.145	0.082	0.132
(r)				(0.875)		(0.805)	(0.833)	(0.892)	(0.821)	(0.971)
F. Interval			13–37	9–36		14–31	14–39	11–36		18–45
Z	—	—	0.108	0.115	—	0.115	0.107	0.112	—	0.139
(r)			(0.897)	(0.936)		(0.886)	(0.883)	(0.935)		(0.945)
Area IV										
M. Interval		13–30	14–29	13–29		11–28		11–29	15–36	19–42
Z	—	0.127	0.083	0.094	—	0.134	—	0.113	0.107	0.140
(r)		(0.896)	(0.763)	(0.791)		(0.892)		(0.863)	(0.944)	(0.978)
F. Interval	16–31	12–29	10–33			12–24	15–30	15–34		18–40
Z	0.118	0.133	0.086	—	—	0.132	0.091	0.138	—	0.139
(r)	(0.919)	(0.898)	(0.888)			(0.740)	(0.839)	(0.940)		(0.974)
Area V										
M. Interval					14–31				11–24	16–36
Z	—	—	—	—	0.099	—	—	—	0.160	0.127
(r)					(0.799)				(0.924)	(0.926)
F. Interval				12–29		14–29	10–29			14–33
Z	—	—	—	0.131	—	0.132	0.102	—	—	0.150
(r)				(0.796)		(0.869)	(0.823)			(0.956)
Area VI										
M. Interval										
Z	—	—	—	—	—	—	—	—	—	—
(r)										
F. Interval										
Z	—	—	—	—	—	—	—	—	—	—
			Whole Area:		M. range	16–46				
					Z	0.139				
					(r)	(0.983)				
					F. range	18–46				
					Z	0.149				
					(r)	(0.984)				

Approach 1

Regression analysis was applied to the age distributions (excluding the younger animals, which as can be seen in Figs 11 and 12, are under-represented in the catch) by season and Area and by sex; the Z value is equal to the gradient (Table 4).

The low sample size and/or correlation coefficient meant that yearly changes in Z could not be examined. For the combined year estimates the values for Areas III (0.132 males, 0.139 females), IV (0.140 males, 0.139 females) and V (0.127 males, 0.140 females) are the most reliable, considering the age distributions. These values are slightly higher in the case of males, and very similar in the case of females, to those obtained by Ohsumi (1979); the values obtained for all Areas combined (0.139 males, 0.149 females) are slightly lower.

Approach 2

If an age distribution is considered to be continuous, the population follows an exponential distribution and thus Z can be estimated as from

$$y\ (x) = Ze^{-zx}$$

Where y = no. of animals and x = age. The mean age (x) in the exponential distribution is thus the reciprocal of Z. Again the fact that younger animals are under-represented in the catches had to be taken into account. The first age chosen for each Area in Approach 1 was therefore considered as 0 year.

Results by year, Area and sex are shown in Table 5, but again yearly changes could not be examined as the sample sizes were too small. The most reasonable results were also those from Areas III (0.153 males, 0.149 females), IV

(0.141 males, 0.153 females) and V (0.140 males and 0.160 females), which for males were considerably higher than in Ohsumi (1979), and for all Areas combined (0.148 males, 0.156 females), very similar to Ohsumi's (1979) values.

Although Approach 2 gave consistently higher values than Approach 1, the differences between the values for all Areas combined are smaller than the differences between each Area, suggesting that with larger sample sizes, both Approaches would probably yield similar results.

In this study, however, it seems reasonable to consider the Z values to be 0.139–0.148 for males and 0.149–0.156 for females, while recognising that a more detailed study should be carried out when more data are available.

FOETAL SEX RATIO

Between 1971/72 and 1979/80, 10,732 foetuses were examined during Japanese whaling operations. Yearly and Area I changes in sex ratio are shown in Table 6 but reveal no significant trends. The highest percentage of males (53.8%) is found in Area I while the lowest (44.7%) was found in Area IV. For all Areas combined the percentage was 47% (5,043 males), between the values of 45.9% and 48.0% found by Masaki (1979) and Ohsumi and Masaki (1975) respectively. The value for all Areas combined was tested under a hypothesis of a 1:1 sex ratio ($\chi^2_{cal} = 9.868 > \chi^2\ (1,0.05) = 3.841$) revealing that the sex ratio cannot be

