Thirty-Ninth Report
of the
International Whaling Commission

Covering the thirty-ninth financial year 1987–1988
Approved by the Commission at its fortieth meeting in Auckland, June 1988
Authorised to be printed together with the Chairman's Report of the fortieth meeting.

Cambridge
1989

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

ISSN 0143-8700
ISBN 0 906975 21 2

The International Whaling Commission

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

Preface

This year's Annual Report contains material from the 40th Annual Commission and Scientific Committee Meetings and a Special Meeting of the Scientific Committee. In addition to the reports of these meetings, 37 papers are included, all of which have been anonymously peer reviewed and revised since their presentation to the Scientific Committee. In view of the number of papers arising out of the 1987 North Atlantic Sightings Survey (NASS-87), a separate section has been incorporated for them.

It is appropriate here to thank the following scientists who acted as referees: A. Aguilar, T. Albert, R. Anderson, A. Anganuzzi, J. L. Bannister, J. Barlow, P. B. Best, N. Bonner, H. Braham, J. Breiwick, S. G. Brown, R. L. Brownell, S. Buckland, D. S. Butterworth, R. Clarke, A. Collet, J. Cooke, W. Ellison, M. Fraker, D. Goodman, J. Gordon, Th. Gunnlaugsson, J. Haldiman, M. Hall, P. S. Hammond, J. Harwood, A. R. Hiby, S. J. Holt, J. Horwood, M.-L. Jones, G. Joyce, F. Kasamatsu, T. Kasuya, H. Kato, G. P. Kirkwood, H. Kishino, K. Lankester, F. Larsen, S. Leatherwood, D. Ljungblad, C. Lockyer, K. Magnusson, W. de la Mare, A. R. Martin, D. DeMaster, E. D. Mitchell, T. Miyashita, S. Mizroch, S. Moore, A. Myrick, M. Nerini, N. Øien, T. J. Quinn II, A. Raftery, G. Rees, R. Reeves, S. Reilly, C. J. Rørvik, W. M. Sackinger, Y. Shimadzu, P. J. Smith, T. Smith, S. Swartz, B. Stonehouse, L. Underhill, A. Ward, A. York, J. Zeh.

I would also like to thank: Helen Coulson who patiently typed and re-typed many of the revised manuscripts; Julie Creek who helped with the final push towards publication; Stella Duff for her usual sterling efforts with tables and keeping typographical errors to a minimum; the staff at Black Bear Press and especially the recently-retired Jim Browning.

As in recent years, résumés of those papers presented to the Scientific Committee but not published in full are included in the final section of the volume. These do not constitute a publication and are included for information only. They must not be cited without the permission of the author. Copies of the full versions of these papers as presented to the Scientific Committee can be obtained from the Office of the Commission at cost price.

G. P. DONOVAN
Scientific Editor

International Whaling Commission
Special Issue Series

1 [1977]—Report of the Special Meeting of the Scientific Committee on Sei and Bryde's Whales.
i–v + 150 pp.; ISBN 0 906975 03 4

2 [1980]—Sperm Whales.
i–iv + 275 pp.; ISBN 0 906975 01 8

3 [1980]—Age Determination of Toothed Whales and Sirenians.
Eds W. F. Perrin and A. C. Myrick.
i–viii + 229 pp.; ISBN 0 906975 05 0

4 [1982]—Aboriginal/Subsistence Whaling (with special reference to the Alaska and Greenland Fisheries).
Ed. G. P. Donovan.
i–v + 86 pp.; ISBN 0 906975 09 3

5 [1983]—Special Issue on Historical Whaling Records.
Eds M. F. Tillman and G. P. Donovan.
i–v + 490 pp.; ISBN 0 906975 11 5

6 [1984]—Reproduction of Whales, Dolphins and Porpoises.
Eds W. F. Perrin, R. L. Brownell, Jr and D. P. DeMaster.
i–xii + 490 pp.; ISBN 0 906975 07 7

7 [1986]—Bibliography of Whale Killing Techniques.
By E. D. Mitchell, R. R. Reeves and A. Evely.
i–v + 162 pp.; ISBN 0 906975 14 X

8 [1986]—Behaviour of Whales in Relation to Management.
Ed. G. P. Donovan.
i–v + 282 pp.; ISBN 0 906975 15 8

9 [1988]—The Biology of the Genus *Cephalorhynchus*.
Eds R. L. Brownell Jr and G. P. Donovan.
i–ix + 344 pp.; ISBN 0 906975 17 4

10 [1986]—Right Whales: Past and Present Status.
Eds R. L. Brownell Jr, P. B. Best and J. H. Prescott.
i–viii + 289 pp.; ISBN 0 906975 16 6

Available from the office of the Commission, The Red House, Station Road, Histon,
Cambridge CB4 4NP, United Kingdom.

List of Members of the Commission

Contracting Government	*Commissioner*
Antigua and Barbuda	Mr J. Fuller
Argentina	Mr E. H. Iglesias
Australia	Prof. J. D. Ovington
Brazil	Mr. L. P. Lindenberg Sette
Chile	Not notified
People's Republic of China	Mr Zhuo Youzhan
Costa Rica	Not notified
Denmark	Mr H. Fischer
Egypt	Dr A. L. A. Fetouh
Finland	Mr A. Haapanen
France	Mr D. Piney
Federal Republic of Germany	Mr N. Kleeschulte
Iceland	Mr K. S. Juliusson
India	Dr M. K. Ranjitsinh
Ireland	Ms N. O'Keefe
Japan	Mr K. Shima
Kenya	Mr N. Odero
Republic of Korea	Mr K. H. Kim
Mexico	Dr. L. A. Fleischer (*Vice-Chairman*)
Monaco	Mr I. S. Ivanovic
Netherlands	Mr F. C. M. van Rijckevorsel
New Zealand	Mr I. L. G. Stewart
Norway	Mr P. E. S. Tresselt
Oman	Mr M. A. Al-Barwani
Peru	Mr J. Vertiz C.
Saint Lucia	Dr J. Edsel Edmunds
Saint Vincent and the Grenadines	Mrs G. Davy-Penningsfeld
Senegal	Not notified
Solomon Islands	Mr S. Diake
Seychelles	Mr R. F. Delpech
South Africa	Dr L. Botha
Spain	Ms P. Garcia Donoro
Sweden	Mr S. Irberger (*Chairman*)
Switzerland	Dr F. von Däniken
USSR	Dr I. V. Nikonorov
UK	Mrs A. Blackburn
USA	Dr W. E. Evans
Uruguay	Not notified

Dr R. Gambell, Secretary to the Commission, 31 August, 1988

Contents

International Whaling Commission Report 1987–88

This report records the activities of the Commission during the year following the 39th Annual Meeting, held in Bournemouth, UK, 22–26 June 1987 under the Chairmanship of Mr I.L.G. Stewart (New Zealand). The Chairman's Report of that meeting was published in the Thirty-eighth Annual Report of the Commission (*Rep. int. Whal. Commn* 38: 10–31).

STOCK CLASSIFICATIONS

The Commission had only to classify the whale stocks at the 39th Annual Meeting, since it took the decision in 1982 that the catch limits for the killing for commercial purposes of whales from all stocks for the 1986 coastal and 1985/86 pelagic seasons and thereafter shall be zero. The classifications adopted last year were unchanged, and are shown on pages 26–27 of *Rep. int. Whal. Commn* 37.

WHALING UNDER OBJECTION

Japan, Norway and the USSR still had objections lodged to the decision to set zero catch limits for commercial whaling, although the Japanese objection was withdrawn with effect from the end of the 1987 season for each of its operations. In fact, the USSR did not catch any whales under objection, but the catches taken by Japan and Norway are shown in Table 1.

Table 1

Catches by IWC Member Nations in the 1987 and 1987/88 seasons. The value in parentheses under 'Operation' signifies the number of catcher boats.

	Fin	Sei	Bryde's	Minke	Sperm	Other	Operation
North Atlantic							
Denmark	9	–	–	90	–	–	aboriginal catch
Iceland	80	20	–	–	–	–	1 land station (2) (Special Permit)
Norway	–	–	–	375	–	–	small-type whaling (Objection)
St. Vincent & the Grenadines	–	–	–	–	–	2[1]	aboriginal catch
North Pacific							
Japan	–	–	317	304	200	–	shore stations and small-type whaling (Objection)
USSR	–	–	–	–	–	158[2]	aboriginal catch
USA	–	–	–	–	–	31[3]	aboriginal catch
Antarctic							
Japan	–	–	–	273	–	–	1 factory ship (2) (Special Permit)

[1] Humpback whales. [2] Gray whales, including 4 lost.
[3] Bowhead whales, of which 9 struck and lost.

CATCHES UNDER SPECIAL SCIENTIFIC PERMIT

The Government of Iceland issued a Special Permit under Article VIII of the Convention, for catches of fin and sei whales to be taken as part of a larger research programme it is undertaking in the North Atlantic. The catches taken are shown in Table 1.

The Government of Japan issued a Special Permit for the taking of minke whales in the Antarctic, as part of a feasibility study for a wider ranging and longer term research programme in the area. The catches taken are shown in Table 1.

ABORIGINAL SUBSISTENCE CATCHES

Catches taken by IWC member states under the aboriginal subsistence whaling regulations are also shown in Table 1.

INTERNATIONAL OBSERVER SCHEME

No observers were appointed by the Commission for the 1987/88 Southern Hemisphere pelagic season, since there was no commercial whaling in this region, and no observers were appointed for the final season of the Japanese commercial coastal whaling, nor the Norwegian whaling operations.

INFRACTIONS

Infractions of the Commission's regulations for commercial whaling reported by Contracting Governments for the 1987 season outside the Antarctic are summarised in Table 2. Infractions reported in aboriginal subsistence whaling operations in 1987 are summarised in Table 3.

Table 2

Summary of infractions reports outside the Antarctic 1987 (excluding aboriginal subsistence operations). The percentage value for lactating animals under individual species refers to the percentage of females. The percentage values under 'total' for all species refer simply to the total catch. No protected whales were taken (other than in aboriginal fisheries).

		Lactating		Other		Total	
	Catch	No.	%	No.	%	No.	%
Bryde's	317	1	1.6	0	0	1	0.3
Sperm	200	0	0	0	0	0	0
Minke	979	0	0	0	0	0	0
Total	1,496	1	0.1	0	0	1	0.1

Table 3

Summary of infractions reports in aboriginal subsistence whaling in 1987.

	Catch	Infractions
Minke	85	10, quota exceeded
Fin	9	None
Humpback	2	1 lactating, 1 calf*
Bowhead	31 strikes	None
Gray	158	None

* = Prior to setting of catch limit.

SCIENTIFIC RESEARCH

The 10th Antarctic Minke Whale Sightings Cruise was conducted under the Second International Decade of Cetacean Research programme in Area III (0°-70°E). Two Japanese vessels took part from 10 December 1987 to 8 February 1988, with scientists from Japan, New Zealand and USA.

The related validation and analysis of the results from this cruise and the preceding cruises in the Antarctic were continued.

As part of the Comprehensive Assessment of whale stocks programme, a contract study on Southern Hemisphere minke whale marking data was undertaken; and a two year investigation of whale stock identification through DNA probes was started.

The Commission also provided partial funding for a five-year radio-telemetry study of the blue, fin and humpback whales off California.

SCIENTIFIC COMMITTEE

A Special Meeting of the Scientific Committee was held in Cambridge, UK, 15–17 December 1987 to review and comment on a research proposal put forward by the Government of Japan for a feasibility study involving a take of minke whales in the Antarctic under the Special Permit provision of the Convention.

A conference on the Use of Non-Lethal Techniques, especially Photo-identification Techniques, to Estimate Cetacean Population Parameters was co–sponsored with the US National Marine Fisheries Service, in La Jolla, California, 29 April – 4 May 1988.

The data entry programme of catch records world-wide has been completed for North Pacific 1949–85, Antarctic 1980/81–1986/87 and South Atlantic coastal 1970–85 to extend the previously available series. Minke whale mark-recapture records from the International Whale Marking Scheme in the Southern Hemisphere have also been coded for 1972/73–1983/84.

BUREAU OF INTERNATIONAL WHALING STATISTICS

The catch records from the current whaling activities have been received and coded by the Secretariat. The material relating to the final two seasons of whaling before commercial catch limits were set at zero have been prepared for publication in the same format as used by the Bureau of International Whaling Statistics.

IWC ACTIVITIES

Following the December 1987 Special Meeting of the Scientific Committee, a postal vote of Commissioners was called by the Commissioner for the United Kingdom on a Resolution requesting the Government of Japan to refrain from issuing or to withdraw the Special Permit for its Antarctic feasibility study. The Chairman ruled that this was adopted by a simple majority of Commissioners eligible to vote.

In preparation for the 40th Annual Meeting, the Commission established a Working Group of the Aboriginal Subsistence Whaling Sub-committee to consider questions relating to the definitions of aboriginal subsistence whaling as compared with other types of whaling for the purpose of the Schedule; and a Working Group charged with the responsibility of examining questions related to the operation of the 1946 Convention. Both these Working Groups corresponded through the year.

In addition, the Commissioner for the USA initiated an exchange of views by correspondence on the Review of Special Permit Proposals for Scientific Research by the Scientific Committee, and the Government of Iceland stimulated a similar exchange of views on Scientific Committee Procedures.

The Commission co-sponsored, with UNEP, an Indian Ocean Sanctuary Administrative meeting attended by IWC members and non-member Indian Ocean coastal states. This was held by kind invitation in Canberra, Australia, 18-20 May 1988.

COOPERATION WITH OTHER ORGANISATIONS

The Commission was represented in an Observer capacity at meetings of: CCAMLR, Hobart, Tasmania, October-November 1987; ICES, Santander, Spain, October 1987; ICSEAF, Madrid, Spain, November-December 1987; IATTC, La Jolla, California, USA, March 1988.

FINANCE

The statement of estimated income and expenditure for the financial year ending 31 August 1987 was approved by the Commission at the 39th Annual Meeting. The audited accounts appear on pages 3–4 of the 38th Annual Report (*Rep. int. Whal. Commn* 38).

The budget approved for the financial year 1987/88 amounted to £546,550, including an allocation of £157,500 to the Research Fund.

Contributions were required from Contracting Governments amounting to £416,180, but there was a shortfall of £89,108 in this income due to the failure to pay, in whole or in part, of 11 Governments: Antigua & Barbuda, Belize, Chile, Costa Rica, Kenya, Mauritius, Peru, Philippines, Senegal, Solomon Islands and Uruguay.

The sanction of the addition of 10% interest was applied to those Governments which had not paid their contributions by the due date in March 1988.

A further sum of £261,106 was still outstanding in non-payments from previous years from 9 Governments: Antigua & Barbuda, Belize, Costa Rica, Kenya, Mauritius, Peru, Philippines, Senegal and Uruguay.

In addition, the two former members Dominica and Jamaica still owe £41,443 for unpaid contributions.

The sanctions of suspension of the right to vote and the withholding of Commission documentation for a Government more than 21 months in arrears with its annual payments came into effect in April 1988 for the Government of Antigua & Barbuda.

Eight Governments continued under these sanctions from previous years: Belize, Costa Rica, Kenya, Mauritius, Peru, Philippines, Senegal and Uruguay.

MEMBERSHIP

Three Contracting Governments gave notice of withdrawal from the International Convention for the Regulation of Whaling, 1946 – Belize, Mauritius and the Philippines, with effect from 30 June 1988. The members of the International Whaling Commission and their Commissioners are listed on page v of *Rep. int. Whal. Commn* 38.

Accounts for the year ended 31 August 1988

Report of the Auditors to the Commission

We have audited the financial statements set out below in accordance with approved Auditing Standards. In our opinions 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 1988 and of its deficit for the year ended on that date.

Spicer and Pegler, Chartered Accountants, Leda House, Station Road, Cambridge.

Balance Sheet 31 August 1988

	Note		1988		*1987*
Current Assets					
Cash on short term deposit:					
General Fund		279,330		*242,183*	
Research Fund		73,189		*74,547*	
Severance Pay		—		*97,617*	
Publications Fund		29,665		*7,417*	
			382,184		*421,764*
Cash at bank on current account & in hand:					
General Fund		1,000		*1,000*	
Research Fund		1,000		*1,000*	
Cash in hand		42		62	
			2,042		*2,062*
Outstanding contributions from members (including interest)		404,959		*387,133*	
Less provision for doubtful debts		(378,968)		*361,199)*	
			25,991		*25,934*
Other debtors and prepayments			81,412		*60,132*
			491,629		*509,892*
Current Liabilities					
Creditors			80,214		*53,108*
Net Current Assets			411,415		*456,784*
Severance Pay Provision	1 & 6		95,631		*98,500*
			£315,784		*£358,284*
Financed by					
Publications Fund	3		33,260		*14,374*
Research Fund	4		70,993		*50,185*
General Fund	5		211,531		*293,725*
			£315,784		*£358,284*

Ray Gambell *Secretary*

Income and Expenditure Account

	Note		1988		*1987*
Income					
Contributions			416,293		*421,920*
Interest receivable			34,265		*36,577*
Sales of publications			6,035		*21,592*
Sales of sponsored publications			1,432		*5,357*
Voluntary contributions to research			—		*4,371*
Voluntary contributions to sponsored publications			15,901		*2,670*
Value added tax recoverable			11,312		*15,189*
Staff assessments			35,355		*43,082*
NGO registration fees			10,623		*8,558*
Interest on overdue financial contributions			42,353		*19,135*
Expenditure			£573,569		*£578,451*
Secretariat costs		308,444		*277,413*	
Publications		7,707		*25,531*	
Costs of sponsored publications		3,560		*18,024*	
Annual meetings		55,715		*48,170*	
Other meetings		917		—	
Research		126,327		*142,193*	
Provisions made (released) against					
Unpaid contributions		(6,762)		*68,068*	
Unpaid interest on overdue contributions		24,530		*12,583*	
Severance Pay		(10,980)		*13,671*	
			509,458		*605,653*
Excess of Income Over Expenditure			64,111		—
Excess of expenditure over income			—		*(27,202)*
Extraordinary item					
Provision against deposit balances held in Barlow Clowes International Ltd	2		106,611		—
Deficit after extraordinary item			(42,500)		*(27,202)*
Net transfers (to) from Funds					
Publications Fund	3	(15,484)		*8,537*	
Research Fund	4	(24,210)		*(30,034)*	
			(39,694)		*(21,497)*
Deficit for the year	5		£(82,194)		*£(48,699)*

Notes to Income and Expenditure Account

	1988	*1987*
Secretariat Costs		
Salaries and national insurance	179,068	*177,255*
Pension and other benefits	26,287	*20,838*
Travelling expenses	4,656	*1,105*
Office rent, heating and maintenance	30,877	*18,585*
Insurance	1,389	*1,172*
Postages and telecommunications	12,299	*7,094*
Computing & data management	18,606	*20,974*
Office equipment and supplies	29,065	*26,330*
Professional fees	5,665	*2,974*
General expenses	532	*1,086*
	£308,444	*£277,413*

Publications		
37th Annual Report	—	*17,365*
38th Annual Report	447	—
Additional reports	—	*3,728*
Other printing and copying	7,260	*4,888*
	£7,707	*£25,531*

The 38th Annual Report was not completed until December 1988 and consequently printers' publication costs and sales income arising thereon have been excluded from these accounts.

Other Meetings		
Scientific Committee, Special Permits	917	—
	£917	—

	1988	*1987*
Research		
Southern Hemisphere minke whale assessment cruises		
1985/86	—	*1,398*
1986/87	(30)	*58,306*
1987/88	33,558	—
Cruise data analysis		
Minke whales	24,304	*8,307*
Other species	1,919	*266*
Data preparation	—	*15,000*
Discretionary support (invited participants)	6,862	*3,628*
Galapago sperm whale project	—	*10,000*
Indian Ocean sanctuary meeting	—	*10,237*
Comprehensive assessment reviews	—	*24,000*
Comprehensive assessment workshops	—	*11,051*
Computing assistant	8,762	—
Computing projects	2,000	—
DNA contract study	19,300	—
Mark-recapture contract study	10,000	—
Natural markings/photo I.D. workshop	13,098	—
Radio tagging project	6,000	—
Other costs	554	—
	£126,327	*£142,193*

Notes to the Accounts

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.

Publications

The full cost of printing publications is written off in the year. No account is taken of stocks 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 all full time 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 annual provision is made to bring the total provision up to the maximum liability. This liability is now calculated after adjusting for staff assesssments, since they would not form part of the Commission's liability. The cumulative effect of this change in calculation is to reduce the charge in the year by some £26,000.

Interest on overdue contributions

In accordance with the Commission's Financial Regulations the interest received on overdue contributions from Contracting Governments is credited to the General Fund. It was until 26 June 1987 credited to the Research Fund.

Interest is included in the accounts on an accruals basis and provision is made where its recoverability is in doubt.

Leases

The costs of operating leases are charged to the income and expenditure account as they accrue.

Equipment held under finance leases is not capitalised as expenditure on fixed assetts is expensed as incurred.

2. Extraordinary Item

Full provision has been made against balances invested by the Commission in Barlow Clowes International Limited which is now in liquidisation.

3. Publications Fund

	1988	*1987*
Transfers (to) from income and expenditure account:		
Voluntary contributions	15,901	*2,670*
Interest receivable	1,711	*1,460*
Sales of sponsored publications	1,432	*5,357*
Expenditure on sponsored publications	(3,560)	*(18,024)*
Net transfers (to) from Income and Expenditure Account	15,484	*(8,537)*
Transfer from Research Fund	3,402	*10,794*
Opening balance at 1 September	14,374	*12,117*
Closing balance at 31 August	£33,260	*£14,374*

4. Research Fund

	1988	*1987*
Transfers (to) from income and expenditure account:		
Voluntary contributions to research	—	*4,371*
Allocation for research	138,000	*153,700*
Value added tax recoverable	788	*638*
Profit on sales of promotional itmes	114	*412*
Interest receivable	11,635	*6,554*
Interest received on overdue financial contributions	—	*6,552*
Research expenditure	(126,327)	*(142,193)*
Net Transfers (to) from Income and Expenditure Account	24,210	*30,034*
Transfer to Publications Fund	(3,402)	*(10,794)*
Opening balances at 1 September	50,185	*30,945*
Closing balances at 31 August	£70,993	*£50,185*

5. General Fund

	1988	*1987*
Opening balances at 1 September	293,725	*342,424*
Deficit transferred from income and expenditure account	(82,194)	*(48,699)*
Closing balances at 31 August	£211,531	*£293,725*

6. Severance Pay Provision

	1988	*1987*
Opening balances at 1 September	98,500	*75,000*
Transfer from income and expenditure account	(10,980)	*13,671*
Interest receivable	8,111	*9,829*
Closing balances at 31 August	£95,631	*£98,500*

7. Financial Commitments

The Commission had an annual commitment at 31 August 1988 under non-cancellable finance and operating leases for office equipment as follows:

	1988	*1987*
Leases which expire in the second to fifth year	£18,090	*£17,969*

40th Annual Meeting: May/June 1988 – Auckland List of Delegates and Observers Attending

(C) Commissioner (A) Alternate Commissioner (I) Interpreter (S) Support Staff.

Antigua and Barbuda

J.E. Fuller (C)
R. Payne
J. Petterson

Argentina

E.H. Iglesias (C)
D.C. de Newton
A. Lichter

Australia

J.D. Ovington (C)
D.W. Dobinson (A)
A.I. Gregory
W.K. de la Mare
D. Nicol
M.J. Tucker

Brazil

J.G. Marques Porto (C)
O.A.B. Goncalves
V.M.F. da Silva

People's Republic of China

Y. Zhuo (C)
H. Zhang (I)
R. Zhang

Denmark

H. Fischer (C)
O. Samsing (A)
K. Hoydal
A. Jakobsen
H. Kass
N. Knudsen
F. Larsen
F. Lynge
A. Olafsson
J. Olsen
J. Pilegaard
B. Sloth
K. Trolle

Finland

E. Jaakkola (C)

France

D. Piney (C)

Federal Republic of Germany

N. Kleeschulte (C)
P. Deimer
F. de Soye

Iceland

H. Asgrimsson (C)
G. Eiriksson (A)
K.S. Juliusson (A)
G.M. Gislason
A. Kolbeinsson
K. Loftsson
J. Sigurjonsson
H. Sveinbjornsson

India

M.K. Ranjitsinh (C)

Japan

K. Shima (C)
H. Nitta (A)
T. Nogami (A)
M. Morimoto (A)
K. Arai
C. Higashi
H. Hiroyama
I. Ikeda
T. Isogai
M. Iwasaki
F. Kasamatsu
T. Kasuya
A. Koyama
A. Mae
K. Matsubara
K. Matsuzaki
S. Misaki (I)
T. Miyoshi
H. Nagao
F. Nagasaki
T. Nakamura (I)
T. Nakao
S. Ohsumi
M. Okuno
Y. Shimomichi
T. Suzuki
J. Takahashi
T. Takayama
T. Tamazawa
S. Tamura
K. Tanaka
S. Tanaka
K. Yamamura

Republic of Korea

K.H. Kim (C)
Z.G. Kim (A)

Mexico

L.A. Fleischer (C)
M.A. Lopez Ortega (A)
D. Luna

Netherlands

F.C.M. van Rijckevorsel (C)
K. Lankester

New Zealand

I.L.G. Stewart (C)
P.N. Aitken (A)
M.F. Donoghue
L.J.W. Ludbrook

Norway

P.E.S. Tresselt (C)
A. Bjørge
O. Gregussen
M. Hauge
T. Norendal
E. Øen
T. Øritsland
H. Rasmussen
J. Strand
O. Wikse

Oman

M.A. Al-Barwani (C)

St Lucia

J.E. Edmunds (C)

St Vincent and the Grenadines

G. Davy-Penningsfeld (C)

Seychelles

R.F. Delpech (C)
S.J. Holt

Solomon Islands

S. Diake (C)
D.M. Gottheil (A)

South Africa

L. Botha (C)
W.L.-E. Brewis

Spain

G. Ortiz (C)
E.R. Molero (A)
P. Gonzalez
H. Quiroga

Sweden

S. Irberger (C)
T. Arnbom (A)

Switzerland

W. Schmid (C)

Union of Soviet Socialist Republics

I.V. Nikonorov (C)
M.V. Ivashin
V.G. Makeyev
A.A. Matveev
V.L. Minin
V.K. Vasiliev

United Kingdom

A.M. Blackburn (C)
M.J. Ibbotson (A)
P. Birnie
J. Horwood
W.J. Jordan
C. Philips

United States of America

W.E. Evans (C)
N.C. Roberts (A)
N. Azzam
D. Bodansky
S. Brandt-Erichsen
S.R. Braund (S)
J.W. Brennan
A. Brower, Jr
R.L. Brownell, Jr
D.A. Carr
A. Crichton
C.M. Crosby (S)
R. Ellis
M.A. Fraker (S)
D. Kava
C. Kendrew
D.M. Kohler (S)
J.A. Kruse (S)
J.W. Leach (S)
T. Melius
T. Napageak
D. Olsen (S)
R.S. Rootes
N. Solomon
S.W. Stoker (S)
D. Swanson
M. Tillman
L.J. Weddig
L.C. Williams

Chairman of the Scientific Committee

G.P. Kirkwood

GOVERNMENT OBSERVERS

Canada
M. Freeman
D. Goodman
S.I. Hewlett

INTERNATIONAL GOVERNMENTAL ORGANISATION OBSERVERS

European Economic Community
P. Hillenkamp
W. Wijnstekers

International Council for the Exploration of the Sea
T. Øritsland

United Nations Environment Programme
B.H. Nielsen

INTERNATIONAL NON-GOVERNMENTAL ORGANISATION OBSERVERS

African Wildlife Foundation
D.C. Esty

American Association of Zoological Parks and Aquariums
B. Andrews

American Cetacean Society
B.H. Britten

American Friends Service Committee
S.L. Sutcliffe

American Protection Institute of America
N.D. Hicks

Antarctic and Southern Ocean Coalition
T. Gentle

Assembly of Rabbis
L.A. Carter

Center for Environmental Education
S.L. Swartz

Cetacean Society International
R. Barstow

Earth Co-Existence Organisation
M. Mathias

Earth Island Institute
D. Phillips

Earthtrust
M. Bailey

Environmental Investigation Agency
D. Currey

FBCN
J.T. Palazzo, Jr

Friends of the Earth International
G. Peet

Greenpeace International
D. McTaggart
P. Whitehouse (Alt)

Indigenous World Association
E. Edgington

Institute for European Environmental Policy
R. Parmentier

Institute for the Study of Animal Problems
P. Forkan

International Association for Religious Freedom
M. Adams

International Commission of Jurists
J.S. LeFevre
D. Gottheil (Alt)

International Environmental Advisors
J. Frizell

International Fund for Animal Welfare
I.S. MacPhail

International Institute for Environment and Development
E. Kemf

International League for the Protection of Cetaceans
L. Busby

International Marine Animal Trainers Association
J. Pearson
D. Murphy (Alt)

International Ocean Institute
O. Lindquist

International Transport Workers Federation
T. Nakao
J. Beatty (I)

International Wildlife Coalition
D.J. Morast

Inuit Circumpolar Conference
G.A. Ahmaogak

Inuit Circumpolar Conference Environmental Commission
N. Doubleday

Long-Term Research Institute
K.M. O'Connell

Marine Mammal Interest Group
J. Haun
D. Murphy (Alt)
R. Brill (Alt)

Minority Rights Group
O. Swan

Monitor
C. Van Note

Nordic Society for the Conservation of Sea Mammals
M.G. Nielsen

People's Trust for Endangered Species
W. Jordan

Royal Society for the Prevention of Cruelty to Animals
I. McCrea

Save the Children
L.F. Kagak
E. Edgington (Alt)

Survival International
B. Rexford

Waterlife Association
C. Plowden

Werkgroep Zeehond
G.A.A. Drieman

Whale Center
M.J. Palmer

Whale Conservation Society
K. Mulvaney

Whaling Problem Discussion Committee
J.S. Henke

Windstar Foundation
N.C. Azzam

Women's International League for Peace and Freedom
H. Okhtokiyuk
M. Adams (Alt)

World Association for World Federation
E. Rock
Sr T. Anungazuk (Alt)

World Council of Indigenous Peoples
T. Anungazuk

World Society for the Protection of Animals
N. Wells

World Wildlife Fund
A. Schiøtz

Agenda of 40th Annual Meeting

1. ADDRESS OF WELCOME

2. OPENING STATEMENTS (Papers IWC/40/OS —)

3. ADOPTION OF AGENDA

4. ARRANGEMENTS FOR THE MEETING

5. APPOINTMENT OF COMMITTEES
(Rules of Procedure, Rule M.1.)

6. REVISION OF THE CONVENTION
(Chairman's Report of the 39th Meeting, paragraph 6)
   - 6.1 Report of Working Group (Paper IWC/40/14)
   - 6.2 Listed species
   (Chairman's Report of the 39th Meeting, paragraph 9)
   - 6.3 Action arising

7. SOCIO-ECONOMIC CONSIDERATIONS
(Chairman's Report of the 39th Meeting, paragraph 7)

8. SCIENTIFIC PERMITS
(Chairman's Report of the 39th Meeting, paragraph 8)
   - 8.1 Result of Postal Vote proposed by the United Kingdom (Paper IWC/40/22)
   - 8.2 Report of Scientific Committee (Paper IWC/40/4)
   - 8.3 Action arising

9. COMPREHENSIVE ASSESSMENT OF WHALE STOCKS
(Chairman's Report of the 39th Meeting, paragraphs 10 and 11)
   - 9.1 Report of Scientific Committee (Paper IWC/40/4)
   - 9.2 Report of Joint Working Group (Paper IWC/40/15)
   - 9.3 Action arising

10. INDIAN OCEAN SANCTUARY
(Chairman's Report of the 39th Meeting, paragraph 12)
   - 10.1 Report of Indian Ocean Meeting (Paper IWC/40/16)
   - 10.2 Report of Technical Committee Indian Ocean Sanctuary Administrative Sub-committee (Paper IWC/40/17)
   - 10.3 General review of prohibition on commercial whaling in the Indian Ocean Sanctuary (Schedule paragraph 7)
   - 10.4 Action arising
   (Any changes to the provisions of Schedule paragraph 7 may require amendment of the Schedule)

11. INFRACTIONS, 1987 SEASON
(Chairman's Report of the 39th Meeting, paragraph 13)
   - 11.1 Report of Technical Committee Infractions Sub-committee (Paper IWC/40/7)
     - 11.1.1 Infractions reports from Contracting Governments (Paper IWC/40/6)
     - 11.1.2 Other matters from earlier years
   - 11.2 Action arising
   (Changes to the observer scheme may require amendment of the Schedule, paragraph 21; changes in the information required under Section VI of the Schedule may require amendment of that Section.)

12. COMMISSION'S COMPETENCE TO SET CATCH LIMITS FOR BAIRD'S BEAKED WHALE IN THE NORTH PACIFIC
(Chairman's Report of the 39th Meeting, paragraph 14)

13. WHALE STOCKS
(Chairman's Report of the 39th Meeting, paragraph 15)
   - 13.1 Report of Scientific Committee (Paper IWC/40/4)
   - 13.2 Action arising
   (Changes of classification, or seasons, or areas or sub-areas, or of size limits will require amendment of the Schedule including paragraphs 2, 4, 5, 9, 15, 16, 18 and Tables 1, 2 and 3)
     - 13.2.1 Sperm whales
     - 13.2.2 Minke whales
     - 13.2.3 Fin whales
     - 13.2.4 Sei whales
     - 13.2.5 Bryde's whales
     - 13.2.6 Bottlenose whales
     - 13.2.7 Protected species

14. ABORIGINAL SUBSISTENCE WHALING
(Chairman's Report of the 39th Meeting, paragraph 16)
   - 14.1 Report of Scientific Committee (Paper IWC/40/4)
   - 14.2 Report of Technical Committee Aboriginal Subsistence Whaling Sub-Committee (Paper IWC/40/13)
     - 14.2.1 Report of Definitions Working Group
     - 14.2.2 Bering Sea stock of bowhead whales
     - 14.2.3 Eastern Pacific stock of gray whales
     - 14.2.4 West Greenland stocks
     - 14.2.5 Central Atlantic minke whales
     - 14.2.6 St Vincent and the Grenadines humpback whales
     - 14.2.7 Small-type whaling in Japan's coastal seas
   - 14.3 Action arising
   (Changes of catch limits or other regulations including definition of terms will require amendment of the Schedule, paragraphs 1, 12, 13 or Table 1)

15. SECONDINTERNATIONAL DECADE OF CETACEAN RESEARCH
(Chairman's Report of 39th Meeting, paragraph 17)
    - 15.1 Report of the Scientific Committee (Paper IWC/40/4)
    - 15.2 Action arising

16. DATA AND STATISTICS
(Chairman's Report of the 39th Meeting, paragraph 18.2)
    - 16.1 Access to IWC data
    - 16.2 Action arising

17. ADOPTION OF REPORT OF THE SCIENTIFIC COMMITTEE (to be circulated as Paper IWC/40/4)

18. HUMANE KILLING
(Chairman's Report of the 39th Meeting, paragraph 20)
    - 18.1 Report of Technical Committee Humane Killing Working Group (Paper IWC/40/18)
    - 18.2 Action arising

19. REGISTER OF WHALING VESSELS
(Chairman's Report of the 39th Meeting, paragraph 21)
(Paper IWC/40/12)

20. ADOPTION OF REPORT OF THE TECHNICAL COMMITTEE (to be circulated as paper IWC/40/5)

21. FINANCE AND ADMINISTRATION
(Chairman's Report of the 39th Meeting, paragraph 23)
    - 21.1 Review of provisional financial statement, 1987/88 (Paper IWC/40/8)
    - 21.2 Consideration of estimated basic budget, 1988/89 (Paper IWC/40/8)
    - 21.3 Consideration of supplementary budget
        - 21.3.1 Research
        - 21.3.2 Meetings
        - 21.3.3 Other
    - 21.4 Consideration of advance budget estimates for 1989/90 (Paper IWC/40/8)
    - 21.5 Contributions by Contracting Governments
        - 21.5.1 Proposals for scale of contributions (Chairman's Report of the 39th Annual Meeting, paragraph 23.5.1)
        - 21.5.2 Arrears of contributions (Paper IWC/40/20)
    - 21.6 Numbers attending Committees and Working Groups
    - 21.7 Amendment of Rule of Procedure E.3
    - 21.8 Invited participants to the Scientific Committee

22. DATE AND PLACE OF ANNUAL MEETING
(Rules of Procedure, Rule B1)

23. ADOPTION OF REPORT OF FINANCE AND ADMINISTRATION COMMITTEE
(to be circulated as Paper IWC/40/9)

24. CO-OPERATION WITH OTHER ORGANISATIONS (Paper IWC/40/10)
    - 24.1 CCAMLR
    - 24.2 ICES
    - 24.3 ICSEAF
    - 24.4 IATTC

25. THIRTY-NINTH ANNUAL REPORT
(Paper IWC/40/11 Draft)

26. ELECTION OF CHAIRMAN
(Rules of Procedure, Rule F.1)

27. ELECTION OF VICE CHAIRMAN
(Rules of Procedure, Rule G.1)

28. ANY OTHER BUSINESS

Chairman's Report of the Fortieth Annual Meeting

1. DATE AND PLACE

The Fortieth Annual Meeting of the Commission was held, at the invitation of the Government of New Zealand, at the Sheraton Hotel, Auckland, 30 May – 3 June 1988. The proceedings were chaired by Mr I.L.G. Stewart (New Zealand).

2. REPRESENTATION

Commissioners and delegates from 29 of the 41 member governments of the Commission attended the meeting. One non-member government, Canada, was represented by observers, together with observers from five inter-governmental organisations:

Convention for the Conservation of Antarctic Marine Living Resources;
European Economic Community;
International Council for the Exploration of the Sea;
International Council for Southeast Atlantic Fisheries;
United Nations Environment Programme.

Also present were observers from the International Union for the Conservation of Nature and Natural Resources and 51 international non-governmental organisations.

3. ADDRESS OF WELCOME

The Hon. Fran Wilde, Associate Minister of Foreign Affairs, gave an address of welcome on behalf of the New Zealand Government. She spoke of the great significance of whaling in the European development of her country from the early 1800s, an example of excessive exploitation which it is now recognised will take decades or even centuries of protection to put right. This has encouraged New Zealand to take a more active part in promoting the conservation aspects of the IWC's mandate.

4. OPENING STATEMENTS

Opening statements by Commissioners and Observers were distributed in written form and included in the meeting documentation, in line with the Commission's recent practice.

5. ADOPTION OF AGENDA

It was agreed that the Provisional Agenda circulated sixty days in advance of the meeting should be amended by the deletion of an item on the 'Result of Postal Vote Proposed by the United Kingdom' as a separate item. Japan proposed that a new item should be inserted after Item 14 on Aboriginal Subsistence Whaling to allow 'Consideration of the Situation of Various Types of Small-type Whaling', with the deletion of Item 14.2.7 on 'Small-type Whaling in Japan's Coastal Seas'. This was agreed, the new item being designated 14a for convenience. It was also agreed, at the request of the Secretary, to add an item on UNEP as 24.5, to allow discussion of a proposal for a meeting from that organisation.

With these changes, the Agenda was adopted and the Chairman referred Items 10 to 20 inclusive to be considered first by the Technical Committee.

6. REVISION OF THE CONVENTION

A Working Group to Examine Questions Related to the Operation of the International Convention for the Regulation of Whaling was chaired by Mr D. Luna (Mexico) and attended by representatives from Australia, Brazil, People's Republic of China, Denmark, Iceland, Japan, Republic of Korea, Mexico, New Zealand, Norway, Seychelles, Spain, Sweden, Switzerland, USSR, UK and USA.

A discussion was held about the operation of the 1946 Convention, how the operation of the Convention could be improved and whether the Convention should be revised.

A number of concerns about the 1946 Convention were expressed relating to its objects and purpose and scope of application; the lack of definition of major terms; membership in the IWC, in particular, the need for parity of interest and involvement in whaling among member states; the need for greater consensus in IWC decision making; the need for improvements in the operation of the Scientific Committee; the relative interests of coastal states and the IWC in whale management; and the lack of provisions on the responsibilities of contracting parties and dispute settlement mechanisms.

Several delegations stated that, due to changed circumstances, the Convention needed to be revised; the Convention was not infinitely flexible since international law imposes limits on ways in which treaties may be interpreted. The suggestion was made to revise the Convention to focus on the conservation and study of whales, rather than the regulation of whaling.

Other delegations expressed satisfaction with the current Convention, noting that it had demonstrated its flexibility to take account of new circumstances and problems. They observed that, to the extent changes were needed, these could generally be accomplished by changes in the Schedule to the Convention, and questioned the need for revising the Convention at the present time, if at all.

Other delegations indicated that their governments did not yet have a clear view on the need for a revision.

In order to guide its work, the Working Group developed a list of questions, which was neither exhaustive nor exclusive, nor implied that revision of the Convention is deemed necessary, but was to be understood as a list of concerns and questions voiced for discussion purposes. Following a general discussion of these questions, the Working Group agreed that sufficient progress had been made to submit its report to the Commission so that the Commission could decide how best to proceed with this matter.

In the Commission, Argentina proposed that the Working Group should convene again immediately before the 41st Annual Meeting and report to that meeting; that Contracting Governments should be invited to send comments or proposals based on the list of questions contained in the report of the Working Group to the Secretary by 31 January 1989 for circulation in advance of the next meeting of the Working Group; and that a Draft Resolution from the USSR should be held over for possible consideration at the next Annual Meeting.

Brazil, Iceland, Australia, Japan, Norway, Mexico, the Netherlands and Oman all spoke in support of this proposal, which was then agreed. Commissioner Iglesias (Argentina) was asked to convene the next meeting of the Working Group.

7. SOCIO-ECONOMIC CONSIDERATIONS

The Commission noted that the Working Group on the Socio-Economic Implications of a Zero Catch Limit, chaired by Brazil, will meet again immediately before the 41st Annual Meeting. Member governments have been invited to present their submissions three months in advance of that meeting.

8. SCIENTIFIC PERMITS

The Report of the Special Meeting of the Scientific Committee held in December 1987 to review the Japanese proposal for a feasibility study had been forwarded to the Commission at the time and was not discussed further by the Scientific Committee, apart from the recommendations it contained.

8.1 Report of the Scientific Committee

The Commission noted that the Scientific Committee had considered a paper suggesting a mechanism to resolve the overlap between the Commission's Resolutions and the Committee's guidelines for reviewing scientific permits. The 18 guidelines were grouped under 5 general headings: the proposal; objectives; methodology; effect of catches; and participation in research by other nations. Although the Committee had believed it inappropriate to alter the wording of the Commission's guidelines at the present meeting, it had noted that separate treatment of each of the 18 guidelines had proved an extremely cumbersome and time-consuming procedure at both the Special and the present meetings. It will attempt to revise the current guidelines at its next meeting in order to simplify its work and more effectively provide advice to the Commission.

A. Existing scientific permits

(i) *Japan*

The Scientific Committee noted that Japan had taken 273 animals out of a proposed catch of 300 minke whales over a wide latitudinal range from 55°S to the ice edge, including one animal of the diminutive form at 58°S, the most southerly record of this form. The proposed random sampling scheme had proved relatively easy to implement, and several members commented on the useful biological information presented. However, some members pointed out that the preliminary results indicated that one of the primary aims, to test the procedure for collecting a representative sample of the population, had not been entirely successful. The Japanese scientists appreciated these comments, and were taking action to overcome the problems.

Reference was made to difficulties in analysing data with the level of variability revealed, and to the previously discussed underlying methodological problems of determining age-specific natural mortality. It was noted that the results presented were preliminary, and some members thought it premature to draw final conclusions.

In the Commission, Japan emphasised its view that the natural mortality coefficient can be estimated using an appropriate cohort model, and stated that results of further simulations will be presented next year. It defended its feasibility study as a contribution to the Comprehensive Assessment programme, since it provides data on many parameters required by the Scientific Committee. It will continue with the programme and analyses because it considers them indispensable for progress in stock assessment, and regretted the criticisms levelled by certain scientists.

The Netherlands voiced its disappointment that the feasibility study was carried out in spite of concerns expressed in the Special Meeting of the Scientific Committee and a Commission Resolution adopted by postal vote.

The UK reiterated its concerns over the random sampling and methodology of determining age specific mortality, but was pleased to learn that more simulations will be done. Sweden concurred with this statement, while Iceland recognised the preliminary status of the study, and commended the research activity.

Japan pointed out the conflict it sees between the intersessional Resolution adopted and its rights under Article VIII of the Convention to conduct scientific research under special permit, and considered that the Resolution had not taken full account of the scientific examination at the Special Meeting of the Scientific Committee.

Brazil recorded its view that, while recognising Japan's rights under the Convention to carry out scientific programmes, it regretted that this programme was carried out in spite of contrary opinions of the Scientific Committee and even before the Commission had time to have an opinion. Argentina associated itself with this position.

Australia also associated itself with the comments by Brazil, and added that Article VI provides the basis by which 'the Commission may from time to time make recommendations to any or all Contracting Governments on any matters which relate to whales or whaling and to the objectives and purposes of the Convention'.

New Zealand shared the concerns expressed by the Netherlands, and took the view that the procedure by which the postal vote was recorded was valid and legitimate. It considered that the rights under Article VIII are not unfettered and must be exercised in good faith and in light of other provisions of the Schedule. Antigua & Barbuda associated themselves with this view and the statement of Brazil.

The Commission noted these comments and the Scientific Committee's report.

(ii) *Iceland*

In 1987 Iceland took 80 fin whales and 20 sei whales under its four-year programme. Progress on biochemical and other more general studies was noted by the Scientific Committee, but some members commented on the difficulties of evaluating the results of permit catches because the reports presented combined these with data from previous commercial catches. Icelandic scientists pointed out that the results were for two years of a four-year programme designed to continue to monitor the stocks and should not be seen in isolation. Other members stated their belief that the programme is wide-ranging and that the results were improving knowledge of the stocks.

In the Commission, Iceland pointed out that the objectives of the programme launched in 1986 are to improve the assessment and monitor the status of the whales. This includes studies on age, reproduction, CPUE, and body condition with special reference to environmental conditions, energetic status and reproductive success. Results and the status of over 30 separate research projects had been reported to the Scientific Committee. These and experiments to improve interpretation of sightings surveys will lead to better knowledge of the status of the stocks in question and have general applicability within the scope of the Comprehensive Assessment. Particular stress was placed on monitoring dynamic features of the stocks, such as pregnancy rates and age at sexual maturity, as well as techniques bearing on stock identity.

Japan commented favourably on the Icelandic research, and the Commission took note of the Scientific Committee's report.

B. New and continuing scientific permit proposals

The Scientific Committee was informed that Japan will decide what research programme it will implement once the analysis of data collected in 1988/89 had been completed. The Committee had agreed that it was therefore not possible to discuss the matter further at its meeting. Should a proposal arise during the coming year, the Committee drew the Commission's attention to its view that intersessional reviews of scientific permits can best be achieved by special meetings.

Japan was confident that its research programme made a significant contribution to the advancement of whale science, while India expressed its view that whales should only be killed if it is essential for their long-term survival and management, or for human survival.

(i) *Norway*

A Norwegian programme to study and monitor Northeast Atlantic minke whales in 1988–1992 called for the capture of 35 whales for four studies on the feasibility of radio tagging, food selection and intake, food digestion and body composition. The Scientific Committee had agreed that the question of whether or not a special permit was required to live capture whales for anaesthetisation and the attachment of radio tags was beyond its competence and referred this to the Commission.

The Scientific Committee reviewed the proposal for the take of whales in terms of the various guidelines and agreed that it adequately specified both the general and specific objectives of the research. The main part of the programme involves ecological studies designed to provide information for future multi-species management of the Barents Sea. Some members thought these would address questions of interest to the Commission's Comprehensive Assessment, in the long term, while others thought there was too little information to make an evaluation. Concerning methodology, some members questioned the small sample sizes proposed, which were decided to test both the methodologies proposed and the operational capabilities of two vessels working for three weeks. A number of members foresaw severe methodological problems in the ecological studies, and were concerned that the planning of these was not fully described. Considerable concern was expressed over the plan to anaesthetise and live capture five animals, which it was believed was unlikely to be successful due to the voluntary respiratory system of whales. While some of the projects as specified in the proposal could not be addressed by non-lethal research techniques, some members believed that their value was difficult to assess without further details, and thus whether non-lethal programmes could be designed to achieve the same results. There were comments both commending the ambitious research intentions and the competence of the research workers, and others noting deficiencies of detail in the proposal. It was agreed that the effect of a take of 30–35 animals would be negligible on the stock, as a small take in a single year will always be.

In the Commission, Norway spoke of its programme to repair deficiencies in knowledge of the stock as a basis for management policies. It had taken account of comments from the Scientific Committee in the preparation of the programme, but had some concern whether such a varied group could reach consensus on value judgements. It regarded the ecological studies as being critically important to its own management responsibilities. The question of finding the wintering grounds of the whales was also an important matter, to be addressed by radio tagging. Norway was unsure if this segment which, while not intended to be lethal carried some risk of deaths occurring, required the issue of a special permit. The first year programme will develop the methodology, and any future modifications will take note of comments by the Scientific Committee. Norway pointed out that the only agreed substantive conclusion of the Scientific Committee on this programme is that the effect of the take will be negligible.