Table 5

Yearly and areal changes in the total mortality coefficient (Z) using approach (2)

	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	Total
Area I										
M. (Z)	—	—	—	—	0.167	—	—	—	—	0.140
Interval	—	—	—	—	10–	—	—	—	—	13–
F. (Z)	—	—	—	—	—	0.134	—	—	—	—
Interval	—	—	—	—	—	15–	—	—	—	—
Area II										
M. (Z)	—	—	—	—	—	—	—	—	—	—
Interval	—	—	—	—	—	—	—	—	—	—
F. (Z)	—	—	—	—	0.173	—	—	—	—	0.168
Interval	—	—	—	—	13–	—	—	—	—	15–
Area III										
M. (Z)	—	—	—	0.148	—	0.139	0.121	0.150	0.113	0.153
Interval	—	—	—	9–	—	16–	13–	13–	12–	18–
F. (Z)	—	—	0.118	0.137	0.123	0.145	0.133	0.125	—	0.149
Interval	—	—	13–	9–	11–	14–	14–	11–	—	18–
Area IV										
M. (Z)	—	0.156	0.118	0.141	—	0.169	—	0.134	0.145	0.141
Interval	—	13–	14–	13–	—	11–	—	11–	15–	15–
F. (Z)	0.130	0.161	0.114	0.143	—	0.198	0.159	0.174	0.117	0.153
Interval	16–	12–	10–	12–	—	12–	15–	15–	16–	18–
Area V										
M. (Z)	—	—	—	—	—	—	—	—	—	0.140
Interval	—	—	—	—	—	—	—	—	—	16–
F. (Z)	—	—	—	0.163	—	0.168	0.140	—	—	0.160
Interval	—	—	—	12–	—	14–	10–	—	—	14–
Area VI										
M. (Z)	—	—	—	—	—	—	—	—	—	—
Interval	—	—	—	—	—	—	—	—	—	—
F. (Z)	—	—	—	—	—	—	—	—	—	—
Interval	—	—	—	—	—	—	—	—	—	—

Whole Area:	M. (Z)	0.148
	Interval	16–
	F. (Z)	0.156
	Interval	18–

Table 6

Male foetal sex ratio of the Antarctic minke whale in each Area from 1971/72 to 1979/80

Season	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	Total
Area										
I	—	—	—	—	52.3	54.8	—	—	—	53.8
II	—	—	52.6	49.7	50.0	—	—	—	—	50.3
III	48.4	—	46.3	41.5	45.2	50.7	50.9	50.8	47.8	47.8
IV	45.4	44.0	42.8	37.7	38.4	43.1	52.3	53.4	48.2	44.7
V	—	—	—	49.8	46.7	44.8	49.7	53.7	51.7	48.2
VI	—	—	—	—	46.7	52.6	51.7	—	—	47.2
Total	45.7	44.0	44.9	45.0	45.5	48.6	50.4	49.5	48.5	47.0

Table 7

Litter size of the Antarctic minke whale in each Area from 1971/72 to 1979/80

Season	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	Total
Area										
I	—	—	—	—	1.008	1.005	—	—	—	1.013
II	—	—	1.000	1.010	1.025	1.007	—	—	—	1.022
III	1.000	—	1.006	1.002	1.011	1.007	1.008	1.003	1.009	1.005
IV	1.007	1.008	1.007	1.000	1.000	1.004	1.000	1.003	1.003	1.005
V	—	—	—	1.000	1.000	1.009	1.009	1.015	1.011	1.007
VI	—	—	—	—	1.000	1.000	1.000	—	—	1.000
Total	1.006	1.008	1.006	1.004	1.010	1.006	1.006	1.004	1.006	1.006

considered as 1:1. However, it must be remembered that the biologically more important sex ratio is that at birth, and unfortunately this is very difficult to estimate, in particular due to the low occurrence of large foetuses during the whaling season.

LITTER SIZE

Twins were found in 60 and triplets in 3 of the 10,675 pregnant females examined. There appear to be no trends in litter size by year or Area (Table 7). The average value for all Areas combined (1.006) is very similar to the values found by Ohsumi and Masaki (1975) and Masaki (1979).

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REFERENCES

Best, P. B. 1982a. Southern Hemisphere IDCR minke whale assessment cruise, 1980/81 cruise report. Paper SC/Jn81/MiS19 (published in this volume).