Iceland and Japan voiced support for the Norwegian research activity, while the UK emphasised the various concerns expressed by the Scientific Committee. The People's Republic of China accepted that small catches for research which do not endanger the stocks can be taken, but is opposed to commercial whaling. The Netherlands recognised the merits of the Norwegian proposal but believed it did not meet all the criteria established by the Commission.

(ii) *Iceland*

The Scientific Committee has examined the ongoing Icelandic proposal at three previous meetings. This year it considered it only against the latest set of guidelines established by the Commission last year.

Differing views were expressed by members of the Committee on whether the programme addresses questions related to the Comprehensive Assessment or other critically important research needs, the effect on the stocks, whether existing data or non-lethal techniques could be used instead, and the value of the results obtained.

In the Commission, Iceland emphasised its view that none of the main objectives of the research can be met with non-lethal techniques, especially changes in pregnancy and growth rates and their relation to environmental factors, within a reasonable time-frame and economic framework.

Norway and Japan spoke in appreciation and support of the Icelandic research programme.

8.2 Action arising

(i) *Norway*

Australia introduced a Resolution jointly sponsored with Finland, the Federal Republic of Germany, India, the Netherlands, New Zealand, Oman, Sweden, Switzerland and the UK. They believed that the scientific justification for and relevance of the results from special permit proposals should be fully presented. While mindful of the wide range of projects in the Norwegian programme which do not involve the killing of whales, but taking account of the comments by the Scientific Committee, they believed there is a need for a revision and re-thinking of the proposal before embarking on a feasibility study which would be the basis for a longer term research programme.

The USA associated itself with these comments, Mexico asked for clarification of the text concerning the UN Convention on the Law of the Sea, and Norway indicated that it could not accept either the legality or practicality of the procedure being followed and also disagreed with the judgements contained in the Resolution.

On being put to the vote, the Resolution was adopted, receiving 14 votes in favour, 4 against, with 10 abstentions. The text adopted is shown in Appendix 1.

Brazil explained its vote in favour as support for a serious attempt to reach consensus. Switzerland explained its view that killing animals for scientific research can only be permitted under the strictest conditions. It noted the concerns in the Scientific Committee about some aspects of the research proposed, and saw no legal impediment to the action taken by the Commission.

(ii) *Iceland*

A Resolution sponsored by Australia, the Federal Republic of Germany, India, the Netherlands, New Zealand, Oman, Seychelles, Sweden, Switzerland and the UK was proposed by the latter. The value of the sightings surveys and other work carried out by the Icelandic scientists was recognised, but the concerns expressed within the Scientific Committee particularly over the objectives of the programme and the difficulty of separating out the results from the research catches led to the view that the programme does not satisfy each of the Commission's criteria for special permit catches.

The USA seconded and spoke in support of the Resolution, as did Finland, while Japan was critical of the Resolution because of the difficulty of obtaining a consensus view on all the criteria applied.

Iceland suggested the addition of a clause inviting it to report in writing for consideration at the next Annual Meeting. This was seconded by Switzerland, and with this amendment the Resolution (shown in Appendix 2) was adopted without vote. Iceland maintained its reservation on the legal question involved.

(iii) *Other business*

Sweden spoke of its concern over scientific whaling as a potential way to circumvent the moratorium on commercial whaling.

The UK proposed a Resolution on the issuance of special permits for scientific research designed to remove a gap in the existing procedures. This provides for a 60 day period between the circulation of a report from an intersessional meeting of the Scientific Committee and the issue of a permit, and was seconded by Switzerland.

Brazil suggested an amendment to stress the exceptional character of intersessional meetings of the Scientific Committee, and another to reflect the recommendatory powers of the Commission and the sovereign rights of members. These were seconded by Argentina.

Norway and Iceland expressed support for the amended Resolution, but Japan thought it beyond the mandate of the Commission and the USSR was also opposed because of its view of Article VIII of the Convention. After several suggestions for re-wording the second amendment were discussed, Japan indicated it was not ready to go to a vote on the matter, and Mexico suggested the proposal should be considered by the Working Group looking into questions related to the operation of the Convention.

Before the Resolution was put to the vote, Norway explained that in the light of the exchanges on the subject, it must abstain, a position shared by St Lucia, Mexico and St Vincent & the Grenadines. Japan stated that it would abstain because it thought that the proposal was not understandable. Argentina could not accept to vote on the particular matter of Article VIII.

When the Resolution was adopted by 13 votes in favour to 1 against, with 13 abstentions, Japan recorded its reservation. The amended text is given in Appendix 3.

9. COMPREHENSIVE ASSESSMENT OF WHALE STOCKS

Following the recommendation agreed last year, the Joint Working Group of the Technical and Scientific Committees on Comprehensive Assessment met to review the development of the work carried out during the year and to discuss the future work of the Scientific Committee. It was chaired by Dr L. Fleischer (Mexico), Vice-Chairman of the Technical Committee, and attended by delegates from Australia, Denmark, Iceland, Japan, Republic of Korea, Mexico, the Netherlands, New Zealand, Norway, Seychelles, Sweden, UK, USSR and the USA.

9.1 Report of Scientific Committee

The Scientific Committee reviewed the reports of four contract studies carried out during the past year and made a number of recommendations. The programmes covered biochemical genetics, analysis of Southern Hemisphere minke whale marking data and non-minke sightings data, and a Galapagos sperm whale study.

Reports of intersessional meetings and activities were also reviewed, concerning the photo-identification workshop, analysis of catch curves, management procedures and biological parameters. Other studies discussed in the Scientific Committee included sightings surveys, telemetry and remote sensing, follow-up to the CPUE workshop, and estimating Maximum Sustainable Yield rate.

Future work includes a Workshop on the Feeding Ecology of Southern Baleen Whales, to be held jointly with CCAMLR. A joint steering committee met and proposed revised objectives and terms of reference.

A working group was established to consider how to proceed with the further evaluation of management procedures, and it recommended that an intersessional workshop be held in the coming year, with certain preparatory work to be completed in advance.

With respect to priority groups/stocks and studies, the Scientific Committee recognises that a major problem it faces is the question of stock identity. Therefore, in most cases priorities must be considered in terms of broad population/regions rather than stocks. It agreed that priority should be assigned to the following categories:

(a) those for which substantial work is underway, i.e. Southern Hemisphere minkes, North Atlantic minke, fin and sei whales; North Pacific Bryde's and minke whales;
(b) those which have been protected from commercial whaling which are now showing varying degrees of recovery, i.e. the eastern North Pacific stock of gray whales and the Bering-Chukchi-Beaufort Sea stock of bowhead whales;
(c) those other fully protected stocks for which considerable data bases exist, the study of which will help resolve general methodological problems and improve our knowledge of whale population dynamics, e.g. some stocks of right and humpback whales.

The Scientific Committee must also carry out a Comprehensive Assessment of stocks subject to aboriginal subsistence whaling. It was agreed by the Committee that, before 1990, the eastern North Pacific gray whales should be the subject of an assessment in greater breadth and depth than is usually possible at an annual meeting for the following reasons: (1) there is no problem with stock identity; (2) it falls in category (b) above; (3) it is subject to aboriginal subsistence whaling.

The Scientific Committee outlined its work plan for 1988/89, including additional work to be carried out by the Secretariat which will require extra data analysis staff. The work plan for the following year will be developed at the 1989 meeting, and this meeting should be devoted to planning the preparation of a detailed progress report on the Comprehensive Assessment. Other matters should be reduced to a minimum, although an item addressing the implications for whale management of interspecific interactions will be included.

9.2 Report of Joint Working Group

In discussing the report of the Scientific Committee, members of the Joint Working Group made a number of observations on the various items summarised above.

(1) Japan commented that although the problem of possible mark shedding still exists with respect to using mark-recapture analyses to estimate population size, it believes the Discovery mark data base will have considerable value for ecological studies such as migration, growth and age.

(2) The Joint Working Group expressed its gratitude to Japan for the continuing major contribution it has made to the IDCR Southern Hemisphere minke whale assessment cruises. Japan recalled that it has provided vessels, personnel and finance, and abundance data have resulted for minke whales and other species. Seychelles warned of the danger of an imbalance between the effort to collect new data, and analysis and interpretation of existing data, with insufficient time allocated for processing and evaluation of results.

(3) Discussion of the photo-identification workshop led Japan to comment that the problems facing the Scientific Committee can most efficiently be addressed only if lethal and non-lethal sampling methods are combined. Australia responded that such a general statement cannot be supported. Lethal and non-lethal research methods should be examined on their merits in the light of the objectives of the research and on a case by case basis. Seychelles associated itself with this view.

(4) Norway, while congratulating the Scientific Committee on the progress made on modelling related to management procedures, recalled that setting management objectives required a policy decision which must not be prejudged by the current studies by the Scientific Committee. Seychelles noted that this work impinges directly on the Technical Committee and is conducted at a technical level which places the IWC in a lead among world fishery organisations.

Seychelles also noted it would be timely if the Scientific Committee could prepare for the benefit of Commissioners and others an easily comprehensible document explaining the characteristics of the procedures being explored.

This suggestion was supported by Australia, noting it is important that first stage work is presented in the way suggested, so that the Technical Committee and the Commission, in any reconsideration of the objectives of management, can work from an understanding of the levels of performance that various styles of management procedures might achieve. Time should be put aside next year for consideration of this subject. Japan concurred, encouraged to find the Tanaka procedure, which was once criticised, is now evaluated as promising. Seychelles observed that if, in the interests of time, it refrained from comment on such evaluations, it would hope that such lack of comment would not be taken to imply concurrence.

(5) Iceland commented on the importance of the North Atlantic sightings survey to Comprehensive Assessment noting that last year several North Atlantic nations participated. It believed it was important that the Joint Working Group endorse the 1989 Survey and recommend North Atlantic nations, in particular IWC members, to consider active participation by financial contributions or technical assistance in the forthcoming survey. Norway supported the Iceland proposal and confirmed its commitment to cooperate in the 1989 survey.

The Scientific Committee had recommended that the Commission instruct the Secretary to contact the Government of Canada informing it of the survey planned for 1989 and requesting its cooperation and participation in this survey.

Seychelles endorsed the importance of sightings surveys, and the right whale surveys off South Africa and Argentina, eastern North Pacific gray whales, and surveys for right and humpback whales off Australia were all mentioned.

(6) Australia expressed its view that reanalysis of existing data sets for estimating the Maximum Sustainable Yield rate is timely as many of the analyses defining the ranges of MSY rates go back to the 1960s and suggested that, although methodology has been reviewed, the existing data have not been reanalysed.

It also commented that some analyses are based on biological information from catches and that these data should be available to the Committee. As an example it referred to the excellent data set from Japan and asked if these data would be available.

Japan noted that as clarified at the last Committee Meeting there is some limitation on availability but if requested by the Scientific Committee this limitation could be modified for use in the Comprehensive Assessment.

(7) Iceland concurred with the Scientific Committee's recommendation for holding the Feeding Ecology Workshop, and further recommended that the Committee should have on its agenda at the next and subsequent meetings a special item on ecological questions related to whales. Norway endorsed this but noted that at this stage such considerations should not distract from the completion of the Comprehensive Assessment. USA and Seychelles associated themselves with the Norwegian statement. Japan stated it would also participate in the Feeding Ecology Workshop believing that this would ultimately contribute to the Comprehensive Assessment.

UK, Australia and Japan noted that while ecological studies are important, care should be taken to consider the workload of the Scientific Committee and to remain aware of the need to complete the Comprehensive Assessment. Seychelles noted their reservations about the amount of work which can be achieved on next year's agenda, and suggested that only a general exploration of the subject should be attempted. The Working Group endorsed this approach by the Scientific Committee.

(8) In discussion of the future work of the Scientific Committee, Japan stressed that IWC has a commitment to Comprehensive Assessment of stocks by 1990 and questioned whether the goals could be met. Norway regarded completion of the Comprehensive Assessment as the most urgent task before the Scientific Committee and IWC, noting that the Scientific Committee report shows a net gain in organisation and practical progress. Contract and intersessional work is also a positive contribution, but it is imperative that the Scientific Committee be in a position to provide by 1990 something the Commission could regard as a Comprehensive Assessment.

Seychelles expressed its concerns regarding the setting of priorities and specifically to the proper development of recommendations made in one year by the Committee. These are in some cases delayed, or not implemented, in part because of differing national priorities or lack of research workers' time.

Australia agreed, noting that the Scientific Committee meets for two weeks per year and it cannot alone complete the Comprehensive Assessment which depends in very large part on the efforts of individuals. The Committee is only in a position to review and synthesise material presented at its meeting.

Iceland stated that the Commission must recognise the level of funding required to complete this work.

USSR commented on the scope of the work and levels of funding required, noting that the IWC cannot rely on countries to carry this out on a national basis. It believes it would be reasonable to organise a centralised fund in the IWC through which work could be properly directed, and all nations should contribute to this type of science.

Concerning the future work plan, Japan reiterated its desire for a concentrated effort on stock assessment for Comprehensive Assessment and asked the Chairman of the Scientific Committee if it was possible for the Committee to complete the Comprehensive Assessment by 1990. The latter noted that this matter had not been fully considered by the Scientific Committee, but in his personal view it would not be possible to complete by 1990 a full Comprehensive Assessment as envisaged by the Scientific Committee at its special meeting in 1986.

However, he drew attention to the intention of the Committee to devote most of its 1989 Annual Meeting to planning for preparation of a detailed report on progress towards a Comprehensive Assessment to be presented to the Commission in 1990. This report should contain, *inter alia*, as broad and in-depth an assessment of the identified major priority stocks as was possible with the information available at that time. He emphasised however, that this would only be possible if the Committee was able to devote the required time to this process during its 1989 meeting, if the necessary funding was provided and if members of the Committee were able to devote sufficient time to this work during 1989/90.

USA stated that the Commission should place the Scientific Committee in the best possible position to complete its agenda for 1989, and that the Joint Working Group should concur with the Scientific Committee's proposals and endorse the 1988/89 work plan. Norway agreed with this view.

(9) The Joint Working Group received and discussed a chronological review paper of the Comprehensive Assessment prepared by the Secretary. Norway commented that the document points out the ambiguity of the term 'Comprehensive Assessment'. The work done by 1990 will be used as a basis for the future, even if not in all respects perfect. Japan joined in the call to the Scientific Committee to complete the Comprehensive Assessment on priority stocks by 1990 based on the best available knowledge. Iceland concurred with these two views, and Seychelles emphasised the development of consensus in the Scientific Committee.

9.3 Action arising

The Commission noted and endorsed all the recommendations from the Scientific Committee through the Joint Working Group as given below:

(1) Funds for the contract study for DNA experiments on stock identity and school structure should be continued for the second year of a two-year project.

(2) The IWC should establish a database containing information on the availability of existing, preserved cetacean tissue samples. This information, stored in a standard format, would be available to investigators requiring tissue samples. The investigators would then make their own arrangements with the caretakers of the samples.

(3) The IWC Secretariat should approach the Secretariat of CITES with a view to promoting the exchanges of cetacean tissues between scientific institutions. Member governments should also facilitate scientific institutions' export of tissue samples for studies related to the Comprehensive Assessment.

(4) The proposed workshop on the genetic and biochemical analysis of tissue samples collected by biopsy sampling and other means should be held.

(5) The IWC Secretariat should complete the coding project on Antarctic whale marking and recovery data.

(6) An international workshop should be held to evaluate management procedures and elaborate second stage screening. A discretionary fund of £5,000 should also be provided for 1988/89 for members of the Scientific Committee to carry out further development of management procedures.

Seychelles suggested that some time be set aside at next year's meeting of the Joint Working Group to have a presentation by the Chairman of the Scientific Committee or other appropriate scientists about the current work on proposed management procedures. It was agreed that it would be useful to do this, especially if visual aids were used.

(7) Monitoring studies including the Antarctic IDCR cruises, the North Atlantic surveys, and surveys of the eastern North Pacific gray whales, the South African right whales and Bering-Beaufort-Chukchi Seas bowhead whales should continue.

(8) The Secretary should contact Service Argos, NOAA and NASA urging them to implement the concept of a dual beam interferometer on future satellites to provide location from single messages.

(9) Member governments are urged to provide adequate funding to allow the development and use of telemetry to progress rapidly and further recommends such funding be of several years continuous duration to allow projects to be continued to completion.

(10) Countries holding potentially useful data sets should be encouraged to respond to the request for submission to the data inventory.

(11) The Workshop on the Feeding Ecology of Southern Baleen Whales should be held jointly with CCAMLR.

In the Commission, Iceland spoke strongly of the importance it places on the Comprehensive Assessment using modern methods of management incorporating an ecological multi-species approach. It cited the examples of the capelin and cod stocks in its waters which are strongly dependent on each other, and the cod worm and seal problem, to illustrate the kind of food web models required for future decision taking.

(12) The Scientific Committee should continue its activities in accordance with the work plan and priorities identified, and with an appropriate budgetary allocation.

10. INDIAN OCEAN SANCTUARY

10.1 and 10.2 Report of Indian Ocean Meeting and Report of Technical Committee Indian Ocean Sanctuary Administrative Sub-committee

Mr R. Delpech (Seychelles), as Chairman, presented the reports of the Indian Ocean Sanctuary Administrative Meeting held in Canberra, Australia, attended by representatives from Australia, Japan, Oman and Seychelles, and the Indian Ocean Sanctuary Administrative Sub-committee held in Auckland, attended by delegates from Antigua & Barbuda, Australia, Iceland, Japan, New Zealand, Norway, Oman, Seychelles, Sweden, USA and USSR.

The Canberra meeting, although it had small participation, had a fruitful exchange of views and made the eight recommendations given below.

(1) The IWC Scientific Committee should be requested to bring together and assess relevant information about cetaceans since the establishment of the Indian Ocean Sanctuary. In particular, the Committee should as far as possible compare information from within and outside the Sanctuary as a means of evaluating the recovery of whale stocks with the more general suspension of commercial whaling.

(2) The Scientific Committee should be requested to make suitable arrangements through the Secretariat to contact IWC and non-IWC Indian Ocean States to obtain the information.

(3) The Scientific Committee should be requested to give higher priority to the Sanctuary and particularly to seek to encourage a more co-ordinated approach so as to make research and monitoring more effective.

(4) The IWC Secretariat, prior to the 41st Annual Meeting, should be requested to contact Indian Ocean States to obtain copies of existing legislation concerning cetaceans and cetacean research and to provide the information to Commissioners with a summary statement in time for consideration at that meeting.

(5) The Secretariat should be requested to prepare a paper, to accompany the request for legislation, which would provide background information about the Sanctuary to Indian Ocean States. The Committee also felt it would be helpful if Commissioners encouraged interest in the Sanctuary in their countries, e.g. by the preparation of informative leaflets and posters.

(6) A small Committee of Commissioners should be appointed to check the paper by the Secretariat proposed in (5) before submission to other nations.

(7) At this stage the Sanctuary should be considered as a whole but the Committee recognised that in some circumstances it would be beneficial to encourage regional co-operation for greater efficiency of operations.

(8) Different views were expressed on the future of the Sanctuary. It was agreed that in order for the IWC to make a decision on this issue, detailed documentation should be prepared. This would include the documentation identified above but also could include other documents such as the views of Contracting Governments. This documentation needs to be distributed in adequate time to enable Commissioners to have an informed discussion when considering the future of the Sanctuary.

The Auckland meeting reviewed the work carried out in Canberra and endorsed the recommendations given above. A number of comments were made concerning the need for more research in the Sanctuary area and the meeting received summary statements on further activities by IWC member and non-member states.

Japan stated that it had been opposed to the Indian Ocean Sanctuary and had doubts on its necessity given the general pause in commercial whaling. Although Japan had contributed to the research in the Indian Ocean it believed that the status of the sanctuary should be reviewed in the broader context of research activity throughout the world.

The USA asked if the Scientific Committee could meet the requests contained in the recommendations, and the Chairman of the Scientific Committee indicated that, although this specific topic had not been discussed, the Scientific Committee had identified that its highest priority for 1989 related to the Comprehensive Assessment. It had hoped that the Commission would reduce requests for other work to a minimum.

Australia pointed out that the Indian Ocean Sanctuary was a major initiative of the Commission and that the Commission must carry out its responsibilities under the Schedule in time for the review at next year's meeting. This matter therefore had some priority.

The USSR spoke of the necessity for a broadening of the scientific function of the Commission and believed that questions relating to sanctuaries should be considered within a general context of reviewing the Convention.

10.3 General review of prohibition on commercial whaling in the Indian Ocean Sanctuary

It was noted that the work identified at the Canberra meeting will provide material needed in preparation for the review of the Sanctuary which will be addressed at the 1989 Annual Meeting.

10.4 Action arising

The Technical Committee agreed that the small group of scientists who attended the Seychelles meeting should arrange for the collation of the relevant information required under Recommendation (1) for presentation to the Scientific Committee. It was agreed that much of the work requested could be carried out by correspondence before the Annual Meeting, and the Technical Committee endorsed all the recommendations above which were adopted by the Commission.

11. INFRACTIONS, 1987 SEASON

11.1 Report of Technical Committee Infractions Sub-committee

The Infractions Sub-committee met under the Chairmanship of Dr J.E. Edmunds (St Lucia), and was attended by delegates from Australia, Brazil, Denmark, Iceland, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, St Lucia, St Vincent & the Grenadines, Sweden, UK and the USA.

11.1.1 Infractions reports from Contracting Governments

The Sub-committee reviewed the infractions reports from commercial whaling operations in 1987 in which only one infraction occurred.

Infractions from aboriginal subsistence whaling operations were noted. This included the exceeding of the quota in West Greenland due to administrative problems. St Vincent & the Grenadines stated that every effort was being made to ensure that its operation does not take calves or female whales accompanied by calves in the future as happened in 1987. Domestic legislation and appropriate sanctions for non-compliance are under discussion.

In discussing the surveillance of whaling operations, Denmark had noted that the opportunistic nature of the Greenlandic hunt made the logistics of inspection very difficult. The Sub-committee, whilst appreciating the difficulties involved in surveillance of such opportunistic operations, recommended that the Technical Committee suggests that the Government of Denmark investigates the possibility of establishing an inspection procedure for Greenlandic aboriginal subsistence whaling.

The Sub-committee reviewed the responses to the checklist of information required or requested under Section VI of the Schedule and a document compiled by the Secretariat summarising the national laws and regulations submitted by member nations.

The Sub-committee noted that only one infractions report remains outstanding from previous years; that for the catch of 160 whales authorised to be taken by Peru in 1984. The Sub-committee repeated its previous recommendation that the Government of Peru be urged to submit its outstanding Infractions report.

The Sub-committee noted the response of the Philippines Government to a request made last year that it should comment on a document presented to the Sub-committee containing allegations of infractions. The Government informed the Sub-committee that whaling operations had ceased on 24 April 1986.

11.2 Action arising

The report of the Sub-committee was adopted by the Technical Committee after amendment of various tabulated information, and its recommendations endorsed by the Commission.

12. COMMISSION'S COMPETENCE TO SET CATCH LIMITS FOR BAIRD'S BEAKED WHALE IN THE NORTH PACIFIC

There was no discussion of this item but the Netherlands, seconded by the UK and New Zealand, proposed that it should be retained on the agenda and this was agreed.

13. WHALE STOCKS

13.1 Report of the Scientific Committee

The Chairman of the Scientific Committee presented the report of the discussions held on the various whale stocks given below, and this material and any recommendations were considered by the Technical Committee in reaching its conclusions. Only a brief resume of the Scientific Committee's deliberations on each stock is given in this report.

13.2 Action arising

The Commission, in reviewing the Report of the Technical Committee, adopted the various recommendations as noted below. It also agreed that all the references to whaling seasons in the Schedule should be updated to reflect the catch limits and stock classifications for 1988–89 and 1989 as appropriate.

13.2.1 Sperm whales

The Scientific Committee had considered the results of sperm whale studies around the Galapagos Islands in 1985 and 1987. These studies had been partially funded by the Commission and the Scientific Committee re-iterated its support for this work.

13.2.2 Minke whales

Southern Hemisphere minke whales

As in previous years, the Scientific Committee concentrated on obtaining abundance estimates of Southern Hemisphere minke whales from sightings data obtained from the IWC/IDCR cruises carried out between 1978/79 and 1986/87. The agreed best estimates, obtained using a methodology adopted the previous year, are given in Table 1. These estimates apply only to that part of each area (in general, approximately 60% of the area south of 60°S) which had been surveyed.

Table 1

Best estimates of Southern Hemisphere minke whale population sizes. 'Pooled' survey mode = pooled closing + passing without IO.

			Total		Takeable	
Area	Year	Survey mode	Population	CV	Population	CV
I	1982/83	Closing	55,050	0.203	36,223	0.206
II	1981/82	Closing	37,306	0.213	24,547	0.216
	1986/87	Passing	121,549	0.285	79,979	0.288
III	1979/80	Closing	61,272	0.188	40,317	0.191
IV	1978/79	Closing	72,357	0.156	47,611	0.160
IVW*	1984/85	Pooled	19,980	0.181	13,147	0.185
V	1980/81	Closing	133,382	0.216	87,765	0.219
	1985/87	Passing	303,284	0.172	199,520	0.176
VI	1983/84	Closing	80,283	0.232	52,826	0.235

* = 70°–100°E

These estimates differ from those provided in 1987 (*Rep. int. Whal. Commn* 38: 43) in that all were obtained using the same agreed procedure and that estimates from the 1985/86 and 1986/87 surveys have been provided. A preliminary attempt to obtain comparable estimates from different surveys in the same areas had been made but further work was needed in this regard.

Japan commented on the success of the IWC/IDCR programme, noting that it had considerably improved knowledge of the abundance of minke whales over the past decade. Its own commitment to the programme was witnessed by the fact that since the inception of the programme in 1978/79, it had donated the operation costs, 2–3 vessels, experienced crews and research scientists each year. Last year its contribution was £1m, almost twice as much as the IWC's annual budget. It expressed regret that the USSR had not contributed a vessel last year but it hoped that a Soviet vessel may be made available in the future. The estimated abundance of minke whales in the surveyed area was now over 600,000 as compared to the estimate made last year of 450,000 – in 1973 some scientists had believed that the Southern Hemisphere population was as little as 70,000, while others believed it was 350,000. Japan stressed that such a gap of the abundance estimates would be narrowed by more research activities. Japan believed that rational management of these stocks required information on their dynamics and structure as well as absolute abundance and had for this reason developed its own research programme, which could under no circumstances be considered as commercial whaling, and such a viewpoint has not been found in the Scientific Committee report.

The Scientific Committee had made a number of research recommendations and these were endorsed by the Commission.

North Atlantic minke whales

The Scientific Committee had before it a series of papers arising out of the 1987 North Atlantic Sightings Survey (NASS-87), an international survey comprising aerial and shipboard surveys which covered some 30,000 n.miles on transect. The Committee recognised the large amount of work represented by the planning and execution of the Survey and by preliminary analyses of the data. It expressed appreciation to the scientists involved in the survey and to Iceland, Norway, Denmark, the Faroe Islands, Spain, the Nordic Council of Ministers, the USA, Japan and the UK for making the research possible, and it looked forward to the results of further analyses at next year's meeting.

Data from these surveys were used in obtaining preliminary estimates of abundance for three North Atlantic minke whale management stocks. The Northeastern stock is discussed below. The Central and West Greenland stocks are discussed under Item 14. A further survey (NASS-89) is discussed under Agenda Item 9 above.

Northeastern stock of minke whales

The Scientific Committee examined the results of NASS-87. A provisional estimate of either 19,112 (CV = 0.163) or 17,014 (CV = 0.179) animals, depending on the survey area considered, was obtained. These estimates were considered provisional as they were based on shipboard surveys with low coverage and no estimate of how many whales were missed on the trackline.

For several reasons discussed in its report, the Scientific Committee agreed not to attempt an assessment of the stock at this year's meeting. Consequently the Committee was unable to provide further advice on the classification of the stock to that given last year (*Rep. int. Whal. Commn* 38: 45), when some members had believed the stock should remain classified as a Protection Stock and others that there was no basis for providing advice on classification.

The Scientific Committee noted that part of the Norwegian five-year programme to study and monitor Northeastern Atlantic minke whales was a major sightings survey in 1988 using six ships and one helicopter. The survey will include an examination of methodological problems identified during NASS-87 and the Scientific Committee welcomed the survey as a valuable contribution to its work.

Okhotsk Sea-West Pacific stock of minke whales

The Scientific Committee examined two papers relating to this stock, one concerning biological and the other sightings data. With respect to the latter, in addition to suggesting improvements to the analysis of existing data, the Committee also requested that the range of future sightings surveys be expanded with the co-operation of the USSR and the USA, since much of the summer distribution of this stock occurs within the 200-mile EEZs of these two countries.

Japan commented that it is important that an analysis of this stock includes an examination of those components found within the waters of the USSR and USA and expressed its willingness to co-operate in research with those nations.

13.2.3 Fin whales

East Greenland-Iceland stock of fin whales

Data from NASS-87 were considered by the Scientific Committee and a preliminary estimate of 5,757 (CV =

0.132) animals for the areas covered by Icelandic vessels was obtained. If an estimate from a Norwegian vessel which covered a different part of the stock area is added, a preliminary estimate of 6,436 (the CV could not be calculated) was obtained.

A simulation programme had been used in conjunction with the preliminary stock estimate, but the Committee agreed that it was inappropriate to utilise this assessment, as it was at a preliminary stage. The Committee recommended a series of simulation studies which should be carried out in order to improve the situation. No recommendations concerning stock classification were made.

Iceland noted that substantial new information on the catch history and current abundance had been presented to the Scientific Committee this year. The stock trajectories given in the Scientific Committee's report indicated that the stock was well above the SMS level and possibly even an Initial Management Stock. However it agreed with the Scientific Committee that the assessment deserves further consideration, particularly with respect to the apparently high MSY rates, and therefore Iceland proposed a deferment of the question of any re-classification of the stock at this meeting. Iceland will carry out the recommendation of the Scientific Committee for more detailed simulation studies during the current year.

The Commission agreed to defer discussion of the classification of this stock at this meeting.

British Isles-Spain-Portugal stock of fin whales

The Scientific Committee had noted a preliminary estimate for the area covered by NASS-87 of 4,485 (95% CI: 3,369–5,600).

13.2.4 Iceland-Denmark Strait stock of sei whales

The Scientific Committee examined the results from NASS-87 but concluded that the estimates obtained could not be used for assessment purposes as the surveyed area did not cover the population's summer distribution. The Scientific Committee had recommended that the survey area be extended to cover as much as possible of the population's summer distribution.

Iceland informed the Commission that it would carry out the Scientific Committee's recommendation in the NASS-89 survey.

13.2.5 Western North Pacific stock of Bryde's whales

The Scientific Committee examined an analysis of sightings data obtained during two cruises in the western North Pacific in 1983 and 1984. The Committee identified a series of problems with the analysis and agreed that the estimate obtained could not be used for assessment purposes. It identified further work that was necessary before the stock is next assessed. No recommendations on classification were made.

New Zealand noted that it had last year proposed that this stock be declassified but had agreed to defer its proposal until this meeting. In the light of the Scientific Committee's Report it agreed to again defer its proposal but expressed its hope that the Scientific Committee would attempt to assess this stock at its next meeting if possible.

13.2.6 Bottlenose whales

The only stock of bottlenose whales included in the Schedule is the North Atlantic stock. This was not assessed by the Scientific Committee.

13.2.7 Protected species

The only stocks of protected species assessed by the Scientific Committee were those subject to aboriginal subsistence whaling. These are discussed under Item 14 below.

14. ABORIGINAL SUBSISTENCE WHALING

14.1 and 14.2 Report of Scientific Committee and Report of Technical Committee Aboriginal Subsistence Whaling Sub-committee

The Technical Committee had available to it the report of the Scientific Committee and of the Technical Committee Aboriginal Subsistence Whaling Sub-committee. The latter was chaired by Mr P. Aitken (New Zealand) and attended by delegates from Antigua & Barbuda, Australia, Brazil, People's Republic of China, Denmark, Iceland, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, St Lucia, St Vincent & the Grenadines, Seychelles, Solomon Islands, Spain, Sweden, UK, USA and USSR. The relevant sections of each Committee's Report were presented by their Chairmen in relation to the following items.

14.2.1 Report of the Definitions Working Group

An *Ad Hoc* Working Group on Consideration of the Definition of Aboriginal Subsistence Whaling was attended by delegates from Antigua & Barbuda, Argentina, Australia, Brazil, People's Republic of China, Denmark, Iceland, Japan, Republic of Korea, New Zealand, Norway, St Lucia, St Vincent & the Grenadines, Sweden, Switzerland, UK, USA and USSR under the Chairmanship of Professor J.D. Ovington (Australia). Considerable discussion of the question of small-type whaling took place and this is considered further under Item 14A of the agenda. The *Ad Hoc* Working Group made three recommendations:

(1) that there be no change to the definitions of Aboriginal Subsistence Whaling, Local Aboriginal Consumption and Subsistence Catches as currently applied by the International Whaling Commission;
(2) that at present no additions be made to the category of Aboriginal Subsistence Whaling;
(3) that the Commission give consideration to the situation of various kinds of small-type whaling.

These recommendations were endorsed by the Technical Committee. In discussion of the Working Group's report in the Aboriginal Subsistence Whaling Sub-committee, the USSR had stated its view that only aboriginal subsistence and commercial whaling can be recognised under the present Convention; proposals for other categories of whaling can only be considered in the context of a revision of the present Convention. Seychelles had concurred with this on the understanding that such revision may include amendment of the Schedule.

In the Technical Committee, Japan expressed the view contrary to those of USSR and Seychelles. Japan indicated its belief that a new category of whaling could be established because differences exist in the kinds of whaling currently considered aboriginal subsistence whaling. It stressed that Japanese coastal small-type whaling has some elements of both aboriginal subsistence whaling and commercial whaling. It noted that in the course of a natural progression from aboriginal subsistence whaling to small-type whaling even in developed nations such as the USA, USSR and Denmark local communities exist for which it is considered that they have the right to continue a traditional way of life. Japan believes its small-type whaling communities should be allowed the same rights. It expanded its views on this matter under Item 14A.

14.2.2 Bering Sea stock of bowhead whales

The Scientific Committee reviewed the recent catch data and struck and lost rates. The mean length of the catch (12.4m) and the percentage of females in the catch (32%) in 1987 were slightly higher than in 1986. The struck and lost rate (29%) was the same as in 1986.

The Scientific Committee accepted an estimate of current population size of 7,800 (95% confidence interval 5,700–10,600). This, together with an updated catch series, was used in a simulation run. This indicated that the stock had increased under an estimated annual average removal since 1910 of 27 animals, but the Scientific Committee had no information on the appropriate MSY rate to use. In the absence of this information it was agreed that the most appropriate range of replacement yield to consider was 56–192. It noted that under the provisions of the Aboriginal Whaling Scheme only a proportion of the replacement yield should be taken, to allow the stock to increase to MSY level; the smaller the proportion taken, the greater the rate of population increase. The Committee also continued to recommend that the catch should be directed at smaller (<13m) animals but it will review this matter at its next meeting. In most cases, the simulations indicated classification as a Protection Stock and the Committee therefore recommended that the stock remain a Protection Stock. The Scientific Committee also made a number of research recommendations with respect to this stock.

The Aboriginal Subsistence Whaling Sub-committee considered an updated analysis of the subsistence need of Alaskan Eskimos, which addressed concerns expressed in 1986 with respect to: (i) gaps in the data; (ii) the use of different base periods for different whaling villages; (iii) estimated growth in the Eskimo population.

After some discussion, the Sub-committee accepted the US analysis and agreed to recommend that the aboriginal subsistence need for Alaska Eskimos for 1989 is for 41 landed bowhead whales.

The USA presented a proposal in Technical Committee which it believed was justified by the discussions of the Scientific Committee, the Humane Killing Working Group and the Aboriginal Subsistence Whaling Sub-committee. In view of the improvements in the killing power of its traditional weapon, it noted that its proposal assumed a considerably lower struck and lost rate than had been used in the past. Its proposal was that:

> 'For each of the years 1989, 1990 and 1991, the total number of whales struck shall not exceed 46 and the total number of whales landed shall not exceed 41, except that if, in either 1989 or 1990, less than 41 whales are landed and less than 46 whales are struck, unused strikes up to a maximum of 3 shall be transferred only to the following year.'

The proposal was seconded by Iceland, Japan, Republic of Korea, St Lucia, St Vincent & the Grenadines and the USSR, all of whom commented on the extensive research work carried out on this stock. Iceland noted that the proposed strike level was lower than the most conservative estimate of replacement yield made by the Scientific Committee.

Australia, while appreciating the research effort and improved efficiency of the hunt, believed that further improvements in efficiency should be encouraged and to this end introduced an amendment to the US proposal. This was seconded by the United Kingdom, the Netherlands, Switzerland and Oman. After some revision, this following amendment was adopted by consensus in the Technical Committee and by the Commission:

> 'For each of the years 1989, 1990 and 1991, the total number of whales struck shall not exceed 44 and the total number of whales landed shall not exceed 41, except that in 1988, 1989 or 1990, any unused strikes up to a maximum of 3 shall be transferred to the following year.'

The Commission agreed that the stock should remain classified as a Protection Stock. It also endorsed the research recommendations of the Scientific Committee.

14.2.3 Eastern North Pacific stock of gray whales

The Scientific Committee accepted a new point estimate of current population size of 21,113 animals. Methodological differences precluded comparison of this estimate with previous estimates at this year's meeting. The Committee noted that this stock is of special importance to its work in the context of the Comprehensive Assessment, because of its demonstrable recovery under harvesting and the considerable information available on stock identity, population size and trends in abundance.

The Scientific Committee agreed that this stock is well above its minimum population size. While its classification will have to await a broad, in-depth assessment, the Scientific Committee noted that the population had increased by about 2.5% per year between 1967 and 1980, despite an annual catch of about 179 animals, which comprises only 0.8% of the best estimate of current population size. Pending such an assessment, the Scientific Committee therefore recommended no change in the catch limit in 1988.

The Scientific Committee also made a number of research recommendations for this stock.

The Aboriginal Subsistence Whaling Sub-committee examined the conclusions of a detailed study submitted last year by the USSR. After discussion, the Sub-committee agreed to recommend that the need of aboriginal populations would be satisfied in each of the years 1989–1991 by continuation of the current catch limit of 179 animals.

After a clarification by the USA that it did not intend to take gray whales in the coming season, the Technical Committee endorsed the recommendation of the Aboriginal Subsistence Whaling Sub-committee to establish a three-year quota for 1989–1991 providing that the number of gray whales taken for the need of aboriginal populations in any of these years shall not exceed 179. This was approved by the Commission, which also endorsed the research recommendations of the Scientific Committee.

14.2.4 West Greenland Stocks

(a) Fin whales

The Scientific Committee had available an estimate of 1,693 whales from NASS–87. It noted the large CV of the estimate (0.47) and the unknown reliability of the mean surfacing rate used in the estimate. Despite this, the population estimate represented a considerable improvement on previously available information. However, given uncertainty over stock identity and the population estimate, and the lack of information on the stock's status, the Scientific Committee was unable to predict the long-term effect of a continuing take of 10 whales. The Scientific Committee made two research recommendations for the stock.

After the presentation of the Scientific Committee's report, Denmark requested that at its next meeting, the Scientific Committee should discuss the relevance of the minimum size limit currently in force for this stock.

(b) Minke whales

The Scientific Committee accepted an estimate of 1,153 (CV = 0.42) whales as an estimate of the number of whales in the management stock area, although it recognised that some minke whales were known to occur outside the surveyed area. The Scientific Committee reiterated its previous concern about the question of stock identity, noting the considerable evidence (e.g. absence of calves and lactating females, continuing high proportion of females in the catch) that the management stock did not constitute a separate biological stock. Resolving this question was of crucial importance to the assessment of minke whales off West Greenland in relation to the provision of advice to the Commission about the aboriginal subsistence take in this area.

Despite these concerns, the Committee had insufficient information to suggest a change in stock boundary for West Greenland minke whales. It agreed to attempt to provide advice on the basis of the existing stock boundary.

Although some members of the Committee had requested simulation runs using the new abundance estimate, the Committee agreed that it was difficult to interpret the result of these simulations, especially in light of the marked difference between the observed sex ratio in the catch and the predicted sex ratio in the population.

Nevertheless, given that the stock (estimated to be 1,153 animals) was smaller than had previously been thought and that the average annual catch during the last 10 years had been 263 animals per year, the Scientific Committee believed that the stock was severely depleted, below the level believed in 1985. The Scientific Committee recommended that the stock remains a Protection Stock. It agreed that it had no evidence that any catch would allow the stock to move towards its MSY level.

The Scientific Committee made a number of research recommendations concerning this stock.

After requesting some clarification from the Chairman of the Scientific Committee, Denmark noted a number of concerns which led it to doubt the value of the assessment carried out on this stock. These included:

(i) severe doubts about stock identity and hence the use of the sightings estimate as an estimate of abundance of the total stock and not just an estimate of a segment of the stock;

(ii) doubts about the appropriateness of the model used, given its prediction that all mature females should have disappeared from the population in 1985. It noted that this model also formed part of the Scientific Committee's assessment in 1985.

The Aboriginal Subsistence Whaling Sub-committee had considered both the fin and minke whale stocks together. It had examined a document from Denmark which stated that the annual need of West Greenlanders is for 670 tonnes of whale meat, blubber and other edible whale products. It noted that one minke whale yields 2 tonnes of edible products and one fin whale 10 tonnes.

There was considerable discussion of this matter in the Sub-committee, with some delegations expressing reservations about expressing need in terms of tonnes of whale products.

During the Technical Committee discussions, Denmark noted the need for Greenlanders of 670 tonnes of edible products. Despite its reservations noted earlier about the Scientific Committee's assessment of minke whales, it recognised the need for striking a balance between the needs of people and conservation of the stocks. It also drew attention to its commitment to research on these stocks. It therefore proposed that for the 1989 season, catch limits of 60 minke whales and 23 fin whales should be set for the West Greenland fishery.

This was adopted by consensus by the Technical Committee and the Commission, with many nations stressing the need for increased research on these stocks. Iceland indicated that it was willing to co-operate in research in this area. The UK noted the potential vulnerability of this group of minke whales, and that its support for the proposal was based upon the understanding that there was to be a significant research effort devoted to determining stock size and stock integrity.

14.2.5 Central Atlantic minke whales

The Scientific Committee had before it estimates of abundance from NASS-87. A provisional estimate of 17,091 (CV = 0.330) or 19,484 (CV = 0.292), depending on the survey area considered, was accepted.

Some members of the Scientific Committee believed that an assessment should not have been carried out for similar reasons to those stated for the northeastern stock: the lack of an acceptable CPUE series and the lack of an agreed basis to choose an appropriate range of MSY rates. Other members believed an assessment should be attempted using the new abundance estimate.

Those members who believed that an assessment should not be attempted at this meeting consequently also believed that no advice on classification of the stock could be given, and that the stock should remain unclassified.

Those members in favour of the assessment believed that the results of this simulation showed that the Central Stock, currently unclassified, should be classified as a Sustained Management Stock.

After the presentation of the Scientific Committee's report, Iceland noted the improved estimates available for this stock from the extensive aerial and shipboard surveys carried out as part of NASS-87. It noted that some members of the Scientific Committee had not agreed that an assessment should be carried out for two reasons. The first, the lack of an accepted CPUE series, is invalid; the model used does not require CPUE data. The second, the lack of a basis for choosing an appropriate range of MSY rates, is more substantial. However, the assessment carried out shows that even the most conservative MSY rate of 1% shows the stock to be a Sustained Management Stock. Iceland shared the view that the stock estimate is provisional, in that further analysis of the shipboard survey data is to be carried out. However, as noted by one member of the Scientific Committee, even if only the accepted estimate from the aerial survey (about 10,000 animals) is considered, consideration of earlier assessments by the Scientific Committee imply that the stock is above the Protection Stock level. In conclusion, Iceland stated that while it believed the stock should be classified as a Sustained Management Stock, it noted that the matter will be discussed at next year's Scientific Committee meeting, and hence it would not propose re-classification of this stock at the present meeting.

The Aboriginal Subsistence Whaling Sub-committee noted that Denmark had reported that the catch limit of 12 set last year was sufficient for the needs of the East Greenlanders. After some discussion on the relevance of the stock boundaries used, the Sub-committee agreed to recommend that the aboriginal subsistence need for East Greenlanders for 1989 is twelve minke whales.

The Technical Committee endorsed this recommendation and the Commission agreed to the continuation of a quota of 12 minke whales for 1989.

14.2.6 St Vincent & the Grenadines humpback whales

The Scientific Committee had available a new best estimate of the total population size of western North Atlantic humpback whales (5,505 ± 2,617 for the years 1979 – 86). The Scientific Committee had agreed that although the direct relationship between animals from the Bequia-St Vincent breeding area and other humpbacks in the northwest Atlantic is unknown, a catch of up to 3 animals would be unlikely to harm the stock unduly.

The Aboriginal Subsistence Whaling Sub-committee had noted that a three-year quota was in effect and that there was therefore no need for it to put forward a recommendation on the question of need. In the Technical Committee the Netherlands noted that legislation to implement IWC regulations is being discussed and that the delegation of St Vincent & the Grenadines had indicated that the phasing-out of whaling would take place naturally as the single harpooner was 67 years of age. The Netherlands therefore understood that the whaling operations will cease when the present harpooner ends his activities.

The Commission noted that no action was necessary as a three-year block quota was in effect.

14A. CONSIDERATION OF THE SITUATION OF VARIOUS KINDS OF SMALL-TYPE WHALING

In the Technical Committee, Japan referred to the report of the *Ad Hoc* Working Group on Consideration of the Definition of Aboriginal Subsistence Whaling and noted that it had submitted information on the subject of small-type whaling within its 200 mile Zone at the previous two Commission meetings. It had stated its belief that this activity shares some features of both commercial and aboriginal subsistence whaling but is not properly characterised by either description; it had received indications neither of strong objections nor strong support for this idea. Japan had been involved in three kinds of whaling: large scale pelagic whaling, large scale coastal whaling, and small-type coastal whaling for minke whales. All of these have ceased, the latter in April 1988. The cessation of these operations has caused hardship to the affected communities in the form of socio-cultural, dietary, religious, occupational and psychological stresses and Japan hoped that the Commission will recognise the sacrifices it has made in order to implement the pause in commercial whaling. It reiterated its request to have its small-type whaling treated fairly and justly by the Commission.

Japan had received a voluntary offer of help to those engaged in its small-type whaling activities to provide better information on the subject. As a result an international workshop comprising twelve experts from six countries had been held in April 1988 to examine objectively socio-economic aspects of small-type whaling. The report of this workshop had been submitted to the Commission and contained six main findings:

(1) that the activity was historically based with centuries of tradition;
(2) it is small scale but functional, exploiting unendangered species and is remarkably stable;
(3) a significant proportion of the products is distributed through non-commercial channels including gifting throughout many elements of the community;
(4) the activity has some commercial characteristics but is not totally market oriented;
(5) it satisfies regionally diverse diet preferences – no community uses all parts of the whale but a historically organised distribution network ensures total use;
(6) the activity has a socio-religious basis.

Thus, the workshop, by its holistic approach, identified the socio-economic, cultural, religious and nutritional factors that were important to the continued existence of the small-type coastal whaling communities.

In response to requests for clarification from the UK about the level of products distributed through non-cash channels, Japan commented that because of their welfare, religious, symbolic and cultural values, the products have a unique intrinsic value, but this is qualitative and not easily quantified. St Lucia wished to applaud the authors of the report which identified attributes of Japanese small-type whaling which might deserve consideration separately from commercial whaling or aboriginal subsistence whaling categories. Japan then referred to the rigorous debate on this matter which had occurred in the *Ad Hoc* Working Group on Consideration of a Definition of Aboriginal Subsistence Whaling and the Aboriginal Subsistence Whaling Sub-committee, and proposed, based upon a Recommendation of the *Ad Hoc* Working Group, a draft Resolution calling for the establishment of a Technical Committee Working Group 'to consider the situation of various kinds of small type whaling and to report on its deliberations to the 41st Annual Meeting'.

The USSR was generally supportive of this Resolution but wished to propose a number of editorial amendments as well as adding wording which would link the work of the proposed Working Group with the possible examination of questions related to the operation of the Convention. Brazil questioned the wisdom of such a linkage and indicated a preference for the original Resolution with minor amendments. Expressions of support for the Japanese proposal were given by Iceland, Norway, France, Republic of Korea, Mexico, Federal Republic of Germany, People's Republic of China and St Vincent & the Grenadines, which formally seconded the proposed Resolution. A number of these delegations and others also indicated some concern at the suggestion of the USSR to link consideration of small-type whaling with discussions on the operation of the Convention. France pointed out that there was a clear recommendation from the *Ad Hoc* Working Group to establish the Working Group referred to in the Japanese proposal. The UK considered it important that the IWC was fully informed about all factors which impinge on or are affected by its decisions. The study should however be made without any implications for the current provisions concerning commercial whaling. The Republic of Korea drew some parallels between its former coastal whaling and that described by Japan and accordingly expressed its support for the proposed Working Group.