Best, P. B. 1982b. Seasonal abundance, feeding, reproduction, age and growth in minke whale off Durban. Paper SC/Jn81/MiS4 (published in this volume).

Best, P. B. and Butterworth, D. S. 1980. Report of the Southern Hemisphere minke whale assessment cruise, 1978–79. *Rep. int. Whal. Commn* 30: 257–83.

Best, P. B. and Ohsumi, S. 1980. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR). Southern minke whale assessment cruise, 1978–79. *Polar Record*, 20(124): 52–7.

Da Rocha, J. M. and Braga, N. M. A. 1982. Brazil progress report on whale research. (Published in this volume).

Gambell, R. 1968. Seasonal cycles and reproduction in sei whales of the Southern Hemisphere. *Discovery Rep.*, 35: 31–134.

Gambell, R. 1973. Some effects of exploitation on reproduction in whales. *J. Reprod. Fert., Suppl.*, 19: 533–53.

Horwood, J. W. 1981. Result from the IWC/IDCR minke whale marking and sighting cruise, 1979/80. *Rep. int. Whal. Commn* 31: 287–313.

Horwood, J. W., Best, P. B. and Ohsumi, S. 1981. International Whaling Commission/International Decade of Cetacean Research (IWC/IDCR), Southern minke whale assessment cruise, 1979–80. *Polar Record*, 20(129): 565–9.

International Whaling Commission. 1981. Report of the sub-committee on minke whales. *Rep. int. Whal. Commn* 31: 103–21.

International Whaling Commission. 1982. Report of the special meeting on Southern Hemisphere minke whales, Cambridge, 22–26, June 1981 (published in this volume).

Kasamatsu, F. and Ohsumi, S. 1981. Distribution pattern of minke whales in the Antarctic with special reference to the sex ratio in the catch. *Rep. int. Whal. Commn* 31: 345–8.

Lockyer, C. 1972. The age at sexual maturity of the southern fin whale (*Balaenoptera physalus*) using annual layer counts in the ear plug. *J. Cons. int. Explor. Mer.* 34(2): 276–94.

Lockyer, C. 1974. Investigation of ear plug of the southern sei whales (*Balaenoptera borealis*) as a valid means of determining age. *J. Cons int. Explor. Mer.*, 36(1): 78–81.

Lockyer, C. 1979. Changes in a growth parameter associated with exploitation of Southern fin and minke whales. *Rep. int. Whal. Commn* 29: 191–6.

Masaki, Y. 1973. Some notes on age estimation of baleen whales based upon the ear plugs. Paper RI presented to the meeting on age determination in baleen whales, Reykjavik, April 1973.

Masaki, Y. 1979. Yearly changes of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 375–95.

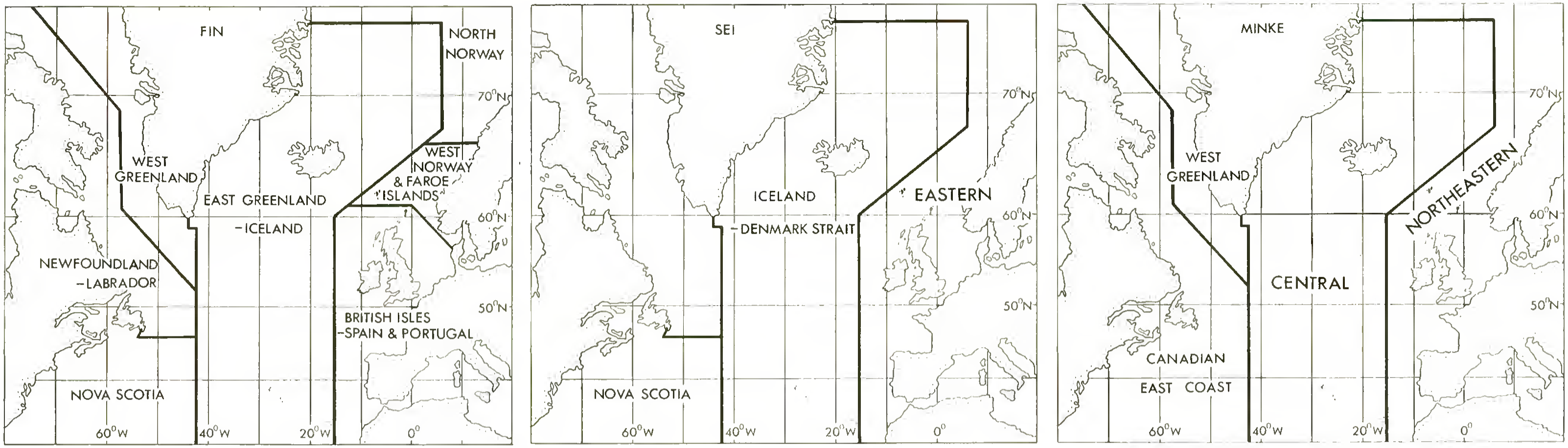
Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 407–20.

Ohsumi, S. and Masaki, Y. 1971. Revised estimates of population size and MSY of the Antarctic minke whale. Paper SC/23/4 presented to the IWC Scientific Committee, June 1971.

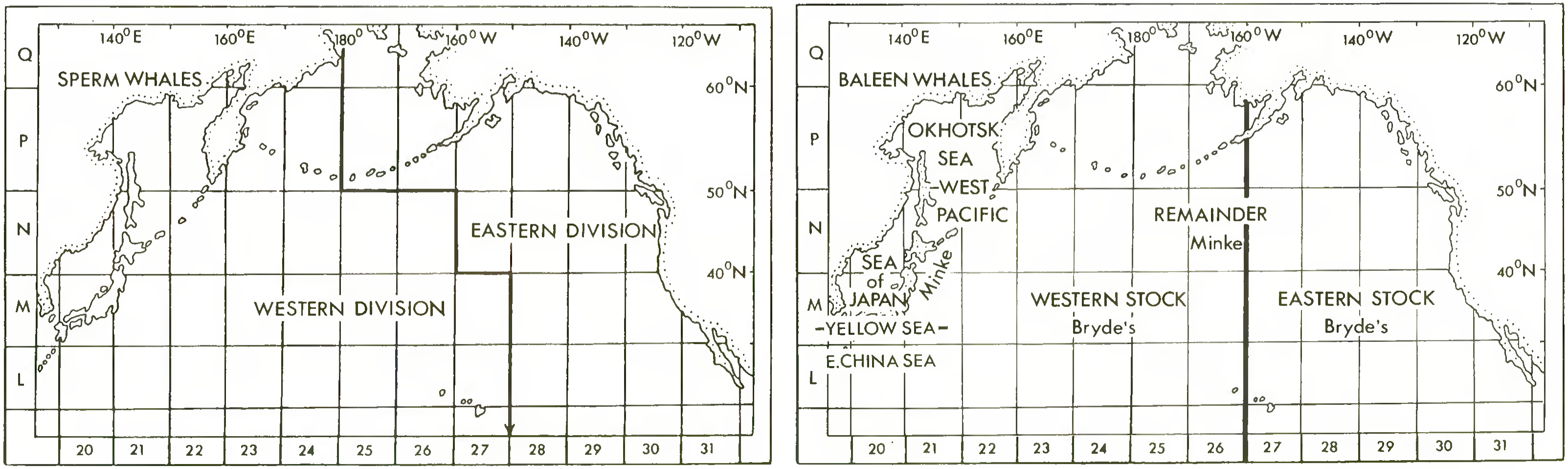
Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish. Res. Board. Can.*, 32(7): 995–1,004.

Ohsumi, S., Masaki, Y and Kawamura, A. 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst.*, Tokyo, 22: 75–125.