Australia pointed out that, in discussion in the *Ad Hoc* Working Group, Japan had insisted that its small-type whaling should not be included within the aboriginal subsistence whaling category, and therefore suggested that the words 'non-aboriginal' might usefully be inserted before 'small-type whaling' in all future references. Switzerland supported this suggestion and also pointed out that the Commission had not yet decided how it would deal with the report from the Working Group to Examine Questions Related to the Operation of the International Convention for the Regulation of Whaling, so that it was premature to attempt to associate work on these separate issues.

In response to the suggestion from Australia, Japan indicated that its proposed Resolution used the wording from the report of the *Ad Hoc* Working Group on Consideration of a Definition of Aboriginal Subsistence Whaling which had been developed only after intense discussion within the Working Group, and therefore considered that it was important to retain that original wording.

After further discussion of these points and of the most effective way to proceed, the Chairman adjourned the debate to allow time for consultation and the development of wording which would be distributed in written form.

When the debate was resumed the Technical Committee had before it an amended form of the Japanese proposed Resolution and an alternative resolution submitted by the USSR. There was further extended discussion during which most delegations indicated their support for the concept of the proposed Working Group, noting the importance of developing appropriate terms of reference which adequately define the subject to be addressed without inhibiting consideration of all the complex issues involved. Brazil reiterated its view that it was unwise to associate the work of the proposed Working Group with consideration of the operation of the Convention and many delegations associated themselves with this view.

The USA reverted to the suggestion of Australia that in the title of the Working Group the words 'small-type whaling' be prefaced by the term 'non-aboriginal'. This was supported by Switzerland, Antigua & Barbuda, Australia, New Zealand and the UK. Japan indicated that it would be prepared to accept this on the understanding that such a modification would not preclude consideration of its small-type coastal whaling. The USSR expressed strong opposition to the inclusion of these words and insisted on the inclusion of a paragraph stipulating that consideration of the situation of various kinds of small-type whaling acquires special importance in the context of efforts aimed at improvement of the operation of the Convention.

Sweden questioned whether a resolution is an appropriate medium in this situation and considered that a decision by the Commission would be effective and proper. Switzerland and Brazil supported this view and Norway suggested that the Technical Committee should endorse the first two recommendations of the *Ad Hoc* Working Group and, in so doing, provide the necessary guidance to the presiding officer of the proposed Working Group for Consideration of the Situation of Various Kinds of Small-type Whaling. After detailed discussions about the best way to proceed and a further intervention by Brazil in support of the Norwegian suggestion, the Technical Committee agreed to adopt this approach and accordingly recommended:

(1) that there be no change to the definitions of Aboriginal Subsistence Whaling, Local Aboriginal Consumption and Subsistence Catches as currently applied by the International Whaling Commission;
(2) that at present, no additions be made to the category of Aboriginal Subsistence Whaling;
(3) the establishment of a Working Group to consider the situation of various kinds of small-type whaling, and to report on its deliberations to the Technical Committee at the 41st Annual Meeting of the Commission.

Japan then asked for an interim relief allocation for the balance of the whaling season, 1 June – 30 September 1988, of 210 minke whales from the Okhotsk Sea-West Pacific stock to be taken off the coast of Japan and entirely within Japan's 200-mile zone. It further requested that, if the Working Group to consider the situation of various kinds of non-aboriginal small-type whaling did not meet or no decision of the Commission on the matter was made before the next whaling season, 1 April 1989, there should be another interim relief allocation of 160 whales in the period 1 April – 30 June 1989.

Japan based its request on the fact that since its small-type coastal whaling operations came to an end on 1 April this year the affected communities are already experiencing hardship and in the absence of any relief will continue to do so. Moreover, the specialised dietary, cultural and traditional needs of many other local communities in remote locations have been recognised by the IWC. For example, special provisions have been made to accommodate the needs of the Alaskan Eskimos and of native communities of the USSR, Denmark (Greenland) and St Vincent & the Grenadines, while Norway is able to meet the needs of its specialised communities through continued whaling under objection. Some non-member countries such as Indonesia are also able to continue their dietary traditions.

Japan asked for compassionate consideration of its position.

The Chairman then adjourned the discussion to allow time for consideration of the Japanese proposal. When the discussion resumed, Japan added that it will abide by the pause in commercial whaling; that is why it has requested an interim relief allocation. Japan continued that the Technical Committee has agreed to recommend the establishment of a Working Group to consider *inter alia* a category of whaling between aboriginal subsistence and commercial whaling and posed the question of what will happen to those of its people whose livelihoods depend upon whaling during the period in which the Commission is examining these matters. There is a strong human need which must be met. Referring to suggestions that making an exception of this nature would diminish the effectiveness of the pause in commercial whaling, Japan commented that before the moratorium it utilised 15,000 tons of meat and other edible products from Antarctic and small-type whaling, of which only 600 tons came from small-type coastal whaling. It has been trying to cope with this drastic reduction over the last three years and repeatedly presented its case to the Commission. However, the Commission has ignored or evaded the issue and has thus forced the present imminent situation, which threatened the right of livelihoods. The Aboriginal Subsistence whaling category had been set up because the IWC had taken cognisance of the 1946 Convention which recognises the needs of local people. For all of these reasons it again appealed for the most careful consideration of its request.

The Technical Committee took note of the Japanese statement and request and decided to refer the matter to the Plenary for further consideration.

In the Commission, Japan introduced a formal request for an interim relief allocation and restated the basis for its proposal as previously detailed to the Technical Committee. Iceland expressed its sympathy with the request but asked for governments to have more time before making a decision. Many delegations then indicated their sympathy with the Japanese communities affected. However, Brazil thought it inappropriate to give any allocation now lest it prejudice the question of coastal whaling to be examined next year, a view shared by France and Mexico. Norway was sympathetic to the Japanese request, as were St Lucia and St Vincent & the Grenadines. The Federal Republic of Germany voiced the difficulties it saw against the background of the moratorium on commercial whaling, as did Switzerland, a position also taken by the Netherlands and Sweden. The UK shared this view and that of Brazil, and Australia and New Zealand spoke in similar vein. Spain, the Republic of Korea, the People's Republic of China, the USA and Argentina were in favour of creating the Working Group to analyse the problem. Denmark looked for a solution in the light of the moratorium and the Comprehensive Assessment, and Finland associated itself with this statement.

Japan thanked all Commissioners for their expressions of sympathy for the affected communities, but asked for the matter to be referred back to the member governments. After discussion of the practical aspects, it was agreed that 'Governments which, after reflecting on the Japanese request, have further views to express should be invited to convey those views to the Secretary by 31 July 1988 for circulation to Contracting Governments and Commissioners.'

It was further agreed that the Japanese position would be a matter of priority for the Working Group established to consider various kinds of small-type whaling.

15. SECOND INTERNATIONAL DECADE OF CETACEAN RESEARCH

The Chairman of the Scientific Committee pointed out that increased concentration on Comprehensive Assessment activities meant that fewer items featured under the IDCR heading in 1987/88. Progress had been made in a continuing radio-telemetry study of the behaviour of blue and fin whales and the Scientific Committee had received results from a study of the social organisation of sperm whales off the Galapagos. The 1987/88 IDCR Southern Hemisphere minke whale assessment cruise is the latest in the series of cruises which constitute a major contribution to both the second IDCR and the Comprehensive Assessment. These three activities had all received funding from the IWC.

The Scientific Committee had recommended five projects for support in 1988/89, noting that they would all be subject to the Committee's guidelines on data availability (discussed under Item 16 below):

(a) continuation of the radio-telemetry study;
(b) analysis of photographs of North Pacific humpback whales;
(c) IWC/IDCR Southern Hemisphere minke whale cruise;
(d) analysis of IDCR photographs of minke whales;
(e) proposed meeting on mortality of cetaceans in fishing nets and traps.

The Chairman of the Scientific Committee observed that all of these had funding requirements which he had reported to the Finance and Administration Committee; the Technical Committee endorsed the recommendations that these projects be supported, subject to the deliberations of that Committee, which the Commission noted.

16. DATA AND STATISTICS

Continuing the process began last year of refining and modifying the Commission's policy on access to data to meet new situations, particularly in the context of the Comprehensive Assessment, the Secretary had submitted a discussion paper to the Scientific Committee. The Scientific Committee had subsequently developed revisions to its Rules of Procedure, providing alternative forms of words in two places. While the aim of the Scientific Committee is to encourage as much data as possible to be made available, it believed it to be more appropriate for the Commission to choose among the alternatives.

The Commission, on the proposal of New Zealand, then adopted one of these alternatives. It noted the problem that Norway has national legislation which requires it to enter a reservation with respect to the submission of its small-type whaling statistics which have been released under a special exemption for use in the Scientific Committee only. The revised Guidelines are shown in Appendix 4.

17. ADOPTION OF THE REPORT OF THE SCIENTIFIC COMMITTEE

In adopting the Report of the Scientific Committee, the Technical Committee and the Commission noted the views of the Scientific Committee and where appropriate endorsed its recommendations on the following matters:

National Progress Reports

Revised guidelines for the submission of progress reports were adopted. All member nations are urged to provide them following the approved guidelines.

Data collection, storage and manipulation

Some problems had been identified concerning the reliability of catch records forming the basis of the Bureau of International Whaling Statistics (BIWS) data base. Users of the data base should be made aware of the problems and those with relevant expertise in the area of past data collection for BIWS should be encouraged to provide further information.

Small cetaceans

The Scientific Committee this year conducted a review of the beaked whales including their distribution stock identity, abundance, migration, life history, exploitation and status. Two unidentified types of beaked whale had been observed. Little is known about most of the beaked whales and a number of general research recommendations aimed at expanding existing knowledge were adopted. In response to a request for clarification from Australia the Chairman of the Scientific Committee indicated that there was a specific recommendation intended to promote an increase in the extent of monitoring of offshore gillnet fisheries to improve the knowledge of mortality. A number of other research recommendations relating to dolphin mortality were primarily directed towards the Inter American Tropical Tuna Commission which was represented at the Scientific Committee's meeting by four observers.

Scientific Committee Procedures

In response to views expressed by some Commissioners at the last Annual Meeting about the style of presentation of its report, the Scientific Committee had carried out a detailed review and developed a modified procedure. This was accepted by the Committee although some scientists expressed reservations about the resulting procedure because of its perceived closeness to a voting process. The Scientific Committee also developed procedures to deal with the planning and conduct of special (i.e. intersessional) meetings, and suggested a 60 days minimum period of notification.

The UK stated that it would welcome the introduction of a 60 day minimum period of notice before the calling of future special meetings, but shared the concern expressed by some scientists about the reporting procedure. This would have to be handled with great care and sensitivity to avoid creating a voting situation since, in that event, the Committee would cease to be a scientific body.

Brazil commented that it had already made known its views about the holding of intersessional meetings and repeated its view that the concept of exceptional circumstances which might lead to consideration being given to the calling of an intersessional meeting must be very strictly interpreted.

Data processing and computing

Good progress has been made with the data processing projects including checking the coding of the non-Antarctic catches from the 1949 season to the present. A validated dataset of South Pacific and Australasian land station catches was available, in addition to the North Pacific and South Atlantic datasets, and about half the data from the International Marking Scheme. Rather slower progress had been made in validating programs, but the appointment of a programming assistant in December 1987 would permit second stage testing of management procedures. Work on cruise data was completed up to and including 1986/87, and coding of 1987/88 data had been completed although time constraints had not allowed analysis to date. The Scientific Committee identified a number of data coding and computing priorities for the coming year. In addition to these the Secretariat has also taken over coding, validation and written analysis of IDCR cruise data in association with which a number of additional sets of analyses are required by the Scientific Committee. The resulting workload is substantially more than 12 man months. The Committee therefore recommended that the replacement for the existing Data Analyst, whose contract expires in Summer 1989, be appointed by November 1988 to assist in completing this workload.

Japan stated that it was once more making available two vessels and crew to undertake survey work in Antarctic Area IV and was pleased to note that the continuation of the series of IDCR cruises would provide a more accurate estimate of abundance of stocks which formed an integral part of the Antarctic ecosystem.

Initial agenda for 1989

The Scientific Committee recognised that if it is to present to the Commission in 1990 a detailed report on progress towards the Comprehensive Assessment, it is essential that its 1989 Annual Meeting should concentrate on planning for the preparation of such a report, and urged the Commission to minimise the amount and scope of other advice requested from the Committee at its 1989 meeting. It identified priorities under the Comprehensive Assessment as further development of management procedures, MSY rates, stock identity (including genetics and photo-identification studies) and sightings surveys. It also agreed to include an agenda item addressing the implications for whale management of interspecific interactions in the light of the proposed Workshop on the Feeding Ecology of Southern Hemisphere Baleen Whales and the ICES Multispecies Management Workshop.

Iceland expressed satisfaction that the Scientific Committee had planned to include consideration of interspecific interactions in its agenda for next year.

Other matters

The Chairman of the Scientific Committee noted that the use of microphones at this year's meeting had facilitated the work of the Committee and recommended that this practice be continued. He further noted that his term of office as Chairman of the Committee expired at the conclusion of the present meeting and was pleased to announce that Dr R.L. Brownell Jr (USA) had been elected Chairman and Dr P.H. Hammond (UK) Vice-Chairman. Brazil proposed a vote of thanks to Dr Kirkwood for his work during the last three years and this was warmly endorsed by the Technical Committee.

18. HUMANE KILLING

18.1 Report of the Technical Committee Humane Killing Working Group

Mr M. Hauge (Norway) introduced the report of the Humane Killing Working Group which he had chaired, and which had been attended by delegates from Australia, Brazil, Denmark, Iceland, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Seychelles, Solomon Islands, Sweden, UK and the USA.

The Working Group had discussed at length the status of a document submitted to it from a non-governmental source, and concluded that for a paper to be considered by the Working Group it should either be submitted by a Contracting Government or adopted by consensus. The Chairman hoped that this might provide a useful clarification to other Working Groups which may be requested to receive documents with similar standing. The UK, whilst not objecting to the procedure adopted by the Chairman of the Working Group, expressed regret and disappointment that consensus had not been obtained and that a document of potential interest to the Working Group had not been discussed. It could not agree that the procedure which had been followed was helpful and expressed the hope that it would not be followed by other groups.

Norway expressed a different view and noted that documents not formally accepted by the Commission can still be freely available to interested parties. The issue is the status to be accorded to documents prepared by private persons not within the framework of the organisation, and in that context it is reasonable that the groups involved determine their own procedures. Any National Delegation may afford status to a document by submitting it in its name and accepting responsibility for it. Japan concurred with this view and Denmark observed that the opportunity had been given to governments participating in the Humane Killing Working Group to endorse the document in question and none had chosen to do so. Denmark also referred to its endorsement (upon request) of a paper submitted to the Aboriginal Subsistence Sub-committee by the Greenland Government.

Alaskan bowhead hunt

The Humane Killing Working Group noted that positive progress had been made in the Alaskan Eskimo hunt for bowhead whales, specifically in the areas of improved killing power of traditional weapons, the use of sonic devices and continued training of crews. This had led to significant improvements in time to death or loss of consciousness. The Working Group looked forward to a report on further progress in 1989.

In the Technical Committee, Switzerland congratulated the Alaskan Eskimos on the improvements. Japan expressed satisfaction that the Alaskan Eskimos were adopting penthrite projectiles and commented that this technology had been developed in Japan in 1983. It had been enthusiastically received by the IWC and it is ironic that its use is spreading elsewhere when Japanese whaling has ceased.

Replies by Denmark to questions raised on the Greenland hunt

Denmark had submitted a paper in response to questions raised at last year's meeting of the Working Group and indicated that detonating harpoons will be used in 1989 on an experimental basis and progress in training for the use of this weapon will be reported to the Working Group next year. In the Working Group, Australia had noted that many questions remained unanswered and Denmark stated that it is seeking to provide the next Working Group with available information on these questions.

In the Technical Committee, the UK welcomed the information supplied so far by Denmark and its undertaking to pursue the outstanding matters.

Progress report by Denmark on Faroese pilot whale fishery

In response to its commitment to answer two specific questions raised at the 1986 Annual Meeting, Denmark presented to the Working Group a document on the methods used in the hunt. The use of the spear has been eliminated and the use of the gaff from a boat considerably reduced, being employed only in defined circumstances. Authorisation of one bay for the hunt has been withdrawn and two other bays modified to reduce the duration of the hunt. Training for whalers on how to shorten the hunt has taken place and measures for monitoring the activity are in effect.

Additional material on the hunt was available bilaterally but Denmark would not provide it to the Working Group as a whole. It reiterated its view that the IWC does not have competence over small cetaceans and that the IWC should not discuss the pilot whale hunt any further unless it changed its position on small cetaceans, and decided to take up humane killing problems in small cetacean fisheries in a general context. The UK, in the Technical Committee, expressed regret that the progress report supplied by Denmark was not comprehensive and, particularly, that the Danish delegation had, on its own admission, more information available to it which it had not submitted. The UK believed this should be made available to the Commission as a whole and urged Denmark to return to the matter next year and to fulfil the undertaking given at the 39th Annual Meeting. Antigua & Barbuda associated itself with this view as did New Zealand which re-stated its belief that the IWC does have competence with respect to small cetaceans, pointing out that pilot whales are already included in the Schedule to the Convention. Switzerland and the Netherlands expressed appreciation of the information supplied so far but, because of the intense public interest in their countries, considered it vitally important that all relevant information is made available to the Commission. They hoped the Danish and Faroese authorities would reconsider their position on this matter.

Denmark responded by reminding the Technical Committee that in 1986 it had undertaken to answer specific questions relating to the spear and the gaff and certain other questions later. It had confirmed the undertaking in 1987 and with the report presented it has now met those undertakings. Denmark stated that it was willing to provide additional information available bilaterally to interested delegations and considers accordingly that this item should not be a standing item on the Commission's agenda.

The Technical Committee took note of the different views which had been expressed.

In the Commission, the UK reiterated its hope that additional information would be submitted by Denmark next year, and the Netherlands, New Zealand and Australia associated themselves with this position.

Argentina, Brazil, France, Japan and Mexico all stated their belief that questions relating to small cetaceans are outside the competence of the IWC, while Switzerland voiced the opposite conviction.

National laws on killing animals

The Secretary had introduced to the Working Group a summary of the responses received from member governments dealing with humane killing methods used for wild animals in general and whales in particular, and indicated that more detailed information was available in the Secretariat. The Working Group accepted the Secretary's conclusion that there is no global definition for humane killing, noting also that many Contracting Governments had not responded to the questionnaire.

The Technical Committee noted the Working Group's observations and Iceland stressed the need for continued efforts to obtain the relevant information about the national laws of governments which have, so far, not responded to the questionnaire.

Other substances which might be used for killing whales

No new information had come to light on this subject. The Working Group decided that if any information should be forthcoming the item could be included on next year's agenda. The Technical Committee took note.

Taking of humpback whales by St Vincent & the Grenadines

The USA referred to the reported taking of one humpback whale and one calf in 1987 and possibly a calf in 1988 by St Vincent & the Grenadines. It was concerned about the humane killing aspect of these takes and indicated its understanding that St Vincent & the Grenadines would be willing to provide a paper to next year's Working Group on the subject of the humaneness of the hunting methods used. St Vincent & the Grenadines agreed to this.

18.2 Action arising

The Commission received the report of the Technical Committee on all these matters, and took note of the actions proposed.

19. REGISTER OF WHALING VESSELS

The Secretariat presented the seventh edition of the Commission's International Register of Whaling Vessels, noting that it contained amendments notified during the last year and requesting that any further revisions should be supplied no later than three months before the next Annual Meeting.

Australia requested the Republic of Korea to clarify an entry relating to the former whale catcher/factory *Faith No. 1* (*Cebu*) reported as sold for re-conversion to a fishing vessel. The Republic of Korea was not in a position to do so immediately but indicated that it would be pleased to provide the requested information by next year's meeting. The UK pointed out that there are some deficiencies in the information supplied and expressed the hope that these will be remedied by next year. The Netherlands added its support, stating that it is essential that all member states provide the necessary information to ensure that the Register is as accurate and up to date as possible.

20. ADOPTION OF REPORT OF THE TECHNICAL COMMITTEE

Commissioners agreed to elect the officers of the Technical Committee before adopting the report in that Committee. Dr L.A. Fleischer (Mexico) was elected Chairman and Mr D. Piney (France) Vice-Chairman.

In adopting the Report of the Technical Committee, the Commission noted that its work programme and agenda for next year will be developed as customary by consultation between the Secretary and the Chairman on the basis of the plenary agenda.

21. FINANCE AND ADMINISTRATION

The Finance and Administration Committee was chaired by Mr F. de Soye (Federal Republic of Germany) and attended by delegations from Argentina, Brazil, Federal Republic of Germany, Iceland, Japan, Mexico, Norway, Spain, Sweden, USSR and USA.

21.1 Review of Provisional Financial Statement 1987/88

The Finance and Administration Committee noted that the amendments to the Financial Regulations adopted at last year's Annual Meeting have had an overall positive effect on its financial situation. An unforeseen development, however, was that a number of member governments delayed the payment of their contributions until the newly introduced latest date. On the other hand, additional income is generated by the payment of interest for late payment.

Concern was again expressed that, despite the improvement, there will be a shortfall against the budget figure because the contributions of some Contracting Governments have not been received. Furthermore, in spite of the revolving nature of a part of the shortfall and late payments, a financial gap is accruing every year which in the long run will lead to a depletion of the General Fund to a critical level. The Commission decided therefore to appeal to member governments: (1) to pay their contributions at the earliest possible date in the year; (2) to fulfill outstanding obligations; (3) to agree to an augmentation of available income of the Commission in order to maintain the General Fund at its agreed level of £300,000.

No action was taken on the last point, however, in respect of the budget for the following year.

The Commission approved the Provisional Financial Statement, subject to audit.

21.2 Consideration of Estimated Basic Budget 1988/89

The Finance and Administration Committee considered the provisional estimated budget for 1988/89 based on a similar level of activity to that of the current year except that the Scientific Committee had requested a higher level of funding for research. After allowing a factor of 4% for inflation the proposed budget would have resulted in an increase in contributions for member governments of the order of 17% which was recognised as unacceptable, a number of delegations stating that they were committed to a policy of zero real growth.

The Committee therefore examined the individual components of the budget in detail: it proposed a reduction of £1,000 in the provision for travel, the deletion of the provision of £15,700 for 'Other Meetings' and a reduction of £35,000 from the proposed allocation for research, with £30,000 saved by postponing the 'Meeting on cetacean mortality in fishing nets' and £5,000 from the overall research budget as circumstances permit. A number of delegations expressed the view that work on the Comprehensive Assessment should not be hampered by budgetary constraints. However, the Chairman of the Scientific Committee assured them that the suggested cuts will not adversely affect this. Finally, the Committee recommended that any increase in the fee for NGO observers should be similar to the increase in costs due to inflation borne by member governments, and accordingly that the fee should be set at £210 for 1988/89.

This set of amendments produced a budget in which the total contributions of Contracting Governments is only 4% more than the previous year, i.e. zero real growth. This was approved by the Commission, although France commented that the minimum individual contribution has still increased by 13%.

21.3 Consideration of Supplementary Budget

The Finance and Administration Committee did not discuss any supplementary budget items separately but its consideration of a number of general points which will have budgetary consequences in the future were reflected in its reporting under Items 21.1 (possible augmentation of the General Fund), and 21.4 (unavoidable cost increases in 1989/90 and, especially, 1990/91).

21.4 Consideration of Advance Budget Estimates for 1989/90

The Secretariat had prepared a forecast estimate for 1989/90 based, as is customary, on the expenditure recommended for 1988/89. It pointed out, additionally, that the expiry of the current lease on the Headquarters Offices in 1990, together with the need to replace some obsolete equipment, meant that a substantial increase in costs was inevitable at that time. The Finance and Administration Committee endorsed this assessment which, with the necessity to maintain the General Fund at the agreed level of £300,000, could lead to a real budgetary increase of the order of 6% in 1990/91. The Committee had an exchange of views on whether it would be prudent to provide for some increase in the budget for 1988/89 in order to smooth the transition to the higher level. Although some delegations were in favour of such an approach, others were of the opinion that it was too early to anticipate the exact amount of the additional requirements and would prefer to postpone the question to next year. The Commission, however, took no action, simply noting the forecast estimate for 1989/90.

21.5 Contributions by Contracting Governments

21.5.1 Proposals for scale of contributions

The Finance and Administration Committee reported that some delegations believed that none of the previously submitted proposals for a new scale of contributions reflected the necessity to abolish the distortion in contribution levels, nor contained elements to maintain the universality of the Commission's membership, while at the same time bringing the contributions in line with the respective capacity to pay. In the Commission, Mexico and Brazil emphasised the burden on the less economically favoured members, while Norway spoke of the need for a shared concern and interest to be related to a shared financial burden. Other delegations expressed the view that the financial burden should reflect interest in the Commission's work, and it was suggested that national research funding should be taken into account as well as whaling and membership.

In the absence of any prospect for agreement on a new formula, the Commission accordingly endorsed the recommendation to retain the present arrangement for determining contributions, while keeping the matter under review.

21.5.2 Arrears of contributions

The Secretariat had proposed, and the Finance and Administration Committee recommended, that it would be advantageous administratively to fix a single common date for the annual compounding of interest in respect of outstanding contributions. The Commission agreed that this should be 1 March of any year.

Belize had made a formal request to the Commission for a waiver or reduction in its outstanding contribution, but discussion in the Finance and Administration Committee revealed that a decision on this matter had a variety of implications for both present and former members. The Commission decided, therefore, that the complexity of the issue makes it necessary to conduct further discussion at next year's Annual Meeting. In the meantime it instructed the Secretary to communicate with the Government of Belize to the effect that its request was still under consideration.

Norway regretted that it was not possible to progress beyond a holding operation to find a solution which might also resolve other problems relating to outstanding contributions.

Brazil and Mexico perceived that there could be an intimate connection between the treatment afforded to a country, like Belize, about to withdraw from the Convention and others which remain members. They also drew attention to the problem faced by states which wish to participate but may not have the power to make financial contributions regularly and punctually. The UK agreed with Norway, and suggested that the Finance and Administration Committee look next year in particular at the question of how to deal with countries with substantial arrears. This was seconded by New Zealand, Oman and Australia, and agreed by the Commission.

21.6 Numbers attending Committees and Working Groups

In accordance with the request of the Finance and Administration Committee at its 1987 meeting the Secretary had circulated a paper outlining the administrative difficulties and unnecessary additional costs created by the failure of member governments to notify in advance the number of expected participants in Committees and Working Groups. On the recommendation of the Finance and Administration Committee the Commission agreed that in future:

(1) governments should notify the number of participants at least four weeks before the beginning of any meeting of Committees or Working Groups;
(2) non-complying governments will have to bear any administrative inconvenience resulting from the default. Any inconvenience should not be detrimental to governments which do comply.

In addition, the Secretariat will, at the time the Agenda is circulated, send to member governments a reply form in order to remind them to notify the number of participants.

21.7 Amendment of Rule of Procedure E.3

Following the postal vote conducted early in 1988 the Secretary had suggested that some clarification of Rule of Procedure E.3 (dealing with the postal voting procedure) may be desirable. A full discussion of the intent of this Rule by the Finance and Administration Committee led to a recommendation, which the Commission adopted by consensus, that Rule E be clarified as follows:

(1) paragraph 1(a) be renumbered 1;
(2) paragraph 1(b) be renumbered 2;
(3) the remaining paragraphs are renumbered consecutively;
(4) the final phrase of Paragraph E.3 (old) E.4 (new) be amended to read:

'shall be of the total number of Contracting Governments whose right to vote has not been suspended under Paragraph 2.'

The Chairman of the Commission indicated that since formal amendment of the Rules of Procedure requires notification of the amendment 60 days in advance of the meeting, this recommendation will be included in the agenda for adoption at the next Annual Meeting. The Commission agreed to this procedure with the understanding that, if the question should arise in the meantime, the Commission will act in accordance with the amended form of the Rule.

On Norway's request to be permitted to comment on the issue which gave occasion to the proposal to clarify the Rules, the Chairman explained, by way of introduction, that the situation arose when an inter-sessional postal vote was requested and the number of Commissioners or Contracting Governments to be taken into account in determining a majority became significant. There was no precedent, and the Rules of Procedure were, to some extent, confused. Circumstances had not permitted time for full consultation with other Commissioners, and he had therefore adopted one interpretation which was based on legal advice.

Norway explained its view that postal voting is in its nature very different from voting in a meeting. In the latter it is always possible to clarify the modalities of the vote on the floor, the Chairman is able to offer guidance in the form of a ruling and the Commission may determine that it did not agree with his ruling. In addition, votes are cast according to a clear and established procedure and Commissioners are able to hear each vote as it is given. That element is absent from the postal vote procedure which liberates Commissioners to state their views in the manner they choose, not necessarily in the form of 'yes', 'no' or 'abstain'. In the recent postal vote Norway had indicated that it was not in a position to support the proposal. This was recorded as a 'no' vote whereas it was intended to mean that Norway was not saying whether it voted 'no' or whether it abstained, thus giving expression to an attitude towards the vote. Norway considered that these difficulties are inherent in a postal voting procedure and was not sure that the clarification of the Rules of Procedure would necessarily prevent future Chairmen from facing similar difficulties.

Brazil drew attention to comments it had circulated on these issues and reiterated its belief that the fundamental consideration is not one of procedure but of attitude. It therefore urged that in future postal votes should be resorted to only in situations of *force majeure* and that in such situations consultation should take place to the fullest extent possible. Above all political sensibility and sensitivity must be exercised before any member embarks on initiatives which will require a pronouncement from the Commission in an intersessional period. Mexico associated itself with these remarks.

Switzerland stated that, on the basis of a detailed study of the question of the basis for determining a voting majority involving reference to many international treaties and commentaries, it believed that the Chairman's interpretation of the rules was, indeed, correct.

21.8 Invited participants to the Scientific Committee

The Finance and Administration Committee had examined the list of invited participants and noted the view of the Scientific Committee that their presence is vital to the work of the Scientific Committee, particularly in the context of the Comprehensive Assessment. The Commission noted that many invited scientists attended the meeting at no cost to the IWC, although Mexico expressed a dissenting view, believing that the invited participants enjoyed facilities and accommodation provided by the Commission.

22. DATE AND PLACE OF ANNUAL MEETINGS

22.1 Arrangements for 1989

The Government of the United States of America had indicated at the previous Annual Meeting that it was considering an invitation to the Commission to hold the 1989 Annual Meetings of the Scientific Committee, Technical Committee and Commission in the USA. It formally confirmed its invitation for these meetings to take place in San Diego, California, during the period 15 May–16 June 1989. The Commission accepted the invitation with gratitude.

The Chairman of the Finance and Administration Committee drew the attention of the Commission to the fact that it had already established eight Committees and Working Groups to meet in the week prior to the next Annual Meeting. There is a limit to the number of groups that can be accommodated in a given time and the agreed programme will inevitably require some undesirable overlapping of groups. The Chairman of the Commission urged Commissioners to consider the time available when establishing new Committees and Working Groups in future.

22.2 Arrangements for 1990

No Contracting Government had indicated that it might offer an invitation for 1990. The Secretary reported that it seemed unlikely that a booking could be made at the usual time in the UK. In consequence, the 42nd Annual Meeting, if held in the UK, would probably have to take place in late July or even August 1990.

23. ADOPTION OF THE REPORT OF THE FINANCE AND ADMINISTRATION COMMITTEE

One other item of business, concerning the grading of the post of Executive Officer to the Commission, had been referred by the Finance and Administration Committee directly to the Commissioners. The Chairman of the Commission raised this question with Commissioners who decided that the holder of the post should receive a personal upgrading to the equivalent of the United Nations P2 grade. The Report of the Finance and Administration Committee was adopted by the Commission.

24. COOPERATION WITH OTHER ORGANISATIONS

The Scientific Committee considered the reports from IWC observers who had attended meetings of CCAMLR, ICES and IATTC. These were noted by the Commission, which also received a report from the observer to the ICSEAF meeting.

In addition, UNEP had written to the IWC requesting consideration of co–sponsorship of a meeting to review the status and problems of small cetaceans worldwide. The Scientific Committee agreed that such a meeting could be an important step towards improving our understanding of small cetacean problems and developing approaches to their solution. It therefore recommended cooperation, but with no financial implications, consistent with the Commission's Resolution of 1980 on the mandate to discuss scientific matters relating to small cetaceans. After discussions involving the views of Argentina, Brazil, France, Japan and Mexico on the issue of the Commission's competence with respect to small cetaceans, the UK stressed the need to act without prejudice to delegates' positions, and the Commission agreed to take note that the Scientific Committee will cooperate in the planning and conduct of the meeting.

25. THIRTY-NINTH ANNUAL REPORT

The Commission received and approved the Thirty-Ninth Annual Report for 1987/88, circulated in draft, and subject to any updating required.

26. ELECTION OF CHAIRMAN

Mr I.L.G. Stewart (New Zealand) completed his three-year term as Chairman of the Commission at this meeting. On the proposal of Denmark, adopted by acclamation, Mr S. Irberger (Sweden) was elected Chairman for the next three years.

27. ELECTION OF VICE-CHAIRMAN

Mr M.T. Haddon (UK) had resigned as Vice-Chairman of the Commission and Chairman of the Technical Committee shortly before the meeting on changing his responsibilities on his home administration. On the proposal of France, Dr L.A. Fleischer (Mexico) was elected Vice-Chairman by acclamation.

28. ANY OTHER BUSINESS

Under this item both Antigua & Barbuda and the UK offered to host the Scientific Committee's Management Workshop. It was agreed that the Chairman of the Scientific Committee would consult with the Secretary when the written invitations were received to select the most suitable venue.

29. AMENDMENTS TO THE SCHEDULE

The amendments to the Schedule adopted at the 40th Annual Meeting are shown in Appendix 5.

Appendix 1

RESOLUTION ON NORWEGIAN PROPOSAL FOR SPECIAL PERMITS

WHEREAS the International Whaling Commission adopted in 1986 a Resolution on Special Permits for Scientific Research (IWC/38/28) and in 1987 a Resolution on Scientific Research Programmes (*Rep. int. Whal. Commn* 38: 27);

WHEREAS the Commission has considered the Report of the Scientific Committee (IWC/40/4) concerning the research programmes to be conducted under special permits, and recognises that the continuation of sighting surveys of the Norwegian Research Programme would continue to make an important contribution to knowledge of the distribution and abundance of whales in the Northeast Atlantic, and further encourages the implementation of the projects dealing with natural marking studies and the development of passive acoustic methods;

WHEREAS the Commission takes cognizance of Article VIII of the International Convention for the Regulation of Whaling, under which the granting by any Contracting Government to its nationals of a special permit authorising the killing, taking or treatment of whales for purposes of scientific research remains the responsibility of each Contracting Government, exercising its sovereign rights in respect of maritime areas under its jurisdiction and freedom of the high seas;

Now, THEREFORE, the Commission

CONSIDERS; taking into account the comments of the Scientific Committee; that the proposed kill of minke whales in the North Atlantic under the research programme described in SC/40/Mi7 does not satisfy each of the criteria specified in both the 1986 Resolution on Special Permits for Scientific Research and the 1987 Resolution on Scientific Research Programmes in that the proposed research is not structured so as to contribute information essential for rational management of the stock and that the proposed kill will not materially facilitate the Comprehensive Assessment, and further that it has not been established that the proposed research addresses critically important research needs;

REQUESTS the Secretary to inform the Government of Norway accordingly.

Appendix 2

RESOLUTION ON THE ICELANDIC PROPOSAL FOR SCIENTIFIC CATCHES

WHEREAS the International Whaling Commission adopted in 1986 a Resolution on Special Permits for Scientific Research (IWC/38/28) and in 1987 a Resolution on Scientific Research Programmes (*Rep. int. Whal. Commn* 38: 27);

WHEREAS the Commission has considered the Report of the Scientific Committee (IWC/40/4) concerning the research programmes to be conducted under special permits, and it is recognised that the sighting survey of the Icelandic Research Programme has made an important contribution to knowledge of the distribution and abundance of whales in the North Atlantic;

WHEREAS the Commission takes cognizance of Article VIII of the International Convention for the Regulation of Whaling, under which the granting by any Contracting Government to its nationals of a special permit authorising the killing, taking or treatment of whales for purposes of scientific research remains the responsibility of each Contracting Government, exercising its sovereign rights in respect of maritime areas under its jurisdiction and freedom of the high seas;

WHEREAS at the 1987 meeting the Commission adopted the view that the proposed take of fin, sei and minke whales under special permit did not fully satisfy the criteria set forth in the 1986 Resolution on Special Permits for Scientific Research and recommended that the Government of Iceland revoke and refrain from issuing special permits to its nationals until the uncertainties identified in the Scientific Committee Report (IWC/39/4) had been resolved to the satisfaction of the Scientific Committee;

WHEREAS the Government of Iceland has announced its intention not to issue special permits to take minke whales as described in SC/37/O 20 and as modified in SC/38/ProgRep Iceland;

Now, THEREFORE, the Commission

CONSIDERS; taking into account the comments of the Scientific Committee in 1987, and 1988; that the proposed take of fin and sei whales under special permit as described in SC/37/O 20 and as modified in SC/38/ProgRep Iceland does not satisfy each of the criteria specified in both the 1986 Resolution on Special Permits for Scientific Research and the 1987 Resolution on Scientific Research Programmes;

REQUESTS the Secretary to inform the Government of Iceland accordingly;

INVITES the Government of Iceland to report in writing to the Commission in time for consideration by the Commission at its 41st Annual Meeting.

Appendix 3

RESOLUTION ON THE ISSUANCE OF SPECIAL PERMITS FOR THE PURPOSES OF SCIENTIFIC RESEARCH

WHEREAS it is desirable to operate within the annual calendar of the International Whaling Commission and of its Scientific Committee and that in normal circumstances the procedure for consideration of special permits for the purposes of scientific research is for them to be considered by the Scientific Committee and with its report by the Commission and that intersessional meetings should normally be avoided and called only in exceptional circumstances;

WHEREAS there is no clear procedure for the consideration of reports of the Scientific Committee on the results of intersessional meetings called to consider special permits for the purposes of scientific research and FURTHERMORE it is not the general practice of the IWC to convene intersessional meetings of Commissioners;

WHEREAS it is a responsibility for all Commissioners to have due opportunity to consider and discuss with one another the outcome of the deliberations of the Scientific Committee on all matters, and in particular on any proposals for special permits for the purposes of scientific research;

Now THEREFORE the Commission

RECOMMENDS that following consideration of any special permit(s) for the purposes of scientific research at any intersessional meeting of the Scientific Committee, the Contracting Government(s) responsible for the proposed special permit(s) refrain from issuing any special permit until the expiry of sixty days from the date of circulation of the report of the meeting, to give the Chairman of the Commission sufficient time to consult with the Contracting Governments in order to reach a decision as to how the Commission proceeds.

Appendix 4

RULES OF PROCEDURE OF THE SCIENTIFIC COMMITTEE: REVISED APPENDIX 1

GUIDELINES FOR AVAILABILITY OF DATA HELD BY THE IWC

1. Information identified in Section VI of the Schedule that shall be notified or forwarded to the IWC or other body designated under Article VII of the Convention.

This information is available on request through the Secretariat to any interested persons with a legitimate claim relative to the aims and purposes of the Convention.*

2. Information and reports provided where possible under Section VI of the Schedule.

When such information is forwarded to the IWC, a covering letter should make it clear that the information or report is being made available, and it should identify the pertinent Schedule paragraph under which the information or report is being submitted.

Information made available to the IWC under this provision is accessible to accredited persons as defined below, and additionally to other interested persons subject

---

* The Government of Norway notes that for reasons of domestic legislation it is only able to agree that data it provides under this paragraph are made available to accredited persons.

to the agreement of the government submitting the information or report.

Such information already held by the Commission is not regarded as having been forwarded until clarification of its status is received from the government concerned.

3. Information neither required nor requested under the Schedule but which has been or might be made available to the Commission on a voluntary basis.

This information is of a substantially different status from the previous two types. It can be further divided into two categories:

(a) Information collected under International Schemes

(i) Data from the IDCR projects.
(ii) Data from the International Marking Scheme.
(iii) Data obtained from international collaborative activities which are offered by the sponsors and accepted as contributions to the Comprehensive Assessment, or proposed by the Scientific Committee itself.

Information collected as the result of IWC sponsored activities and/or on a collaborative basis with other organisations, governments, institutions or individuals is available within those contributing bodies either immediately, or, after mutual agreement between the IWC and the relevant body/person, after a suitable time interval to allow 'first use' rights to the primary contributors.

(b) Information collected under national programmes, or other than in (a)

Information in this category is likely to be provided by governments under specified conditions and would hence be subject to some degree of restriction of access. This information can only be held under the following conditions:

(i) A minimum level of access should be that such data could be used by accredited persons during the Scientific Committee meetings using validated techniques or methods agreed by the Scientific Committee. After the meeting, at the request of the Scientific Committee, such data could be accessed by the Secretariat for use with previously specified techniques or validated programs. Information thus made available to accredited persons should not be passed on to third parties but governments might be asked to consider making such records more widely available or accessible.
(ii) The restrictions should be specified at the time the information is provided and these should be the only restrictions.
(iii) Restrictions on access should not discriminate among accredited persons.
(iv) All information held should be documented (i.e. described) so that accredited persons know what is being held, along with stated restrictions on the access to it and the procedures needed to obtain permission for access.

Accredited persons

Accredited persons are those scientists defined under sections A.1, 2, 3 and 6 of the Rules of Procedure of the Scientific Committee. Invited participants are also considered as 'accredited' during the intersessional period following the meeting which they attend.

Appendix 5

AMENDMENTS TO THE SCHEDULE ADOPTED AT THE 40TH ANNUAL MEETING

(changes in bold type)

(1) In sub-paragraph 13(b)(1) replace the words 'Bering Sea' by **'Bering–Chukchi-Beaufort Seas'**
(2) In sub-paragraph 13(b)(1)(i) replace the text by **'For each of the years 1989, 1990 and 1991, the total number of whales struck shall not exceed 44 and the total number of whales landed shall not exceed 41, except that in 1988, 1989 or 1990, any unused strikes up to a maximum of 3 shall be transferred to the following year'**
(3) In sub-paragraph 13(b)(2) replace '1988' by **'each of the years 1989, 1990 and 1991'**
(4) Amend Table 1 to reflect an aboriginal catch limit of **60** for the West Greenland stock of minke whales, **23** for the West Greenland stock of fin whales, and **12** for the Central Atlantic stock of minke whales all with the footnote 'Available to be taken by aborigines pursuant to paragraph 13(b)3.'
(5) Revise paragraphs 11 and 12, and Tables 1, 2 and 3, by substitution of the dates **1988/89** pelagic season, **1989** coastal season, **1989** season, or **1989** as appropriate.

Report of the Scientific Committee

The Committee met at 9.00am on 6 May 1988 and following days at the Catamaran Hotel, San Diego, USA, under the chairmanship of G.P. Kirkwood. A list of participants is given in Annex A. Many members of the Committee expressed their regret that there were no scientists present from the USSR for the first time since the IWC was established.

Credentials

The Scientific Committee followed the Commission's Rule of Procedure D1.

One scientist's credentials arrived during the opening day. The credentials of a second scientist who arrived on the third day of the meeting were received the next day; however, three days later his Government indicated that it was not participating in the meeting and the scientist concerned withdrew.

The *ad hoc* credentials group established under Rule of Procedure D1 (d) noted that resolution of these matters caused a significant loss of working time.

1. CHAIRMAN'S WELCOME AND OPENING REMARKS

The Chairman welcomed the Committee Members and Invited Participants. In the past year, two biologists taking part in the North Atlantic Sightings Survey, Tim Waters and Fred Fairfield, died in a survey plane crash. The Committee observed a minute's silence in their memory.

2. ADOPTION OF AGENDA

The Agenda adopted is given in Annex B. Statements concerning the Agenda are given in Annex Q.

3. ARRANGEMENTS FOR MEETING

3.1 Appointment of rapporteurs

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

3.2 Meeting procedures and time schedule

As last year, the Commission decided that the Committee should address the Comprehensive Assessment as well as its normal business. The Commission, primarily in response to the Committee's failure to agree a complete report last year, allocated an extra day to this year's meeting.

The Committee agreed to a work schedule proposed by the Chairman. This took fully into account comments, suggestions and procedures agreed to at earlier meetings (*Rep. int. Whal. Commn* 33: 36; *Rep. int. Whal. Commn* 38: 59) and the list of priority stocks developed in accordance with the procedure agreed to in 1982 (*Rep. int. Whal. Commn* 33: 65). Sub-committees were reminded that a full day must elapse between receipt of their reports by the Committee and discussion of them in Plenary Session. Further discussion of Scientific Committee procedures occurs under Item 11.

3.3 Establishment of sub-committees

The following sub-committees were established: Southern Hemisphere minke whales; North Atlantic minke whales; other baleen whales; protected species and aboriginal/subsistence whaling; and small cetaceans. Reports arising are dealt with under the relevant Agenda Items and Annexes.

Annex D	Southern Hemisphere minke whales
Annex E	North Atlantic minke whales
Annex F	Other baleen whales
Annex G	Protected species and aboriginal/subsistence whaling
Annex H	Small cetaceans

An *ad hoc* sub-committee on Comprehensive Assessment was also established. Its report, and those of working groups, are incorporated under the relevant Agenda Items or as Annexes.

3.4 Computing arrangements

Allison outlined the arrangements for access to the University of Cambridge computer system. A digital link had been installed from the hotel to the international packet switching system (IPSS) via the Tymnet network, providing up to eight communications channels.

In addition four personal computers running MS-DOS were set up for the use of Committee members, with a variety of word processing, spread sheet and statistical analysis software installed on them.

4. REVIEW OF AVAILABLE DATA, DOCUMENTS AND REPORTS

4.1 Documents submitted

A list of documents is given in Annex C.

4.2 National Progress Reports

At last year's meeting (*Rep. int. Whal. Commn* 38: 32) a correspondence group was established to examine

> 'ways to improve the consistency of Progress Reports and review the types of information included within them.'

The report of the group is given as Annex I. The Committee agreed to the revised guidelines given that Annex. The Committee re-affirms its view of the importance of progress reports to its work and again

recommends that the Commission urges member nations to provide them following the approved guidelines. A minority statement is given in Annex Q.

4.3 Data collection, storage and manipulation

In SC/40/O 20 the reliability of the official catch records that formed the basis of the BIWS data base was discussed. Problems were identified in species identification, unreported catches, inconsistency in methods of length measurement, falsification of reported lengths, incomplete reporting of foetuses and inaccurate determination of their length and sex, and incomplete examination of stomach contents. Some of these features were obvious from an inspection of the basic statistics, others were not, and the quality of the data probably differed between operations and almost certainly with time. Several members of the Committee with personal experience confirmed that such problems had occurred. Users of the data base should be made aware of such problems, and it was suggested that others familiar with the data collection process for their national industry (or that of another region) should be encouraged to provide specific information as had been done in SC/40/O 20.

4.3.1 Catches and other statistical material from the previous season

Catch data for the 1987/88 season had been received by the Secretariat from Japan and Iceland. This had been coded and the summary statistics circulated. A computer tape containing individual catch records for Norwegian bottlenose, killer and pilot whales from 1938–81 had also been provided. This completed the provision of coded historical catch and effort data for Norwegian small-type whaling for the years 1938–1986. The Committee expressed its appreciation to Norwegian scientists for the work involved in the provision of these data.

Japan noted that it had supplied data to the Secretariat for its research catches, in the format in which it had previously supplied commercial catch data.

The Committee was disappointed to learn that Norway had not yet supplied the 1987 catch data as required by the Schedule. Norway referred to the submission of summary catch data for 1987 in its Progress Report and indicated that coded data for that year will be forwarded to the Secretariat within 2–3 weeks of the close of the Commission meeting.

4.3.2 Progress on data coding projects

Allison reported that good progress continued to be made with the data coding projects.

The systematic checking of the coding of the non-Antarctic catches from the 1949 season to the present had continued and it was expected that this would be completed within the next few months. A validated dataset containing details of the South Pacific and Australasian land station catches was available in addition to the North Pacific and South Atlantic (1970 onwards) datasets already completed.

Approximately half of the data from the International Marking Scheme have been coded and fully validated. This covers the Southern Hemisphere marking since 1960 and includes all minke whale data.

Borchers reported that validation of the 1986/87 IWC/IDCR cruise data had been completed. All data from the 1987/88 cruise had been encoded but have yet to be validated.

4.3.3 Progress on computing projects

At the start of the meeting, Allison reported that the validation of the estimation programs written by de la Mare, which fitted a population model to catch data and absolute abundance and/or abundance index data (HITTER & FITTER), was almost complete. During the course of the meeting the validation was completed and the program ready for use.

Little progress had been made on documenting existing programs held by the Secretariat.

Last year the Committee recommended that a programmer be appointed to allow the IWC computing facility to carry out second stage testing of selected management procedures. A programming assistant was appointed in December 1987 in order to free Allison to do this work.

Borchers reported that updated validation, analysis and graphics programs for the IWC/IDCR cruise data had been implemented on the Cambridge computer system. Data validation, routine abundance estimation and analysis of experiments from the 1986/7 cruise and coding of the data from the 1987/8 cruise had been completed.