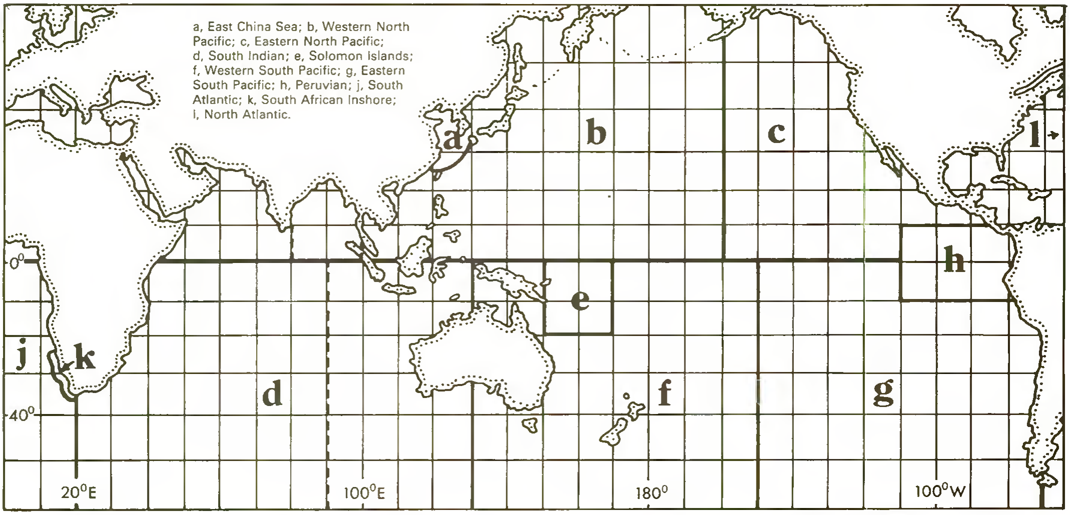
North Atlantic Stock Divisions



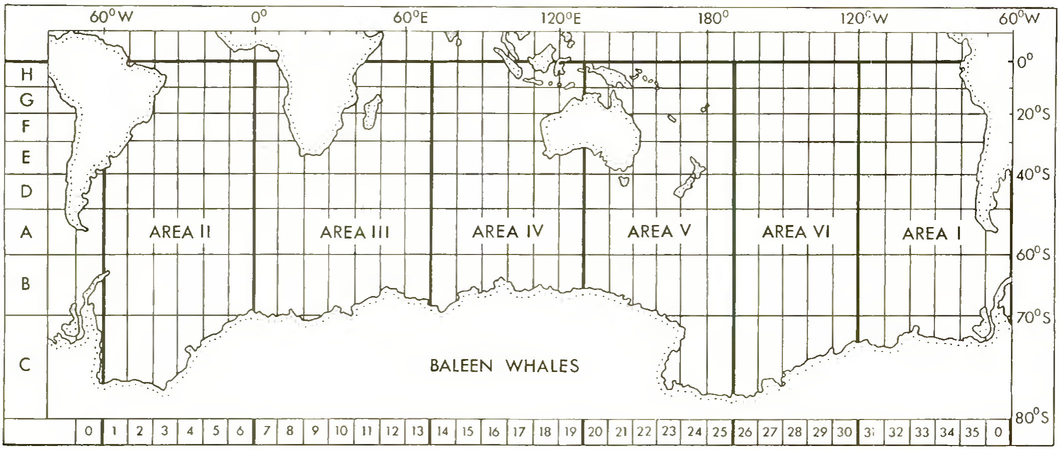
North Pacific Stock Divisions