4.4 Whale marking

No 'Discovery' marks were recovered in the 1987 or 1987/88 seasons. Three minke whales were marked in the North Atlantic (SC/40/ProgRep Norway). Information on research involving natural marks is given in SC/40/Rep 1 and discussed under Item 6.2.1. The Committee agreed that such information on natural marking might be included in future Annual Progress Reports (and see Annex I).

5. CO-OPERATION WITH OTHER ORGANISATIONS

5.1 Observers' reports

5.1.1 CCAMLR

The Committee had before it the report of the IWC observer at the sixth meeting of the Scientific Committee of CCAMLR (SC-CAMLR) in Hobart in October 1987 (IWC/40/10A). The organisation of the joint IWC/CCAMLR Workshop on the Feeding Ecology of Southern Baleen Whales is discussed under Item 6.2.2.

SC-CAMLR has recommended that krill predator monitoring studies should now begin in three monitoring regions. The initially selected predator species are fur seals, black-browed albatross and certain penguin species. SC-CAMLR also recommended further work on the utility of other potential predators (including minke whales).

SC-CAMLR is also attempting to keep under review the status of krill-dependent predators, especially those which are known or suspected to have changed significantly in abundance. In response to a request from Dr G. Chittleborough, who is compiling a list of such species for CCAMLR, Kirkwood has provided relevant extracts of IWC Scientific Committee reports and suggested further experts to contact.

The Committee thanked de la Mare for attending the SC-CAMLR meeting on its behalf and noted that he was representing CCAMLR at the IWC Scientific Committee meeting.

Kirkwood agreed to act as the IWC observer at the 1988 SC-CAMLR meeting.

5.1.2 ICES

The Committee had before it the report of the IWC observer at the 75th meeting of ICES held in Santander from 1–9 October 1987 (IWC/40/10B). Three cetacean papers, two of which concerned strandings, were discussed by the Marine Mammals Committee. It recommended that the special theme for next year's meeting be 'Ecological interactions among fish populations, fisheries and top predators'.

The Committee was informed that ICES is organising a symposium on 'Multi–species Management of Marine Ecosystems' which will be held before the 1989 Statutory Meeting in the Netherlands. The symposium will include papers on marine mammals; members of the Scientific Committee who are interested in contributing should contact Harwood.

The Committee thanked Bjørge for attending the meeting on its behalf and he agreed to represent it at the next meeting.

5.1.3 ICSEAF

No observer's report was available at this year's meeting. The Committee noted that the IWC observers at ICSEAF meetings represented the Commission rather than the Scientific Committee itself and their reports were discussed at Commission meetings. It agreed that in future it would only consider the reports of IWC observers at ICSEAF meetings if they contained matters of special interest to the Committee.

5.1.4 IATTC

The Committee was pleased to welcome four observers from IATTC to the meeting. Matters of special interest to the IATTC were discussed at the meeting of the sub-committee on small cetaceans (Annex H). The Committee had before it the report of the IWC observer at the 45th meeting of the IATTC held in La Jolla, California, 8–10 March 1988 (IWC/40/10C). The Committee thanked Perrin for attending the meeting on its behalf. Le Gall agreed to represent the Committee at the next meeting of the IATTC in Paris in May 1989.

The Committee took note of the courses on marine mammal biology and assessment organised by IATTC and funded by UNEP and IATTC that have been held in five Latin American countries in 1986–87. The 130 students, from 11 countries, have included graduate students and working professionals in conservation and management. The courses have dealt with both the large and small cetaceans. The Committee notes the value of these courses in increasing marine mammal expertise in the nations of the region, and hopes that they will continue.

5.2 UNEP meeting on small cetaceans

UNEP wrote to the IWC in February 1988 requesting that the IWC considers co-sponsoring a meeting to 'review the status and problems of small cetaceans worldwide'. It noted that the meeting would probably be held in the USSR in late 1988 or early 1989 (IWC/40/10D).

A small working group of the sub-committee on small cetaceans was convened to examine the proposal. The working group's report is given in Annex H, Appendix 2. The Committee endorsed the working group's report and **recommends** that it be forwarded to UNEP.

The Committee agreed that the proposed meeting could be an important step towards improving our understanding of small cetacean problems and developing approaches to their solution.

For this reason and because members of the Committee have considerable expertise in the topics proposed to be addressed and the problems involved in convening such a meeting, the Committee **recommends** that the IWC co-operates in the planning and conduct of the meeting. It was agreed that this co-operation might include:

(i) assistance in the development of a list of potential participants;
(ii) provision of a member of a steering group;
(iii) dissemination of information concerning the meeting to the committee by the Secretariat.

The Committee noted that this level of co-operation, with no financial implications, was consistent with the 1980 resolution (*Rep. int. Whal. Commn* 31: 31) concerning its mandate to discuss scientific matters relating to small cetaceans.

5.3 Other matters

Last year the Committee had noted with regret that no advisors from FAO, UNEP or IUCN were present and had recommended that the Secretary write to these organisations informing them of the importance it attached to continuing co-operation. The Secretary reported that all three organisations had replied. IUCN explained that its observer to the 1987 meeting had been unable to attend at the last moment; FAO explained that while it valued co-operation with the IWC, in its current financial position it was unable to send an advisor; UNEP explained that the 1987 IWC meeting had conflicted with the meeting of its governing council.

An adviser from UNEP was present at this year's meeting.

6. COMPREHENSIVE ASSESSMENT OF WHALE STOCKS

6.1 Review of reports of contract studies

6.1.1 Biochemical genetics

A working group was set up to review the application of molecular genetic techniques for the identification of stocks and individuals, to discuss new methodologies and to make recommendations for future studies related to the Comprehensive Assessment. The report of this working group is given in Annex J1.

The Committee **recommends** that funds for the contract study for DNA experiments on stock identity and school structure be continued for the second year of the two year project.

The Committee **recommends** that the IWC Secretariat establish a data base containing information on the availability of existing, preserved cetacean tissue samples. This information, stored in a standardised format, would be available to investigators requiring tissue samples. The investigators would then make their own arrangements with the caretakers of the samples.

The Committee also **recommends** that the IWC Secretariat approach the Secretariat of CITES with a view to promoting exchanges of cetacean tissues between scientific institutions. Member Governments should also facilitate scientific institutions' export of tissue samples for studies related to the Comprehensive Assessment.

The Committee also **recommends** that the proposed workshop on the genetic and biochemical analysis of tissue samples collected by biopsy sampling and other means be held as outlined in Annex J2.

6.1.2 Analysis of Southern Hemisphere minke whale marking data

The Committee's discussion of the results of the analysis of Southern Hemisphere minke whale marking data (SC/40/Mi6) is given under Item 7.1.6.

The Committee also discussed the value of re-analysing the marking data for other species, and the status of the earlier recommendation for computerisation of all Antarctic mark and recovery data. The Committee reiterated the value of being able to examine these data, and **recommends** that the Secretariat complete the coding project. No new 'Discovery' marking experiments were recommended, but the potential value of studies using naturally marked individuals was noted (Item 7.1.7).

6.1.3 Analysis of Southern Hemisphere non-minke sighting data

In 1985 the Committee identified the need to examine the sightings data for species other than minke whales arising out of the IDCR surveys (*Rep. int. Whal. Commn* 36: 38).

This work was not completed by the time of this meeting and the Committee urges that it be completed as soon as possible. The results of this study will also be relevant to the Workshop on the Feeding Ecology of Southern Baleen Whales (Item 6.2.2).

6.1.4 Galapagos sperm whale study

The Committee welcomed the results of sperm whale studies at the Galapagos Islands carried out in 1985 and 1987 (Annex J11). The latter study was funded partially by the Commission. The Committee noted that results of studies on the breeding system, calving season, social organisation and movement of groups provided information relevant to the Comprehensive Assessment.

Planned development of the Galapagos sperm whale research includes: potential improvements in the clustering process by which identified whales are allocated to groups; investigation of reproductive rates from calf sightings and length distributions; additional field studies for several months in the Galapagos every two years, principally concentrating on the acquisition of fluke photographs; collection of sloughed skin and/or biopsy samples for DNA analysis of relatedness between and within groups; the development of computer-assisted matching techniques for individual photographic identifications of sperm whales; comparison of results from the field research with analysis of logbooks of 19th century sperm whalers in the Galapagos region.

The Committee re-iterated its support for this work and noted that a detailed research proposal concerning the continuation of the study would be received during the coming year for discussion at next year's meeting.

6.2 Review reports of intersessional meetings

6.2.1 Photo-identification workshop

The Committee had before it the Workshop Report (SC/40/Rep1). It noted that the main body of the report was still in draft form and would be agreed by correspondence. However, the recommendations in Section II of SC/40/Rep1 had been agreed by the participants before the end of the Workshop. Annex E, containing information on sampling strategies, was not available for circulation.

The Workshop was planned in accordance with the objectives, terms of reference and proposed topics detailed in *Rep. int. Whal. Commn* 38: 132–3. It was preceded by a successful symposium involving some 240 participants, from which there were 37 contributed papers and 26 posters (as listed in SC/40/Rep1, Annex C).

The Workshop discussions comprised three main elements: Methodology, End Uses and Recommendations. The Workshop had addressed not only the methodology of photo-identification, but also DNA fingerprinting and acoustic methods in so far as they relate to individual identification. It agreed that acoustic methods were unlikely to be useful at present for identifying individuals. DNA fingerprinting, on the other hand, can be used to identify all individuals sampled (which is not always the case in photo-identification studies), but has the drawback that the procedure takes more time and effort, both in collecting samples and analysis of results.

Natural marking photographs are a well-established technique for several species, particularly humpback and right whales. An indication of the extent of interest in the methodology was given by the tabulation of current and past activities (SC/40/Rep1, Table 1) which provides information on some 13,500 identified animals from 10 species of whale of particular interest to the IWC, involving more than fifty separate programmes or catalogues. The Committee noted that activity was centered in the Northern Hemisphere, with some 75% of the programmes.

Many studies were based on relatively small populations in restricted, particularly coastal, areas and it was recognised that the Scientific Committee would require information on their possible extension to large pelagic populations. To indicate the feasibility of such studies, estimates were provided of the approximate sample sizes needed (using capture-recapture methods) to estimate fin and minke whale populations of different sizes (SC/40/Rep1, Annex D). If high precision was not required, 270 fin whale 'encounters' per year (assuming 75% would be photographed and 100% would be individually identifiable) would be sufficient to estimate a fin whale population of 10,000. By contrast, some 19,000 encounters (assuming 75% would be photographed and 50% would be individually identifiable) would be needed in each of two years to estimate a minke whale population of 500,000 animals with high precision.

SC/40/Rep1, Annex E provided a review of sampling strategies, constraints and trade-offs in photo-identification studies in nine baleen whale and four toothed whale species. Frequently, compromises are necessary between obtaining broad geographical coverage, maximising the number of individuals sampled and dedicating sufficient sampling time per individual. Studies have a variety of objectives: behavioural studies, for example, may not be ideal for estimating population size and vice-versa. It was noted that in addition to providing information on population size, such studies can provide information on trends in population growth. In reviewing the uses to which such techniques can be put, the Workshop also agreed that they could be used for differentiating between populations and for identifying relationships of animals within populations. It was necessary to bear in mind that animals frequently show site and seasonal specificity, and that parameters may have to be estimated for a particular age or sex class of a population.

The Workshop had collated detailed information on techniques, including those involved in biopsy sampling, compiling genetic catalogues, photography (including archival storage of photographs) and production of catalogues.

In reviewing methods for reidentifying individuals, SC/40/Rep1 draws attention to computer assisted techniques, involving, on the one hand, computerised storage and sorting of images (described in SC/A88/ID11 for humpback fluke photographs) and, on the other, a computerised 3-D model of the relevant target (SC/A88/ID9, developed for North Atlantic grey seals). The latter might be especially useful where there are complex pigmentation patterns (e.g. blue whales) or where the angle of the photograph can cause problems (e.g. right whale heads, see Item 6.4).

The Workshop examined the use of individual recognition studies in estimating population size and/or trends using capture-recapture techniques (Section 10.1). Strong emphasis was placed on the need to design specific estimating procedures for each particular set of circumstances; no single existing model can routinely be applied and statisticians should be involved in such studies at an early stage. There is a need to distinguish clearly between 'closed' and 'open' populations.

The estimation of survival rates (including juvenile survival) and reproductive parameters (such as age at first reproduction, calving interval and reproductive rate) were also addressed in some detail.

The Committee commented favourably on the Workshop and its outcome. In considering the eight Workshop recommendations that addressed matters of specific interest to the Commission (six of which sought IWC funding) the Committee agreed that a Working Group should review the recommendations and determine whether they were appropriate for discussion under the heading of the Comprehensive Assessment or by other sub-committees. The Committee endorsed the conclusions of the Working Group as given in Annex J3.

These are discussed further under Item 6.6 and Item 14.

6.2.2 Feeding Ecology Workshop

The Committee noted that recommendations for holding a Workshop on the Feeding Ecology of Southern Baleen Whales have been made by the Committee since 1983. At its last annual meeting, the Committee had recommended that this Workshop be held jointly with CCAMLR, with an associated IWC budgetary contribution of £13,500 (*Rep. int. Whal. Commn* 38: 134). This recommendation was adopted by the Commission.

When this matter was then discussed by CCAMLR at its 1987 meeting, it was agreed by the CCAMLR Scientific Committee that further refinement of the terms of reference proposed in *Rep. int. Whal. Commn* 38: 134 was needed, and it recommended that a joint CCAMLR/IWC steering committee should meet to accomplish this. Two members of the CCAMLR Scientific Committee were nominated (Miller, Shimadzu) to serve on the joint steering committee and they were present in San Diego on 9–10 May.

Best, Harwood, Kirkwood and Lockyer represented the IWC Scientific Committee on the joint steering committee with the CCAMLR representatives, and this Committee met to develop revised terms of reference and plans for the Workshop. The report of this steering committee is given in Annex J4.

After discussion, the Committee endorsed the proposed objectives, terms of reference, workshop topics and pre-workshop tasks outlined in Appendix 4, and **recommends** that this joint workshop take place. It noted that no additional budgetary allocation was needed from the IWC, and that CCAMLR would consider the steering committee's proposals at its meeting in October 1988. Harwood was nominated as a co-convenor representing the IWC Scientific Committee.

6.3 Review reports of intersessional working groups

6.3.1 Analysis of catch curves

Horwood reported on the working group on catch-at-age data, established last year (*Rep. int. Whal. Commn* 38: 41), which had corresponded during the year (SC/40/O 5). In December 1987, the Scientific Committee met in Cambridge to review the Japanese Research Permit (Feasibility Study). Various documents presented at that meeting had addressed the question of information which can be obtained from catch-at-age-data (SC/D87/32, 34, 36, 37 and SC/40/O 1).

It was agreed that a contract study was not required to address the question, but several members agreed that a protocol should be adopted for the consistent evaluation of any proposed techniques. The report of the working group established to develop such a protocol is given in Annex J5. The Committee received the Report and agreed that the implementation of a final agreed protocol should be discussed at its next meeting if progress with the development of the techniques warrants this.

The Committee then discussed several papers addressing questions of what can be obtained from catch-at-age-data. SC/40/O 23 reports on simulations conducted to test a method (Tanaka, *Rep. int. Whal. Commn* 38: 140–2) which estimates the trend of age-dependent natural mortality. Simulations were conducted for two patterns of recruitment. In one, constant recruitment is assumed regardless of year and in the other, recruitment increased from 1940 to 1970 at a rate of 5% per year. Two sets for natural mortality at age (M_a), were assumed: M_a constant at 0.12 and M_a increasing linearly from 0.08 at age 10 by 0.008 per year. Sample size was assumed either to be 1,650 in year one and five, or 825 in year one, two, five and six. Simulations were conducted 100 times for each case and increasing trends of M_a were measured by the regression slope (b). Although the variability of the estimated b was large, it is likely that an increase of M_a as large as 0.008 per year is detectable. When a constant M_a was assumed, absolute values of b were generally small in comparison with 0.008. Changes in recruitment and past commercial catches had little effect on the estimated b value.

Horwood commented that the recruitment rate in the simulation reported in SC/40/O 23 ceases to increase in 1970 and its effect on the sampled age distributions (taken from 1986 and truncated at age 30) is negligible. In the subsequent estimation a value $\bar{R} = 0$ is imposed. It is thus best to regard the exercise as independent of the possible problems of estimating $\bar{R}$.

Horwood further indicated that the mathematics show that the estimated average mortality (a Heinke-like M) is weakly biassed as a function of $\bar{R}$ (providing $\bar{R}$ is constant) as reported last year (*Rep. int. Whal. Commn* 38: 141). Deviations of the age-specific rate from the average are independent of a constant value of $\bar{R}$. The simulation shows that under the assumptions of the simulation a linear trend in age-specific rates can be estimated. He further pointed out that the simulation assumes multinomial sampling above some age (1 or 10 years). For 'research' sampling (q=1, a>1), the CV on the linear slope, of M_a with a, is 40–60%, (with M_a increasing by 0.008/yr). The results imply that, for this sample strategy and this magnitude of increase in M_a, trends could be detected but with high CVs. The exercise is based on strong assumptions, as it assumes unbiassed sampling of the population, random selection at age, exact ageing, essentially a value of $\bar{R} = 0$ and constant, and a specific pattern of variation in assumed natural mortality with age.

Responding to the comments by Horwood, Sakuramoto and Tanaka conducted further simulations for the case where recruitment increased up to the present at 5% per year (Annex J6). They stated that these showed that the effect of increasing recruitment is negligible.

A Bayesian cohort model for analysing catch-at-age data was presented in SC/40/O 25. The model assumes the usual form of population dynamics equations. It also assumes that catches are unselective with respect to age, and that they are small compared with the population size. Sampling variability in catch-at-age is assumed to have a lognormal distribution. The procedure uses prior information on the approximate level of fishing effort in each year. In the case of research catches, the level of effort is approximately known. Therefore, the number of whales taken in the research is expected to be proportional to population size.

Some members felt that this was generally a promising method for estimating natural mortality rate and recruitment but various concerns were expressed. These concerns included: (1) the prior assumptions essentially represent prior knowledge of the parameters of interest which is not enhanced by the age data; (2) that the prior assumptions would lead to estimates with reduced trends (although deterministic results do not show this property, it is not clear that this would be robust to the effects of sampling variability); and (3) that variability in catch and effort data is likely to lead to poor precision in any estimates. It was agreed that the next step should include incorporation of variability in the parameters of the model and that both deterministic and stochastic estimation be tested relative to the agreed protocol.

SC/40/O 1 examined the extent to which a time series of catch-at-age data could be used to calculate age-dependent natural mortality rates, recruitment rates and trends in population size for the case where samples can be collected free of the effects of age-specific selectivity. The analysis considered that population age distributions are known without error. The analyses, as do those in SC/D87/32 and SC/40/O 25, indicate that without prior information it is not possible to estimate a time series of recruitment rates and age-dependent mortality rates from catch-at-age data. It was also demonstrated that estimates of age-specific mortality and net recruitment rates were very sensitive to errors in the prior assumptions.

Butterworth (Annex J7) argued that it might be possible to assess recruitment trends adequately from catch-at-age data augmented by information that did not necessarily include relative abundance time series, and correspondingly that age-structure data may improve or extend recruitment trend estimates based on relative abundance time series. The presence of nonlinear effects in the analysis of age-structure data meant that Tanaka's method (*Rep. int. Whal. Commn* 38: 140–2) of estimating R was not necessarily undetermined. Arguments and calculations in SC/D87/32 and 34 suggested that continuing catch-at-age data from Southern Hemisphere minke whales might enable the effects of recruitment trends and age-specific natural mortality to be distinguished, as the latter effect could reasonably be assumed to be time invariant, while the former might not be so. He commented that stochastic simulations were necessary to determine the time periods and data sample sizes required to be able to estimate adequately the effects in question.

6.3.2 Management procedures

The Workshop on Management Procedures (*Rep. int. Whal. Commn* 38: 163–70) had elaborated a standard protocol for first stage simulation testing of management procedures. Four papers were presented which contained results for some or all of the tests on several potential management procedures. In SC/40/O 19, the standard screening protocol was applied to a management procedure based on explicit feedback principles. The procedure adjusts catch limits according to whether the estimate of stock depletion is above or below a specified target level. Although it is difficult to draw concise conclusions, the results indicate that the procedure is quite successful at maintaining stocks at, or restoring them to, a level above a protection level. The author made suggestions for further development of the procedure.

Sakuramoto commented that the simulations in SC/40/O 19 were based on estimates using the standard baleen whale model and that the results may change if other population models are assumed. De la Mare responded that tests were conducted for data corresponding to different MSY levels to that assumed by the estimation procedure, which is similar to testing the management procedure on alternative population models.

SC/40/O 24 reported on a simulation study to test the approach of Sakuramoto and Tanaka (SC/38/O 10). The information needed to apply the management procedure is the index of abundance, one sighting survey before the whaling commences, and the age at sexual maturity. Information about the reproduction curve, such as MSY or MSYL, was not used. In no cases investigated did the procedure lead to extinction.

Butterworth reported that SC/40/O 26 was an investigation of an extension to the procedure of SC/39/O 17. The basic algorithm in SC/40/O 17 is replaced by one fitting a population model to time series data, in years in which this model fit to the data satisfies specified consistency criteria. The primary initial purpose of the work was to determine if a simple approximate estimator for the population model performed adequately, because, if so, considerable computer time could be saved in conducting the simulation tests required. The management procedure proposed in conjunction with this estimator was incompletely developed at this stage; difficulties had been encountered for the case of a depleted resource with no relative abundance information available for the period over which the depletion took place.

SC/40/O 40 reported on the results of simulation trials on a modification of the management procedure of Cooke (SC/A86/CA9). The procedure appears to be effective at avoiding excessive depletion of any stock.

A Working Group was established to consider how to proceed with the further evaluation of management procedures. Its report is given in Annex J8. The Committee accepted the report and **recommends** that the Workshop described therein be held (see Item 6.6).

As it did last year (*Rep. int. Whal. Commn* 38: 40), the Committee also **recommends** that a discretionary fund of £5,000 be provided for 1988/89 to which Scientific Committee members carrying out further development of management procedures may apply (maximum of £1,000 per member/group of members).

6.3.3 Biological parameters

Last year the Committee established a correspondence working group that was to develop appropriate terms of reference to review biological parameters and their changes over time. Ohsumi reported that the group had not corresponded over the past year. No additional work was proposed but the Committee believed that this topic was an important one which needed consideration at next year's Annual Meeting.

The Committee also had available to it SC/40/Ba1 that presented an analysis of BIWS pregnancy rate data on Southern Hemisphere fin whales. The author (who was not present) concluded that the most significant factors explaining the variation in the relationship between the proportion of females pregnant and their length were expedition and season. He further concluded that there had been a significant increase over season in maximal pregnancy rate and a corresponding decrease in length at which pregnancy rate is half the maximum rate. These latter conclusions were at variance with the conclusion of an earlier analysis of these data (*Rep. int. Whal. Commn* special issue 6: 401- 410).

In discussion of the analysis and conclusions drawn in SC/40/Ba1, a number of points were made, including (i) while nation and season had also emerged in earlier analyses as significant factors, so had month, whereas surprisingly it had not been found significant in SC/40/Ba1; (ii) in the presence of a strong expeditions effect, it is very difficult to draw reliable conclusions on true seasonal trends in pregnancy rate; (iii) data from biological samples do not support a decline in mean length at sexual maturity; (iv) in any case, because of inconsistent reporting, the BIWS foetus data are unreliable.

On the basis of these comments, the Committee concluded that the BIWS pregnancy rate data were sufficiently flawed (and see SC/40/O 20) that further analyses were not called for. Further description of the analyses in SC/40/Ba1 and more detailed comments on the paper are given in Annex J12.

6.4 Other studies

6.4.1 Sighting surveys

All sub-committees noted that data from sighting surveys were becoming an important, if not the most important, aspect of the assessments that their groups were conducting. Special attention was drawn to the continued development of the Southern Hemisphere IDCR survey, which Japan has indicated a willingness to continue this next season, and the work of the international North Atlantic Sighting Survey (NASS-87).

The Southern Hemisphere minke whale assessment cruise is discussed further in Annex K. It was noted that NASS-87 provided the first ever estimates of abundance for some North Atlantic stocks, and the Committee believed that continuing these surveys would greatly improve the assessments of important stocks. Several separate studies were planned for the present year (Annex E) and a second international survey in the North Atlantic is planned for 1989. The value of timely planning for the 1989 survey was recognised, and informal discussions began at the present meeting. Such planning is particularly important as suitable procedures for surveys in the North Atlantic are still being developed, and several specific problems identified in the presently available data need to be addressed.

The Committee agreed to repeat its **recommendation** of previous years calling for the continuation of monitoring studies including the Antarctic IDCR cruises, the North Atlantic surveys, and surveys of the eastern North Pacific gray whales, the South African right whales and the Bering Sea bowhead whales. The Committee noted that information from the gray and right whale surveys will be important to its consideration of maximum sustainable yield rate (Item 6.4.4).

In this connection, and in view of the recommendation in SC/40/Rep1 that high priority be given to providing one-year only bridging funding to monitoring studies where the absence of one year of data in a series seriously limits the value, the Committee strongly **recommends** that SC/40/RP11, to continue right whale aerial surveys off South Africa, be funded (and see Annex G).

In the light of SC/40/O 41, the Committee discussed the utilisation of the results of sighting surveys, including the need to evaluate how to utilise data that cover only a portion of a stock, and to what degree densities can be extrapolated from other areas, and objective criteria for deciding when surveys could not be used to estimate abundance. The importance for identifying the intended use of sighting survey data during the planning stage, and for identifying how various logistic and related problems would be handled in advance, was noted. Some members noted that some of the survey data that the Committee had used had been collected incidentally during cruises for other purposes, such as fish distribution and abundance, and that such results may be difficult to interpret, especially for estimating absolute abundance. The Committee agreed that this subject should be considered further next year.

6.4.2 Telemetry and remote sensing

The report of a working group established to discuss telemetry and remote sensing is given as Annex J9. Discussions focussed on the application of this field of work to determining aspects of the assessment of large whale stocks. While recognising the role of photogrammetry and satellite imagery, the working group considered that radio telemetry would provide information of more direct value to the Committee, in particular, by establishing stock identity and stock boundaries. 'Conventional' telemetry, using VHF or HF transmitters has been successfully utilised by cetacean biologists for many years but it has significant restrictions, particularly in the relatively short range of its output. However, 'satellite' telemetry, whereby signals are relayed via Earth orbiting satellites, provides excellent potential for gaining long-term data from free-swimming whales.

The Committee considered the causes of earlier problems in the application of radio telemetry to whales and determined several ways in which these problems are being, or can be, overcome. As the availability of this technology improves, three areas need to receive more attention to ensure optimal use of the technology in addressing concerns of the IWC: (i) investigators need increased interactions through regular meetings to maximise speed of development of technological aspects; (ii) proposals for telemetry studies would benefit from increased peer review; (iii) approaches for efficiently analyzing the large amount of data that can be obtained and for designing studies need to be developed, perhaps using data from the successful studies to date.

The Committee **recommends** that the Commission request the Secretary to write to Service Argos, NOAA and NASA urging them to implement the concept of a dual beam interferometer on future satellites to provide locations from single messages.

The Committee also **recommends** that the Commission urges member governments provide adequate funding to allow the development and use of telemetry to progress rapidly, and further **recommends** that such funding be of several years continuous duration in recognition of the fact that although considerable development work has been undertaken, the benefit of this will be lost if these projects are not continued to completion. The Committee noted that telemetry, particularly using satellite-linked transmitters, provides and will increasingly provide valuable information of use in the assessment of the status of whale stocks in relation to management.

6.4.3 Follow up to CPUE Workshop

Last year the Committee agreed that as part of its programme for the Comprehensive Assessment of whale stocks, the CPUE series for the North Atlantic minke whale fisheries warranted detailed examination of the kind outlined in SC/39/Rep2. It had recommended, and the Commission agreed to request, that those nations who have exploited minke whales in the North Atlantic (i.e. Norway, Iceland, Denmark (Greenland) and a non-member nation, Canada) should supply a detailed description of the methods and strategy of these operations (*Rep. int. Whal. Commn* 38: 39)

The Secretary therefore wrote to those countries in September 1987, asking if they could provide the information in sufficient time for it to be circulated to interested members of the Scientific Committee for analysis and evaluation at the May 1988 meeting of the Committee.

Norway replied that a partial description of its minke whaling operations has already been provided. It would attempt to provide a further response in the spring, but owing to the pressure of time this might still only be provisional.

Iceland responded that its coastal fishery was described in *Rep. int. Whal. Commn* 32: 287–95. This paper includes an account of the history of exploitation of minke whales in Icelandic waters (up to and including the 1980 season); vessel types and catch equipment used; processing; catch regulations; estimated and recorded catches; distribution of catches and the CPUE relationship. Updating of CPUE series has been presented annually in the Icelandic progress reports. However, it is clear that much of the information described in SC/39/Rep2 will never be available for this fishery or will require substantial efforts. Such a study might be conducted in the near future, but in the light of the promising results of aerial sightings surveys in the area in the recent two years, this will probably not be regarded as a task of high priority.

SC/40/Mi22 discussed the strategy of the Norwegian small-type whaling vessel operating off West Greenland from 1979–85 (and see Annex E, Item 6.4.2).

During the meeting, a paper from Canada was received describing the Canadian east coast minke whale fishery (SC/40/Mi25).

The Committee welcomed these replies to its request.

The Committee agreed that, at this stage, reanalysis of existing CPUE data was not a high priority. However, because CPUE data are the only historical abundance data available for some stocks the Committee again identified three potential areas of future work for 'stocks' identified as having high priority in terms of the Comprehensive Assessment. These areas include:

(1) obtaining detailed operational information;
(2) use these data to develop models of the CPUE/abundance relationship;
(3) develop models to determine the effects of whale movement.

Øritsland noted that CPUE studies were given a lower priority in the Norwegian national program for minke whale research (SC/40/Mi7) because the many problems in quantifying factors affecting CPUE would limit the utility of such indices in an overall effort to establish acceptable estimates of current stock size and recent trends. Allowance has been made, however, for future studies of the properties of CPUE indices within the framework of the program.

Øritsland indicated that in general the description given in SC/40/Mi22 would also apply to offshore Norwegian small-type whaling in other areas of the North Atlantic but would not be valid for coastal whaling in nearshore or inshore waters along the coast of the Norwegian mainland.

6.4.4 Estimating maximum sustainable yield rate

Butterworth (Annex J10) considered the question of MSY % (maximum sustainable yield rate, i.e. the ratio of MSY to MSYL expressed as a percentage, where MSYL is the population size at which MSY is achieved – SC/39/Rep3) and suggested that: (1) sources of existing estimates (or opinions) should be listed; (2) the methods and assumptions used in reaching these estimates should be critically reviewed; and (3) future research priorities, particularly as regards the development of absolute or relative abundance time-series from direct surveys, should be specified.

The Committee agreed that this problem warrants more study and that papers dealing with this should be prepared for the next Annual Meeting. Butterworth presented some suggestions in this regard which are detailed in Annex J10 addendum. The Committee agreed that (1) existing data sets should be examined and reanalysed; (2) consideration be given to the design for collecting adequate data and the procedures for analysing them; and (3) the justification for interspecific and inter-stock comparisons should be examined.

6.5 Data inventories and coding

Donovan reported on the current status of replies to the data inventories (Table 1). Members noted with appreciation that most of the countries had now responded. However, several members identified potentially useful data that existed in some of the countries that had not yet responded (e.g. Chile, Peru, New Zealand, the Netherlands). The Committee **recommends** that the countries holding such data be further encouraged to respond. The Committee noted that the inventories were being coded so that they could be made available on floppy disc to interested members of the Committee.

Table 1

Summary of data inventory replies to date. Key: x = information supplied; – = no information available. A space signifies that these data may be submitted later.

	Data						
Country/ Notes	Catch	Effort	Age	Sight- ings	Natural marking	Artificial marking	Repro- ductive
Argentina Not yet complete			x				x
Australia Almost complete	x	x	x	x	x	x	x
Brazil Complete	x	x	–	x	–	–	–
Canada Not yet complete	x		x	x			x
Denmark (Greenland) Complete	x	x	x	x	x	x	x
Ireland No data							
Iceland Complete	x	x	x	x	x	x	x
Japan Complete	x	x	x	x	x	x	x
Republic of Korea Not yet complete	x						
Mexico Complete	–	–	–	x	x	–	–
Norway Complete?	x	x	x	x	–	x	x
South Africa Complete	x	x	x	x	x	x	x
Spain Complete	x	x	x	x	–	x	x
USSR Complete	x	x	x	x	–	x	x
UK Complete	x	x	x	x	–	x	x
USA Complete	x	x	x	x	x	x	x

6.6 Future work

6.6.1 Priority groups/stocks and studies

As last year, the Committee recognises that one of the major problems it faces is the question of stock identity. Therefore, in most cases priorities must be considered in terms of broad population/regions rather than stocks. Exceptions to this include the eastern North Pacific stock of gray whales and the Bering-Chukchi-Beaufort Seas stock of bowhead whales. Following its comments of last year, the Committee agreed that from a scientific viewpoint priority should be assigned to the following categories:

(a) those for which substantial work is underway i.e. Southern Hemisphere minke whales; North Atlantic minke, fin and sei whales; North Pacific Bryde's and minke whales;

(b) those which have been protected from commercial whaling for some period and which are now showing varying degrees of recovery i.e. eastern North Pacific stock of gray whales and the Bering-Chukchi-Beaufort seas stock of bowhead whales noted above;

(c) those other fully protected stocks for which considerable data bases exist, the study of which will help to resolve general methodological problems and improve our knowledge of whale population dynamics, e.g. some stocks of right and humpback whales.

After a request from the Committee last year, the Technical Committee indicated that it believed that 'the Scientific Committee should give priority to those stocks on which there was substantial whaling activity before the moratorium, and where much information has been accumulated and substantial scientific work is underway.' The Committee recognised that this is similar to its category (a) above.

The Committee also noted that it must carry out a Comprehensive Assessment of stocks subject to aboriginal subsistence whaling (Schedule Para 13(a)(3)).

It was agreed that, before 1990, the Eastern North Pacific gray whales should be the subject of an assessment in greater breadth and depth than is usually possible at an annual meeting (Annex G), for the following reasons:

(i) there is no problem with stock identity;
(ii) it falls into category (b) above;
(iii) it is subject to aboriginal/subsistence whaling.

Braham indicated that the US National Marine Mammal Laboratory was attempting to synthesise and provide relevant information to assist the Committee in conducting an assessment of gray whales by 1990 under the Comprehensive Assessment.

As agreed at the planning meeting for the Comprehensive Assessment (*Rep. int. Whal. Commn* 37: 152), the Committee reiterates that priority studies are those which address methodological problems common to a number of stocks or specific problems which arise in the Comprehensive Assessment of particular priority populations/regions as noted above. Addressing either of these may require analysis of data from populations/regions not given priority above. The Committee again notes the importance of the development of management procedures which take into account uncertainty in stock identity and population parameters (*Rep. int. Whal. Commn* 38: 40).

These priorities are reflected in the Committee's funding priorities noted under Item 14, and in its workplan for 1988/89.

6.6.2 Work plan for 1988/89 and 6.6.3 Preliminary workplan for 1989/90

During the discussion of Item 6 above, the Committee has made several recommendations for work to be carried out in the coming year. The Committee's views of how it should consider Comprehensive Assessment matters at next year's Annual Meeting are given under Item 15.

7.1 Southern Hemisphere minke whale stocks (see also Annex D)

The Committee concentrated on providing assessments of the minke whale stocks in the Southern Hemisphere using a consistent procedure with the data collected on IWC/IDCR cruises conducted between 1978/79 and 1986/87. For those Areas which had been surveyed twice, it developed adjustment factors to make the two sets of results more comparable.

7.1.1 Estimates of stock size and abundance from sightings

Until the 1984/85 sightings cruise, all surveys had been carried out in Closing Mode (where the survey vessel closes with each school of whales that it detects in order to determine the species, the school size and the percentage of takeable animals). From 1984/85 onwards, surveys had been conducted both in Closing Mode and in Passing Mode (where the vessel does not close with the schools it sights, but their species composition and size are estimated by the observers) because the Committee had identified a number of problems with the analysis of Closing Mode data which it hoped could be overcome by surveying in Passing Mode. From 1985/86 onwards, observations had also been made by an independent observer (the IO) who collected information independently from the top men in the barrel. The IO's observations can be used to attempt estimation of g(0), the proportion of whales on the trackline which are actually seen by the observers in the barrel.

The Committee agreed that the best estimates of school density for Southern Hemisphere minke whales came from Passing Mode surveys with an IO. No IO had been present on the 1984/85 cruise and it was agreed to use a pooled value from the Passing Mode and Closing Mode surveys as the best estimate of abundance from this cruise. It was also agreed to calculate estimates of abundance based on Closing Mode results for all surveys so that results from repeat surveys in the same Area could be compared.

Last year the Committee had developed an agreed protocol for analysing the data from all of the IWC/IDCR cruises conducted up to 1986/87, but it had not had time to complete the necessary calculations for all of the cruise results. That process was completed at this meeting.

Appropriate hazard rate functions had been fitted to data from all of the cruises up to 1983/84 last year. The same methodology has since been applied to the data from the 1984/85, 1985/86 and 1986/87 cruises. In the case of the surveys conducted in Closing Mode in 1986/87, so few schools had been sighted in some strata that it was necessary to pool results to obtain a satisfactory fit. It was agreed to pool all transects from the 'near ice' strata of Area II, and to do the same for all transects in the 'far ice' strata.

The analyses described above provide an estimate of the density of whale *schools* in each stratum. To obtain an estimate of the density of *whales*, it is necessary to multiply these density estimates by an estimate of mean school size. Last year it had been agreed to estimate school size in each stratum by reanalysing the distribution of perpendicular distances to sightings obtained in Closing Mode using sightings of whales rather than schools. School size is then estimated by dividing the density estimate based on whales by that based on schools. The protocol for doing this is described in *Rep. int. Whal. Commn* 38: 84. Only results from Closing Mode surveys were used in this analysis because school size tends to be underestimated in Passing Mode. Mean school sizes were estimated for all of the surveys up to 1986/87 at this meeting. The Committee noted that the variances that had been calculated for these estimates were approximate and it **recommends** further work to develop a more accurate estimator.

Last year the Committee had agreed on a suitable stratification of the data from all cruises. However, in the time available it had been unable to carry out the stratification procedure agreed upon for Area IV. Since that meeting the data had been reanalysed using the agreed statification and the results of this analysis were reported in SC/40/Mi14.

The Committee noted that the cruises from 1984/85 onwards had been designed with a view to applying the variable coverage probability analysis described in SC/37/Mi21. It therefore **recommends** that a computer program to implement this method should be added to the existing suite of IDCR programs by the Secretariat's computing staff with the assistance of the author of SC/37/Mi21.

Estimates of density from line transect data have to be corrected for deviations from the assumption that all whales, or schools, on the track line are seen. Over the course of the IDCR cruises a number of experiments have been conducted in an attempt to estimate g(0). SC/40/Mi 20 described two different procedures for estimating g(0) from data collected on the 1985/86 and 1986/87 cruises. Neither method provided a satisfactory description of the observed distribution of duplicate sightings (schools which were seen both by the IO and the barrel). The Committee considered a number of hypotheses which would have explained the fact that more duplicates than expected were seen at some distance from the vessel and fewer than expected were seen close to it, but was unable to evaluate the relative merits of these different hypotheses in the time available.

The Committee recognised the advances that had been made in the analysis of these data in the past year. However, further analysis of the data was clearly necessary. The Committee therefore **recommends** that more work be carried out on the identification of duplicates in the parallel ship experiments and on the theoretical basis for the estimation of g(0) from the independent observer data. A satisfactory expression for the variance of the estimate of g(0) would also be required. In addition, it noted that, ultimately, estimates of g(0) were required which were appropriate for the surveys carried out in Closing Mode only until 1984/85.

In the absence of an agreed estimate for g(0) for the recent cruises, it was decided to continue using a value of 1.0 for g(0) and the correction factor h.

The Committee had no new information on the effects of whale movement (m) and of the percentage of takeable animals (t). It agreed to continue to use a value of 0.985 for the correction factor m, and of 0.658 for t. Some members considered that 'percent takeable' was irrelevant for stock estimation in Southern Hemisphere minke whales because, in general, there has been no legal size limit for these stocks. The Committee therefore agreed to calculate estimates of total stock size as well as of takeable stock. It noted that a considerable amount of information on the proportion of animals that were classified as takeable in each sub-Area had accumulated since it had decided to use a single value for this parameter in all Areas. It therefore **recommends** that the data on the proportion of takeable animals and on estimated size should be reanalysed in time for its next meeting to determine whether any changes in this correction factor were required.

7.1.2 Population estimates

The agreed best estimates from each survey are shown in Table 2.

These estimates apply only to that part of each Area (in general, approximately 60% of the area south of 60°S) which had been surveyed.

The results from the repeat surveys in Areas II, IVW and V shown above are not strictly comparable because different survey methods were used in each survey. Even if results from Closing Mode surveys only are used, there is a problem that different parts of each Area were surveyed in different years. In particular, vessels usually surveyed further north in the second survey in each Area. The results can be made more comparable by adjusting the

Table 2

Best estimates of Southern Hemisphere minke whale population sizes. 'Pooled' survey mode = pooled closing + passing without IO.

			Total		Takeable	
Area	Year	Survey mode	Population	CV	Population	CV
I	1982/83	Closing	55,050	0.203	36,223	0.206
II	1981/82	Closing	37,306	0.213	24,547	0.216
	1986/87	Passing	121,549	0.285	79,979	0.288
III	1979/80	Closing	61,272	0.188	40,317	0.191
IV	1978/79	Closing	72,357	0.156	47,611	0.160
IVW*	1984/85	Pooled	19,980	0.181	13,147	0.185
V	1980/81	Closing	133,382	0.216	87,765	0.219
	1985/88	Passing	303,284	0.172	199,520	0.176
VI	1983/84	Closing	80,283	0.232	52,826	0.235

* = 70°-100°E

Table 3

Comparison of results for surveys in the same Areas in different years (see text). P = probability that difference is due to chance.

Area	Year	Total population	CV	P
II	1981/82	37,306	0.213	0.020
	1986/87	71,973	0.206	
IVW (70–100°E)	1978/79	33,983	0.198	0.045
	1984/85	18,484	0.215	
V	1980/81	133,382	0.216	0.517
	1985/86	160,256	0.186	

estimates to take account of this difference in area coverage. The resulting set of comparable results is shown in Table 3.

The Committee noted that there were significant differences between the two sets of estimates for Area IVW and for Area II. In the case of Area IVW, different vessels had been used in the two surveys and there was evidence (SC/40/Mi20) that the distribution of sightings from these vessels was different. In addition, the timing of the two cruises had been different, with Area IVW being surveyed in the first half of the cruise in 1978/79 and in the second half of 1984/85. The Committee also noted that large concentrations of whales were seen in Prydz Bay in 1978/79 but few whales were seen there in 1984/85. It was suggested that some of the difference may have been due to changes in the distribution of krill swarms in Area IV.

In the case of Area II, the ice edge had extended so far north in 1986/87 that the most southerly stratum surveyed between 40°W and 20°W was north of the most northerly stratum surveyed in 1981/82. The Committee had adopted an *ad hoc* measure to correct this.

The Committee recognised that there were problems with the somewhat arbitrary procedures it had adopted to make the results from repeat surveys in the same Area more comparable. It **recommends** further work on the development of procedures for comparing estimates of abundance obtained in the same Area in different years.

7.1.3 Description of differences from previous assessments

The estimates given above differ from those provided in 1987 in that the stratification procedure agreed last year has now been applied to the surveys carried out in Area IV, and estimates from the surveys of Area V in 1985/86 and of Area II in 1986/87 have been provided.

7.1.4 Other sightings techniques

During the 1986/87 IWC/IDCR cruise, observers on one vessel (the SM2) had carried out the cue counting procedure on all transects conducted in Passing Mode (SC/40/Mi4). On some transects an IO had also collected cue counting data. From this information it was possible to calculate the density of whales in the area surveyed by SM2 in a manner analogous to that used with the line transect data. However, in this case it was also possible to estimate q(0), the probability that a cue is seen close to the vessel, which is analogous to g(0). The density estimate using a value of 0.717 for q(0) is 0.162 whales/n.miles^2. The equivalent value from line transect data collected in passing mode on the same vessel is 0.205 whales/n.miles^2.

The Committee recognised that cue counting had now been used on three IWC/IDCR cruises and had provided density estimates which could usefully be compared with those from conventional line transect analysis. In addition, the technique avoided some of the problems that made the analysis of line transect data for large whales difficult. It therefore **recommends** that consideration should be given to carrying out cue counting and line transect sampling simultaneously on one of the vessels in any future IWC/IDCR Southern Hemisphere sightings cruise. It also **recommends** that blow rate information should be collected at regular intervals during such a survey.

7.1.5 Reports on IWC/IDCR Cruises

SC/40/O 16 provided a compendium of the results from the ten years of data which had been collected on the Southern Hemisphere IWC/IDCR sightings cruises. The Committee congratulated the authors on producing a valuable report and noted that it would undoubtedly prove extremely useful to any other organisation that was planning sightings cruises of this general nature. It also noted that SC/40/O 16 did not provide any description of the methods which had been used for analysis of the data and of the theoretical rationale behind the many experiments which had been conducted on these cruises. It **recommends** that a complementary review along these lines should be prepared in time for its next meeting, and suggested that consideration should be given to preparing a Special Issue on the Southern Hemisphere cruises which would include both reviews.

The Government of Japan had indicated that it intended to make two vessels available for a further cruise in 1988/89. The Committee welcomed this generous offer and **recommends** that such a cruise should take place (see Item 12.2). It also **recommends** that some of the experimental data collected on the 1987/88 cruise should be analysed in time for the planning meeting for the 1988/89 cruise (detailed in Annex D).

7.1.6 Mark-recapture analysis

Buckland reported on the results of a reanalysis of the mark-recovery data for Southern Hemisphere minke whales which he had conducted under contract to the IWC (SC/40/Mi6). A number of mark-recapture models were used to provide estimates of abundance and survival. The major potential sources of bias in the estimates are likely to lead to overestimation of abundance and underestimation of survival. These biases can be corrected for if there is information on rates of mark shedding, marking mortality, geographical variation in the probability that a whale is taken, discovery and reporting rates for marks, mis-reporting of the numbers effectively marked, and inadvertent and unrecorded double-marking. There were too few recoveries to yield meaningful estimates of abundance for Areas I, II and VI, but estimates were obtained for the remaining three Areas both separately and combined. The total stock size in the combined Areas III+IV+V was estimated to be 400,000 to 450,000. Annual survival was estimated to be between 0.902 and 0.933. Little evidence was found for long-term mark shedding.

The Committee welcomed this thorough analysis of a difficult data set. In discussion it was noted that the variances of the estimates of abundance were undoubtedly underestimated because of heterogeneity in the probability of marking and recapture. Some simulation work had indicated that the methods used might be robust to these effects if a number of areas were pooled, the Committee therefore **recommends** an analysis of the effect of these heterogeneities on mark-recapture estimates. Such analyses might be used in the future in interpreting the results of studies based on individual recognition or biopsy dart sampling.

The Committee discussed at some length the usefulness of mark-recapture experiments based on Discovery tagging for estimating abundance. Some members considered that the method was flawed because estimates were subject to an unquantifiable bias if there was substantial short-term mark shedding or marking-related mortality. In addition, they noted that the available variance estimates were unreliable.

Studies of captive animals (Geraci and St Aubin, 1986) have indicated that metal objects inserted into the flesh of dolphins tend to be rapidly ejected if any part protrudes into the blubber layer, whereas they are quickly encapsulated and retained if they are entirely within the muscle layer. The Committee recognised that data from the test firing of marks into whale carcasses on Japanese factory ships, and on mark site and wound condition in actual mark recoveries, might provide some insight into the level of short-term mark shedding and mortality. It therefore **recommends** that these data be examined to see if they can provide an insight into this difficult problem.

In conclusion, the Committee noted that many of the problems encountered in the analysis of the data from marking with Discovery-type marks could be overcome if biopsy darts were used to 'mark' whales using the DNA fingerprinting technique (see *Rep. int. Whal. Commn* 38: 138). However, if this marking was carried out in the absence of any commercial catch, sample sizes of at least 500 whales marked per season in each Area would be necessary to obtain reliable estimates of abundance and survival.

7.1.7 Potential of individual recognition methods

The Committee noted that the report of the Workshop on Individual Recognition (SC/40/Rep1) had recommended that 'in the event of a further IWC/IDCR minke whale assessment cruise, the equivalent of 1–2 days work under good conditions be allocated to photo-identification of minke whales, as a feasibility study.' The Committee had reservations about the usefulness of the technique for estimating the abundance of Southern Hemisphere minke whales because of the large sample sizes which would be required (see SC/40/Rep1, Annex D). It was also concerned about dedicating two of the small number of days of good conditions usually encountered on the IWC/IDCR cruises to this experiment. Joyce indicated that he intended to coordinate an analysis of a collection of photographs of minke whales which had been collected on the IWC/IDCR cruises to determine whether Southern Hemisphere animals could be recognised individually. Persons experienced in identifying individual minke whales will be involved. The Committee **recommends** that this analysis should be carried out before any time is dedicated to this activity on an IWC/IDCR cruise. It noted that there were a large number of photographs of minke whales taken on board Japanese factory ships. It considered that it would be very useful if these could also be made available for this analysis.

The Committee also noted that the photo-identification technique would be particularly appropriate for a study of minke whales off the coast of Brazil, where animals are found within a well-defined area (*Rep. int. Whal. Commn* 33: 419–427; SC/40/ProgRep Brazil). A study in this region could provide extremely useful information on biological parameters, in particular on calving intervals. The Committee **recommends** that a shipboard survey along these lines should be carried out off the coast of Brazil.

7.2 North Atlantic minke whale stocks (see also Annex E)

Stock identity

The Committee had no new information to allow it to address the question of stock identity. It recognised, however, that this issue was of crucial importance, particularly with respect to the provision of management advice to the Commission on the status of West Greenland minke whales (see Item 7.2.3). The Committee **recommends** that genetic studies, as outlined in Annex J1, (see Item 7.2.3.4) and telemetry studies, as outlined in Annex J9, be initiated to try to resolve the question of stock identity.

North Atlantic Sightings Surveys

The Committee received several papers relating to the North Atlantic Sighting Survey which took place in the summer of 1987 (NASS-87). The objectives of NASS-87 were to investigate the distribution and estimate the abundance of the three primary target species; fin, minke and pilot whales. Shipboard surveys undertaken by Iceland, Norway, the Faroe Islands and Spain and aerial surveys undertaken by Iceland, Norway and Denmark searched a total of almost 30,000 n.miles on transect. Data from these surveys have been used in preliminary analyses to estimate numbers of minke whales in the North Atlantic.

The Committee recognised the large amount of work represented by the planning and execution of NASS-87 and by preliminary analyses of the data. It expressed appreciation to the scientists involved in the survey and to Iceland, Norway, Denmark, the Faroe Islands, Spain, the Nordic Council of Ministers, the USA, Japan and the UK for making the research possible, and it looked forward to the results of further analyses at next year's meeting.

The report of the joint post-cruise meeting of the 1987 North Atlantic Sightings Survey (SC/40/O 28) had recommended that the next coordinated international survey effort be postponed until 1989. The Committee welcomed the intentions of Norway, Iceland and Denmark to conduct another such survey at that time because of the importance of obtaining estimates of absolute abundance. It noted that the participation of the Faroe Islands and Spain had greatly increased the value of the 1987 survey and urged participation by these and other countries in 1989.

Recognising the importance of such surveys covering as wide an area as possible, the Committee **recommends** that the Commission instruct the Secretary to contact the government of Canada informing it of the survey planned for 1989 and requesting their cooperation and participation in this survey.

Table 4

Estimates of numbers of minke whales from the 1987 North Atlantic sightings survey

	Shipboard	Aerial
1. Northeastern stock		
Norwegian survey block A (part)	2,961 (0.287)	
Norwegian survey aerial part of block A	547 (0.287)	244 (0.517)
Norwegian survey block B1	5,787 (0.415)	
Norwegian survey block B2 (part)	2,098 (0.316)	
Norwegian survey block C1	2,625 (0.477)	
Norwegian survey block C2	-	
Norwegian survey Svalbard area	-	787 (0.451)
Faroese survey blocks 11-14	4,610 (0.220)	
Icelandic survey ship block 7	-	
2. Central stock		
Norwegian survey block A (part)	729 (0.287)	-
Norwegian survey block B2 (part)	2,393 (0.316)	-
Icelandic aerial area/ship blocks 1,2,10 form part of this area	6,456 (0.099)	8,645 (0.202)
Iceland survey ship blocks 3-6, 8, 9	7,717 (0.139)	
3. West Greenland stock		
Danish survey		1,153 (0.417)

Notes to the Table:

(1) Norwegian shipboard estimates have been recalculated by fitting a hazard rate model to unsmeared data truncated at 0.5 n.miles pooled over both closing and passing mode for all blocks. They have then been assigned to stock area as in SC/40/Mi9.

(2) Norwegian aerial estimates have been calculated from the total estimate given in SC/40/O 12, adjusted for a mean surfacing rate of 53/hr.

(3) Icelandic shipboard estimates are those presented in SC/40/O 30 multiplied by 1.39 to convert the effective search width from twice the median perpendicular distances to that for the negative exponential.

(4) Icelandic aerial estimate is that presented in SC/40/O 12 using the effective search area stratified by Beaufort, adjusted for a mean surfacing rate of 53/hr.

(5) Faroese shipboard estimates are as presented in SC/40/O 30.

(6) Danish aerial estimate has been calculated using the effective search area in SC/40/O 12, the number of cues and coverage probabilities from SC/40/O 11 and a mean surfacing rate of 53/hr.

(7) CVs for all aerial estimates include components for inter-transect and effective search area variability but not for variability in mean surfacing rate.

(8) CVs for Icelandic and Faroese shipboard estimates do not include components for variability in effective search width or mean school size.

7.2.1 Northeastern stock

7.2.1.1 Sightings estimates

The Committee examined estimates of abundance calculated from the Norwegian shipboard surveys (SC/40/Mi9). It noted the large apparent difference between the distributions of perpendicular distance collected during passing and closing mode. This difference was tested and found not to be significant for the data truncated at 0.5 n.miles; the data were pooled to estimate a single effective search width. There was no significant difference between the sighting rates in closing and passing modes and a single population estimate was calculated for each block using the pooled data. These estimates were accepted by the Committee as provisional estimates of the number of whales in each survey block. They are presented in Table 4.

This management area also includes the area covered by the Faroese ship survey, provisional results of which are presented in SC/40/O 30 and Table 4.

The Committee examined an analysis of the Norwegian aerial survey data (SC/40/O 12). The data were collected according to the cue counting method as described in SC/40/Mi4. This method calculates the density of cues (surfacings in the case of North Atlantic minke whales) seen in an effective search area estimated from the radial sightings distances. Density of cues is then divided by a mean surfacing rate. The method uses duplicate sightings of the same cue to check the accuracy of the radial distance estimates and to account for whales missed at zero radial distance. SC/40/O 12 presented a combined estimate of minke whales from both the aerial surveys in Norway. This figure was recalculated using a mean surfacing rate of 53 surfacings/hour (based on data presented in SC/40/Mi15 and SC/40/Mi23) for Svalbard and north Norway separately.

The Committee accepted these aerial estimates of the number of animals in these areas at the time of the survey. They are given in Table 4. Members noted that the density in the area west of Svalbard was considerably lower than the density from a shipboard survey conducted in 1985 in the same area (SC/37/Mi3).

The Committee agreed that a provisional estimate of total stock size was the sum of the estimates for each survey block from Table 4 using aerial estimates where available. This gives a figure of 19,112 (CV=0.163) animals. There was very little survey effort in the part of block B2 in the Northeastern stock management area (SC/40/Mi9). If block B2 is excluded, the estimate is 17,014 (CV=0.179) animals. These estimates are considered to be provisional because they are based largely on shipboard sightings surveys with a very low coverage and no indication of how many animals were missed on the transect line.

7.2.1.2 CPUE analyses

At last year's meeting the Committee recommended that new analyses be undertaken taking account of discussions at that meeting (*Rep. int. Whal. Commn* 38: 90). No new analyses were presented to the meeting. Further analyses of CPUE series using detailed information available from ship's logbooks might be undertaken as part of the Norwegian five year programme of research (SC/40/Mi7). It was noted that Norwegian catch data and effort data, insofar as they exist, for the period 1938–1986 had been lodged with the Secretariat as recommended last year (*Rep. int. Whal. Commn* 38: 91) and were thus available according to the normal rules of the Commission. Data on operational details had to be sought in deck-logbooks of individual ships. Øritsland reported that work on further analyses of CPUE series would receive a low priority in the Norwegian programme of research.

7.2.1.3 Stock assessment

The Committee agreed that it was important to try to assess this stock because the five year programme of research proposed by Norway involved a scientific take, although no indication had been given of when commercial whaling might resume.

However, several reasons for not attempting an assessment at this meeting were put forward: (i) the unresolved problems with CPUE series; (ii) no agreed basis for choosing a range of MSY percents; (iii) the provisional nature of the stock estimate; and (iv) the likelihood of a change in age at recruitment over the period of the catch. Although not all members agreed with all of these reasons, the Committee agreed not to attempt an assessment at this meeting.

7.2.1.4 Management advice

At last year's meeting (*Rep. int. Whal. Commn* 38: 45) some members believed that the assessment attempted showed that there was no basis for changing classification of the stock and that it should remain classified as a Protection Stock. Other members believed that there had been no basis for attempting an assessment and that there was consequently no basis for providing advice on the classification of the stock.

This year, in the absence of a new assessment, the Committee was unable to provide further advice on classification of the stock.

Horwood noted that if the stock size was about 20,000, as indicated above, then previous modelling (*Rep. int. Whal. Commn* 37: 103) showed that the stock was in the Protected category. Holt and de la Mare associated themselves with this view.

7.2.1.5 Norwegian programme to study and monitor Northeastern Atlantic minke whales, 1988–1992

Last year, the Committee discussed a provisional programme of research proposed by Norway (SC/39/O 11). This year, the Committee received SC/40/Mi7, a revised Norwegian programme to study and monitor Northeastern Atlantic minke whales, 1988–1992.

The revised proposal was much more broadly based than SC/39/0 11 both in the scope of the research and in the organisations involved. The objectives of the programme were to conduct research leading to identification of stocks, stock assessments and quantifying the role of the minke whale in the environment.

Those aspects of the programme related to the catches to be taken under Scientific Permit are discussed under Item 10.4.

The work planned for 1988 included a major sightings survey in the northeastern Atlantic using six ships, one of which would carry a helicopter. The duration of this survey was expected to be 5 weeks. The Committee noted that plans to develop methodology to estimate the proportion of whales missed on the transect line from shipboard surveys were included in SC/40/Mi7 and that such estimates could be applied to earlier survey results. It also noted that it was planned to cover some areas by ship and helicopter, and independent observer experiments could be attempted on a limited scale in high density areas. The Committee noted the importance of addressing the problems in estimating absolute abundance and it welcomed this survey as a valuable contribution towards this end.

7.2.2 Central stock

7.2.2.1 Sightings estimates

The Committee examined estimates of abundance calculated from the Icelandic shipboard surveys (SC/40/O 30) and discussed some of the sources of negative bias identified by the authors. Part of the searching effort had been conducted in weather conditions unsuitable for sighting minke whales, because the surveys were also for fin whales, although it should be possible to account for this in further analyses. The observers were used to searching out to the horizon for fin whales and may have missed minke whales on the transect line. No independent observer experiments to estimate the proportion of animals seen on the transect line had been planned because the personnel required could not be accommodated on the vessels.

The Committee recalculated the abundance estimates using a negative exponential model to estimate effective search width. These were accepted as provisional estimates because of the problems discussed above, and are given in Table 4.

SC/40/O 12 presented two abundance estimates for the Icelandic aerial survey. One was calculated using an unstratified effective search area, the other using an effective search area stratified by sea state. The Committee agreed to accept the preferred stratified estimate from the survey, using 53 surfacings/hour (see Item 7.2.1.1). This estimate is presented in Table 4.

The Committee accepted as a provisional estimate of stock size the sum of the aerial estimate and appropriate shipboard estimates from Table 4. This figure is 17,091 (CV=0.330), or 19,484 (CV=0.292) if the estimate for the Norwegian shipboard block B2 is included (see Item 7.2.1.1).

7.2.2.2 Stock assessment

Some members believed that a stock assessment should not be attempted at this year's meeting for similar reasons as stated for the Northeastern stock: the lack of an acceptable CPUE series and the lack of an agreed basis from which to choose an appropriate range of MSY percents.

Other members believed that an assessment should be attempted in light of the new estimates of abundance from NASS-87. The results of a simulation procedure using program HITTER (Annex L) are given in Table 5.

Table 5

Results of an assessment of the Central stock of minke whales (see text). Model parameter values: MSY level = 60%; Natural mortality rate = 0.1; Age at maturity = 6; Age at recruitment = 4; 1987 stock size = 17,091 (total stock aged 1 and over); No CPUE data.

MSY%	A	Total exploitable stock in 1941	Total exploitable stock in 1988	1988 stock size / 1941 stock size
1%	0.135	17,593	12,457	70.8%
2%	0.270	16,531	12,360	74.8%
3%	0.405	15,658	12,286	78.5%
4%	0.539	14,943	12,234	81.9%

7.2.2.3 Management advice

Those members who believed that an assessment should not be attempted at this meeting consequently also believed that no advice on classification of the stock could be given, and that the stock should remain unclassified.

Those members in favour of the assessment believed that the results of this simulation showed that the Central Stock, currently unclassified, should be classified as a Sustained Management Stock. Horwood also believed that the stock should be classified as a Sustained Management Stock for the reasons given in Annex E.

7.3 Other Baleen Whale Stocks (see also Annex F)

7.3.1 Western North Pacific Stock of Bryde's whales

Stock identity

A comparison of biological data obtained from catches of Bryde's whales taken by land-based fisheries off the Bonin Islands in 1981–87 with those taken off the Pacific coast of Japan in 1981–86 was presented (SC/40/Ba2). From differences in the mean length at sexual maturity of males and females and in length frequency distributions, it was suggested that different stocks might inhabit the coastal Kuroshio current area and the offshore Kuroshio counter–current area.

During discussions of this paper it was pointed out that a refined statistical analysis was needed to ascertain whether the differences found for age at maturity were statistically significant. Otherwise, it was thought that these findings would not necessarily provide evidence of stock separation. The Committee noted that biochemical analyses were under way which might provide definitive information on genetic differences between Bryde's whales in these two areas and looked forward to receiving these results.

Estimates of abundance

In response to last year's recommendation of the Scientific Committee, SC/40/Ba3 presented an analysis of the sightings data obtained from 1983 and 1984 summer cruises in the Western North Pacific which used the smearing technique and a hazard-rate model fitted to the perpendicular sighting distance distribution (*Rep. int. Whal. Commn* 38: 257–63). Correcting for animals missed along the trackline, for a divergence from the trackline in 1984 and for stock areas surveyed in earlier years, and then extrapolating to the unsurveyed area of the entire range of the stock, a total population estimate of 18,000 Bryde's whales was obtained. Survey data from 1985–87 were not used since these cruises were not targeted on Bryde's whales and hence covered only a small proportion of the total stock area.

Taking account of the generic problems regarding sightings estimates given in SC/40/O 41 and other observations arising during discussions, it was thought that the following problems were applicable to this estimate of abundance:

(i) the selection of particular years as a basis for estimating abundance from among a series of annual surveys may introduce bias; hence the selection of 1983 and 1984 may be problematical;
(ii) the 1983 and 1984 surveys failed to cover the entire stock area and biases may arise in selecting and combining data from previous surveys to estimate abundance for the areas missed;
(iii) some areas of the stock's summer distribution had never been surveyed and it was unclear as to whether or not the estimate for the surveyed areas should be extrapolated to these areas. Moreover, it was unclear what the boundaries were for the Bryde's whales' summer distribution and if and how they might vary with environmental variables such as sea surface temperature;
(iv) rather than obtaining a new estimate of the probability of missing animals along the trackline, the estimate obtained by Miyashita and Kasamatsu (*Rep. int. Whal. Commn* 35: 363–8) had been used.

Consequently, the Committee noted that, because of these problems, the sub-committee on Other Baleen Whales had not made use of this estimate for assessment purposes. It **recommends** that the following analyses addressing these and other problems be undertaken before the stock is next assessed:

(i) a re-analysis of all available sightings data by 5° squares as outlined in Appendix 2 of Annex F;
(ii) a synthesis of all information on the summer distribution of Bryde's whales to ascertain the appropriate range for stock estimates and future survey coverage. This should also examine the factors affecting inter-annual variability of distribution, such as sea surface temperature;

The Committee also **recommends** re-examination of the mark-recapture data with the view of obtaining an alternative estimate of abundance. It was noted that, since these data arose from the Japanese national research programme, a Japanese scientist would be responsible for this task.

Catch data

The Committee noted that Appendix 3 in Annex F provides an accepted, refined historical catch series for this stock and requested that they be entered into the IWC database.

7.3.2 Okhotsk Sea-West Pacific stock of minke whales

An analysis of size distribution, sexual maturity and apparent pregnancy rate based upon biological data collected from 1969–86 catches (SC/40/Mi17) showed marked latitudinal segregation, as has been the case for many other minke whale stocks.

In response to last year's recommendation of the Scientific Committee, SC/40/Mi16 presented abundance estimates based on sightings cruises from 1978–86. These estimates were considered preliminary only and the Committee **recommends** that further studies should include analysis by 5° squares, investigation of the results of seasonal trends in distribution, and examination of stratification boundaries. The Committee also requested that the range of future sightings surveys be expanded with the cooperation of the USSR and the USA, since much of the summer distribution of this stock occurs within the 200-mile EEZ of these two countries.

7.3.3 East Greenland-Iceland stock of fin whales

Biological parameters

Preliminary studies of reproductive data (SC/40/Ba12) found that there was stability in length at sexual maturity and suggested that changes in age at sexual maturity and in the proportion of the catch having a corpus luteum were correlated with environmental (and hence feeding) conditions. However, the Committee noted that, because of no specific presentation of quantitative data on environmental conditions, it was not possible to evaluate these suggestions at this meeting.

Given the lack of a significant trend with time, the Committee agreed that it would assume a constant age at sexual maturity for assessment purposes.

Sigurjónsson noted that SC/40/Ba8 showed that the apparent pregnancy rate in recent years had varied considerably, and this was to be studied further in relation to the energetic condition of the animals.

Estimates of abundance

SC/40/O 30 provided a line transect estimate of abundance of fin whales based upon sightings data obtained from Icelandic surveys undertaken during NASS-87. Upon discussing the estimate, it was noted that parts of some Icelandic survey blocks actually belonged to other stock areas and should be omitted. Taking account of these adjustments gave an estimate of 5,757 (CV = 0.132) fin whales in the Icelandic survey area. It was further noted that data from the Norwegian survey around Jan Mayen provided additional sightings of fin whales which could be included in the estimate for the East Greenland-Iceland stock area. The Norwegian sightings effort was not available at the meeting to estimate the abundance in this northern sector directly but a simple approximation yielded an estimate of 679 fin whales, for which the coefficient of variation could not be determined. Combining these two estimates gave an estimate of 6,436 for the stock area which was used for assessment purposes. However, the Committee regarded this to be a preliminary estimate of abundance and **recommends** that it be updated by undertaking an appropriate line transect analysis of the Norwegian sightings data.

Stock trajectories and stock assessment

SC/40/Ba4 provided an analysis of possible population trajectories from an initial 1883 stock size using the HITTER/FITTER computer program, which incorporates a Pella-Tomlinson stock recruitment function. The trajectories obtained were compared with a crude catch per boat series available for 1895–1915, and modern CPUE series for 1962–87. The authors concluded that if the MSY-rate was much lower than 7%, the early CPUE series overestimated the population decline and that the recent series underestimated it. They concluded that the possibility of the MSY rate for this stock being higher than 4% thus could not be ruled out.

Several members of the Committee pointed out that the outcome of this interpretation was largely dependent upon the admittedly crude early CPB series, together with the consequences of the variability in the modern series. They indicated that a thorough examination of this early series was needed, including a detailed description and analysis of the methods and strategy of the coastal whaling operation at that time, in accordance with the view agreed agreed by the Scientific Committee in receiving the report of its CPUE Workshop last year (*Rep. int. Whal. Commn* 38: 35). Until such an analysis was available and its sensitivity to variability in the modern series had been examined, they would be unable to accept these findings as being any more than qualitative speculations.

Magnusson responded that the whole point of the simulations was that, if the stock had collapsed, as was indicated by the CPB series, then the catches which were taken during the modern era could only have been possible if there had been a MSY rate greater than 4%. Several other scientists associated themselves with this view.

Holt and others observed that there was no way to discriminate the level to which the population had collapsed in the beginning of the century, and that such discrimination is critical to the evaluation being offered.

Butterworth and Magnusson pointed out that results in Appendix 4 of Annex F showed that the estimated stock trajectory and MSY-rate were hardly changed if the early CPB series (which indicated a stock collapse at the beginning of the century) was excluded from the analysis This suggested to them that acceptance or otherwise of this CPB series as an index of abundance was not critical to the stock trajectory evaluation offered.

The simulation program HITTER/FITTER was used to compute stock trajectories, given the agreed population estimate of 6,436, the catch series from 1883–1987 and a selection of CPUE series. Results of this assessment exercise were problematical, particularly in that the estimated MSY rate of 11–13% exceeded the gross recruitment rate values of 4–6% previously estimated from catch curves (*Rep. int. Whal. Commn* 33: 125). Some members of the Committee believed that the exercise indicated that either there were problems in using a Pella-Tomlinson stock-recruitment function, or there were problems with the CPUE series or that problems with both the function and the CPUE confounded the result. It was noted that the inclusion of the early CPUE series made little difference in the results.

Butterworth, Magnusson and Horwood commented that while they had separate reservations about the high estimates for MSY rate, the above simple comparison made to the gross recruitment rate estimates was inappropriate and did not allow immediate inferences to be drawn. This is because the population trajectories shown in Appendix 4 of Annex F indicated that the population was generally well above MSY level for the period to which the gross recruitment rate estimates applied, and accordingly the population simulation model would reflect a net recruitment rate considerably less than MSY rate over that period.

The Committee agreed that it would be inappropriate to utilise the assessment discussed by the sub-committee at this very preliminary stage of development. It **recommends** that more detailed simulation studies be carried out in relation to the stock-recruitment function, the CPUE series and the possible effects of environmental conditions on biological parameters. The Committee also requested that the results be presented with the calculated confidence bounds.

7.3.4 Iceland-Denmark Strait stock of sei whales

Estimate of abundance

SC/40/O 30 presented estimates of sei whale abundance arising from sightings obtained during the Icelandic portion of the 1987 North Atlantic sighting survey. The estimates were considered inappropriate for assessment purposes in that the survey had not attempted to cover the population's summer distribution. The Committee **recommends** that an estimate of abundance which is appropriate for assessment purposes be obtained by extending the survey area to cover as much as possible the population's summer distribution. The Committee noted the intention to take up this recommendation in planning the next survey, to be undertaken in 1989.

7.3.5 British Isles – Spain – Portugal stock of fin whales

Sightings of fin whales obtained during the Spanish component of NASS-87 (SC/40/Ba13) yielded a line transect estimate of exploitable population size of 4,127 with a total population size of 4,485 (95% CI: 3,369–5,600) for the area surveyed. The Committee suggested that the 1987 results be compared with previous population estimates, and to pool across years if possible. However, it was pointed out that the 1987 survey used a different cruise track design, and unlike previous years most of the sightings effort was conducted in passing mode.

8. PROTECTED SPECIES AND ABORIGINAL SUBSISTENCE WHALING

(see also Annex G)

8.1 Bering – Chukchi – Beaufort Seas stock of Bowhead whales

Recent catches

A total of 31 of the allowed strike quota of 32 were taken in 1987. By 2 May 1988, 18 had been taken of the 35 allowed for 1988.

Of the 22 whales landed in 1987, 45% were over 13m in length. The mean length of the catch was 12.4m, adult females comprising 32%, both slightly higher than previously (mean length 11.8m, 1981–86; adult females 25%, 1978–86).

A bisexual animal taken in 1987 is the third reproductively aberrant individual recorded since 1981. The Committee believes that because of this relatively high incidence (3 out of 81 animals examined since 1980) the situation should continue to be monitored. Genetic implications for the population are being investigated. It was noted that if the population genetics of the trait can be adequately modelled, it may be possible to estimate the population size at its lowest level.

Struck and lost rates

The 1987 rate (22 landed, 9 lost: 29%) was the same as in 1986, maintaining the significant decrease in struck and lost rate since 1982. The Committee believes that efforts to reduce the rate further should continue.

A penthrite bomb is being developed which should be more reliable and powerful than existing bombs. Four small whales have been killed with it so far in 1988.

Incorporation of radio-transmitters into floats has continued. Since 1983 at one village (Kaktovik) and 1986 at another (Nuiqsut), 11 whales have been struck with harpoons attached to radio-instrumented floats; one whale which would otherwise have been lost was relocated. The use of the device is believed worthwhile where open water allows the float to surface and transmit a signal. Evaluation of the programme is continuing. Where radio transmitters are unsuitable e.g. in thick ice, sonic devices attached to the harpoon are again being considered.

Biological information

Studies of the anatomy of the bowhead's digestive tract (SC/40/PS7) suggest that the narrow diameter of the connecting channel forming the third stomach chamber could lead to blockages if pollutants such as tarballs or discarded plastics are ingested.

Information was available in SC/40/PS8 on length at sexual maturity, the mechanism of ovulation, dates of conception and birth gestation and calving interval, based on material from 15 sexually mature females This was compared with similar reproductive parameters provided by the US National Marine Fisheries Service in their study of 13 sexually mature females (Nerini, Braham, Marquette and Rugh, 1984, *J. Zool.*, 204: 443–68). The Committee recognised the physical difficulties of obtaining biological material from the catch, particularly small foetuses, especially where technicians are no longer present in each of the villages.

The Committee was unable to determine whether the poor correlation between body length and corpora number (from corpora counts from ovaries of 10 animals) was due to a lack of relationship between body size and corpora accumulation or because corpora do not persist in the ovaries. An independent age determinant is required, but bowhead earplugs are unreadable, age determination using the baleen is not yet considered reliable and routine examination of the animal's physical maturity is impractical. As a long-term alternative, natural marking data could provide age-specific reproductive information, particularly since 1,400 animals have now been individually identified. The Committee is concerned that continuation of the photoidentification programme is jeopardised because of funding constraints.

The Committee strongly **recommends** that the morphological analyses continue and that aerial photoidentification surveys should resume in spring 1989, particularly given that each can potentially enhance the other. It noted that continuation of the series of photoidentification surveys would be in accord with the strong view expressed in SC/40/Rep1 that the value of such studies lies largely in the fact that they should be long-term and uninterrupted.

Distribution

Aerial surveys in the eastern Alaskan and western Canadian Beaufort Sea in August/September from 1979 to 1986 show that bowhead whales consistently occur near the US/Canadian border and from 50–150km north of Barter Island, Alaska (SC/40/PS2). Sighting rates were lowest in the second half of August. Bowheads move into relatively shallow water (<50m) in early September, swimming mainly northwest but alternating bouts of swimming with feeding, milling or resting. Feeding was observed most commonly in shallow water (<20m) east of the US/Canadian border.

The Committee is concerned that large-scale surveys are now being curtailed. It noted that passive acoustic monitoring can be used to supplement information from aerial surveys in bad weather or darkness (as described in SC/40/PS3) and **recommends** that acoustic monitoring should continue to be used to supplement aerial surveys rather than to replace them.

Aerial transect surveys off Pt. Barrow in the spring of 1984–1986, flown to determine the offshore distribution of migrating whales and the proportion of offshore animals missed by the shore-based census, gave rather different results to those from photogrammetric surveys. Between 6 and 58% of whales have been recorded beyond the ice-based observers' maximum visual range of 5km. Immature whales were found further offshore in 1986 than mature whales.

The Committee recognises the difficulties inherent in both transect and photogrammetry flights. Photogrammetry flights have tended to concentrate on inshore areas; both are affected by the degree of ice cover. It **recommends** that both kinds of flights should continue and that ice cover should be constantly monitored on the flights. Given the need to assign priority to these costly programmes of aerial survey, transect flights and photogrammetry flights, the Committee believes that highest priority should be given to the photogrammetry flights.

Stock size - initial

Data on animals landed since 1816 were provided from a literature search and interviews with Eskimo people (SC/40/PS10). The Committee agreed that the 157 landed whales not previously included up to 1977 should be added to the existing catch data set used in estimating historical population size. However, there was no new independent information available on initial stock size.

Stock size - current

Acoustic analysis of hydrophone array recordings resulted in an estimate of 5,633 for the total number of vocalising bowheads off Point Barrow in 1986 (SC/40/PS4). This number differed from last year's estimate based on 1986 data, particularly because more data had been analysed and a geometric correction factor based on empirical results had been used. To improve confidence in the choice of input parameters and hence reduce the variance of the population estimate, preliminary analysis had been undertaken of bowhead swimming tracks based on the characteristics of individual animals' calls (Annex G, Appendix 2). The aim is to provide information on whale swimming parameters independent of visual observations, particularly minimum swimming speed and direction of migration. Calling can be used by the whales to coordinate group movement, to navigate by determining distance from heavy ice floes and perhaps to assess changes in their environment.

Two estimates of stock size were provided to the Committee, each using the same data set but different methodology. A new mark-recapture estimate of 1986 population size, using visual and acoustic data (SC/40/PS5) and methodology described last year (Zeh, Turet, Gentleman and Raftery, 1988, *Rep. int. Whal. Commn* 38: 349–64) but with several innovations, was recomputed using a correction for whales travelling close together, as agreed by the Committee and detailed in Annex G, Appendix 3. The population estimate obtained was 8,200 (SE 2,000). The weighted average of that estimate and the estimate of the 1985 population provided last year (*Rep. int. Whal. Commn* 38: 49) was 7,800.

A new approach, using the Bayes empirical Bayes method (SC/40/PS6), provided a probability distribution of the number of whales in the population, taking into account current gaps in knowledge, errors arising from the use of the tracking algorithm and uncertainty in the tracking parameters. The confidence intervals obtained also take account of the main sources of variability. However, the population estimate obtained in SC/40/PS6 used a minimum swimming speed of 1–3 km/hr. Adjusting the estimate for a minimum swimming speed of 1km/hr, as described in Annex G, Appendix 3, gave a population estimate of about 8,200, similar to that obtained by the mark-recapture method.

The Committee agreed that the approach used in SC/40/PS6 provides more realistic confidence intervals than obtained using normal distribution theory. It therefore accepted the average point estimate of population size of 7,800 (obtained by adjusting the mark-recapture estimate of PS/40/PS5), with a 95% confidence interval of 5,700 to 10,600 (obtained by using the probability distribution approach of SC/40/PS6, as described in Annex G, Appendix 3).

Effects of industrial development

Although it had no new information on this matter, the Committee is concerned over the decrease in aerial survey effort, since large-scale monitoring surveys remain the best method for detecting the cumulative effects of industrial activities over a number of years. It therefore **recommends** that large scale surveys be continued, and that they be carried out objectively to determine the effect of any future impacts.

The Committee was informed that the recently available study on the importance of the eastern Alaskan Beaufort Sea for feeding in this population (noted in *Rep. int. Whal. Commn* 38: 111) concluded that the area is not a significant contributor to the stock's energy needs. A peer review had found that the data presented do not support that conclusion.

The Committee agreed that this emphasises the need for careful design of such large studies to fulfil their objectives.

Management advice

A simulation was undertaken using the HITTER program with the same input values as last year (*Rep. int. Whal. Commn* 38: 116) and an updated population estimate, but with the catch series adjusted to incorporate the additional data from SC/40/PS10, as described in Annex G, Appendix 4.

Annex G, Appendix 5, Table 1, gives the calculated replacement yields for MSY rates of 1–5%, using the agreed weighted average point estimate of population size of 7,800 and the agreed range (5,700–10,600). The calculated replacement yields are given in Table 6.

Table 6

Calculated replacement yields for bowhead whales (see text).

Population estimate	MSY rate				
	1%	2%	3%	4%	5%
5,700	43	77	107	132	155
7,800	56	99	135	165	192
10,600	71	119	153	178	196

Although the sensitivity tests recommended last year (*Rep. int. Whal. Commn* 38: 50) had not been carried out because the model had only recently been validated, the Committee accepted the simulation results as the basis for recommending stock classification. In most instances the simulation indicated classification as a Protection Stock, and the Committee therefore **recommends** that the stock remains a Protection Stock.

The Committee noted that the simulation indicated an increase under an estimated annual average removal since 1910 of 27 animals, but it had no information on the rate of increase and therefore which MSY rate to use. The most appropriate values of replacement yield are those associated with the weighted average point estimate of the population size i.e. 7,800. It **recommends** that efforts be made to determine any population trends from the population estimates now available since 1978. It also **recommends** that sensitivity tests and reconciliation of current estimates with previous studies be undertaken as described in Annex M.

Under the provisions of the Aboriginal Whaling Scheme only a proportion of the replacement yield should be taken, to allow the stock to increase to MSY level, and the Committee notes that the smaller the proportion taken, the greater the rate of population increase.

While the benefits to the stock may only be marginal, the Committee again **recommends** that any catch should be directed to smaller (<13m) animals, but it will review the situation again next year, given that views on the status of the stock have altered since the question was last considered in detail (*Rep. int. Whal. Commn* 37: 50).

8.2 Eastern North Pacific gray whales

A total of 158 whales were reported taken by the USSR from the stock off Chukotka, Bering Sea in 1987, of which 154 were landed (SC/40/ProgRep USSR). The catch, below quota, was restricted by a late start to the season and bad weather. There were no whales caught by the USA in 1987.

A recent census had addressed the three questions of offshore distribution, missed whales and estimation of animals passing in early and late migration (SC/40/PS12). Using two independent observation posts (to give a mark-recapture correction factor for missed whales) and aerial surveys (to determine offshore distribution) a population estimate was obtained of 21,113 (SE = 688). The small standard error was questioned. The possibility that swimming speeds are different between day and night was raised but previous radio tagging had shown little difference between day and night travel rates. The Committee accepted the point estimate of 21,113 whales.

Because a different model and a new correction factor were used to obtain the 1987/88 estimate, it is not possible to compare the current result with previous population estimates. The Committee agreed that while the new estimate represents a considerable improvement in estimation of this stock's abundance, recent trends in abundance also need to be examined. Either the earlier data require analysis of the kind used for the 1987/88 data, or the 1987/88 data should be reanalysed using the earlier model and information from only one of the two observation posts. Offshore distance-correction factors would also need to be developed for the 1984/85 and 1985/86 data. The Committee **recommends** that such analyses should be carried out before the next meeting.

This stock may now be near its original abundance. Shore censuses should therefore continue, although depending upon the expected rate of population change and accuracy of monitoring needed it may be possible to reduce their frequency. The Committee **recommends** that an analysis of the survey frequency requirement be undertaken before the next meeting.

Because of the potential of photo-identification for providing information on calving intervals, age at first parturition and juvenile survival rates, the Committee **recommends** that all groups currently and previously involved in this work should be contacted to evaluate the status of their photographic collections and to investigate what information is available. A proposal for this to occur, involving relevant Mexican and US scientists, and with appropriate statistical advice, was developed during the meeting. The Committee agreed that the extent of interchange of animals between the breeding lagoons and outside waters should be included in the items to be considered.

The Committee **recommends** that the current Magdalena Bay study (see SC/40/ProgRep Mexico) should continue, to provide estimates of reproductive parameters and survivorship from an uninterrupted time series.

The eastern North Pacific stock of gray whales is of special interest and importance to the Committee because of its demonstrable recovery and the considerable amount of information available on stock identity, population size and trends in abundance. The importance of this stock in the context of the Comprehensive Assessment is discussed under Item 6.6.1.

The Committee would welcome receiving the results of recent Soviet biological work on this species, including age distribution and reproductive parameters. It reiterates its previous request that photo-identification studies be undertaken of the animals off Chukotka.

The stock is well above its minimum population size. While its classification will have to await a broad, in-depth assessment, the population increased by about 2.5% (0.3–4%, Reilly, 1987, *Rep. int. Whal. Commn* 37: 347–9) per year between 1967 and 1980, despite an annual catch of about 179 animals, which comprises only 0.8% of the best estimate of current population size. Pending such an assessment, the Committee therefore **recommends** no change in the catch limit in 1988.

8.3 West Greenland fin whales

A stock estimate of 1,693 whales, was available from the North Atlantic minke whale sub-committee, based on the NASS-87 aerial survey off West Greenland in July/August (SC/40/O 11). Because of inter-transect variation in cue sighting rate, and variability in the estimated effective search area, the coefficient of variation of the estimate was large (0.47). The reliability of the mean surfacing rate estimate was also unknown.

While the discreteness of this population is uncertain, and no information is available on its status, the population estimate represents a considerable improvement on previously available information. Nevertheless, at this stage the Committee is unable to predict the long-term effect of a continuing aboriginal take of 10 whales, in the absence of a more robust estimate and more information on stock identity and status.

The Committee **recommends** that aerial surveys of this stock should continue and that experiments designed to estimate surfacing rates, including radio-tagging, should be undertaken. It was pleased to note that Danish authorities intend undertaking aerial surveys in 1988 at double the 1987 effort. It also **recommends** photo-identification of this population for comparison with results already available from other areas of the Northwestern Atlantic.

8.4 Western North Atlantic humpback whales

New mark-recapture estimates based on photo-identified individuals were available (SC/A88/ID2). That using all photographs from the northern areas of the feeding grounds was considered the best estimate for total population size, i.e. 5,505 ± 2,617, for the years 1979–1986. A rate of population increase of 10.3% (95% confidence interval 2–23%) using photo-identified animals from the Gulf of Maine was obtained.

Fifteen dead humpback whales stranded off Cape Cod and New York in late 1987, including thirteen previously photo-identified individuals. The reason appeared to be ingestion of mackerel contaminated with 'red tide' biotoxins (SC/40/ProgRep USA). Four others washed ashore in the Dominican Republic. The mortality reported for the northeastern United States represents 6.25% of the estimated Gulf of Maine feeding aggregation (240 ± 93; SC/A88/ID2) although that population size may be underestimated (SC/A88/ID4).

The Committee was informed of the catch of one calf in Bequia in 1987. It agreed that although the direct relationship between animals from the Bequia–St. Vincent breeding area and other humpback whales in the northwest Atlantic is unknown, a catch of up to three animals would be unlikely to harm the stock unduly. It **recommends** that photo-identification studies should be undertaken in the Bequia region.

8.5 West Greenland stock of minke whales (see also Annex F)

Sightings estimate

The Committee received an estimate of 1,153 (CV = 0.417) from the West Greenland aerial survey calculated from data in SC/40/O 11, SC/40/O 12 and using a mean surfacing rate of 53 surfacings/hour (see Item 7.2.1.1). It noted that the CV did not include a component for variability in mean surfacing rate. Although minke whales were known to occur north of the survey area (north of 71°30'N) and to the west of it (west of 57°W, between 67°N and 69°N), the Committee agreed that most of the stock could be expected to be within the survey area. The aerial survey estimate was accepted as an estimate of the number of animals in the management area.

CPUE data

In response to the recommendation from the CPUE Workshop that such details be made available, SC/40/Mi21 described operational details for the Norwegian small-type whaling vessel *Kato* working off West Greenland during the period 1979–85. Searching was not at random but was based on information from previous catches and on weather and ice conditions. It was also based on information from other fishing vessels acting effectively as 'scouts' in the area. Data on operational details and time budgets would be provided to the Commission before the end of the year and would be available according to the normal rules of the Commission.

The Committee welcomed the information contained in SC/40/Mi21. It was confirmed that *Kato's* pattern of searching was typical of offshore Norwegian small-type whaling operations. The Committee recognised that it would be difficult to quantify the effects of this searching strategy, especially as fishing vessels outside the whaling fleet were acting as 'scouts'.

Stock assessment and management advice

At its 1985 meeting most members of the Committee believed that this stock should be classified as a Protection Stock. This was based on the stock assessment presented at that meeting (*Rep. int. Whal Commn* 36: 43) which indicated a probability of 0.74 that the stock was in the Protection Stock category. Other members, however, expressed doubts about the validity of this assessment and believed that the stock should remain unclassified. At that meeting, the Committee recommended that a catch limit of less than 50 whales be set for one year only. The stock was subsequently classified by the Commission as a Protection Stock, but an aboriginal subsistence catch limit substantially higher than this number was set.

At its 1987 meeting, the Committee drew to the attention of the Commission that the catch limit recommended in 1985 had not been put into effect (*Rep. int. Whal. Commn* 38: 51). It reminded the Commission of the continuing uncertainties about the identity, current size and replacement yield for the stock.

At this meeting, the Committee reiterates its concerns about the question of stock identity. There was substantial evidence, relating to the absence of calves and lactating females and the continuing high proportion of females in the catch (SC/37/Mi4 and subsequent Danish Progress Reports), that the minke whales off West Greenland did not constitute a separate biological stock. Resolving this question was of crucial importance to the assessment of minke whales off West Greenland in relation to the provision of advice to the Commission about the aboriginal subsistence take in this area.

Despite these concerns, the Committee had insufficient information to suggest a change in stock boundary for West Greenland minke whales. It agreed to attempt to provide advice on the basis of the existing stock boundary.

This year, for the first time, an estimate of the size of the management stock was available. Some members believed that a simulation using the program HITTER (Annex L) would help them in formulating their advice to the Commission. The results of this simulation are given in Table 7.

Table 7

An assessment of the West Greenland stock of minke whales (see text). Model parameter values: MSY level = 60%; Natural mortality rate = 0.1; Age at maturity = 7; Age at recruitment = 5; 1987 stock size = 1,153 (total stock aged 1 and over); No CPUE data.

MSY	A	Exploitable stock in 1948	Exploitable stock in 1988	$\frac{\text{1988 stock size}}{\text{1948 stock size}}$	1988 RY
1%	0.135	7,100	904	12.7%	–48
2%	0.270	6,809	904	13.3%	–47
3%	0.405	6,549	904	13.8%	–47
4%	0.539	6,315	904	14.3%	–47

The results show that under the range of parameter values chosen, neither the predicted level of depletion nor the 1988 replacement yield was sensitive to the range of values of MSY% chosen. The Committee agreed that it was difficult to interpret the result of these simulations, especially in light of the marked difference between the observed sex ratio in the catch and the predicted sex ratio in the population (Appendix 3, Annex E).

Nevertheless, given that the stock (estimated to be 1,153 animals) was smaller than had previously been thought and that the average annual catch during the last 10 years had been 263 animals per year, the Committee believed that the stock was severely depleted, below the level believed in 1985. The Committee **recommends** that the stock remain a Protection Stock. It agreed that it had no evidence that any catch would allow the stock to move towards its MSY level.

8.2.3.4 Priorities for future research

It was important to try to resolve the question of the identity of this stock. The Committee welcomed the existence of research programmes in Denmark, Iceland and Norway which were trying to address this issue. It noted that Danish research in this area includes the use of a large number of samples of existing tissue from West Greenland. Samples would also be taken from animals taken under aboriginal subsistence whaling from East Greenland where possible. The Committee **recommends** that biopsy samples from whales in the Central stock management area be collected as a matter of urgency. It noted that Norway may be able to take such samples from whales encountered during surveys around Jan Mayen if suitable equipment could be provided.

The Committee noted that information on the relationship of minke whales off West Greenland to those off eastern Canada is also of interest. It **recommends** that the Commission instruct the Secretary to contact the Government of Canada to inform it of the useful work being undertaken in Greenland and Denmark on analysis of genetic material from minke whales found in the Davis Strait, and requesting their cooperation in providing old materials and new biopsy materials from the Canadian East Coast Stock for comparative studies.

The Committee agreed that it was important that the number of minke whales in the West Greenland minke whale stock area should continue to be monitored, and recommends that further surveys be conducted. It welcomed the intention of Denmark to conduct an aerial survey off West Greenland in 1988 with twice the survey effort expended in 1987, and a further aerial survey in 1989 as part of the proposed international North Atlantic Sightings Survey.

8.6 Information on other stocks

A collation of information from documents available at the meeting is included in Annex G as Item 7.

9. SMALL CETACEANS
(see also Annex H)

9.1 Beaked whales (including bottlenose whales)

The sub-committee on small cetaceans conducted a review of the beaked whales, giving attention to distribution, stock identity, abundance, migration, life history, exploitation and status. The results are summarised in section 5 of Annex H.

9.1.1 Stocks of Baird's beaked whales

Judging from new information on migration, at least three stocks of Baird's beaked whales exist in the western portions of the range of the species: a western Pacific stock; a Sea of Japan stock; and an Okhotsk Sea stock. The whales have not been observed to cross the shallow-water barriers between these regions. The western Pacific stock and Okhotsk Sea stocks migrate in and out of Japanese waters, but the Sea of Japan stock may be resident year round. Another stock may exist around the Kurile Islands and still others to the east in North American waters.

In part to resolve questions about the oceanic distribution of Baird's beaked whale so that more reliable population assessments can be accomplished, Japan this summer will conduct a 4-vessel survey between 3° and 45°N across the North Pacific from Asia to North America. An additional single-vessel survey will be carried out in Japanese coastal waters to gather data for an estimate of abundance in the region. The Committee looks forward to receiving the results of these surveys at next year's meeting.

9.1.2 Higher mortality rates in female beaked whales than in males?

In the beaked whales for which sufficient data exist to allow estimation of sex ratio, it appears that females may have much higher mortality rates than males. For example, in juvenile Baird's beaked whales, the ratio is about 1:1, but males predominate in adults; the oldest female in catches sampled in Japan was 54 (had 54 GLGs in the teeth) and the oldest male 84. A similar skew was seen in stranded specimens and in a large series of stranded *Ziphius cavirostris*; the maximum age known for *Ziphius* females is 28 and for males 47. A fishery sample of northern bottlenose whales contained 75 males and 53 females. While it is possible that these samples are biased, the phenomenon is general enough to merit attention; it may reflect unusual life histories and breeding systems among these whales.

9.1.3 Unidentified bottlenose whale in the tropical Pacific

There is a large unidentified beaked whale species in the tropical Pacific that may prove to be a species of *Hyperoodon* or an undescribed species of beaked whale of some other genus. Individuals have been seen and photographed numerous times by different investigators in the western Pacific, mid-equatorial Pacific and eastern Pacific. It may prove to be *H. planifrons* (the type specimen of which came anomalously from 20° S), but this would be an extraordinary extension of the range of that supposedly cool– and cold-water species. Because of the value to science of determining the identity of this whale, the Committee **recommends** that an effort be made to collect two adults (a male and a female) in the western Pacific. The possibility of collecting biopsy samples for molecular analysis was also raised, but there likely would be difficulty in collecting a sufficient number of samples from the Antarctic, the North Atlantic and the western Pacific to resolve the unknown whale's identity.

9.1.4 Unidentified Mesoplodon in the eastern tropical Pacific

Another unidentified and possibly undescribed beaked whale inhabits the eastern tropical Pacific and is relatively common there. It has been encountered and photographed frequently during dolphin abundance surveys and most likely is a species of *Mesoplodon*. It was first thought to resemble the strap-toothed whale, *M. layardi*, in coloration, but comparison of photographs during the sub-committee sessions demonstrated that its colour pattern does not match that of any beaked whale for which the colour pattern is known. Only the colouration of *M. pacifus* remains undescribed, and the unknown whale is probably too small to be of that species.

9.1.5 General recommendations on beaked whales

It became evident in the review that extremely little is known about most of the beaked whales. Four general research recommendations are offered:

(1) *Non-lethal research* — The Committee **recommends** that the new techniques for studying living cetaceans, such as individual identification using natural marks, which have proven successful for larger whales, be encouraged for application to the beaked whales, particularly where there are reasonably consistent concentrations of a well-marked species for which concern exists about population size and stock identity (e.g. the northern bottlenose whale in the North Atlantic).

(2) *Effects of gillnets* — It is **recommended** that offshore gillnet fisheries be monitored to determine the nature and extent of impact on beaked whales.

(3) *Sampling catches* — The Committee **recommends** that, when possible, beaked whales taken in direct fisheries be examined thoroughly by biologists to collect data and samples that can be used to estimate life history parameters.

(4) *Strandings* — Because information on life history is so sparse for most of the beaked whales, the Committee **recommends** that efforts be made to collect full suites of data and specimens for all stranded animals.

9.2 New information on other stocks

Takes of small cetaceans in 1987 are summarized in Appendix 3 of Annex H.

9.2.1 Dolphins associated with tuna in the eastern Pacific

The sub-committee on small cetaceans received and briefly discussed several papers relating to dolphins associated with the international tuna fishery in the eastern tropical Pacific. The sub-committee did not carry out a substantive review of the issue but recommended that such be done in the future. In response to requests made last year, papers were submitted this year re-analysing data on abundance collected aboard commercial tuna boats to compensate for biases in the data and presenting indices of abundance based on data collected in a large sightings survey employing research vessels. The Committee expressed its appreciation to the scientists involved. Annex H summarises the discussions of the papers; four research recommendations are given below.

(1) The Committee is concerned that the mortality of dolphins (estimated by one method at 115,000 in 1987) remains high when compared to the most recent estimates of absolute abundance (based on surveys conducted in 1979) and **recommends** that every effort be made to reduce this mortality and to assess its impact on the stocks. An attempt should be made to produce updated estimates of absolute abundance.

(2) Beyond the substantial improvement that could be expected to result from better application of existing dolphin-rescue gear and techniques, further reduction of the kill would probably require development of new technology. For example, members noted that kill rates are very much higher for common dolphins than for other species involved in the fishery and that research into the behavioural reasons for this could well lead to design of new gear and procedures to reduce the high kill rates. The Committee **recommends** that such research aimed at lowering kill rates be undertaken.