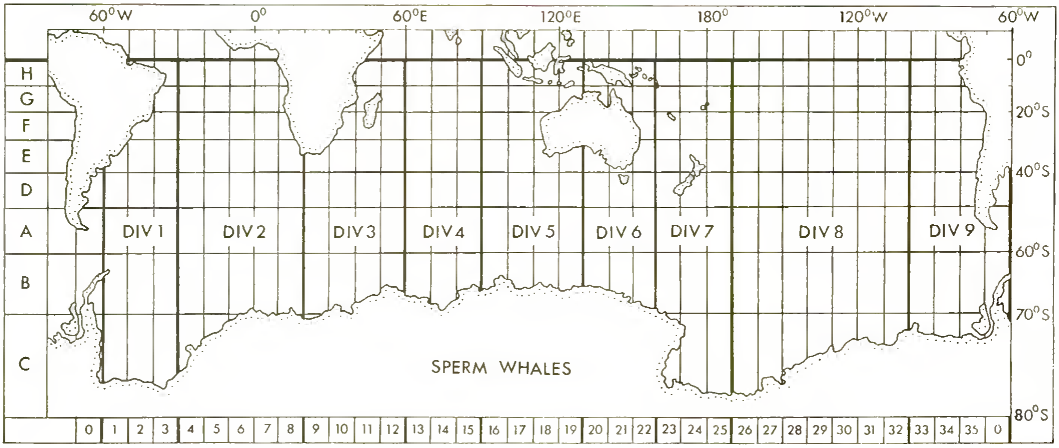


Bryde's Whales Stock Divisions

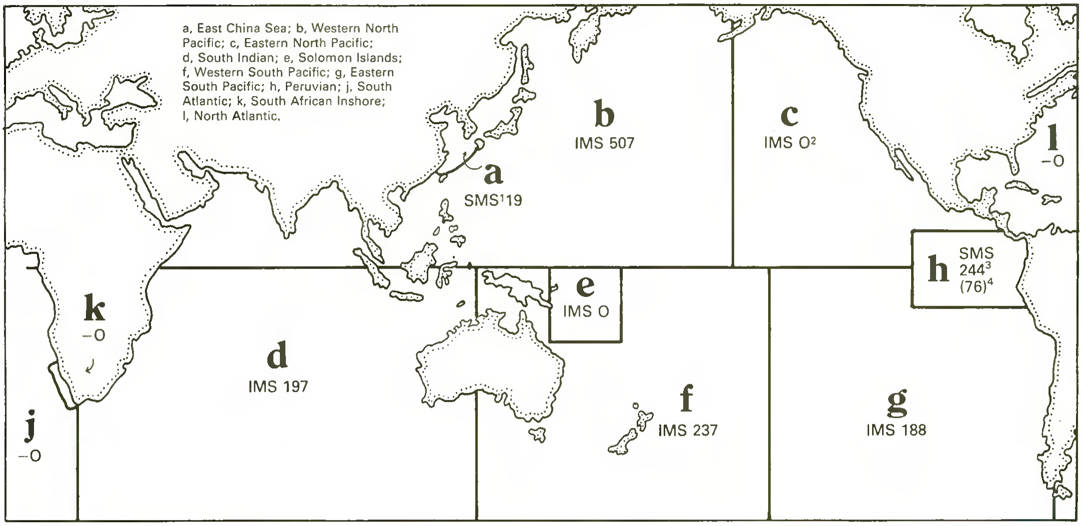


Southern Hemisphere Stock Divisions (excluding Bryde's whales)