(3) Kill estimates would be most useful for purposes of comparisons with estimates of abundance if they were calculated on a stock-by-stock basis; the Committee **recommends** that this be done where possible.

(4) Only about one quarter of the dolphins killed by vessels carrying scientific observers are presently examined to obtain biological data and samples. On occasion, 50 or more dolphins are killed in a single net set. Complete suites of data and samples from such large series would be extremely valuable in population analysis, and the Committee **recommends** that the level of biological sampling be increased, if necessary by returning the carcasses from large-kill sets to research facilities ashore for processing.

9.2.2 White whales in Alaska

New data indicate that estimated subsistence removals from some white whale stocks are large enough (up to 6.7%) to cause concern about their sustainability, and the Committee agrees with the **recommendation** of the authors of SC/40/SM4 that the estimates of abundance and harvests be refined and further work carried out on stock identity.

9.2.3 Other species

New information on pilot whales, killer whales, harbour porpoises, and a large number of other small cetacean species is summarised in Annex H.

9.2.4 Nomenclature

The Committee **recommends** two changes in the 'List of smaller cetaceans recognised' (*Rep. int. Whal. Commn* 27: 30); from *Globicephala melaena* to *G. melas* for the long-finned pilot whale, and from *Phocoena dioptrica* to *Australophocaena dioptrica* for the spectacled porpoise.

10. SCIENTIFIC PERMITS

10.1 Report of the special meeting

The Committee received the report of the special meeting of the Scientific Committee to consider the Japanese Research Permit (Feasibility Study). It noted that this had already been forwarded to the Commission. Recommendations to the Scientific Committee contained in the report are discussed under Item 11.

10.2 Guidelines for the review of scientific permits

SC/40/O 4 provided a suggested mechanism to resolve the overlap between Commission resolutions (*Rep. int. Whal. Commn* 37: 25; 38: 27) and guidelines developed by the Scientific Committee (*Rep. int. Whal. Commn* 36: 133) on the procedures for reviewing scientific permits. It was proposed that discussions should be grouped under five general headings: (1) the proposal; (2) objectives; (3) methodology; (4) effect of catches; and (5) participation in research by other nations. The author had attempted to combine similar guidelines among the total of 18, using wording close to the original guidelines but attempting to clarify them in places.

The Committee believed that it was inappropriate to alter the wording of the Commission's guidelines at the present meeting. However, it agreed to structure its discussions under the headings proposed in SC/40/O 4, but keeping all 18 guidelines in their original wording (Annex O).

The Committee noted that separate treatment of each of the 18 guidelines at the Special Meeting and at this meeting had proved an extremely cumbersome and time consuming procedure. This has led to an unhelpful degree of cross-referencing and difficulties in providing an easily understandable report. It draws the Commission's attention to the fact that it intends to attempt to revise the current guidelines at its next annual meeting in order to simplify its work in reviewing scientific permits and more effectively provide advice to the Commission.

10.3 Review of research results based on existing Scientific Permits

10.3.1 Japan

SC/40/Mi18 provided a report on catches taken under the Special Permit issued by the Government of Japan in 1987. A total of 273 animals out of a proposed catch of 300 had been taken over a wide latitudinal range from 55°S to the ice edge. This included one diminutive form minke whale taken from a school of two at 58°S. This is the most southerly record for this form. Appropriate samples were taken and the skeleton was retained. Earplugs had been collected from 271 animals. These included the fragile plugs from smaller animals which had proved difficult to extract undamaged in the past.

It was reported that it had proved relatively easy to implement the proposed random sampling scheme. Preliminary results indicated that sexually mature females tended to concentrate along the edge of the pack ice whereas mature males appeared both close to the pack ice and offshore. Small and immature animals tended to be solitary whereas larger or mature males tended to occur in larger schools associated with similar sized females. No lactating females had been taken. The average size of the animals taken was substantially less than that in the commercial catch. Where two animals were taken from the same school, the lengths of the first and second animals were not significantly different.

Hester, Best, Sigurjónsson, Le Gall, Kato and Øritsland commented on the useful biological information presented in the preliminary analysis given in SC/40/Mi18.

The Committee noted that one of the primary aims of the feasibility study was to test a protocol for collecting a representative sample from the population. However, some members (Chapman, de la Mare, Harwood, Holt, Horwood, Lankester, Tillman) pointed out that the preliminary results indicated that the protocol had not been entirely successful. First, it had proved more difficult to sample animals in schools of three or less individuals than those in larger schools. This, combined with the fact that at most two whales were taken from each school meant that some transformation of the sampled age structure would be necessary to generate a representative sample. Second, schools were not sampled at random because large schools were known to be relatively more sightable than small ones. In addition, it was necessary that animals were sampled in proportion to their density. However, density was extremely variable in the ice edge area where the largest concentrations of animals were found. This would introduce an additional element of variability into the estimated population structure. The evidence that there was a differential segregation of males and females, which could not be distinguished at sea, and the lack of lactating females added to the sampling difficulties.

In response the Japanese scientists expressed their appreciation of these comments. They indicated that they had already recognized many of these problems and were taking action to modify any future sampling programme in an appropriate way.

Harwood and Reilly commented that even if random sampling could be achieved, they believed that the results in SC/40/Mi18 revealed that the expected level of variability would render the analysis of the data proposed in the original proposal problematic. Some members (Arnbom, Chapman, de la Mare, Holt, Horwood, Lankester, Tillman) drew attention to the underlying methodological problems as expressed at the December special meeting and in Item 6.3.1 of this report, i.e. that it had not been demonstrated that the main objective of the original proposal, the determination of age-specific natural mortality, could be achieved with the proposed methods. They concluded that although the results of the feasibility study might provide information of general biological interest, neither those results nor the objectives and described methodology of the original proposal would contribute to the rational management of stocks nor the Comprehensive Assessment.

In response the Japanese scientists reported that the preliminary results of the feasibility study had provided them with information on how to improve their sampling procedure such that they could obtain random samples, and had thus fulfilled its objectives.

Some members (Gunnlaugsson, Hester, Kato, Magnusson, Øritsland, Vikingsson) noted that SC/40/Mi18 reported preliminary results and therefore it was improper to draw final conclusions as to the value of the research from the data, although other members of the Committee were willing to do so. In their opinion, criticism concerning randomness of sample collection was premature since this was a feasibility study to address this very point. The same variety of problems and uncertainties apply to the design and execution of the IWC/IDCR sighting surveys, which apparently are to form the basis for the assessment of this stock(s). The addition of biological information, such as segregation of whales by length (age) and sex suggested in the report, appears useful for improving assessments based on such sighting surveys. Further, biological sample data has the potential for improving some population and biological parameter estimates.

10.3.2 Iceland

SC/40/O 8 reported on the status of the different research projects undertaken under Iceland's 4-year research programme. The Committee noted that in 1987 Icelandic permits allowed the catch of 80 fin and 20 sei whales, of which 80 fin and 20 sei whales were caught. Progress on electrophoretic and biochemical studies, as well as on 6 general studies was specifically noted.

In SC/40/Ba9, a simple isoenzyme system (carbonic anhydrase) was reported to demonstrate that fin whales caught off Iceland in 1971 and 1981–87 belong to a breeding unit in Hardy-Weinberg equilibrium, with some young males coming from other units in some years. SC/40/Ba10 described a study of enzyme loci which showed that there were no differences between fin whales caught off Iceland and Spain. SC/40/Ba11 reported on progress in undertaking electrophoretic analyses of liver esterases in fin whales from Icelandic and Spanish waters.

SC/40/O 34 reported the occurrence of polymorphisms of C4 genes in fin and sei whales using a human cDNA probe; data on mother-foetus pairs demonstrated simple allele transmission. The fact that the human C4 probe hybridises with cetacean DNA demonstrated that it is possible to use human probes under some conditions. Species-specific patterns were noted as well as polymorphic patterns within fin and sei whales.

Studies on growth layer formation in tympanic bullae of fin whales caught during the 1986 and 1987 season were presented (SC/40/Ba5). Preliminary results show a relationship between ear plug growth layers and tympanic bullae growth layers for immature animals only.

Preliminary work on chlorophyll and zooplankton densities collected during whaling operations was presented (SC/40/O 33) in an attempt to monitor oceanic conditions on the whaling grounds.

A progress report on sei whale morphometric studies was presented (SC/40/Ba6). Results indicate isometric growth, with a slight tendency towards positive allometry of the head region. Further studies will include a Principal Component Analysis of the measurements, and additional comparative studies with data from sei whales caught in other regions.

A preliminary report on energy content of blubber and muscle of fin and sei whales was presented (SC/40/Ba7). It concluded that for fin whales the females had a slightly higher lipid content in 1987 than in 1986, but that the reverse was true for the males. Because the study followed Lockyer's (1986, *Can. J. Fish. Aquat. Sci.* 43: 142–7) approach which had demonstrated a relationship between reproductive status and energetic status, the Committee suggested that the data should be analysed in greater detail by sexual and reproductive class.

A progress report on hormonal levels in whales caught in Icelandic waters was presented (SC/40/Ba8). Results confirm that serum progesterone seems to be a good indicator of pregnancy condition in fin whales. There is also a correlation between age and hormonal levels, and for length and hormonal levels in females. There is also an apparent rise in testosterone levels in males during the whaling season, the implications of which will need further examination.

Some members (Arnbom, Chapman, Cooke, de la Mare, Harwood, Holt, Horwood, Lankester, Tillman) commented on the difficulties of evaluating the results of the permit catches on the basis of the studies presented to the meeting, which combined these with results from previous commercial catches. They believed that more detailed analyses of the commercial and research data should be provided (e.g. of CPUE data, reproductive data), and that the existing data should be presented in such a way that the research component is clearly shown. They believed that the results so far produced do not show that the programme is assisting the Comprehensive Assessment or providing information of importance to management.

Sigurjónsson, Gunnlaugsson and Magnusson responded that the results presented so far were from two years of a four-year programme to improve assessments and monitor the stocks. They believed that the results on progress on over 30 projects, including those on stock identity, age, reproduction, CPUE evaluation and monitoring and the body condition of animals with respect to environmental conditions and reproductive success, showed that the programme was addressing questions of importance to both the Comprehensive Assessment and management. They believed it inappropriate to present and analyse results from the research programme separately from previous results as the programme was designed to continue to monitor stocks and should not be seen in isolation.

Hester, Ikeda, Kato, Le Gall, Ohsumi, and Øritsland stated that they believed the Icelandic programme to be wide ranging and that the results clearly showed that the programme was improving our knowledge of the stocks and contributing to the Comprehensive Assessment.

Further comments on the results of the Icelandic programme so far are included in the discussion of future Scientific Permit catches under the programme in the light of the Commission's guidelines (Item 10.4.3).

10.4 Review of new or continuing Scientific Permit proposals

10.4.1 Japanese proposal, Southern Hemisphere minke whales

The Committee was informed that the Government of Japan will decide what research programme is to be implemented once the analysis of data collected in 1988/1989 had been completed. The Committee agreed that it was therefore not possible to discuss the matter further at this meeting. Should a proposal arise during the coming year, the Committee draws the Commission's attention to its view (Item 11.3) that intersessional reviews of scientific permits can best be achieved by special meetings.

It noted that the effect of continuing takes had been discussed by the sub-committee on Southern Hemisphere minke whales (Annex D).

10.4.2 Norwegian proposal, Northeast Atlantic minke whales (SC/40/Mi7)

The Committee had before it SC/40/Mi7, 'A programme to study and monitor Northeast Atlantic minke whales, 1988–1992', which describes a programme of 19 research projects of which four specifically involve the capture of minke whales under a special permit in 1988. Although SC/40/Mi7 alludes to further catches of unspecified numbers of whales during 1989–92, the Committee agreed to limit discussion under this agenda item to those parts of the programme which required a research take of animals in 1988.

It is proposed that, in 1988, 35 whales be caught for methodological studies under four projects: feasibility of radio tagging – 5 whales; food selection and intake – 10; food digestion – 10; and body composition – 10.

The five whales to be used to investigate the possibility of attaching radio tags to live-captured animals would be anaesthetised and later released if the technique was successful. The remaining 30 whales would be used in as many studies as possible but each project would have priority on ten whales. The Committee agreed that the question of whether or not a special permit was required to experiment on live-captured animals was beyond the competence of the Committee and referred this to the Commission.

Holt wished to record his view that the use of the word 'take' throughout Section 10 of this report, as meaning either to catch and kill or to entrap and attempt to hold a whale alive is confusing and inappropriate since this sense is quite different from that defined in the Convention (Schedule 1C). He also believed that live-capture experiments were inappropriate for discussion under scientific permits and that he considered the permit proposal was thus for 30 whales only.

(A) The Proposal: The relevant guideline is as follows.

'A Statement as to whether the permit proposal adequately specifies the four sets of information required under paragraph 30 of the Schedule.' (*Rep. int. Whal. Commn* 36: 133).

1. 'Objectives of the research;' (Sched. Para. 30)
2. 'Number, sex, size and stock of the animals to be taken;' (Sched. Para. 30)
3. 'Opportunities for participation in the research by scientists of other nations; and' (Sched. Para. 30)
4. 'Possible effect on conservation of the stock.' (Sched. Para. 30)

The Committee agreed that the proposal did adequately specify the objectives of the research. The general objectives of the overall programme were: the identification of stocks; stock assessments; ecological studies. The objectives for the particular studies requiring takes were:

(i) the feasibility of radio-marking minke whales (project 4.1.2) – to evaluate existing knowledge and technology, investigate methods of implantation and to prepare a programme, including experimental work, for adaptation or development of radio-transmitters to track and to record the activity and behaviour-patterns of minke whales;

(ii) minke whale food selection and intake (project 4.3.2) – to provide data on minke whale feeding in relation to energetic requirements and availability of potential prey species;

(iii) food digestion in minke whales (project 4.3.3) – to provide a basis for evaluation and analysis of stomach contents through studies of the transport and digestion of food items;

(iv) the body composition, fat content and thermal radiation of minke whales (project 4.3.4) – to obtain data for calculation of parameters for the whale energetics model (WHAERG).

With respect to the number, sex, size and stock of the animals to be taken, the Committee agreed that all but sex and size were adequately specified. SC/40/Mi7 specified a take of up to 35 whales. Project (i) above for five whales recognised that the study, which involved the live-capture and anaesthetisation of animals, might result in their deaths. Ten whales each were specified for projects (ii)-(iv) although this was an indication of priorities and it was planned to collect information for all three studies from each of the 30 whales where possible. Øritsland reported that the sex of the catches had not been specified as it is impossible to determine the sex of minke whales at sea. The size of animals had not been specified because of the timing and logistics of the sampling programme. Holt noted that he believed that the size of animals to be taken was important to specify and should be seen as an integral part of the methodology.

The Committee agreed that the proposal did specify the opportunities for participation in the research by scientists or other nations.

It also agreed that the proposal did address the question of the possible effect on conservation of the stock.

(B) Objectives

The relevant guidelines are as follows:

1. 'Comments on the objectives of the research to be carried out under the proposed scientific permit, including in particular how they might relate to research needs identified by the Scientific Committee;' (*Rep. int. Whal. Commn* 36: 133)
2. 'The proposed research is intended, and structured accordingly to contribute information essential for rational management of the stock;' (*Rep. int. Whal. Commn* 37: 25)
3. 'The research addresses a question or questions that should be answered in order to conduct the comprehensive assessment or to meet other critically important research needs;' (*Rep. int. Whal. Commn* 38: 27–8)

It should be noted that the discussion below relates only to the objectives of the proposal, and not methodologies.

The Committee noted the similarity of guidelines (1) and (3) above in the light of its discussions on the overall priority it has assigned to the Comprehensive Assessment (Item 14).

Øritsland reported that the ecological studies (projects ii-iv above) were not designed to contribute in an immediate way to the Comprehensive Assessment. In the light of Norway's commitment to a future multi-species management of the Barents Sea, he believed that the lack of information on minke whales for input into a multi-species model (MULTSPEC) being developed for that area rendered the research as meeting a 'critically important research need' of Norway. He believed that this type of research would contribute to the rational management of the stock in the long-term. He noted that the feasibility study on radio-marking minke whales was ultimately aimed at the question of stock identity, which the Committee had identified as a priority under the Comprehensive Assessment.

Bjørge noted that the ecological objectives of the proposal address a recommendation of ICES to consider marine mammals in multi-species assessment as a basis for future ecosystem management. This objective should therefore be considered to address a 'critically important research need'. He noted that this comment referred to objectives and not methodology.

Hester, Le Gall, Ohsumi, and Sigurjónsson believed that the objectives of the research, including those of the ecological studies, did address questions of interest to the Comprehensive Assessment. In particular they noted that the North Atlantic minke whales had been identified as a priority population/region in the Comprehensive Assessment (Item 6.1.1).

Arnbom, Chapman, Clark, Cooke, de la Mare, Holt, Lankester and Perrin noted that the proposal did not give sufficient information to evaluate whether the take of whales was critical to the development of the multi-species model mentioned in the proposal and whether developing such a model constituted a critically important research need.

While the Committee agreed that the first two general objectives of the programme – those relating to stock identity and stock assessment – were relevant to the three guidelines above, it noted that, with the exception of the live-capture experiment, the specific objectives that involved the take of whales in 1988 (listed under (A) above) fell within the third main objective of the programme, namely that relating to ecological studies. Some members felt that those latter objectives were relevant to guidelines (1) to (3) above, while others (Chapman, Cooke, de la Mare, Holt, Lankester) believed that they were of only marginal relevance.

(C) Methodology

The relevant guidelines are as follows:

1. 'Comments on the methodology of the proposed research and an evaluation of the likelihood that the methodology will lead to achievement of the scientific objectives. These comments may also include evaluation of the methodology in terms of current scientific knowledge;' (*Rep. int. Whal. Commn* 36: 133)
2. 'The objectives of the research are not practically and scientifically feasible through non-lethal research techniques;' (*Rep. int. Whal. Commn* 37: 25)
3. 'The research addresses a question or questions that cannot be answered by analysis of existing data and/or use of non-lethal research techniques; (*Rep. int. Whal. Commn* 38: 27–28)
4. 'The number, age and sex of whales to be taken are necessary to complete the research and will facilitate the conduct of the comprehensive assessment;' (*Rep. int. Whal. Commn* 37: 25)
5. 'Whales will be killed in a manner consistent with the provisions of Section III of the Schedule, due regard being had to whether there are compelling scientific reasons to the contrary.' (*Rep. int. Whal. Commn* 37: 25)
   [The Commission agreed that it has been intended by this for the Committee to report if cold grenade harpoons were used in special permit catches. (*Rep. int. Whal. Commn* 38: 13).]
6. 'The research is likely to yield results leading to reliable answers to the question or questions being addressed.' (*Rep. int. Whal. Commn* 38: 27–28)

The Committee agreed that the discussion of these guidelines could be centred on four areas: (i) sample sizes; (ii) whether the proposed methodology will answer the questions being asked; (iii) whether the questions could be answered by analysis of existing data or non-lethal research; (iv) whether non-explosive harpoons were being used.

Lankester, Cooke and Holt inquired why for each of the projects (ii) and (iii) ten whales would be needed, while at the same time the proposal mentions that samples will be collected from all whales taken.

Øritsland reported that the size of the take had been decided via a combination of the number of animals needed to investigate the potential of the methodologies and the operational capabilities of two vessels working for three weeks. He also stated that estimation of sample sizes on statistical grounds was not appropriate for this stage of the programme.

Lockyer noted that the small sample size may mean that little information on stomach contents is obtained and that any results would be confounded by a number of factors (e.g. how long the animal was chased). Øritsland reported that the aim of the first year of the study was more to examine procedures in identification and classification of prey items by species, sex and size structures.

Cooke, Chapman, de la Mare, Holt, Lankester, Perrin, and Tillman believed that the sample sizes proposed were neither justified on methodological grounds nor sufficient to provide a quantitative analysis in terms of their stated objectives. They believed the information obtained will not facilitate the Comprehensive Assessment.

With respect to the ecological studies, a number of members (Clarke, Chapman, Cooke, Hammond, Harwood, Horwood, Lankester, Lockyer, Perrin, Swartz) reiterated that it was difficult to assess the proposed methodologies because of the limited experimental detail provided in SC/40/Mi7. It was also impossible to determine how important these individual projects were to the MULTSPEC model. However, even with the limited information available, it was clear that there were potentially severe methodological problems with aspects of these projects.

Øritsland responded that the funding for the proposal had only recently been agreed by the Norwegian government and so that detailed planning had only recently begun. Furthermore, the research was being carried out by a number of institutions in Norway and he was not capable of responding to detailed inquiries at this meeting. However he welcomed comments on the methodology and would ensure that they would reach the relevant research groups.

Considerable comment was made on the proposal to attempt to anaesthetise and live capture up to five minke whales in order to surgically implant radio-tracking devices. Concern was expressed by many members that the project as specified did not appear to appreciate the difficulties in anaesthetising cetaceans which have a voluntary respiration system (e.g. Schevill, W.E., Ray, C., Kenyon, K. Orr, T. and Van Gelder, R.G. 1967. *Science* 157: 630–1.). They believed the proposed research was unlikely to be successful and suggested that this project be reconsidered by its proponents.

Øritsland responded that the research worker concerned was a veterinarian and had recently reviewed the use of drugs in the humane killing of whales for the IWC Technical Committee (Øen, 1984, TC/36/HK2). He noted that this was a feasibility study and that it was reasonable to assume that the research group would consider all available literature on the subject.

In the discussion of the analysis of existing data, Øritsland reported that preparatory work for all studies would include a review of available information. Tillman and Holt expressed the view that this analysis should be presented before the proposals could be adequately assessed.

Holt noted a problem in addressing the question of whether the research could be achieved by non-lethal means. While certain aspects of the study could be achieved by non-lethal means, others, e.g. detailed examination of stomach contents, could clearly not be achieved by such means. It was not clear from the proposal how the results of that research were to be incorporated into the proposed model. With more information on the model, it might be possible to provide the necessary data using non-lethal techniques.

Hammond, Harwood, Horwood, Lockyer, Mizroch, Perrin, Reilly and Tillman, noted that it had already proved possible to design research programmes to investigate the ecological role of marine mammals which relied solely on non-lethal techniques, although it was not possible to address all of the specific objectives of the Norwegian programme in this way.

Arnbom, Clark, de la Mare, Holt, Lankester and Swartz expressed the opinion that the Norwegian scientists are to be applauded for their ambitious research intentions. However, as a scientific document which is intended to support the validity of the research programme and demonstrate the probability that the research will lead to improvements in our knowledge of the minke whale, they found the proposed Norwegian programme deficient by the usual criteria expected in a scientific research proposal. Good intentions and multidisciplinary involvement do not justify the lack of scientific argument for the necessity of the research catches. Furthermore, the rationale explained in discussion that we will learn more about the limitations of the present methods, and resultant improvements in the methods will lead to a better understanding of these inherent limitations is circular and illogical. Finally, the proposal fails to demonstrate the connection between the proposed research's specific objectives and a more global understanding of ecological relationships, population structures, reproduction, digestion etc. of whales. Although the intentions of the programme as stated are laudable, in reality the possible benefits based on the methods presented are limited and are not likely to contribute to the Comprehensive Assessment or provide solutions to real problems facing the Scientific Committee.

In response to this, Ikeda, Gunnlaugsson, Ohsumi and Sigurjónsson believed that such a categorical statement on a comprehensive research programme was inappropriate. They further noted that the proposed studies involve a number of highly competent researchers at universities and research laboratories in Norway and are thus a serious research effort of great potential value, which should be commended.

Finally, the Committee noted that the thirty animals to be taken for ecological studies would be killed using the penthrite grenade harpoon.

(D) Effect of catches on the 'stock'

The relevant guidelines are:

1. 'A review of the most recent information on the stock or stocks concerned, including information on any exploitation, stock analysis and recommendations by the Scientific Committee to date (including, where appropriate, alternative analyses and conclusions and points of controversy).' (*Rep. int. Whal. Commn* 36: 133)
2. 'An evaluation of the specification in the permit proposal of 'possible effect on conservation of the stock'. As appropriate, the Scientific Committee may carry out its own analysis of the possible effects.' (*Rep. int. Whal. Commn* 36: 133)
3. 'The research can be conducted without adversely affecting the overall status and trends of the stock in question or the success of the comprehensive assessment of such stocks;' (*Rep. int. Whal. Commn* 38: 27–28)

The Committee recognised that it does not have an agreed assessment for this stock, which has been classified as a Protection Stock. It was agreed not to attempt an assessment of the stock at this year's meeting (Annex E). The Committee noted the provisional estimates for this stock from the North Atlantic sightings surveys of around 19,000 (CV 0.16) or 17,000 (CV 0.18) depending on decisions concerning which survey blocks to include (see Item 7.2.1.1 and Annex E).

The Committee noted that the proposed removal of 30 to 35 whales was for the first year of a five year programme. However, SC/40/Mi7 had stated that the 'need for further catches after 1988 must necessarily be evaluated and decided on the basis of results from the first field season. It is anticipated, however, that continued studies of temporal and spatial food selection and intake may require an annual sampling of even larger numbers throughout the program period, i.e. each of the years from 1989 to 1992.'

The Committee was therefore only able to consider the effect of a single take on the status of the stock. It agreed that the effect would be negligible. It stressed, however, that the effect of a small take in a single year would always be negligible. It also agreed, for similar reasons, that the

1988 take would not adversely affect the status or trends in the stock or the success of the Comprehensive Assessment.

The Committee is unable to consider the effects of any takes associated with the entire five-year programme until more details become available.

10.4.3 Iceland, fin and sei whales

The Committee noted that it has examined these proposals at its three previous meetings (*Rep. int. Whal. Commn* 36: 31–2; *Rep. int. Whal. Commn* 37: 29; and *Rep. int. Whal. Commn* 38: 53). It was agreed at this meeting to confine major discussion to the most recent set of guidelines (*Rep. int. Whal. Commn* 38: 27– 8) against which the permit has not yet been addressed.

(1) *The research addresses a question or questions that should be answered in order to conduct the Comprehensive Assessment or to meet other critically important research needs;*

Gunnlaugsson, Hester, Le Gall, Magnusson, Ohsumi, Øritsland and Sigurjónsson referred to their view expressed under Item 10.3.2, that the programme does facilitate the Comprehensive Assessment and is important for management purposes.

Furthermore, Magnusson noted that the narrowing of the range of possible MSY rates has been identified at this meeting as an important task (Item 6). He noted that information on pregnancy rates, and age at maturity (and also natural mortality rates) helps in establishing bounds on MSY rates and believes they are therefore important for management purposes.

In this regard, Holt and de la Mare expressed their view that while past catches had indicated the general values of certain biological parameters such as pregnancy rate and size/age at maturity, continued monitoring of such parameters, even for a long period, could not yield information sufficient for future management unless accompanied by similar monitoring of all the other critical parameters which enter into an estimation of sustainable or replacement yield. These other parameters include, notably, the live birth rate and the juvenile/ pre-recruitment mortality rates, for which no estimation methods exist or have yet been proposed for these stocks.

Chapman, de la Mare, Holt, Lankester and Tillman, referring back to their view expressed under Item 10.3.2, reiterated that they did not believe the programme addressed questions that should be answered in order to conduct the Comprehensive Assessment.

(2) *The research can be conducted without adversely affecting the overall status and trends of the stock in question or the success of the Comprehensive Assessment of such stock;*

The Committee's discussion on the status of the fin whale stock is given under Item 7.3.3 and Annex F. The Committee had before it a preliminary sightings estimate of fin whales in the Icelandic area of 6,436. Although an assessment had been carried out (Annex F), the Committee agreed that it was inappropriate to use this at this meeting.

The Committee's discussion on the status of the sei whale stock is given under Item 7.3.4 and Annex F. Although a sightings estimate was available for the number of sei whales in the Icelandic survey area, this was not considered appropriate for assessment purposes as the survey had covered only a portion of the population's summer distribution.

Proposed catches for 1988 and 1989 are 80 fin and 20 sei whales each year.

Sigurjónsson believed that in the case of fin whales, the estimate of stock size of about 6,000 animals, combined with the results of calculations given in SC/40/Ba4 and Annex F (Appendix 4) which indicated an MSY rate of more than 4%, and, to a lesser extent, the existence of a stable CPUE series since 1962, all indicate that a take of 80 animals (1.2% of the estimated stock) will not adversely affect the status of the stock. Similarly, he believed that the estimate of 1,243 animals for only part of the sei whale stock showed that the take of 20 animals could not affect the status of the stock. Ohsumi concurred with this view.

Chapman did not agree that we have information on MSY rates or replacement yields, but agreed that the proposed catches would not adversely affect the status of the stocks.

De la Mare pointed out that the criterion of stable CPUE series to infer stock stability had not been used by the Committee since 1983 because it is not reliable (*Rep. int. Whal. Commn* 34: 42; SC/39/Rep2).

Holt expressed his view that a take of 320 fin whales over the four-year period may adversely affect the status of the stock.

Bjørge, Gunnlaugsson, Ikeda, Kasamatsu, Kato, Ohsumi, Sigurjónsson and Vikingsson believed that the Committee should consider only the proposal for a catch in 1989 although they also believed the effect of catches in both 1988 and 1989 should be discussed. Brownell, Chapman, Clark, de la Mare, Harwood, Holt, Lankester, Perrin, Tillman and Zeh believed that it was appropriate to discuss both the 1988 and 1989 proposed catches, noting that the 1987 resolution referred to 'existing special permits'.

(3) *The research addresses a question or questions that cannot be answered by analysis of existing data and/or use of non-lethal research techniques;*

Sigurjónsson expressed his belief that none of the major studies underway (e.g. monitoring of pregnancy rates, effects of environmental factors on body condition and reproduction) could be carried out using non-lethal techniques, particularly in view of the time frame of the programme. Although Iceland is intending to begin a fin whale photo-identification catalogue, he noted the practical difficulties in obtaining sufficient sample sizes under the field conditions prevalent off Iceland, where for example SC/40/Rep1 indicates that to obtain a mark-recapture estimate, some 200 photographs in each of two years would be required – representing an estimated 8 months ship time.

Holt agreed that some of the studies underway in the programme could not be carried out using non-lethal techniques. However, as in the case of the Norwegian proposal, he questioned whether these studies were important to either management issues or the Comprehensive Assessment. Non-lethal techniques were already used to estimate abundance (i.e. sightings surveys). Photo-identification studies and DNA fingerprinting (from biopsy samples) have been shown to be of value in stock identity and biological parameter estimation (SC/40/Rep1).

Hester and Kato agreed with Sigurjónsson's concerns about the difficulties of using photo-identification methods. Hester also noted that DNA fingerprinting studies are still in their developmental phase. Ohsumi commented that the Icelandic programme combined lethal and non-lethal techniques and that he believed this was the best scientific approach.

Chapman noted that the difficulties referred to earlier in separating results from the programme made it difficult for him to comment on whether non-lethal techniques could replace the lethal techniques.

(4) *The research is likely to yield results leading to reliable answers to the question or questions being addressed*

The Committee noted that it has addressed this question in previous years (*Rep. int. Whal. Commn* 36: 31–2; 37: 97; 38: 53).

Sigurjónsson referred to his comments under Item 10.3 and in previous years and reiterated his belief that the programme will lead and is leading to reliable answers to the questions being asked.

Tillman commented that he found it difficult to assess the reliability of any analyses as the proposers have not addressed the questions of required sample size or the need for random sampling as has been the case in the Japanese proposal.

Sigurjónsson responded that the Icelandic programme did not aim to achieve random sampling. The limitations of a land-based operation do not allow sampling over the entire summer range of the stock as is the case for the Japanese study on minke whales in the Antarctic. The main point is to continue to monitor the growth rate and fecundity between years. No major differences between age classes in ovulation or pregnancy rates have been demonstrated. This indicates that the sample obtained is representative of the stock. Further the study was designed such that the CPUE series obtained is in all major aspects comparable with earlier series.

Chapman, Cooke, de la Mare, Harwood, and Holt expressed disappointment at the quality of the analysis from the lethal sampling to date, and were concerned that the research may not yield reliable results if the data collected are not to be made available for in-depth analysis by the wider scientific community.

11. SCIENTIFIC COMMITTEE PROCEDURES

11.1 Style of reporting of Committee discussions and conclusions

For many years, the Committee has adopted a form of reporting discussions and recommendations in which individual member's names are rarely assigned to differing views expressed, except in minority statements. At the 1987 Annual Meeting, several Commissioners expressed the desire that the scientists supporting particular views should be identified, especially in relation to consideration of Scientific Permits. The Committee was asked to do everything possible to clarify its reports in future. An *ad hoc* procedure was adopted at the recent Special Meeting whereby it was agreed that members associated with differing views would be identified.

There was considerable discussion of the matter at the present meeting. Arising out of this, the Committee agreed to the following procedure.

(i) Sub-committee reports would continue to be formulated in the traditional manner. As usual, members would have the right to ask for their names to be attached to particular views should they so wish.

(ii) In the full Scientific Committee report, where appropriate, names may be attached to differing views (either directly or in the form of a footnote). Members may associate themselves with particular views at the report reviewing stage.

The Committee noted that (ii) above should particularly be applied in the case of issues directly relating to guidelines or criteria formulated by the Commission itself, for example the review of scientific permits and the classification of stocks.

Sigurjónsson, Øritsland and Best, while reluctantly accepting this procedure, noted their worry that it approached the situation of voting, which they believed to be inappropriate.

11.2 Procedures for the planning and conduct of special meetings

The Committee agreed that special (i.e. intersessional) meetings could be divided into two categories:

(i) those which are arranged at an Annual Meeting of the Committee or Commission and whose reports are submitted to the following Annual Meeting of the Committee;

(ii) those which are established between Annual Meetings under the Commission's Rule of Procedure B1 and whose reports are submitted directly to the Commission.

An example of the latter is the recent Special Meeting to consider the Japanese Research Permit (Feasibility Study). Concern has been expressed that the short notice given for that meeting might have resulted in very few members being able to attend although in fact this was not the case. Table 8 summarises the nature of and participation at recent special meetings of the Committee.

The Committee **recommends** that if such meetings are called in the future, suitable notice is given wherever possible. A minimum period of 60 days is suggested and the Committee urges the Commission to consider adopting Rules of Procedure such that this can normally be achieved.

The Committee also considered the question of the need for a quorum, as raised at the special meeting. It agreed that in terms of formulating advice, the most important factor was the presence of suitable expertise. The precise number of participants or countries present was not directly relevant. In particular it was agreed that a rigid rule would be inappropriate for special meetings on specialised topics where only a small number of Committee members may wish to attend (see Table 8).

It was noted that the problem of limited participation was potentially more serious for meetings in category (ii) above, but that this would be avoided if the recommendation of giving sufficient advance notice is adopted. This would not preclude members from providing written comments.

Given that the Scientific Committee is an advisory, rather than executive body, the Committee draws the Commission's attention to the fact that it believes the rigid application of the concept of a quorum is inappropriate for Scientific Committee meetings.

11.3 Intersessional review of Scientific Permit programmes

Rule F(4) of the Scientific Committee's Rules of Procedure provides for a mail procedure for the review of Scientific Permits between annual meetings of the Committee. The last time this was discussed (*Rep. int. Whal. Commn* 37: 37), the Committee had recognised the difficulties this would lead to in formulating a 'Committee view', although it also noted that at that time the procedure had not yet been invoked. This has become more of a problem given

Table 8

Participation in Special Meetings of the IWC Scientific Committee. Meetings marked with an asterisk are those which reported directly to the Commission. 'IWC' signifies the number of member nations at the time. The number in square brackets signifies the number who elected to be represented on the Scientific Committee. Under 'Present', the first number signifies the number of member governments present; the second the number of intergovernmental observers or advisors. 'People' refers to number of participants, including, in square brackets, the number of invited participants.

Meeting	Venue	Date	IWC	Present	People
Age determination	Oslo	Feb/Mar 1968	16	8 + 2	14
Sperm assessments	Honolulu	March 1970	15	7 + 1	14
Antarctic fin	Honolulu	March 1970	15	7 + 1	14
Sperm	Parksville	May 1972	14	7 + 1	13
Sei + management	La Jolla	Dec 1974	15	9 + 1	24
Sperm	La Jolla	March 1976	15	6 + 1	19
Sei	Tokyo	April 1977	17	5	16
Sperm*	Cronulla	Nov 1977	17	6 + 1	18
S.H. minke	Seattle	May 1978	17	9 + 2	16 [2]
Sperm assessments*	La Jolla	Nov/Dec 1978	17	9 + 2	31 [4]
S.H. sei	Cambridge	June 1979	23 [17]	7 + 2	23 [2]
S.H. minke	Cambridge	June 1981	25 [23]	12 + 1	37 [1]
W.N. Pacific sperm*	Cambridge	Feb/Mar 1982	33 [25]	12 + 1	32 [2]
Comprehensive Ass't	Cambridge	April 1986	41 [24]	15 + 1	38 [5]

the recent Commission resolutions on how the Committee should review such permits, where it is clear that a Committee view, rather than a compilation of individual views, is required.

The Committee believes that, in the exceptional circumstances that a scientific permit is proposed by a Contracting Government between Annual Meetings, it will be necessary to consider it at a Special Meeting of the Scientific Committee called for that purpose. Whilst recognizing the cost of such a procedure, the Committee suggests that at its next meeting it should formulate wording to extend its Rule of Procedure F.4 specifically to provide for review of scientific permit proposals at such a Special Meeting.

In addition to the provision under Rule F(4) of the Committee the Chairman of the Commission can call such a special meeting under the Committee's Rule D1, as was the case for the recent special meeting. The Chairman of the Commission had consulted the Chairman of the Scientific Committee before calling the special meeting. The Committee expressed its appreciation and **recommends** that this practice be continued.

11.4 Policy on access to data

Last year the Commission endorsed several suggestions of the Committee to amend guidelines concerning data availability (*Rep. int. Whal. Commn* 38: 23–24, 59). It also agreed that the Secretariat should develop a discussion paper on the general question of data availability and research carried out under the Comprehensive Assessment. This paper, SC/40/O 2, was prepared and circulated in advance of the meeting. It proposed a new Appendix 1 to the Committee's Rules of Procedure to take these points into account.

The Committee **recommends** that the new Appendix 1 given as Annex P to this report be adopted. It draws the Commission's attention to the fact that on three occasions, alternative forms of words are presented. While noting that the aim of the Committee is to encourage as much data as possible to be made available, the Committee believes that it is more appropriate for the Commission to choose among the alternatives present.

Last year it was noted that the Secretariat would seek clarification from countries over data submitted voluntarily, initially to BIWS and now to the secretariat. The responses from Japan, the USSR and Norway are given in Annex P.

11.5 Other

A series of comments concerning Scientific Committee procedures, particularly with respect to the review of scientific permits, were made by Commissioners during the year. These were compiled and made available to the Committee as SC/40/O 3 and were taken into account during the Committee's discussion of Items 11.1–11.3.

12. SECOND INTERNATIONAL DECADE OF CETACEAN RESEARCH

12.1 Review results from 1987/88

(a) *Radio-telemetric study of the behaviour of blue fin and humpback whales*

SC/40/PS1 reported on progress in the above study. Logistical problems led to a shorter field season than anticipated. As a consequence, field testing of equipment was carried out but no animals were tagged in the first year of the five year programme.

(b) *Galapagos sperm whales*

Results of a study of social organisation of sperm whales off the Galapagos funded by the Commission in 1986 (SC/40/Sp2–4) are discussed under Item 6.1.4.

(c) *IWC/IDCR Southern Hemisphere minke whale assessment cruise 1987/88*

Last year, the Committee agreed that this item should be considered an IDCR item as well as being a contribution to the Comprehensive Assessment (*Rep. int. Whal. Commn* 38: 40). Papers dealing with the 1987/88 IDCR minke whale cruise and earlier cruises are discussed in Annex D. The early date of this year's Scientific Committee meeting had not allowed time for completion of data coding and validation for the 1987/88 cruise. Joyce reported on progress in organising a catalogue of natural marking photographs from IDCR cruises.

12.2 Review proposals for 1988/89

All proposals recommended for support here will be subject to the Committee's guidelines on data availability as agreed under Item 11.4.

(a) *Radio-telemetric study of the behaviour of blue, fin and humpback whales*

This is discussed in Annex G. The Committee **recommends** that the proposal (SC/40/RP2) to continue the study to assess the retention and performance of sub-dermal VHF radio tags in blue, fin and humpback whales be funded.

(b) *Analysis of photographs for North Pacific humpback whales: preliminary work towards estimating juvenile mortality*

This is discussed in Annex G. The Committee **recommends** that this be funded.

(c) *IWC/IDCR Southern Hemisphere minke whale cruise 1988/89*

This is also discussed under Item 6, Comprehensive Assessment. The Committee **recommends** that this cruise be funded as a contribution to the Comprehensive Assessment, as outlined in Annex K.

(d) *Analysis of IDCR photographs of minke whales*
The Committee **recommends** that photographs of minke whales taken on the IDCR cruises should be analysed to determine if they can be used for the identification of individual animals (see Item 7.1.7).

(e) *Proposed meeting on mortality of cetaceans in fishing nets and traps*
In 1985 the Committee recommended that a Workshop be convened to examine the question of the incidental catch of both small and large cetaceans in gillnet and other static net fisheries (*Rep. int. Whal. Commn* 36: 37). The meeting was not held due to funding problems and last year the recommendation to hold the Workshop was repeated and an offer to host the meeting by the Southwest Fisheries Centre in La Jolla, California, was accepted. Perrin was appointed convenor.

At this meeting, a working group was established to examine draft terms of reference and prepare a budget. The report of the group is given as Annex N. The Committee **recommends** that the meeting be held as described in the Annex. A steering group of Perrin, Brownell, Puddicombe, Arnbom, Harwood, Jones and Kasuya was established.

13. DATA PROCESSING AND COMPUTING NEEDS FOR 1987–88

Progress on data processing and computing projects in the past year is discussed under Items 4.3.2 and 4.3.3. For data coding projects to be carried out in 1988–89, the Committee **recommends** the following priority order:

(i) 1988/89 IDCR cruise data coding;
(ii) Comprehensive Assessment data inventory coding;
(iii) completion of coding of catch data from 1949 onwards;
(iv) coding of pre-1932 Antarctic baleen whale catches and 1932–49 Southern Hemisphere land station catches;
(v) completion of coding of marking data.

A number of computing requirements were developed during discussions of the Comprehensive Assessment and of sub-committee reports, and the Committee **recommends** that these be carried out in the following year:

(i) develop programs for screening of management procedures (see Item 6.3.2);
(ii) in preparation for the Feeding Ecology Workshop, prepare data files on Antarctic baleen whale catches in cooperation with Mizroch and on sightings densities by species, month and 1° square (see Item 6.2.2);
(iii) carry out sensitivity tests and associated studies on the use of the HITTER program to fit data from the bowhead whale stock (see Annex — and Item 7.3.3);
(iv) validate new versions of the HITTER/FITTER program that allow estimation of confidence limits (see Annex E);
(v) as a background task, continue documentation of programs held by the Secretariat, with priority given to those now used most frequently by the Committee in assessments.

In relation to the first item in this list, the Committee noted that a junior programmer had been appointed to the Secretariat this year to relieve the burden of routine computing tasks from Allison, leaving her time to undertake the work associated with screening new management procedures developed as part of the Comprehensive Assessment. This appointment had been in response to the Committee's recommendations last year (*Rep. int. Whal. Commn* 38: 60).

In addition to the computing projects listed above, the Secretariat has now taken over the task of data coding, validation and routine analysis of IDCR sightings cruise data, with this task being assigned to Borchers. Under Item 7.1, a number of additional sets of analyses were recommended by the Committee. On examining a consolidated list of analyses needed on these data resulting both from this and last year's meeting, the Committee noted that these would require substantially more than 12 man-months work. It therefore **recommended** that a replacement for Borchers (whose contract expires in mid 1989) be appointed by November this year, so that he could assist in this very important work. A list of the IDCR computing projects identified and associated priorities is given in Annex K.

14. FUNDING

Priorities

The need for revising the guidelines for review of research proposals (*Rep. int. Whal. Commn* 32: 47) was identified. Gambell noted some difficulties in evaluating proposals, especially those received independent of the Scientific Committee, and that the current priority of funding work that directly related to the Comprehensive Assessment is not reflected in the earlier guidelines (*Rep. int. Whal. Commn* 38: 60).

The Committee agreed to the following priorities:

(1) Projects relevant to the Comprehensive Assessment (including those arising from Scientific Committee Workshops). These can be classified as:
    (a) those relating to the specific priority stocks;
    (b) those relating to assessment methodology;
    (c) those relating to the development of management procedures.

Priority among these is determined by examination of the Committee's needs as identified in its most recent Report of this item.

(2) Projects contributing to the second IDCR.
It is suggested that the past practice of preferring to give partial support to a number of projects ('seed money') rather than total funding for a few programmes should be continued.

Awarding of contracts

The procedures used for awarding contract studies were reviewed and Kirkwood identified three problems. One is identifying appropriate potential contractors, especially where the study is in an area where the Committee has relatively little expertise. A second is the basis for selection of one contractor. It was noted that this has been done by consultation among the Secretariat, the Chairman of the Scientific Committee, and the convenors of relevant sub-committees and workshops, where such had resulted in the recommendation of the contract study. The third and related problem was the extent to which a proposal that does not fully address all of the terms of reference should be considered.

The Committee discussed these procedures at some length. It agreed that a possible revised protocol would involve the following elements.

(a) At the time of identifying the need for a contract study, the Committee should identify detailed terms of reference, a budget and a group of reviewers who will be responsible for assessing all proposals received within a specified time interval after the Commission's meeting. This group would evaluate the submissions against the terms and budget of the work proposal. It would normally include the Chairman of the Scientific Committee, the convenor of the appropriate sub-committee (if relevant), the Secretary and nominated specialist reviewers from within or without the Committee. Criteria for review should be based on those used to review research proposals.

(b) A formal request that Committee members and Commissioners bring the contract study to the attention of appropriate scientists who may be interested in submitting proposals.

(c) When written reviews have been received of the proposals submitted, the contract will be awarded to that scientist or group rated most highly by the review panel.

The Committee agreed that some details of this protocol need further thought (especially the mechanism and responsibility for awarding the contract). Since there are no proposed new contract studies this year, it was agreed to defer further discussions on this.

14.1 Comprehensive Assessment

The funding implications of work recommended under Item 6.6 are provided in Table 9. A total of £174,350 is required for these projects, and the Committee **recommends** that these funds be provided.

14.2 Other research items

The Committee **recommends** the projects outlined under Item 12.2 be funded as shown in Table 10.

Table 9

Comprehensive Assessment activities. Item (1) includes £1,500 for the attendance of one researcher at the 1989 Scientific Committee meeting. Item (5) includes £8,200 for a year's salary, £1,500 for attendance at the 1989 meeting and £1,300 running costs. Item (6) includes £13,200 for one person's salary and travel costs, £10,000 for a second person's salary and recruitment costs, £3,000 for the attendance of both at the 1989 meeting and £3,900 running costs.

Activity	£
(1) Funding for year two of Dept of Genetics, Cambridge University contract	32,000
(2) Workshop on the genetic and biochemical analysis of tissue samples collected by biopsy sampling and other means	15,000
(3) Development of a computer-aided matching procedure for photographs of cetacean natural markings	8,750
(4) Management procedures workshop	15,000
(5) Computer programming assistance for management procedures	11,000
(6) Discretionary fund for development of management procedures (< £1,000 per scientist)	5,000
(7) Right whale survey, South Africa	12,000
(8) IDCR Minke Whale Cruise 1988/89	45,250
(9) Analysis of data from previous IDCR Minke Whale Cruises	30,100
(10) IDCR minke photo analyses	250
Total	174,350

Table 10

Activities under the second IDCR

Activity	£
(1) Meeting on cetacean mortality in fishing nets	30,000
(2) North Pacific humpback whale photographs	10,000
(3) Radio-telemetry study	6,000
Total	46,000

14.3 Invited participants

The Committee has on several occasions (e.g. *Rep. int. Whal. Commn* 37: 37) noted the important role played in its work by invited participants. This is particularly true in the context of the Comprehensive Assessment, where new approaches to some of the major problems facing the Committee (e.g. DNA fingerprinting, telemetry) are being considered.

The Committee **strongly recommends** that funding of £9,000 be made available for invited participants.

14.4 Priorities

A total of £229,350 is required for the items identified above. Funds have already been set aside for the Workshop on the Feeding Ecology of the Southern Baleen Whales, for Studies of Southeast Pacific Sperm Whales and for the compilation of an inventory of photographs collected on the Southern Hemisphere IDCR cruises. In addition, a total of £56,000 is in hand from unallocated funds. Thus, the total new money required to implement all the recommended projects in 1988/89 is £173,350.

At its 1987 meeting, the Commission recommended that the Scientific Committee should indicate in its funding request for 1988–89, which activities are of lower priority to allow for a 5% and 15% shortfall (*Rep. int. Whal. Commn* 38: 25). The Committee noted that in developing the list of recommended projects in Items 14.1 and 14.2, it had only included those that it accorded the highest priority, and it **strongly recommends** that all of these projects are funded. However, in response to the Commission's instruction, it further offers the following advice.

If there is a shortfall of 5% in available funding, the Committee **recommends** that the budget for the meeting on cetacean mortality in fishing nets and traps should be reduced to £21,500. The remainder of the funds required for this meeting should then be sought from other national and international organisations (e.g. UNEP). If there is a shortfall of 15%, it **recommends** that, in addition to a reduction in the budget for the meeting on cetacean mortality in fishing nets and traps, the workshop on genetic analysis should be postponed for one year.

15. INITIAL AGENDA FOR 1989

In discussing this agenda item during previous meetings, the Committee had expressed the view that attempting to consider both the Comprehensive Assessment and normal business during its annual meetings has led both to an extremely heavy work-load and a less than adequate amount of time being available to devote to either topic. While acknowledging this problem, the Commission has to date agreed that it does still wish the Committee to provide annually advice on stocks currently being exploited and on scientific permit proposals.

This year, the Committee agreed that, if it is to present to the Commission in 1990 a detailed report on progress towards the Comprehensive Assessment, it is essential that most, if not all of its 1989 Annual Meeting should be devoted to planning for the preparation of such a report. Despite this, the Committee recognises that the Commission may still require advice on other matters. If this is the case, the Committee strongly urges that the Commission consider reducing to a minimum the amount and scope of other advice requested from the Committee at its 1989 Annual Meeting. The Committee agreed that discussion of assessments and other issues outside the Comprehensive Assessment should take place only as specifically directed by the Commission.

The Committee agreed that, in addition to planning for 1990, the following Comprehensive Assessment items should be given priority at its 1989 meeting:

(i) Further development of management procedures;
(ii) MSY rates;
(iii) Stock identity (including genetics and photo-identification studies);
(iv) Sightings surveys (concentrating on any remaining methodological problems, rather than stock assessment).

In view of the proposed Workshop on the Feeding Ecology of Southern Hemisphere baleen whales and the ICES Multispecies Management Workshop to be held in the coming year, the Committee agreed that it would include an agenda item addressing the implications for whale management of inter-specific interactions.

In relation to the organisation of its meeting next year, the Committee agreed that it may no longer be appropriate for the usual sub-committees to be established. Instead consideration should be given to forming sub-committees to consider specific subjects, e.g., sightings surveys.

The Committee agreed that the Chairman should be given maximum flexibility in developing an agenda for its 1989 annual meetings. It requested that a preliminary draft agenda be prepared by the Chairman as soon as possible after the 1988 Commission meeting and circulated to members of the Committee.

The Committee agreed that a similar level of computing support would still be required at its next Annual Meeting, even if the level of assessment work diminishes as much as hoped.

16. PUBLICATIONS

The Committee agreed, in accordance with the procedures outlined in *Rep. int. Whal. Commn* 32: 63, that the Editorial Board should comprise Donovan, Braham, Brownell, Harwood, Hammond, Kirkwood, Perrin and Tillman.

17. ELECTION OF OFFICERS

The Committee accepted with regret, the resignation of Dr G.P. Kirkwood, after three years as Chairman of the Committee, a period during which he had guided its deliberations with fairness, wisdom and good humour.

In accordance with the procedure agreed in 1983 (*Rep. int. Whal. Commn* 32: 61), Brownell and Hammond were elected Chairman and Vice-Chairman, respectively.

18. OTHER BUSINESS

The Committee agreed that the provision of microphones during its plenary and sub-committee sessions had greatly facilitated its discussions, and it **recommended** that similar provision be made at further meetings.

The Committee wished to record its appreciation of the long hours, hard work and cheerful service of the Secretariat during the meeting. It is also very grateful for the hard work of staff of the SWFC in making arrangements for the meeting.

19. ADOPTION OF REPORT

At the request of the Committee, last year the Commission extended the length of the Committee's meeting this year by one day. This additional day was devoted entirely to reviewing the report, and the Committee was able to adopt those sections of the report covering Items 1–11, 13 and 17. The remaining sections of this report are an account of deliberations agreed by the Rapporteur, the Chairman, the Vice-Chairman and sub-committee chairmen. Individual members were invited to submit comments on the report to this group and the comments received have been taken into account.

The Committee **recommends** that the length of its 1989 Annual Meeting should be 14 days, as this year.

Annex A
List of Participants

(I) = Interpreter

AUSTRALIA
W.K. de la Mare
G.P. Kirkwood
R. Puddicombe

BRAZIL
O.A. Botafogo Goncalves
J.M. da Rocha
V. Ferreira da Silva

DENMARK
F. Larsen
H.J. Lassen
P.J. Palsboll

FRANCE
A. Collet
J.-Y. Le Gall

FEDERAL REPUBLIC OF GERMANY
P. Deimer

ICELAND
A. Arnason
T. Gunnlaugsson
K. Magnusson
J. Sigurjónsson
G.A. Vikingsson

JAPAN
I. Ikeda
N. Inagaki (I)
F. Kasamatsu
T. Kasuya
H. Kato
H. Kishino
A. Mae
S. Misaki (I)
T. Miyashita
M. Morimoto
T. Nakamura
T. Nakamura (I)
S. Ohsumi
K. Sakuramoto
Y. Shimadzu
S. Tanaka
K. Yamamura

MEXICO
L.A. Fleischer
D. Luna

NETHERLANDS
K. Lankester

NEW ZEALAND
M. Cawthorn

NORWAY
A. Bjørge
O. Nakken
N. Øien
T. Øritsland
O. Ulltang
L. Walløe

ST VINCENT & THE GRENADINES
F. Hester

SEYCHELLES
S.J. Holt

SPAIN
L. Jover
S. Lens
H. Quiroga
C. Sanpera

SWEDEN
T. Arnbom

UK
P. Hammond
J. Harwood
A. Hiby
J. Horwood
A. Martin

USA
T.F. Albert
H.W. Braham
J.M. Breiwick
G.C. Broadhead
R.L. Brownell Jr
D.G. Chapman
C.W. Clark
D.P. DeMaster
D. Goodman
R.S. Holt
L.L. Jones
S.A. Mizroch
W.F. Perrin
A.E. Raftery
S.B. Reilly
G.P. Scott
T.D. Smith
R.M. Sonntag
R.J. Tarpley
M.F. Tillman
J.E. Zeh

INVITED PARTICIPANTS
W. Amos
U. Arnason
D. Aurioles
K.C. Balcomb III
J.L. Bannister
P.B. Best
S.T. Buckland
D.S. Butterworth
J.G. Cooke
R.N.P. Goodall
J. Heyning
R. Hoelzel
G.G. Joyce
J.S. Leatherwood
D.K. Ljungblad
C. Lockyer
B.R. Mate
J. Mead
S.E. Moore
R.L. Pitman
S.L. Swartz
O. Vidal
H. Whitehead

INTERGOVERNMENTAL ORGANISATION OBSERVERS
A. Anganuzzi (IATTC)
W.K. de la Mare (CCAMLR)
M. Hall (IATTC)
J. Joseph (IATTC)
D. Miller (CCAMLR)
B. Nielsen (UNEP)
M. Scott (IATTC)
Y. Shimadzu (CCAMLR)

IWC
C. Allison
D.L. Borchers
A. Dizon
G.P. Donovan
R. Gambell

Annex B
Agenda

1. Chairman's welcome and opening remarks

2. Adoption of Agenda

3. Arrangements for meeting
    3.1 Appointment of rapporteurs
    3.2 Meeting procedures and time schedule
    3.3 Establishment of sub-committees
    3.4 Computing arrangements

4. Review of available data, documents and reports
    4.1 Documents submitted
    4.2 National Progress Reports
    4.3 Data collection, storage and manipulation
        4.3.1 Catches and other statistical material from the previous season
        4.3.2 Progress on data coding projects
        4.3.3 Progress on computing projects
    4.4 Whale marking

5. Cooperation with other organisations
    5.1 Observers' reports
        5.1.1 CCAMLR
        5.1.2 ICES
        5.1.3 ICSEAF
        5.1.4 IATTC
    5.2 UNEP meeting on small cetaceans
    5.3 Other matters

6. Comprehensive Assessment of whale stocks
    6.1 Review reports of contract studies
        6.1.1 Biochemical genetics
        6.1.2 Analysis of Southern Hemisphere minke whale marking data
        6.1.3 Analysis of Southern Hemisphere non-minke sightings data
        6.1.4 Galapagos sperm whale study
    6.2 Review reports of intersessional meetings
        6.2.1 Photo-identification workshop
        6.2.2 Feeding ecology workshop
    6.3 Review reports of intersessional working groups
        6.3.1 Analysis of catch curves
        6.3.2 Management procedures
        6.3.3 Biological parameters
    6.4 Other studies
        6.4.1 Sightings surveys
        6.4.2 Telemetry and remote sensing
        6.4.3 Follow up to CPUE Workshop
        6.4.4 Estimating maximum sustainable yield rate
    6.5 Data inventories and coding
    6.6 Future work
        6.6.1 Priority groups/stocks and studies
        6.6.2 Work plan for 1988/89
        6.6.3 Preliminary work plan for 1989/90

7. Whale stocks, status and advice
    7.1 Southern Hemisphere minke whale stocks
    7.2 North Atlantic minke whale stocks
        7.2.1 Northeastern stock
        7.2.2 Central stock
    7.3 Other baleen whale stocks
        7.3.1 Western North Pacific stock of Bryde's whales
        7.3.2 Okhotsk Sea – West Pacific stock of minke whales
        7.3.3 East-Greenland – Iceland stock of fin whales
        7.3.4 Iceland – Denmark Strait stock of sei whales
    7.4 Information on other stocks

8. Stocks subject to aboriginal subsistence whaling
    8.1 Bering – Chukchi – Beaufort Seas stock of bowhead whales
    8.2 Eastern Pacific gray whales
    8.3 West Greenland stock of fin whales
    8.4 North Atlantic humpback whales
    8.5 West Greenland minke whales
    8.6 Information on other stocks

9. Small cetaceans
    9.1 Beaked whales
    9.2 Information on other stocks

10. Scientific Permits
    10.1 Report of Special Meeting
    10.2 Guidelines for review of Scientific Permits
    10.3 Review of research results based on existing Scientific Permits
        10.3.1 Japanese feasibility study
        10.3.2 Iceland
    10.4 Review of new or revised Scientific Permit proposals

11. Scientific Committee procedures
    11.1 Style of reporting of discussions and agreements
    11.2 Procedures for planning and conduct of Special Meetings
    11.3 Intersessional review of Scientific Permit proposals
    11.4 Policy on access to data
    11.5 Other matters

12. Second International Decade of Cetacean Research
    12.1 Review results from 1987–88
    12.2 Review proposals for 1988–89

13. Data processing and computing needs for 1988–89

14. Funding requirements for 1988–89
    14.1 Comprehensive Assessment
    14.2 Other research items
    14.3 Priorities

15. Initial Agenda for 1989 meeting

16. Publications

17. Election of officers

18. Other business

19. Adoption of Report

Annex C
List of Scientific Committee Documents

* = published in this volume.

SPERM

SC/40/Sp

1 MULLINS, J., WHITEHEAD, H. and WEILGART, L.S. Behaviour and vocalizations of two single sperm whales, *Physeter macrocephalus*, off Nova Scotia.

2 WHITEHEAD, H., WEILGART, L. and WATERS, S. Seasonality of sperm whales off the Galapagos Islands, Ecuador.*

3 WHITEHEAD, H. and WATERS, S. Social organization and population structure of sperm whales off the Galapagos Islands, Ecuador (1985 and 1987). [*Rep. int. Whal. Commn* (special issue 12)].

4 WHITEHEAD, H., PAPASTAVROU, V. and SMITH, S. Sperm whales and El Nino off the Galapagos Islands.

5 DEIMER, P., GORDON, J. and ARNBOM, T. Sperm whales killed in the Azores during 1987.

MINKE

SC/40/Mi

1 HOLT, S.J. 'The state of the northeast Atlantic minke whale stock'. A critique.*

2 JOYCE, G., KASAMATSU, F., ENSOR, P., NAKANISHI, S., ROWLETT, R., SHIGEMUNE, H., TROUTMAN, B. and YAMASHITA, K. Report of the 1987–88 IWC/IDCR Southern Hemisphere minke whale assessment cruise, Area III.

3 ENSOR, P.H. Minke whales in the pack ice zone, east Antarctica, during the period of maximum annual ice extent.*

4 HIBY, L. and WARD, A. Estimation of minke whale abundance using cue counting results from *Shonan Maru No.2* in Area II, 1986/87.

5 ZAHL, S. Analysis of Brazilian minke whale data from 1966–85.

6 BUCKLAND, S.T. and DUFF, E.I. Analysis of the Southern Hemisphere minke whale mark-recovery data. [*Rep. int. Whal. Commn* (special issue 11)].

7 NORWAY. A programme to study and monitor northeast Atlantic minke whales, 1988–92.

8 [WITHDRAWN]

9 ØIEN, N. Provisional sighting estimates of northeast Atlantic minke whale abundance from the Norwegian shipboard surveys in 1987.*

10 BUSHUEV, S.G. Variability of the quantity of vibrissae in Antarctic minke whales.

11 ANDERSON, R.M., BEVERTON, R.J.H., SEMB-JOHANSSON, A. and WALLØE, L. The state of the northeast Atlantic minke whale stock. (Report of the group of scientists appointed by the Norwegian Government to review the basis for Norway's harvesting of minke whales).

12 ANDERSON, R.M., BEVERTON, R.J.H. and WALLØE, L. The report on the NE Atlantic minke whales and IWC policy.

13 BUSHUEV, S.G. Occurrence of ectoparasites and commensals on bodies of Antarctic minke whales as a marker of natural whale groupings.

14 BUTTERWORTH, D.S. Revised abundance estimates for minke whales in Antarctic areas IVW and V from sightings on the 1978/79, 1984/85 and 1985/86 cruises.

15 JOYCE, G.G., ØIEN, N. and ORITSLAND, T. Surfacing rates of minke whales in Norwegian waters.*

16 KASAMATSU, F. Notes on abundance estimates of western North Pacific minke whale.

17 WADA, S. Latitudinal segregation of the Okhotsk Sea-West Pacific stock of minke whales.*

18 KATO, H., HIROYAMA, H., FUJISE, Y. and ONO, K. Preliminary report of the feasibility study on southern minke whale under the Japanese proposal to the special permit.*

19 BORCHERS, D.L. Estimation of minke whale abundance from the 1986/7 IWC/IDCR sightings cruise in Antarctic Area II.

20 BUTTERWORTH, D.S. and BORCHERS, D.L. Estimates of g(0) for minke schools from the results of the independent observer experiment on the 1985/86 and 1986/87 IWC/IDCR Antarctic assessment cruises (SC/39/Mi17 revised).

21 LARSEN, F. Norwegian minke whaling at West Greenland: operational strategies.*

22 SIGURJÓNSSON, J. Studies on age and reproduction in minke whales, *Balaenoptera acutorostrata*, in Icelandic waters.

23 GUNNLAUGSSON, T. Report on Icelandic minke whale surfacing rate experiments in 1987.*

24 HOLT, S. Nineteenth century minke whaling in the North Atlantic.

25 MITCHELL, E. Note on the nature of catch per unit effort data recorded for minke whales, *Balaenoptera acutorostrata*, in the Canadian east coast land station whale fishery, 1965–1972.

OTHER BALEEN (Fin, Sei, Bryde's)

SC/40/Ba

1 SAMPSON, D.B. Pregnancy rate versus length in Southern fin whales.*

2 YOSHIOKA, M. Bryde's whales taken by the Japanese landbased whaling in the Bonin Islands waters, 1981–1987.

3 MIYASHITA, T. Population estimate for the Bryde's whale stock in the western North Pacific.

4 GUNNLAUGSSON, Th., MAGNUSSON, K.G. and SIGURJÓNSSON, J. Stock trajectories for the East Greenland Iceland fin whale stock based on revised catch statistics, 1883–1987.*

5 KONRADSSON, A. and SIGURJÓNSSON, J. Results of studies on growth layers in tympanic bullae in fin whales, *Balaenoptera physalus*, caught off Iceland.*

6 VIKINGSSON, G.A. Morphometric studies on the sei whale, *Balaenoptera borealis*, – a progress report.

7 VIKINGSSON, G. Chemical composition of blubber and muscle of fin and sei whales from Iceland.

8 KJELD, M. and ARNASON, A. Serum progesterone and testosterone levels in fin whales caught off Iceland caught off Iceland: A progress report.

9 ARNASON, A. and SPILLIAERT, R. Study of carbonic anhydrase polymorphism in fin whales (*Balaenoptera physalus*) caught off Iceland over the years 1971, 1981–1987.

10 DANIELSDOTTIR, A. K., DUKE, E. J., JOYCE, P. and ARNASON, A. Progress report on the study of genetic variation at enzyme loci in fin whales (*Balaenoptera physalus*) caught off Iceland and off Spain.

11 SPILLIAERT, R. and ARNASON, A. A progress report on an electrophoretic study of liver esterases in fin whales (*Balaenoptera physalus*) from Icelandic and Spanish waters.

12 LOCKYER, C. and SIGURJÓNSSON, J. Preliminary note on temporal changes in reproductive data for female fin whales caught off southwest Iceland.

13 SANPERA, S. and JOVER, L. Density estimate of fin whales in the North Atlantic from NASS-87 – Spanish cruise data.*

PROTECTED SPECIES AND ABORIGINAL/SUBSISTENCE WHALING (Bowhead, Right, Blue, Humpback, Gray)

SC/40/PS

1 SWARTZ, S.L., WELLS, R.S. and KRUSE, S. Progress report on radio-telemetric studies of the behaviour of blue, fin, and humpback whales in Monterey Bay and along the central California coast.

2 MOORE, S.E., CLARKE, J.T. and LJUNGBLAD, D.K. Distribution, sighting rate, bathymetric habitat, and behaviour of bowhead whales (*Balaena mysticetus*) during late summer and early fall, in the eastern Alaskan and western Canadian Beaufort Sea.*

3 MOORE, S.E., BENNETT, J.C. and LJUNGBLAD, D.K. Use of passive acoustics in conjunction with aerial surveys to monitor the fall bowhead whale (*Balaena mysticetus*) migration.*

4 CLARK, C.W. and ELLISON, W.T. Numbers and distributions of bowhead whales, *Balaena mysticetus*, based on the 1986 acoustic study off Point Barrow, Alaska.*

5 ZEH, J.E., RAFTERY, A.E. and STYER, P.E. Mark-recapture estimation of bowhead whale, *Balaena mysticetus*, population size and offshore distribution from 1986 visual and acoustic data collected off Point Barrow, Alaska.

6 RAFTERY, A.E., ZEH, J.E. and STYER, P.A. Bayes empirical Bayes interval estimation of bowhead whale, *Balaena mysticetus*, population size based upon the 1985 and 1986 combined visual and acoustic censuses off Point Barrow, Alaska.

7 TARPLEY, R.J., SIS, R.F., ALBERT, T.F., DALTON, L.M. and GEORGE, J.C. Observations on the anatomy of the stomach and duodenum of the bowhead whale, *Balaena mysticetus*.

8 TARPLEY, R., WEEKS, R. and SCOTT, G. Observations on reproductive morphology in the female bowhead whale, *Balaena mysticetus*.

9 FOLLMAN, E.H. and MANNING, A.E. The use of radio telemetry in instrumenting whale floats as an aide in the recovery of struck but lost bowhead whale, *Balaena mysticetus*.

10 BRAUND, S.R., MARQUETTE, W.M. and BOCKSTOCE, J.R. Data on shore-based bowhead whaling at sites in Alaska.

11 WITHROW, D. and GOEBEL-DIAZ, C. Distribution of bowhead whales near Pt. Barrow, Alaska, 1984–1986.*

12 BREIWICK, J.M., RUGH, D.J., WITHROW, D.E., DAHLHEIM, M.E. and BUCKLAND, S.T. Preliminary population estimate of gray whales during the 1987/88 southward migration.

13 BLOKHIN, S.A. Materials on spatial distribution of gray whales off Chukotka.*

14 BLOKHIN, S.A. Results of investigations of gray whales in 1987.

SMALL CETACEANS

SC/40/SM

1 CHIVERS, S.J., HOHN, A.A. and MILLER, R.B. Composition of the 1987 incidental kill of small cetaceans in the US purse-seine fishery for tuna in the eastern tropical Pacific.*

2 HALL, M.A. and BOYER, S.D. Preliminary estimates of incidental mortality of dolphins in the eastern tropical Pacific tuna fishery in 1987.*

3 ANGANUZZI, A.A. and BUCKLAND, S.T. Reducing bias in dolphin abundance estimates derived from tuna vessel data.*

4 LOWRY, L.F., BURNS, J.J. and FROST, K.J. Recent harvests of belukha whales in western and northern Alaska and their potential impact on provisional management stocks.*

5 POLACHEK, T. and SMITH, T.D. A proposed methodology for field testing line transect theory on shipboard survey for small cetaceans.*

6 ROSS, G.J.B., BEST, P.B., BAKER, A.N. and MEAD, J.G. A review of colour patterns and their ontogenetic variation in beaked whales (Ziphiidae, Cetacea).

7 KASUYA, T., BROWNELL, R.L. Jr and BALCOMB, K.C. Preliminary analysis of life history of Baird's beaked whales off the Pacific coast of central Japan.

8 KASUYA, T. and MIYASHITA, T. Distribution of Baird's beaked whales off Japan observed during whale sighting cruises.

9 MIYASHITA, T. and BALCOMB, K.C. III. Preliminary report of an unidentified beaked whale like *Hyperoodon* sp. in the central and the western Pacific.

10 LYNAS, E.M. Transect estimators of cetacean abundance: theory and practice.

11 LODI, L.F., SICILIANO, S. and CAPISTRANO, L. Mass stranding of *Peponocephala electra* (Cetacea, Globicephalinae) on Piracanga Beach, Bahia, Brazil.

12 HOLT, R.S. and SEXTON, S.N. Monitoring changes in dolphin abundance in the Eastern Tropical Pacific using research vessels over a long sampling period: Analysis of 1987 data.*

13 AGUAYO, L.A., AURIOLES, D., URBAN, J.R., SALINAS, M.Z., VIDAL, O. and FINDLEY, L.T. Beaked whales in Mexican waters.

14 PITMAN, R.L., AU, D.W.K., SCOTT, M.D. and COTTON, J.M. Observations of beaked whales (Ziphiidae) from the eastern tropical Pacific Ocean.
15 WALKER, W.A. Preliminary report on the parasites and pathology of Baird's beaked whales taken off the Pacific coast of central Japan, 1985–87.
16 WALKER, W.A. Preliminary report on the food habits of Baird's beaked whales taken off the Pacific coast of central Japan, 1985–87.
17 BROWNELL, R.L. Jr, HEYNING, J.E. and PERRIN, W.F. Reidentification of *Phocoena spinipinnis* specimen from Heard Island.
18 GOODALL, R.N.P. and LICHTER, A.A. The Hector's beaked whale, *Mesoplodon hectori*, off southern South America.
19 GOODALL, R.N.P. and BAKER, A.N. Review of knowledge on the Shepherd's beaked whale, *Tasmacetus shepherdi*.
20 GOODALL, R.N.P., FOLGER, C.L. and LICHTER, A.A. The presence of the Layard's beaked whale, *Mesoplodon layardii*, in the southwest South Atlantic, with a review of strandings worldwide.
21 MEAD, J.G., HEYNING, J.E. and BROWNELL, R.L. Jr Distribution and exploitation of beaked whales in the Northern Hemisphere.
22 HEYNING, J.E. Age determination and reproductive biology of Cuvier's beaked whale, *Ziphiius cavirostris*.
23 ROSS, G.J.B., BAKER, A.N., GOODALL, R.N.P., LICHTER, A.A. and MEAD, J.G. The distribution of beaked whales in the Southern Hemisphere.

OTHER

SC/40/O
1 DE LA MARE, W.K. On the simultaneous estimation of natural mortality rate and population trend from catch-at-age data.*
2 Proposed revision of Rules of Procedure of the Scientific Committee, Appendix 1: Guidelines for availability of data held by the IWC.
3 Scientific Committee procedures [letters from Commissioners + S.J. Holt].
4 DONOVAN, G.P. Suggested mechanism for reviewing scientific permits at Scientific Committee meetings.
5 HORWOOD, J.W. Working group on catch-at-age data.
6 NOT RECEIVED
7 GAMBELL, R. Special meetings of the Scientific Committee – a background note.
8 SIGURJÓNSSON, J. 1987 Progress Report: Iceland program for whale research 1986–1989.
9 CALAMBOKIDIS, J., CHRISTENSEN, I., CUBBAGE, J.C., HARTVEDT, S., JENSEN, P.M., JOYCE, G.G., ØIEN, N., ØRITSLAND, T., TELLNES, K. and TROUTMAN, B.L. Norwegian whale sightings surveys in the North Atlantic, 1987.*
10 DONOVAN, G.P. and GUNNLAUGSSON, Th. North Atlantic sightings survey 1987: Preliminary report of the aerial survey off Iceland.*
11 LARSEN, F., MARTIN, A.R. and NIELSEN, P.B. North Atlantic sightings survey 1987: Report of the West Greenland aerial survey.*
12 HIBY, L., WARD, A. and LOVELL, P. Preliminary analysis of the 1987 North Atlantic sightings survey: aerial survey results.*
13 TOMILIN, A.G. On mechanism and causes of mass stranding of Cetacea.
14 [NOT RECEIVED]
15 LENS, S., QUIROGA, H. and GIL DE SOLA, L. The Spanish cruise of the North Atlantic sightings survey 1987.*
16 JOYCE, G.G., KASAMATSU, F., ROWLETT, R. and TSUNODA, L. The IWC/IDCR Southern Hemisphere minke whale assessment cruises: the first ten years. [*Rep. int. Whal. Commn* (special issue 13)].
17 JOYCE, G.G., KASAMATSU, F. and BARNETT, D. Results and effects of some new procedures used in the 1987/88 IWC/IDCR Southern Hemisphere minke whale assessment cruise.
18 BUTTERWORTH, D.S. A note on the consideration of MSY% in the Comprehensive Assessment.
19 DE LA MARE, W.K. Simulation studies on elements of a revised whale management procedure.
20 BEST, P.B. Some comments on the BIWS catch record data base.*
21 KUROCHKIN, Yu., V. Once more on cyamid (Crustacea: Amphipoda: Cyamidae) fauna of Cetacea.
22 KASAMATSU, F. Preliminary report of minke whale sighting surveys in low latitudinal waters in 1987/88.
23 SAKURAMOTO, K. and TANAKA, S. On the estimation of age dependent natural mortality.*
24 SAKURAMOTO, K., TANAKA, S. and MIYASHITA, T. Initial screening for a whale management procedure.
25 NAKAMURA, T., OHNISHI, S. and MATSUMIYA, Y. A Bayesian cohort model for catch-at-age-data obtained from research takes of whales.*
26 PUNT, A.E. and BUTTERWORTH, D.S. Investigations of some aspects of a potential whale stock management procedure.
27 LOVELL, P., GORDON, J. and HIBY, L. Measuring whales at sea: a simple stereographic technique.
28 N. Atlantic sightings survey 1987 (NASS-87). Joint post-cruise meeting 18 Dec. 1987.
29 SIGURJÓNSSON, J., GUNNLAUGSSON, Th., and PAYNE, M. NASS-87: Shipboard sightings surveys in Icelandic and adjacent waters June-July 1987.*
30 GUNNLAUGSSON, Th., and SIGURJÓNSSON, J. NASS-87: Estimation of abundance of large cetaceans from observations made on board Icelandic and Faroese survey vessels.
31 CANADA. List of research activities.
32 WITHDRAWN
33 ASTTHORSSON, O.S., and GUDMUNDSSON, E. Notes on the densities and composition of zooplankton and surface chlorophyll on the whaling grounds west and south-west of Iceland in 1986 and 1987.
34 SPILLIAERT, R., PALSDOTTIR, A. and ARNASON, A. Analysis of the C4 gene in three species of baleen whales, fin (*Balaenoptera physalus*), sei (*B. borealis*) and minke (*B. acutorostrata*) using a human cDNA probe.
35 GUNNLAUGSSON, Th. and SIGURJÓNSSON, J. Analysis of Icelandic large whale markings 1979–1984 and recoveries up to and including the 1987 season.*
36 OHSUMI, S. A criticism on parameters of stock-recruitment model currently applied to baleen whales by the IWC/SC.

37 BERZIN, A.A. and VLADIMIROV, V.L. Results of observations of distribution and numbers of whales on a whaler "Dobry" in October-December 1987.*
38 AMOS, W. Use of DNA probes for stock identity.
39 GORDON, J., ARNBOM, T. and DEIMER, P. Cetacean research being conducted in the Azores by the International Fund for Animal Welfare.
40 COOKE, J.G. Simulation trials of a whale stock management procedure.
41 COOKE, J.G. Some aspects of the use of sightings and other abundance data for the assessment of whale stocks.
42 MATE, B. Satellite-monitored radio tracking as a method for studying cetacean movements and behavior.*

PROGRESS REPORTS*

SC/40/ProgRep
Argentina
Australia
Brazil
Denmark
Faroes
Federal Republic of Germany
France
Iceland
Japan
Republic of Korea
Mexico
Netherlands
New Zealand
Norway
Seychelles
Spain
Sweden
Switzerland
USSR
UK
USA

RESEARCH PROPOSALS

SC/40/RP
1 BEST, P.B. and RUTHER, H. Measurement of biological parameters important to an understanding of the dynamics of the right whale population off South Africa.
2 SWARTZ, S.L. and WELLS, R.S. Second season of studies to assess the retention and performance of VHF-radio tags for the study of blue, fin, and humpback whales within Monterey Bay and along the central California coast.

SUBMITTED REPORT

SC/40/Rep
1 Draft report of the workshop on individual recognition and the estimation of cetacean population parameters.

WHALING STATISTICS

SC/40/BIWS
Antarctic season 1987/88 and catches outside the Antarctic in 1987.

OTHER DOCUMENTS

The following Annual Meeting documents were also distributed to the Scientific Committee:

IWC/40/
10 Cooperation with other organisations.
19 GAMBELL, R. Comprehensive assessment: a chronology for the International Whaling Commission.

Annex D
Report of the Sub-Committee on Southern Hemisphere Minke Whales

Members: Harwood (Convenor), Arnason (A.), Arnason (U.), Best, Breiwick, Borchers, Buckland, Butterworth, Cawthorn, Chapman, Cooke, da Silva, de la Mare, Goncalves, Goodall, Gunnlaugsson, Hester, Hiby, Holt (R.), Holt (S.), Horwood, Ikeda, Inagaki, Joyce, Kasamatsu, Kasuya, Kato, Kirkwood, Kishino, Lankester, Le Gall, Mae, Magnusson, Miyashita, Mizroch, Morimoto, Nakamura, Nakken, Øien, Ohsumi, Puddicombe, Sakuramoto, Smith, Tanaka, Ulltang, Yamamura, Zeh.

1. ELECTION OF CHAIRMAN AND APPOINTMENT OF RAPPORTEUR

Harwood was elected Chairman and acted as his own Rapporteur.

2. ADOPTION OF AGENDA

The Agenda shown in Appendix 1 was adopted.

3. REVIEW OF DOCUMENTS

The following documents were considered to be of relevance to the sub-committee: SC/40/Mi2, 3, 4, 5, 6, 10, 13, 14, 18, 19, 20; SC/40/O 1, 5, 16, 17, 18, 22, 23, 25, 36; and the following Progress Reports: Australia, Brazil, Japan, New Zealand and UK.

4. REVIEW OF NEW DATA

Borchers reported that data from the 1986/87 IWC/IDCR cruise have been fully validated. Documentation of the data format and validation procedures will be completed in June 1988. Coding of the 1987/88 cruise data has been completed by the IWC Secretariat's data coding staff. Data entered into the micro-computers on the survey vessels has been transferred onto the Cambridge computer system. Validation of all these data has not yet begun.

5. REVIEW OF ACTION ON LAST YEAR'S RECOMMENDATIONS

5.1 Analysis of variance of factors affecting Effective Search Width

Butterworth reported that this analysis had been conducted but that it had revealed no consistent and significant differences between vessels, strata, years, or between the two halves of a survey. This analysis is described in Appendix 2.

5.2 Methods for identifying duplicate sightings

No new analysis had been carried out of the way in which duplicate sightings were identified during the parallel ship and independent observer experiments conducted on the IWC/IDCR cruises. However, Borchers indicated that he intended to investigate different methods during the coming year.

5.3 Studies of the effects of patchiness in whale distribution on sightings estimates

No new work had been conducted on this topic.

5.4 Calculation of estimates of abundance from the results of the 1984/85 – 1986/87 IDCR cruises using a standardised procedure

This analysis had been conducted and was reported in SC/40/Mi14 and 19.

5.5 Further studies of the use of an image processing technique to count layers in minke whale earplugs

Last year the sub-committee had recommended that the device described by Kato, Sone, Kashiwa and Tokiwa (1988, *Rep. int. Whal. Commn* 38: 269–72) should be used to examine the standard sub-set of earplugs provided for the minke whale ageing workshop (*Rep. int. Whal. Commn* 34: 675–700). These plugs had been sent to the Soviet Union from the UK at the end of the workshop. Kato reported that the first batch of plugs which he had received were unusable; it appeared that they had not been stored in formalin. However, he had recently received a further 150 plugs which had been properly stored and he would be analysing these in the near future.

6. ASSESSMENT OF ABUNDANCE FROM SIGHTINGS SURVEYS

At its last meeting the sub-committee had devoted a great deal of time to establishing a consistent procedure for estimating abundance from the results of the IWC/IDCR cruises in the Southern Hemisphere (*Rep. int. Whal. Commn* 38: 76–9). However, in the time available at that meeting it had been unable to produce estimates from all of the survey results. In addition, where more than one survey had been conducted in a particular Area, it had not been able to provide estimates of abundance which were directly comparable. At this meeting the sub-committee endeavoured to supply these values.

6.1 Distribution of perpendicular distances to sightings [g(y)]

The sub-committee had agreed that the distribution of perpendicular distances to sightings, which forms the basis of all its estimates of effective search width obtained from each vessel on each cruise, was best described by a hazard rate function. This function was fitted to the data after they had been suitably smeared to take account of the fact that estimates of the radial distance and angle of a particular sighting are often rounded to varying degrees by observers.

Appropriate hazard rate functions had been fitted to data from all of the cruises up to 1984/85 at the sub-committee's last meeting. The same methodology had since been applied to the data from the 1985/86 and 1986/87 cruises and this was reported in SC/40/Mi14 and 19. The sub-committee had agreed that a separate hazard rate function should be fitted to the data from each vessel in each stratum whenever this was possible. However, in the case of the surveys conducted in Closing Mode in 1986/87, so few schools had been sighted in some strata that it was necessary to pool results to obtain a satisfactory fit. The sub-committee was primarily concerned with obtaining density estimates for as many strata as possible. It also recognised that the hazard rate function was robust to the pooling of different detection functions. It therefore **recommended** that data from all vessels operating in the 'near ice' strata (IIW Bay and IIWS; IIE Bay and IIES – see SC/40/Mi19 for a definition of these strata) should be pooled for each sub-Area, and that the same should be done for vessels operating in the 'far ice' strata (IIWM; IIEM and IIEN). Estimates of effective search width using this pooling are shown in Appendix 3.

6.2 Mean school size

The analyses described in the previous section provide an estimate of the density of whale *schools* in each stratum. To obtain an estimate of the density of *whales* it is necessary to multiply these density estimates by an estimate of mean school size. In the past, the sub-committee had experienced considerable difficulty in estimating this parameter because the sightability of schools was known to be a function of both their distance from the track line and their size. As a result, the distribution of school sizes recorded on each cruise was not representative of the distribution of school sizes in the population. At its last meeting, the sub-committee had agreed to estimate school size in each stratum by reanalysing the distribution of perpendicular distances to sightings obtained in Closing Mode, using sightings of whales rather than schools. School size is then estimated by dividing the density estimate based on whales by that based on schools. The protocol for doing this is described in *Rep. int. Whal. Commn* 38: 84. Only results from Closing Mode surveys were used in this analysis because school size tends to be underestimated in Passing Mode.

At its last meeting the sub-committee had been unable to obtain estimates of school size for the 1984/85 and 1985/86 cruises using this protocol. Such estimates were provided in SC/40/Mi14. However, the sub-committee noted that the author of SC/40/Mi19 had experienced difficulties in fitting the hazard rate function to the distribution of whale sightings in some strata of the 1986/87 cruise. The sub-committee concluded that these problems were probably the result of the small number of schools observed in these strata and **recommended** that the results be reanalysed using the pooling described in Section 6.1. The resulting estimates of school size and associated coefficients of variation are shown in Appendix 3. However, the sub-committee noted that these variance estimates were approximate and **recommended** further work to develop a more appropriate estimator.

6.3 Stratification

At its last meeting the sub-committee had agreed on a suitable stratification of the data from all cruises. However, in the time available it had been unable to carry out the stratification procedure agreed upon for Area IV. Since that meeting the data had been reanalysed using the agreed stratification and the results of this analysis were reported in SC/40/Mi14.

The sub-committee noted that the cruises from 1984/85 onwards had been designed with a view to applying the variable coverage probability analysis described in SC/37/Mi21. It therefore **recommended** that a computer program to implement this method should be added to the existing suite of IDCR programs by the Secretariat's computing staff with the assistance of the author of SC/37/Mi21.

6.4 Animals missed on the track line [1/g(0)]

Estimates of density from line transect data have to be corrected for deviations from the assumption that all whales, or schools, on the track line are seen. Over the course of the IDCR cruises a number of experiments have been conducted in an attempt to estimate the probability that a whale on the track line is seen. The most recent of these have involved the use of an additional, independent observer (the IO) who records sightings independently from the observers in the barrel.

SC/40/Mi20 described two different procedures for estimating g(0) from data collected on the 1985/86 and 1986/87 cruises. One method assumes that, for each platform, the probability of sighting a school is an identical function of its distance from the track line, and that sightings are independent events for the two platforms. Hazard rate functions are fitted to the observed y-distributions for each platform and g(0) is estimated from the number of duplicates. This method is referred to as the 'Product g(y)'s using Hazard Rate functional form' (PGHR). The alternative method uses the sightings from the IO as a sample of those which may be made from the barrel. The proportions of sightings made by the independent observer in each y-interval which are also sighted by the observer in the barrel provide an empirical estimate of g(y) for the barrel observer. Fitting a functional form – in this case the negative exponential – to this observed g(y) distribution can then provide an estimate of g(0) for the barrel observer. This procedure is known as the 'Direct procedure using the Negative Exponential' (DNE).

The PGHR provides a predicted distribution of duplicate sightings with distance from the track line. This did not describe the observed distribution of duplicates very well. In all cases the procedure predicted fewer observations close to the track line and more observations away from the track line than were actually observed. It is more difficult to evaluate the performance of the DNE procedure; however, the authors of SC/40/Mi20 concluded that it performed better than the PGHR estimator.

Five hypotheses which might explain some of the problems encountered with both the PGHR and the DNE procedures had been put forward in IWC/IDCR/10thMi/SM1, a paper prepared for the pre-cruise planning meeting for the 1987/88 IWC/IDCR cruise.

(H1) The probability of sighting a whale has two components, one reflecting the proportion of whales that are objectively visible at a particular distance from the track line, and the other the probability that a cue is within the attention field of the observer at a random moment. If this is the case the probability that a whale is sighted by both observers is not a simple multiple of their independent probabilities.

(H2) Distortions in the allocation of sightings to particular distance classes could cause a peak in observations at a particular distance.

(H3) Whales give more cues when they are close to the vessel.

(H4) Whales are attracted to the vessel and this leads to more cues being observed in its vicinity.

(H5) More schools are identified close to the track line, either because observers are more inclined to identify separate groups of whales as schools when they are close to the track line or because they are more inclined to classify two separate groups as a single school when they are some distance from the track line.

SC/40/Mi20 had attempted to test for the presence of the effects hypothesised in H2 and H4. Doubling the smearing factor had not changed the estimates of g(0) substantially, but the sub-committee noted that smearing alone might not adequately account for misallocation of sightings to distance-classes. A comparison of first sighting positions from the barrel and the IO position showed that as many schools appeared to move away from the track line as moved towards it. Thus there was no evidence of any reaction to the vessel.

The sub-committee was unable to evaluate the relative merits of these hypotheses at this meeting although it recognised that they could all influence the distribution of duplicate sightings. In an attempt to clarify the situation, the analysis of SC/40/Mi20 was repeated for the results of the 1986/87 survey, using sightings of whales rather than schools to determine the relevant distributions. The results of this analysis are shown in Appendix 4.

The sub-committee recognised the advances that had been made in the analysis of these data in the past year. In particular it noted that the senior scientists had found it much easier to identify duplicates in the independent observer experiments. However, further analysis of the data was clearly necessary. The sub-committee therefore **recommended** that more work be carried out on the identification of duplicates in the parallel ship experiments and on the theoretical basis for the estimation of g(0) from the independent observer data. A satisfactory expression for the variance of the estimate of g(0) would also be required. In addition, it noted that, ultimately, estimates of g(0) were required which were appropriate for the surveys carried out in Closing Mode only until 1984/85.

In the absence of an agreed estimate for g(0) for the recent cruises the sub-committee decided to continue using a value of 1 for g(0) and the correction factor h.

6.5 Whale movement

The sub-committee had no new information on the effects of whale movement and therefore agreed to continue to use a value of 0.985 for the correction factor m.

6.6 Length at recruitment and percent takeable

No new information on length of recruitment was available to the sub-committee. However, it noted that a considerable amount of information on the proportion of animals that were classified as takeable in each sub-Area had accumulated since it had decided to use a single value for this parameter in all Areas. It therefore **recommended** that the data on the proportion of takeable animals and on estimated size should be reanalysed in time for its next meeting, to determine whether any changes in this correction factor were required.

Ohsumi and Kato considered that 'percent takeable' is irrelevant for stock estimation in Southern Hemisphere minke whales because, in general, there has been no legal size limit for these stocks.

6.7 Assessment by Area

Since 1984/85, the IWC/IDCR cruises have been carried out both in Closing Mode (where the vessel closes with each school encountered in order to determine species, school size and percent takeable whales) and Passing Mode (where the vessel does not close with the school, but observers estimate the above variables). Since 1985/86, an IO has been in position during most of the Passing Mode surveys on each cruise. Before 1984/85, surveys were conducted in Closing Mode only.

The sub-committee agreed to present estimates of abundance based on Closing Mode results for all surveys, so that results from repeat surveys in the same Area could be compared. A number of problems had been identified with the execution of both Closing Mode and Passing Mode surveys. These are discussed in some detail in *Rep. int. Whal. Commn* 36: 450–70, but the sub-committee noted in particular that SC/39/Mi6 had shown that Closing Mode surveys could produce results which were biased downwards due to the effects of clumping in the distribution of whales. The same process could also lead to an upward bias in estimates of school size. As a result, the magnitude of the bias was likely to vary with the whale density. The sub-committee agreed that the best estimates of school density for Southern Hemisphere minke whales came from Passing Mode surveys with an independent observer. No IOs had been used on the 1984/85 cruise, and the sub-committee agreed to use a pooled value from the Passing Mode and Closing Mode surveys as the best estimate of abundance from this cruise.

The best estimates from the surveys conducted up to 1986/87 are shown in Table 1.

Table 1

Best estimates of the total population and recruited population of minke whales in each Area from the ICDR sighting surveys 'Pooled' survey mode = closing + passing without IO. * = 70-100°E

Area	Year	Survey mode	Total population	CV	Recruited population	CV
I	1982/83	Closing[1]	55,050	0.203	36,223	0.206
II	1981/82	Closing[1]	37,306	0.213	24,547	0.216
	1986/87	Passing[2]	121,549	0.285	79,979	0.288
III	1979/80	Closing[1]	61,272	0.188	40,317	0.191
IV	1978/79	Closing[3]	72,357	0.156	47,611	0.160
IVW*	1984/85	Pooled[4]	19,980	0.181	13,147	0.185
V	1980/81	Closing[1]	133,382	0.216	87,765	0.219
	1985/86	Passing[3]	303,284	0.172	199,520	0.176
VI	1983/84	Closing[1]	80,283	0.232	52,826	0.235

[1] *Rep. int. Whal. Commn* 38:43.
[2] Appendix 3.
[3] SC/40/Mi14.
[4] Appendix 5.

The results from the repeat surveys in Areas II, IVW and V shown above are not strictly comparable because different survey methods were used in each survey. Even if results from Closing Mode surveys only are used, there is a problem that different parts of each Area were surveyed in different years. In particular, vessels usually surveyed much further north in the second survey in each Area.

The results can be made more comparable by adjusting the estimates to take account of this difference in area coverage. In the case of Areas IVW and Area V, this can be achieved by removing the abundance estimates for parts of the more northerly strata from the results of the 1984/85 and 1985/86 surveys. The nature of these corrections is described in SC/40/Mi14. However, in the case of the 1986/87 survey of Area II, the ice edge extended so far north that the most southerly strata surveyed between 40°W and 20°W were north of the most northerly strata surveyed in 1981/82! As an *ad hoc* measure, the sub-committee agreed to divide the results of the surveys in Area II into 'near ice' and 'far ice' strata (as described in SC/40/Mi19) and to adjust these so that equal areas were covered in the two surveys. The calculations involved are described in Appendix 6. The set of comparable results is shown in Table 2.

Table 2

Comparison of closing mode estimates of the total population of minke whales for 'equivalent' areas covered by IDCR cruises in different years

Area	Year	Total population	CV	Probability of difference (P)
II	1981/82[1]	37,306	0.213	P = 0.020
	1986/87	71,973	0.206	
IVW (70°-100°E)	1978/79[2]	33,983	0.198	P = 0.045
	1984/85	18,484	0.215	
V	1980/81[2]	133,382	0.216	P = 0.517
	1985/86	160,256	0.186	

[1] Appendix 6.

[2] SC/40/Mi14.

The sub-committee noted that there were significant differences between the two sets of estimates for Area IVW and for Area II. In the case of Area IVW, different vessels had been used in the two surveys and there was evidence (SC/40/Mi20) that the distribution of sightings from these vessels was quite different. In addition, the timing of the two cruises had been different, with Area IVW being surveyed in the first half of the cruise in 1978/79 and in the second half of 1984/85. The sub-committee also noted that large concentrations of whales were seen in Prydz Bay in 1978/79 but few whales were seen there in 1984/85. It was suggested that some of the difference may have been due to changes in the distribution of krill swarms in Area IV.

The sub-committee recognised that there were problems with the somewhat arbitrary procedures it had adopted to make the results from repeat surveys in the same Area more comparable. For example, the abundance estimates from the northern stratum of the 1984/85 survey in Area IVW had been reduced on the assumption that the density of whales across the stratum was uniform. This was almost certainly not the case. The sub-committee therefore **recommended** further work on the development of procedures for comparing estimates of abundance obtained in the same Area in different years.

6.8 Other sightings techniques

During the 1986/87 IWC/IDCR cruise, observers on one vessel (the SM2) had carried out the cue counting procedure on all transects conducted in Passing Mode. On some transects an observer acting independently of those on the bridge or in the barrel (the IO), had also collected cue counting data. This information was analysed in SC/40/Mi4. It proved possible to identify duplicate cues seen by both the observers on the bridge and the IO simply on the basis of their proximity in time. The distribution of radial distances to cues $q(r)$ is analagous to $g(y)$ for sightings of schools. In the same way, $q(0)$, the probability that a cue is seen close to the vessel, is analagous to $g(0)$. For the observers on the bridge and the IO, $q(0)$ values were estimated using a procedure similar to the DNE (see section 6.4). It was also possible to quantify the degree of disagreement between the two sets of observers in their estimates of the distance of the cues from the vessel. As with the analysis of duplicate sightings of whales or schools, the distribution of duplicate cues with distance from the vessel was much flatter than the distribution of cues seen by each observer.

In order to overcome possible reasons for the apparent excess of duplicate cues at long distance from the vessel and to test the robustness of the procedure, the analysis was repeated using a hazard rate function, rather than the generalised exponential which had been used in SC/40/Mi4, to describe the distribution of duplicate cues. The hazard rate was fitted to the observed distribution, conditioning on the number and position of sightings made by the IO and eliminating cues which were seen by the observers on the bridge but not by the IO. This gave an estimate of $q(0)=0.717$ for the bridge and barrel observers with a hazard rate exponent of 3.02. When the exponent was constrained to be 2 or 4, $q(0)$ was estimated as 0.74 and 0.70 respectively. The density estimate using a value of 0.717 for $q(0)$ is 0.162 whales/n.miles^2. The equivalent values from line transect data collected in passing mode on the same vessel are 0.205 whales/n.miles^2 fitting to the distribution of schools, and and 0.168 whales/n.miles^2 fitting to the distribution of whales. The latter figure is based on data in Table 3 of SC/40/Mi19.

The sub-committee recognised that cue counting had now been used on three IWC/IDCR cruises and had provided density estimates which could usefully be compared with those from conventional line transect analysis. In addition, the technique avoided some of the problems that made the analysis of line transect data for large whales difficult. It therefore **recommended** that consideration should be given to carrying out cue counting and line transect sampling simultaneously on one of the vessels in any future IWC/IDCR Southern Hemisphere sightings cruise. It also suggested that blow rate information should be collected at regular intervals during such a survey.