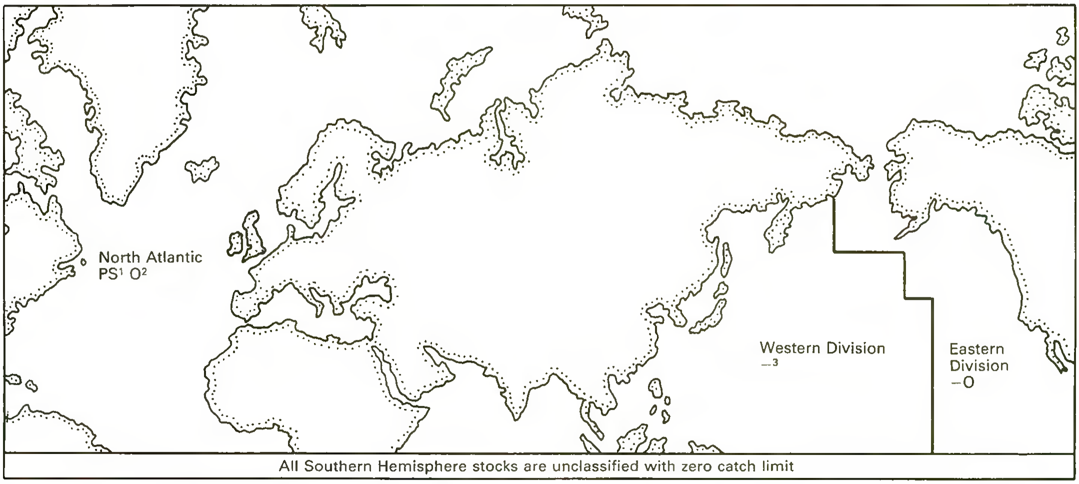


Bryde's Whale Stocks, Classifications and Catch Limits, 1982 Season



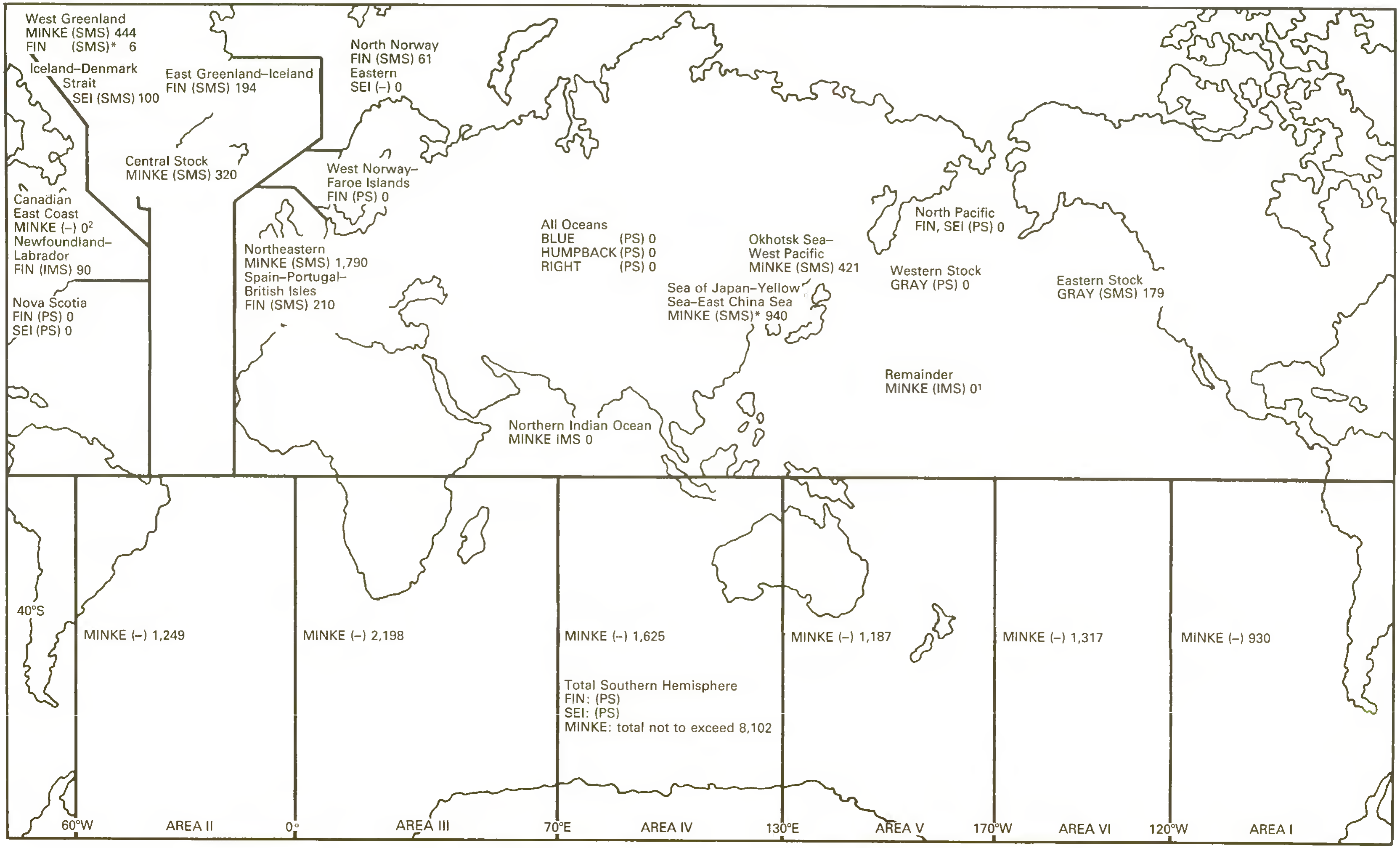
[1] Provisionally listed as SMS for 1982.
[2] Pending a satisfactory estimate of stock size.
[3] Available to be taken in a six month period starting in November 1981.
[4] Special remainder from 1981 that may be taken in a six month period starting in November 1981.

Sperm Whale Stocks, Classifications and Catch Limits, 1982 Season



[1] Provisionally listed as PS for 1982 pending the accumulation of sufficient information for classification.
[2] Provided that the remainder of 130 males for the 1981 season may be taken in the 1982 season.
[3] No whales may be taken from this stock until catch limits including any limitations on size and sex are established.

Baleen Whale (excluding Bryde's Whale) Stocks, Classification and Catch Limits, 1981/82 and 1982 Seasons



Only minke whales may be caught by factory ships

(PS) Protection Stock
(SMS) Sustained Management Stock
(IMS) Initial Management Stock

*Provisional
[1] Pending a satisfactory estimate of stock size
[2] Pending submission of data leading to an adequate assessment