6.9 Reports on IWC/IDCR cruises

SC/40/O 16 provided a compendium of the results from the ten years worth of data which had been collected on the Southern Hemisphere IWC/IDCR sightings cruises. The sub-committee congratulated the authors on producing a very valuable report and noted that it would undoubtedly prove useful to any other organisation that was planning sightings cruises of this general nature. It also noted that SC/40/O 16 did not attempt to provide any description of the methods which had been used for analysis of the data or of the theoretical rationale behind the many experiments which had been conducted on these cruises. It **recommended** that a complementary review along these lines should be prepared in time for its next meeting, and suggested that consideration should be given to preparing a Special Issue on the Southern Hemisphere cruises which would include both reviews.

SC/40/Mi2 provided a report of the data collected on the 1987/88 IWC/IDCR cruise in Area III, and SC/40/O 17 described the effectiveness of some new procedures used on this cruise. Because only two vessels had been available, the cruise had relied on remote sensing data to determine the position of the ice edge. This had caused some problems because the ice edge had actually been encountered much further north than expected. As a result, major modification to the track lines had been necessary. The cruise had taken place earlier than was customary to avoid bad weather but, in fact, 60% of research time had been lost to poor weather. The use of onboard micro-computers to enter survey data each evening had proved very successful and had made it possible to identify and correct errors at an early stage. The cruise had included a number of experiments aimed at assessing the response of minke whales to the vessel.

The Government of Japan had indicated that it intended to make two vessels available for a further cruise in 1988/89. The sub-committee welcomed this generous offer and **recommended** that such a cruise should take place. It also **recommended** that the experimental data collected on the 1987/88 cruise should be analysed in time for the planning meeting for the 1988/89 cruise.

7. OTHER ASSESSMENT METHODS

7.1 Mark-recapture analysis

Buckland reported on the results of a reanalysis of the mark-recovery data for Southern Hemisphere minke whales which he had conducted under contract to the IWC (SC/40/Mi6). A number of mark-recapture models were used to provide estimates of abundance and survival. The major potential sources of bias in the estimates are likely to lead to overestimation of abundance and underestimation of survival. These biases can be corrected for if there is information on rates of mark shedding, marking mortality, geographical variation in the probability that a whale is taken, discovery and reporting rates for tags, mis-reporting of the numbers effectively marked, and inadvertent and unrecorded double-marking. There were too few recoveries to yield meaningful estimates of abundance for Areas I, II and VI, but estimates were obtained for the remaining three Areas both separately and combined. The total stock size in the combined Area III+IV+V was estimated to be 400,000 to 450,000. Annual survival was estimated to be between 0.902 and 0.933. Little evidence was found for long-term mark shedding.

The sub-committee welcomed this very thorough analysis of a difficult data set. In discussion it was noted that the variances of the estimates of abundance were undoubtedly underestimated because of heterogeneity in the probability of marking and recapture. Some simulation work had indicated that the methods used might be robust to these effects if a number of areas were pooled. The sub-committee therefore **recommended** an analysis of the effect of these heterogeneities on mark-recapture estimates, because such analyses might be used in the future for the results of studies based on individual recognition or biopsy dart sampling.

The sub-committee discussed at some length the usefulness of mark-recapture experiments based on Discovery tagging for estimating abundance. Some members considered that the method was fatally flawed because estimates were subject to an unquantifiable bias if there was substantial short-term mark shedding or marking-related mortality, as it would be very difficult to quantify this effect. In addition, they noted that the available variance estimates were unreliable. They also pointed out that the mark-recapture analysis indicated that the stock in Area IV might be larger than that in Areas III and V. However, the results from line transect surveys indicated that the stock in Area V was very much larger than those in Areas III and IV. Other members pointed out that there was no evidence that there was any substantial short–term mark shedding.

Studies of captive animals (Geraci, St. Aubin, Smith and Hicks, 1985*) have indicated that metal objects inserted into the flesh of dolphins tend to be rapidly ejected if they protrude into the blubber layer, whereas they are quickly encapsulated and retained if they are entirely within the muscle layer. The sub-committee recognised that data from the test firing of marks into whale carcasses on Japanese factory ships might provide some insight into the level of short-term mark shedding and mortality. It therefore **recommended** that these data be examined to see if they could provide any insight into this difficult problem.

The sub-committee also considered the usefulness of the estimates of survival obtained from the mark-recapture experiments. Because the estimation methods did not require information on the total number of marks in the population they were not affected by problems associated with short-term mark shedding and marking-related mortality. The sub-committee noted that in order to estimate survival under the most appropriate model it had been necessary to assume that mortality was exactly balanced by recruitment in the stocks under consideration. As a result the estimates of survival can, as an alternative, be considered as estimates of gross recruitment. Because of this they are subject to the same problem of confounding between trends in recruitment and in mortality which make the analysis of catch-at-age data so difficult.

In conclusion, the sub-committee noted that many of the problems encountered in the analysis of the data from marking with Discovery-type marks could be overcome if biopsy darts were used to mark whales using the DNA fingerprinting technique (see *Rep. int. Whal. Commn* 38: 138). However, sample sizes of at least 500 whales marked per season in each Area would be necessary to obtain reliable estimates of abundance and survival.

7.2 CPUE analysis

SC/40/Mi5 described a reanalysis of the CPUE series from the Brazilian minke whale fishery in Area II in the period 1966 to 1985. Most of the variation could be accounted for by factors other than year, such as catch of whales other than minke whales, change in boats and distance to the whaling grounds. The sub-committee agreed with the author's conclusion that the existence, or not, of a trend in CPUE for this fishery cannot be determined from this series.

7.3 Potential of individual recognition methods

The use of individual recognition based on DNA-fingerprinting has already been discussed in Section 7.1.

The sub-committee noted that the report of the Workshop on Individual Recognition (SC/40/Rep1) had recommended that 'in the event of a further IWC/IDCR minke whale assessment cruise, the equivalent of 1–2 days work under good conditions be allocated to photo-identification of minke whales, as a feasibility study'. The sub-committee was informed that the workshop's optimism was based on the experience of one of the participants who had experience with minke whales in both hemispheres and who considered that it was easier to obtain a good photograph of a minke whale than to mark it. However, the sub-committee had reservations about the usefulness of the technique for estimating the abundance of Southern Hemisphere minke whales because of the large sample sizes which would be required (see SC/40/Rep1, Annex D). In addition, Southern Hemisphere minke whales are fast-swimming animals which spend little time

---

* Geraci, J.R., St. Aubin, D.J., Smith, G.J.B. and Hicks, B.D. 1985. Cutaneous response to plastic and metallic implants of potential use for marking cetaceans. *In:* Expanded Studies of the Effects of Oil on Cetaceans. Final report to the US Dept of the Interior, Minerals Management Service, Vienna, VA22180. 120pp.

at the surface and appear to have few individually-identifiable characteristics on the body.

Nevertheless, the sub-committee welcomed the proposal in principle. However it was concerned about dedicating two of the small number of days of good conditions usually encountered on the IWC/IDCR cruises to this experiment. Joyce indicated that he intended to coordinate an analysis of a collection of photographs of minke whales which had been collected on the IWC/IDCR cruises to determine whether Southern Hemisphere animals could be recognised individually. The sub-committee **recommended** that this analysis should be carried out before any time is dedicated to this activity on an IWC/IDCR cruise. It noted that there were a large number of photographs of minke whales taken on board Japanese factory ships. It considered that it would be very useful if these could also be made available for this analysis.

The sub-committee also noted that the photo-identification technique would be particularly appropriate for a study of minke whales off the coast of Brazil, where animals are found within a well-defined area. In particular, such a study could provide extremely valuable information on calving intervals.

8. SPECIAL PERMITS

8.1 Results from catches taken under Special Permits in 1987/88 and associated studies

SC/40/Mi18 provided a report on catches taken under the Special Permit issued by the Government of Japan in 1987. Out of a proposed catch of 300, 273 animals had been taken over a wide latitudinal range from 55°S to the ice edge. This included one diminutive form minke whale taken from a school of two at 58°S. This is the most southerly record for this form. Appropriate samples were taken and the skeleton was retained. Earplugs had been collected from 271 animals. These included the fragile plugs from smaller animals which had proved difficult to extract undamaged in the past.

It was reported that it had proved relatively easy to implement the proposed random sampling scheme. Preliminary results indicated that sexually mature females tended to concentrate along the edge of the pack ice whereas mature males appeared both close to the pack ice and offshore. Small and immature animals tended to be solitary whereas larger or mature males tended to occur in larger schools associated with similar sized females. No lactating females had been taken. The average size of the animals taken was substantially less than that in the commercial catch. Where two animals were taken from the same school, the lengths of the first and second animals were not significantly different.

The sub-committee noted that one of the primary aims of the feasibility study was to test a protocol for collecting a representative sample from the population. However, some members pointed out that the preliminary results indicated that the protocol had not been entirely successful. First, it had proved more difficult to sample animals in schools of three or less individuals than those in larger schools. This, combined with the fact that at most two whales were taken from each school, meant that some transformation of the sampled age structure would be necessary to generate a representative sample. Second, schools were not sampled at random because large schools were known to be relatively more sightable than small ones. In addition, it was necessary that animals were sampled in proportion to their density. However, density was extremely variable in the ice edge area where the largest concentrations of animals were found. This would introduce an additional element of variability into the estimated population structure. The evidence that there was a differential segregation of males and females, which could not be distinguished at sea, and the lack of lactating females added to the sampling difficulties. Finally it was noted that the design of the track line could lead to the sampling vessel spending a disproportionate amount of time close to the ice edge because of unpredicted changes in its position.

Japanese scientists expressed their appreciation of these comments. They indicated that they had already recognised many of these problems and were taking action to modify any future sampling programme in an appropriate way.

The Japanese catch of whales under a Special Permit is part of a larger study of the ecology of Southern Hemisphere minke whales. SC/40/O 22 provided information on another aspect of this study: a survey of the distribution and abundance of minke whales in lower latitudes. Surveys had been carried out between 12° and 40°S at the beginning and end of the expedition to take whales under the Special Permit. Eight minke whales, including four of the diminutive form, were seen in the first part of the survey between 23 November and 6 December. Only one minke whale was seen during the survey from 11 February to 17 March.

8.2 Effects of possible catches under Special Permits in 1988/89

The sub-committee was informed that the government of Japan will decide what research programme is to be implemented once the analysis of data collected in 1987/88 has been completed. The sub-committee could not, therefore, provide specific advice on the possible effects of any proposed catches. However, in order to assist in the evaluation of any future proposals, it decided to use the 'HITTER' procedure with the results of the various sightings surveys which had been conducted in Areas IV and V. The chosen population parameters were:

Age at recruitment 6 years
Age at maturity 7.5 years
Natural mortality 0.086
MSY% 1, 2, 3, 4

The populations were assumed to be at carrying capacity at the start of exploitation. Because there is no size limit for minke whales, the procedure was run using the assessments of total abundance as an estimate of the 1+ population.

The estimates for total population size in Table 1 were used as the target population level in each run. There was an estimate for Area IV from the 1978/79 survey and a further estimate for Area IVW only from the 1984/85 survey. In the latter case only catches taken in the western sector of this Area were used. The results are shown in Appendix 7.

The sub-committee noted that the results indicated that the stock in Area V was still very close to its initial level. In such a case, estimates of replacement yield were inappropriate for assessing the potential effect of catches on the stock. In addition, it recognised that the procedure estimated the replacement yield for the exploited stock whereas animals taken under a special permit would come from the entire stock. However, it noted that although the replacement yield for the entire stock would probably be larger than that calculated, the increase in yield would be less than the ratio of the total stock to the exploited stock.

The majority of catches in Area IV had been taken in the western sector, and the results obtained using the Area IVW assessment showed a substantial reduction in numbers since the start of exploitation. For the range of MSY% values which had been considered, this constituted a drop in total stock size to between 46% and 55% of the pre-exploitation level. The predicted replacement yield in 1988/89 was between 161 and 377. In addition, the sightings estimates from 1984/85 were significantly lower than those from the 1978/79 survey, although the sub-committee had identified a number of methodological and environmental factors which could have contributed to this difference. These findings lead the sub-committee to conclude that catches of 300 animals, if concentrated in this sector, might exceed the replacement yield for the population of animals with Area IVW, if this is considered as a separate stock.

The sub-committee also noted that the sightings estimates implied a very marked change in the density of whales at the boundary between Area IV and Area V. The sub-committee did not have time to consider the significance or implication of this observation.

9. BIOLOGICAL PARAMETERS

No new information on biological parameters was available to the sub-committee. However, it noted that a considerable amount of data pertaining to these parameters was anticipated from the material collected under the Japanese special permit, and it looked forward to receiving a full report on this material at future meetings.

10. STOCK DIVISIONS

Three papers addressed issues that were of relevance to stock divisions.

SC/40/Mi10 analysed differences in the number and distribution of facial vibrissae from minke whales taken in different Areas and found that there were no significant differences between Areas. SC/40/Mi13 considered the occurrence of parasites and commensals on the bodies of minke whales taken in different Areas. Certain species were characteristic of specific Areas. SC/40/Mi3 reported on sightings of minke whales within the pack ice during the austral winter made from an Australian research vessel. If these animals are resident in the ice throughout the year this suggests that there may be local sub-populations with each stock area.

11. DIFFERENCES FROM PREVIOUS ASSESSMENTS

The sub-committee had now been able to complete its reanalysis of all data collected on the IWC/IDCR Southern Hemisphere cruises up to 1986/87 in a consistent manner. This had resulted in changes, in some cases substantial ones, to previously published assessments for certain Areas. In summary the consistent methodology is:

(1) use of a common function (the hazard rate) in the estimation of effective search width;
(2) use of a standard methodology for estimating mean school size;
(3) use of an agreed stratification for each Area.

For those Areas which had been surveyed twice, the second survey had usually covered a larger geographical area than the first, so that the estimates in Table 1 are not strictly comparable. The sub-committee had been able to calculate approximately comparable estimates of abundance from the results of the two surveys. However, it recognised that further work was required on these comparisons. (See recommendation in Section 6.7.)

12. RECOMMENDATIONS

The sub-committee made 14 recommendations which are listed below.

(1) Further analysis of the identification of duplicate sightings in the parallel ship and independent observer experiments should be conducted. In addition, the theoretical basis for the estimation of g(0) from these observations should be investigated, with the ultimate aim of providing estimates that can be used not only with the results of cruises conducted with an independent observer, but also with the results of earlier cruises. These studies should also develop reliable estimators for the variance of estimates of g(0).
(2) A more accurate expression for the variance of the estimates of school size calculated at this meeting should be developed.
(3) The effects of heterogeneity in the distribution of whales, whale marking and catching activities within an Area (or combination of Areas) on estimates of abundance and survival from mark-recapture experiments should be investigated.
(4) Data collected from experimental firings of Discovery tags into whale carcasses should be checked and compared with information on mark site and wound condition from actual recoveries to see if this can provide any insight into the rate of short-term tag loss and post-tagging mortality.
(5) The available data on the proportion of animals classified as takeable and on the estimated length of individual whales collected during the IWC/IDCR Southern Hemisphere cruises should be reanalysed to determine if there are significant temporal and spatial differences.
(6) The review of the methodologies used in the analysis of data collected on the IWC/IDCR Southern Hemisphere cruises should be completed in time for the sub-committee's next meeting. Consideration should be given to publishing this review, together with the review of the events and procedures on these cruises over the last 10 years (SC/40/O 16) in a Special Issue.
(7) Photographs of minke whales collected during previous IWC/IDCR cruises should be analysed to determine whether photo-identification of Southern Hemisphere minke whales is possible on a large scale. It would be very useful if photographs taken of minke whales on board Japanese factory ships could also be made available for this analysis.
(8) Further work is necessary on the development of procedures for comparing estimates of abundance obtained in the same Area in different years. These procedures should be able to take account of variations in the geographical extent of the surveys, variations in the extent of the ice edge, variations in

density of whales across strata that were not covered in all of the surveys, and variations in the distribution of krill.

(9) The sub-committee welcomed the offer from the Government of Japan to provide two vessels for an IWC/IDCR cruise in 1988/89 and **recommended** that such a cruise should take place.

(10) The Planning Meeting for this cruise should consider the desirability that one vessel should carry out cue counting and line transect surveys simultaneously. In doing this it should take account of the analyses of the results from cue counting conducted in 1986/87 which are reported in SC/40/Mi4 and further analyses of data from this and previous cruises which will be carried out before the meeting.

(11) The data collected from the 'closing with independent observer tracking' (CIO) and 'independent observer with tracking' (IOT) experiments conducted on the 1987/88 cruise should be analysed before the planning meeting for the 1988/89 cruise.

(12) If possible, the cruise track for the 1988/89 cruise should be designed so that it can be easily modified to take account of unpredictable changes in the position of the ice edge.

(13) The sub-committee recognised that, for very good reasons, it had not been possible to use the image processing technique to examine the standard set of earplugs from the minke whale ageing workshop (see Section 5.5 and recommendation (6) in *Rep. int. Whal. Commn* 38: 80) as recommended in 1987. It **recommended** that these earplugs should be examined in the coming year.

(14) A computer program should be developed by the Secretariat to implement the variable coverage probability analysis (SC/37/Mi21) with the results from cruises conducted from 1984/85 onwards.

13. DATA AND COMPUTING NEEDS

The sub-committee recognised that the decision that Secretariat staff should take over the job of coding, validating and analysing the data from the IWC/IDCR Southern Hemisphere cruises had required a major rewriting of the associated data handling and analysing programs. This extra computing task had contributed substantially to the apparently slow progress that had been made with the data from the 1987/88 cruise.

14. PUBLICATION OF DOCUMENTS

A list of documents which the sub-committee considered should be published in the Annual Report was submitted to the Editorial Board.

Appendix 1

AGENDA

1. Convenor's opening remarks
2. Election of Chairman
3. Appointment of rapporteurs
4. Adoption of agenda
5. Review of documents
6. Review of action on previous year's recommendations
7. Assessment of abundance from sightings cruises
   - 7.1 Analyses based on standard line-transect methods
   - 7.2 Other sightings techniques
   - 7.3 Review of ICDR cruises
8. Other assessment methods
   - 8.1 Mark-recapture estimates
   - 8.2 CPUE analysis
   - 8.3 Potential of individual recognition methods
9. Special Permits
   - 9.1 Results from catches taken under Special Permits in 1987–89
   - 9.2 Methodology for 1988–1989 proposals
10. Biological parameters
11. Stock divisions
12. Differences from previous assessments
13. Recommendations
14. Data and computing needs
15. Publication of documents

Appendix 2

MULTI-LINEAR FITS TO ESTIMATES OF EFFECTIVE SEARCH HALF WIDTHS (w') FOR THE ANTARCTIC IWC/IDCR CRUISES

D.S. Butterworth, J. de Decker and A.E. Punt

Data

The estimates of effective search half-width for minke schools (w′) used in these analyses are those given in SC/39/Mi18, Tables 2 and 9 for 1979/80 to 1984/85, and in SC/39/Mil6 (addendum), Table 2 for 1985/86. Estimates from the 1978/79 cruise were not utilised, as the T16 and T18 which conducted that survey did not participate in any later cruises. Only closing mode (and not passing mode) estimates of w′ were used for the 1984/85 and 1985/86 cruises for comparability with the earlier years. A total of 30 w′ estimates is thus available.

Model fitted

The most general model fitted to the data is:

$$w'_{vyst} = \mu + \alpha_v + \beta_y + \gamma_s + \delta_t + \varepsilon_{vyst} \qquad \varepsilon \text{ from } N(0,\sigma^2)$$

The factors are:

Factor: Vessel, α_v : v = SM1, SM2, K27, T11; $\alpha_{SM1} = 0$

Year, β_y : y = 1979/80, 81/82, 82/83, 83/84, 84/85, 85/86
$\beta_{79/80} = 0$

Stratum, γ_s : s = I (ice-edge or southern), M (middle), N (northern); $\gamma_I = 0$

Time, δ_t : t = 1 (earlier half survey), 2 (later half)
$\delta_1 = 0$

The data were fitted using the BMDP statistical package.

Results

Results for estimates of the various factors are shown in Table 1. The table includes results for the most general model above, and for special cases thereof. Table 1 also shows the P value associated with the factor estimate, which indicates the probability that the estimate is not significantly different from zero. P_{model} corresponds to a likelihood ratio test of the model attempted compared to the null hypothesis $w'_{vyst} = \mu$.

If a variable selection procedure is used, the only variable selected (at the 5% level) is $\beta_{82/83} = 0.214$ ($\mu = 0.492$).

The following trends in w' estimates are 'apparent':

(i) larger estimates in later years
(ii) smaller values for the K27 and T11 than the SM1 and SM2
(iii) smaller values away from the ice-edge.

However, only the $\beta_{82/83}$ factor estimate is consistently significant at the 5% level. Even this conclusion is in some doubt, because plots of the moduli of residuals show strongly increasing trends with w′; this suggests that large w′ estimates should be down-weighted in the fitting procedure, which would decrease the influence of the 1982/83 w′ estimates, and this may in turn render the $\beta_{82/83}$ factor no longer significant.

The 'design' matrix is such that year and vessel factors (in particular) are partially confounded. Trend (ii), above, only becomes apparent if the year factors are excluded. The (non-significant) negative trend from ice-edge to off-ice-edge strata may be related to the better weather conditions generally experienced closer to the edge. There is no substantial (or significant) effect related to whether estimates are for the first or second half of a cruise.

Table 1

Estimates for the factors in the multi-linear model. The bracketed figure is the probability P that the factor is not significantly different from zero. * = significant at the 5% level

Factor		General model	No vessel factors	No year factors	No stratum factors	No time factors	$\alpha_{SM1}=\alpha_{SM2}$ $\alpha_{K27}=\alpha_{T11}$	$\gamma_M=\gamma_N$
μ		0.364	0.354	0.628	0.310	0.374	0.368	0.348
α	SM2	−0.041 (0.63)	-	−0.046 (0.60)	−0.011 (0.90)	−0.043 (0.61)	-	−0.027 (0.74)
	K27	−0.037 (0.73)	-	−0.166 (0.07)	−0.026 (0.80)	−0.038 (0.71)	−0.014 (0.88)	−0.013 (0.89)
	T11	+0.018 (0.91)	-	−0.229 (0.05)*	+0.029 (0.86)	+0.017 (0.91)		+0.042 (0.78)
β	80/81	+0.070 (0.56)	+0.070 (0.53)	-	+0.070 (0.57)	+0.070 (0.55)	+0.070 (0.54)	+0.070 (0.55)
	81/82	+0.228 (0.19)	+0.209 (0.09)	-	+0.234 (0.19)	+0.231 (0.18)	+0.195 (0.21)	+0.239 (0.16)
	82/83	+0.337 (0.03)*	+0.366 (0.003)*	-	+0.373 (0.03)*		+0.377 (0.03)*	+0.394 (0.02)*
	83/84	+0.222 (0.13)	+0.200 (0.07)	-	+0.181 (0.21)	+0.222 (0.12)	+0.191 (0.13)	+0.213 (0.13)
	84/85	+0.320 (0.06)	+0.297 (0.03)*	-	+0.281 (0.09)	+0.330 (0.04)	+0.289 (0.05)	+0.311 (0.06)
	85/86	+0.249 (0.09)	+0.228 (0.04)*	-	+0.209 (0.15)	+0.249 (0.08)	+0.219 (0.08)	+0.241 (0.09)
γ_M		−0.157 (0.14)	−0.142 (0.13)	−0.149 (0.12)	-	−0.157 (0.13)	−0.144 (0.14)	−0.106 (0.11)
γ_N		−0.089 (0.21)	−0.091 (0.16)	−0.066 (0.35)	-	−0.088 (0.20)	−0.089 (0.19)	
δ_2		+0.019 (0.77)	+0.021 (0.72)	+0.032 (0.62)	+0.016 (0.80)	-	+0.021 (0.73)	+0.021 (0.75)
P_{model}		0.269	0.090	0.197	0.324	0.192	0.143	0.213

Appendix 3

CALCULATIONS OF MEAN SCHOOL SIZE AND EFFECTIVE SEARCH WIDTH FOR SURVEYS CONDUCTED IN AREA II IN 1986/87

D. Borchers

Effective school sizes (s*) have been calculated from closing mode data pooled over 'near-ice' and 'far-ice' strata. Closing mode estimate of effective search half-widths have also been calculated from data pooled in this way. S = stratum, V = vessel.

	S	V	$\frac{n_s}{\bar{L}}$ (CV)	w's (CV)	s* (CV)	D_w (CV)	
(a) Closing mode							
	BAY	SM1	0.203(0.733)	0.353(0.176)	2.337(0.157)	0.672(0.770)	
W	M	SM1	0.003(0.922)	0.531(0.167)	8.0 (-)	0.023(0.937)	
	S	SM2	0.072(0.474)	0.353(0.176)	2.337(1.57)	0.238(0.529)	0.229 (0.431)
	S	K27	0.068(0.471)	0.353(0.176)	2.337(0.157)	0.225(0.527)	
	S	SM1	0.077(0.384)	0.601(0.251)	2.297(0.395)	0.147(0.605)	
	BAY	SM1	0.118(0.405)	0.601(0.251)	2.297(0.395)	0.225(0.619)	
E	M	SM2	0.078(0.309)	0.531(0.167)	2.495(0.127)	0.183(0.373)	
	N	K27	0.116(0.340)	0.531(0.167)	2.495(0.127)	0.273(0.400)	
	S	K27	0.033(0.642)	0.601(0.251)	2.297(0.395)	0.063(0.794)	

	S	V	$\frac{n_s}{\bar{L}}$ (CV)	w's (CV)	s* (CV)	D_w (CV)	
(b) Passing mode							
	BAY	SM1	0.388(0.288)	0.519(0.256)	2.337(0.157)	0.874(0.416)	
W	M	SM1	0 (-)	- -	0 (-)	0	
	S	SM2	0.080(0.393)	0.484(0.193)	2.337(0.157)	0.193(0.465)	0.188 (0.313)
	S	K27	0.077(0.247)	0.499(0.157)	2.337(0.157)	0.180(0.332)	
	S	SM1	0.132(0.332)	0.589(0.217)	2.297(0.395)	0.257(0.560)	
	BAY	SM1	0.284(0.325)	1.254(0.108)	2.297(0.395)	0.260(0.523)	
E	M	SM2	0.154(0.182)	0.882(0.094)	2.495(0.127)	0.218(0.241)	
	N	K27	0.112(0.448)	0.294(0.428)	2.495(0.127)	0.475(0.632)	
	S	K27	0.066(0.091)	0.632(0.203)	2.297(0.395)	0.120(0.453)	

H_0 : R = [D_w(closing)/D_w(passing)] = 1 : R = 0.836; SE = 0.170; z = 0.967 (p=0.166)

Appendix 4

ESTIMATES OF g(0) BASED ON DUPLICATE SIGHTINGS OF WHALES DURING SURVEYS IN AREA II IN 1986/87

D. Borchers

	Barrel			IOP			Combined	
V	w (nm)	g(0)	(SE)	w (nm)	g(0)	(SE)	$g_{B+1}(0)$	(SE)
(a) PGHR method								
SM1	1.079	1.072	(0.194)	0.969	0.795	(0.399)	1.015	(0.060)
SM2	0.633	1.069	(0.468)	0.565	0.707	(0.318)	1.020	(0.126)
K27	0.408	1.085	(0.623)	0.441	0.578	(0.283)	1.036	(0.247)
(b) DNE method								
SM1	1.500	0.810	(0.217)	1.500	0.671	(0.304)	0.938	(0.068)
SM2	1.111	0.780	(0.302)	0.735	0.683	(0.295)	0.930	(0.082)
K27	1.120	0.699	(0.218)	0.412	0.659	(0.230)	0.897	(0.085)

Appendix 5

A POOLED ESTIMATE OF MINKE WHALE ABUNDANCE FOR AREA IV W FROM THE 1984/85 ANTARCTIC IDCR CRUISE

D.S. Butterworth

The pooling of the whale school density (D_{sch}) estimates for closing (C) and passing (P) mode has been carried out using weighting proportional to primary search effort in each mode in each stratum, as previously agreed and implemented in *Rep. int. Whal. Commn* 38: 87 (Appendix 8).

D_{sch} estimates and mean school size CVs are taken from Table 9 of SC/39/Mi18, and estimates of effective mean school size $\bar{s}^*$ from Table 1 of SC/40/Mi14. Results (with CVs in parenthesis) for uncorrected abundances (P^1) of minke whales are given in the Table.

Taking m=0.985 and h=1.0 provides a total population estimate of 19,980 (0.181). Further, taking t=0.658 (0.036) as given in SC/39/Mi18 (Table 7) results in an estimate of the number of takeable minke whales of 13,147 (0.185).

$D_{sch}(nm^{-2})$	Weight	$\bar{D}_{sch}$ (pooled)	$\bar{s}^*$	A (nm^2)	$P^1=\bar{D}_{sch}\bar{s}^*A$
North - K27					
(C) 0.0426(0.331)	0.475	0.0324(0.267)	1.53(0.178)	185,207	9,181(0.321)
(P) 0.0231(0.450)	0.525				
Middle - SM1					
(C) 0.0421(0.390)	0.465	0.0369(0.265)	1.76(0.206)	73,910	4,800(0.336)
(P) 0.0324(0.353)	0.535				
South - SM2					
(C) 0.0564(0.321)	0.432	0.0481(0.227)	2.30(0.094)	53,185	5,884(0.246)
(P) 0.0417(0.321)	0.568				
Prydz Bay - V34					
(C) 0.0267(0.470)		0.0267(0.470)	1.61(0.115)	9,743	419(0.483)
Total					20,284(0.181)

Appendix 6

CALCULATION OF COMPARABLE ESTIMATES OF ABUNDANCE FOR AREA II

Comparison of abundance estimates from the 1986/87 and 1981/82 surveys of Area II. 'Far-Ice' refers to strata not adjacent to the ice-edge.

(a) Comparison of areas of strata surveyed

	1981/2	1986/7	1981/2 1986/7
Near-ice	125,579	205,883	0.610
Far-ice	271,348	289,282	0.938
Totals	396,927	495,165	0.802

(b) Comparison of abundance estimates (Closing Mode only) with adjustments to make the 1986/87 estimates comparable to the 1981/82 estimates. (Total Abundance estimates are shown.)

	1981/2		1986/7 (unadjusted)		1986/7 (adjusted)	
	Est.	(CV)	Est.	(CV)	Est.	(CV)
Near-ice	26,445	(0.241)	43,994	(0.285)	26,836	(0.285)
Far-ice	10,861	(0.455)	48,120	(0.297)	45,137	(0.297)
Totals	37,306	(0.216)	92,114	(0.206)	71,973	(0.206)

Appendix 7

RESULTS FROM USE OF "HITTER" PROCEDURE WITH SIGHTING ASSESSMENTS FROM AREAS IV AND V

The procedure was run with the following parameter values: age at recruitment – 6 years; age at maturity – 7.5 years; natural mortality – 0.086.

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
Area IV W 1984/85 survey, MSY% = 1						
1971	12,452	12,452	11,426	24,904	38,284	0
1972	11,949	12,106	11,080	24,055	37,435	76
1973	10,810	11,060	10,034	21,870	35,193	272
1974	9,664	8,969	7,943	18,633	31,693	563
1975	9,124	8,234	7,208	17,358	29,656	678
1976	9,094	8,306	7,280	17,400	28,804	674
1977	8,961	8,389	7,363	17,350	27,955	638
1978	9,057	8,133	7,125	17,189	27,124	503
1979	8,982	7,772	6,833	16,754	26,141	173
1980	8,020	7,313	6,543	15,333	24,477	163
1981	7,314	6,274	5,567	13,588	22,568	334
1982	7,215	6,195	5,482	13,411	21,947	369
1983	7,208	6,112	5,390	13,320	21,408	328
1984	6,742	5,544	4,845	12,286	19,980	363
1985	6,675	5,593	4,920	12,268	19,492	318
1986	6,566	5,174	4,523	11,741	18,600	167
1987	6,325	4,884	4,324	11,209	17,796	197
1988	6,356	5,034	4,482	11,390	17,684	161
Area IV W 1984/85 survey, MSY% = 3						
1971	11,597	11,597	10,641	23,194	35,655	0
1972	11,094	11,251	10,295	22,345	34,806	76
1973	9,954	10,205	9,249	20,159	32,640	272
1974	8,809	8,114	7,158	16,923	29,361	563
1975	8,269	7,379	6,423	15,647	27,622	678
1976	8,238	7,451	6,495	15,689	27,051	674
1977	8,106	7,534	6,578	15,640	26,463	692
1978	8,226	7,302	6,340	15,529	25,878	660
1979	8,223	7,014	6,071	15,237	25,110	384
1980	7,359	6,652	5,848	14,010	23,641	362
1981	6,744	5,704	4,960	12,448	21,949	519
1982	6,730	5,710	4,959	12,441	21,528	543
1983	6,802	5,707	4,945	12,509	21,196	480
1984	6,407	5,209	4,473	11,616	19,980	502
1985	6,403	5,321	4,613	11,725	19,690	471
1986	6,365	4,973	4,274	11,338	19,007	309
1987	6,189	4,748	4,139	10,937	18,394	345
1988	6,287	4,966	4,357	11,253	18,473	311

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
Area IV W 1984/85 survey, MSY% = 2						
1971	12,008	12,008	11,019	24,016	36,919	0
1972	11,505	11,662	10,673	23,167	36,070	76
1973	10,366	10,616	9,627	20,982	33,866	272
1974	9,220	8,525	7,535	17,745	30,478	563
1975	8,680	7,790	6,800	16,470	28,593	678
1976	8,650	7,862	6,873	16,512	27,887	674
1977	8,517	7,945	6,956	16,462	27,173	665
1978	8,625	7,701	6,718	16,326	26,469	582
1979	8,586	7,377	6,437	15,963	25,598	281
1980	7,675	6,968	6,181	14,642	24,037	266
1981	7,016	5,975	5,250	12,992	22,242	430
1982	6,961	5,941	5,209	12,902	21,728	458
1983	6,995	5,899	5,157	12,894	21,297	407
1984	6,566	5,368	4,649	11,933	19,980	436
1985	6,532	5,450	4,758	11,982	19,595	399
1986	6,460	5,068	4,392	11,529	18,811	242
1987	6,253	4,813	4,227	11,066	18,106	275
1988	6,320	4,998	4,416	11,319	18,092	240
Area IV W 1984/85 survey, MSY% = 4						
1971	11,215	11,215	10,291	22,431	34,482	0
1972	10,713	10,870	9,945	21,582	33,633	76
1973	9,573	9,824	8,899	19,397	31,505	272
1974	8,428	7,732	6,808	16,160	28,335	563
1975	7,887	6,997	6,073	14,885	26,733	678
1976	7,857	7,070	6,145	14,927	26,289	674
1977	7,725	7,152	6,228	14,877	25,818	719
1978	7,857	6,933	5,990	14,791	25,343	737
1979	7,889	6,680	5,732	14,569	24,670	482
1980	7,069	6,362	5,541	13,432	23,284	452
1981	6,496	5,456	4,695	11,952	21,684	602
1982	6,520	5,500	4,732	12,021	21,347	621
1983	6,628	5,533	4,753	12,161	21,104	547
1984	6,264	5,066	4,313	11,329	19,980	561
1985	6,287	5,205	4,481	11,493	19,778	537
1986	6,279	4,887	4,167	11,166	19,190	368
1987	6,130	4,689	4,060	10,819	18,664	408
1988	6,257	4,936	4,303	11,193	18,832	377

[*continued*]

Appendix 7. Table continued.

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY	Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
Area IV 1978/79 survey, MSY% = 1							**Area IV 1978/79 survey, MSY% = 2**						
1970	29,138	29,138	26,737	58,276	89,585	0	1970	28,658	28,658	26,296	57,315	88,108	0
1971	29,129	29,123	26,722	58,252	89,561	2	1971	28,649	28,643	26,281	57,292	88,085	2
1972	28,287	27,541	25,140	55,828	87,134	220	1972	27,807	27,060	24,699	54,867	85,659	220
1973	26,146	25,702	23,301	51,848	82,820	577	1973	25,666	25,222	22,860	50,888	81,451	577
1974	24,777	23,410	21,008	48,186	78,485	906	1974	24,296	22,929	20,568	47,226	77,353	906
1975	24,304	22,668	20,267	46,971	76,106	1,015	1975	23,823	22,187	19,826	46,011	75,276	1,015
1976	24,308	22,786	20,385	47,094	74,978	1,002	1976	23,828	22,306	19,944	46,134	74,445	1,003
1977	23,864	22,682	20,282	46,546	73,315	817	1977	23,384	22,202	19,841	45,586	73,053	892
1978	23,960	22,452	20,159	46,411	72,357	569	1978	23,514	22,007	19,719	45,521	72,357	736
1979	23,688	21,988	19,814	45,676	71,072	247	1979	23,320	21,619	19,406	44,940	71,310	461
1980	22,652	21,544	19,548	44,195	69,360	250	1980	22,382	21,273	19,210	43,655	69,830	461
1981	21,913	20,323	18,387	42,236	67,265	449	1981	21,739	20,150	18,139	41,889	67,992	641
1982	21,519	19,637	17,691	41,156	65,738	534	1982	21,434	19,552	17,532	40,986	66,741	720
1983	21,010	18,830	16,889	39,840	63,834	630	1983	21,010	18,830	16,811	39,840	65,118	798
1984	20,342	18,153	16,223	38,495	61,755	692	1984	20,420	18,230	16,223	38,650	63,323	857
1985	20,143	17,622	15,719	37,765	60,224	727	1985	20,296	17,775	15,789	38,071	62,082	909
1986	19,959	17,182	15,293	37,141	58,753	569	1986	20,195	17,419	15,433	37,614	60,893	764
1987	19,633	16,687	14,896	36,320	57,230	510	1987	19,959	17,013	15,113	36,972	59,647	709
1988	19,745	17,042	15,312	36,787	57,067	314	1988	20,163	17,460	15,611	37,623	59,761	515
Area IV 1978/79 survey, MSY% = 3							**Area IV 1978/79 survey, MSY% = 4**						
1970	28,184	28,184	25,862	56,369	86,653	0	1970	27,718	27,718	25,434	55,436	85,219	0
1971	28,175	28,170	25,847	56,345	86,629	2	1971	27,709	27,703	25,419	55,412	85,195	2
1972	27,334	26,587	24,265	53,921	84,204	220	1972	26,867	26,121	23,837	52,988	82,772	220
1973	25,192	24,749	22,426	49,941	80,103	577	1973	24,726	24,282	21,998	49,008	78,776	577
1974	23,823	22,456	20,134	46,279	76,240	906	1974	23,357	21,990	19,706	45,346	75,146	906
1975	23,350	21,714	19,392	45,064	74,460	1,015	1975	22,884	21,248	18,964	44,131	73,659	1,015
1976	23,355	21,833	19,510	45,187	73,921	1,004	1976	22,888	21,366	19,082	44,255	73,407	1,005
1977	22,911	21,729	19,407	44,640	72,796	967	1977	22,445	21,263	18,979	43,708	72,544	1,042
1978	23,076	21,568	19,285	44,644	72,357	903	1978	22,644	21,137	18,858	43,781	72,357	1,068
1979	22,958	21,257	19,004	44,216	71,540	672	1979	22,602	20,901	18,607	43,504	71,762	879
1980	22,116	21,008	18,878	43,125	70,279	668	1980	21,856	20,747	18,551	42,603	70,706	871
1981	21,569	19,979	17,896	41,548	68,678	830	1981	21,401	19,812	17,657	41,213	69,323	1,016
1982	21,350	19,469	17,376	40,819	67,681	902	1982	21,268	19,387	17,222	40,655	68,558	1,081
1983	21,010	18,830	16,734	39,840	66,316	961	1983	21,010	18,830	16,659	39,840	67,430	1,119
1984	20,494	18,305	16,223	38,800	64,784	1,011	1984	20,567	18,377	16,223	38,944	66,137	1,157
1985	20,442	17,921	15,858	38,362	63,812	1,078	1985	20,580	18,060	15,924	38,640	65,413	1,233
1986	20,418	17,642	15,567	38,060	62,889	944	1986	20,628	17,852	15,694	38,480	64,734	1,109
1987	20,265	17,319	15,317	37,583	61,901	892	1987	20,550	17,604	15,510	38,154	63,983	1,059
1988	20,553	17,849	15,891	38,402	62,273	702	1988	20,915	18,212	16,153	39,126	64,591	872
Area V 1980/81 survey, MSY% = 1							**Area V 1980/81 survey, MSY% = 2**						
1970	45,098	45,098	41,382	90,196	138,655	0	1970	44,960	44,960	41,255	89,919	138,229	0
1971	45,097	45,097	41,381	90,194	138,653	0	1971	44,959	44,959	41,254	89,917	138,227	0
1972	45,097	45,097	41,381	90,194	138,653	0	1972	44,959	44,959	41,254	89,917	138,227	0
1973	45,097	45,097	41,381	90,195	138,653	0	1973	44,959	44,959	41,254	89,917	138,227	0
1974	45,097	45,097	41,381	90,195	138,653	0	1974	44,959	44,959	41,254	89,918	138,227	0
1975	44,860	44,662	40,945	89,521	137,979	61	1975	44,721	44,523	40,818	89,244	137,554	61
1976	44,588	44,409	40,693	88,998	137,367	107	1976	44,450	44,271	40,566	88,721	136,973	108
1977	44,083	43,668	39,951	87,750	135,993	220	1977	43,944	43,529	39,824	87,473	135,652	220
1978	43,839	43,302	39,586	87,141	135,117	274	1978	43,700	43,164	39,459	86,864	134,880	274
1979	43,812	43,200	39,484	87,012	134,669	286	1979	43,674	43,062	39,357	86,736	134,553	286
1980	43,419	42,623	38,906	86,041	133,382	310	1980	43,280	42,484	38,779	85,765	133,382	333
1981	43,258	41,923	38,236	85,181	132,169	355	1981	43,130	41,795	38,109	84,925	132,314	393
1982	43,011	41,416	37,744	84,427	130,968	317	1982	42,900	41,305	37,626	84,205	131,277	390
1983	42,708	40,269	36,645	82,978	129,097	393	1983	42,631	40,192	36,544	82,823	129,585	479
1984	42,381	39,632	36,032	82,013	127,540	464	1984	42,343	39,594	35,962	81,937	128,239	546
1985	42,171	39,432	35,840	81,603	126,463	415	1985	42,171	39,432	35,805	81,603	127,391	519
1986	41,934	39,121	35,568	81,055	125,341	356	1986	41,982	39,168	35,568	81,150	126,496	473
1987	41,833	38,619	35,116	80,452	124,253	333	1987	41,934	38,720	35,160	80,654	125,638	460
1988	41,854	38,905	35,437	80,758	124,076	125	1988	42,012	39,063	35,529	81,076	125,694	275
Area V 1980/81 survey, MSY% = 3							**Area V 1980/81 survey, MSY% = 4**						
1970	44,821	44,821	41,128	89,642	137,803	0	1970	44,683	44,683	41,001	89,365	137,378	0
1971	44,820	44,820	41,127	89,640	137,801	0	1971	44,682	44,682	41,000	89,363	137,376	0
1972	44,820	44,820	41,127	89,640	137,801	0	1972	44,682	44,682	41,000	89,364	137,376	0
1973	44,820	44,820	41,127	89,641	137,801	0	1973	44,682	44,682	41,000	89,364	137,376	0
1974	44,820	44,820	41,127	89,641	137,802	0	1974	44,682	44,682	41,000	89,364	137,376	0
1975	44,583	44,385	40,691	88,967	137,128	61	1975	44,444	44,246	40,564	88,691	136,703	61
1976	44,312	44,132	40,439	88,444	136,580	108	1976	44,173	43,994	40,312	88,167	136,186	108
1977	43,806	43,391	39,697	87,197	135,312	220	1977	43,667	43,252	39,570	86,920	134,971	220
1978	43,562	43,025	39,332	86,587	134,643	274	1978	43,423	42,887	39,205	86,310	134,406	274
1979	43,535	42,924	39,230	86,459	134,437	286	1979	43,397	42,785	39,103	86,182	134,321	286
1980	43,142	42,346	38,652	85,488	133,382	355	1980	43,004	42,208	38,525	85,211	133,382	378
1981	43,002	41,667	37,982	84,669	132,460	431	1981	42,874	41,539	37,855	84,413	132,605	468
1982	42,789	41,195	37,509	83,984	131,585	464	1982	42,678	41,084	37,391	83,762	131,891	537
1983	42,554	40,115	36,442	82,669	130,067	565	1983	42,477	40,038	36,340	82,515	130,542	650
1984	42,306	39,556	35,891	81,862	128,923	629	1984	42,268	39,519	35,820	81,786	129,593	711
1985	42,171	39,432	35,771	81,603	128,290	622	1985	42,171	39,432	35,736	81,603	129,161	725
1986	42,029	39,215	35,568	81,244	127,607	588	1986	42,076	39,263	35,568	81,339	128,672	701
1987	42,034	38,820	35,203	80,854	126,957	583	1987	42,134	38,920	35,246	81,053	128,210	703
1988	42,169	39,220	35,621	81,389	127,221	419	1988	42,324	39,374	35,712	81,698	128,656	556

[*continued*]

Appendix 7. Table continued.

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY	Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
Area V 1985/86 survey, MSY% = 1							**Area V 1985/86 survey, MSY% = 2**						
1970	102,573	102,573	94,121	205,146	315,363	0	1970	102,098	102,098	93,685	204,197	313,903	0
1971	102,572	102,572	94,120	205,145	315,361	0	1971	102,097	102,097	93,684	204,195	313,901	0
1972	102,572	102,572	94,120	205,145	315,361	0	1972	102,098	102,098	93,684	204,195	313,901	0
1973	102,572	102,572	94,120	205,145	315,361	0	1973	102,098	102,098	93,684	204,195	313,901	0
1974	102,573	102,573	94,120	205,145	315,361	0	1974	102,098	102,098	93,684	204,195	313,901	0
1975	102,335	102,137	93,684	204,472	314,688	61	1975	101,860	101,662	93,248	203,522	313,228	61
1976	102,064	101,885	93,432	203,948	314,076	107	1976	101,589	101,410	92,996	202,999	312,648	108
1977	101,558	101,143	92,690	202,701	312,702	220	1977	101,083	100,668	92,255	201,751	311,329	220
1978	101,314	100,777	92,325	202,091	311,830	274	1978	100,839	100,302	91,889	201,142	310,563	274
1979	101,287	100,676	92,223	201,963	311,387	286	1979	100,813	100,201	91,787	201,013	310,246	286
1980	100,894	100,098	91,645	200,992	310,105	310	1980	100,419	99,623	91,210	200,042	309,085	333
1981	100,733	99,399	90,975	200,132	308,900	356	1981	100,269	98,934	90,539	199,203	308,035	394
1982	100,486	98,892	90,483	199,378	307,712	319	1982	100,039	98,445	90,057	198,484	307,024	395
1983	100,185	97,746	89,385	197,931	305,858	397	1983	99,773	97,334	88,975	197,107	305,364	486
1984	99,859	97,110	88,773	196,969	304,328	468	1984	99,488	96,739	88,395	196,227	304,070	553
1985	99,651	96,912	88,582	196,563	303,284	421	1985	99,320	96,580	88,241	195,900	303,284	531
1986	99,417	96,603	88,311	196,021	302,196	365	1986	99,136	96,322	88,007	195,458	302,453	491
1987	99,320	96,106	87,862	195,426	301,144	345	1987	99,096	95,882	87,604	194,979	301,661	483
1988	99,346	96,397	88,186	195,743	301,007	144	1988	99,185	96,236	87,981	195,421	301,789	312
Area V 1985/86 survey, MSY% = 3							**Area V 1985/86 survey, MSY% = 4**						
1970	101,634	101,634	93,259	203,269	312,477	0	1970	101,181	101,181	92,843	202,363	311,084	0
1971	101,634	101,634	93,258	203,267	312,475	0	1971	101,180	101,180	92,843	202,361	311,082	0
1972	101,634	101,634	93,258	203,267	312,475	0	1972	101,181	101,181	92,843	202,361	311,082	0
1973	101,634	101,634	93,258	203,267	312,475	0	1973	101,181	101,181	92,843	202,361	311,082	0
1974	101,634	101,634	93,258	203,267	312,475	0	1974	101,181	101,181	92,843	202,361	311,083	0
1975	101,396	101,198	92,823	202,594	311,802	61	1975	100,943	100,745	92,407	201,688	310,409	61
1976	101,125	100,946	92,571	202,071	311,254	108	1976	100,672	100,493	92,155	201,165	309,893	108
1977	100,619	100,204	91,829	200,823	309,988	220	1977	100,166	99,751	91,413	199,917	308,682	220
1978	100,375	99,839	91,463	200,214	309,330	274	1978	99,922	99,386	91,048	199,308	308,130	274
1979	100,349	99,737	91,362	200,086	309,139	286	1979	99,896	99,284	90,946	199,180	308,065	286
1980	99,955	99,159	90,784	199,115	308,099	356	1980	99,502	98,706	90,368	198,209	307,147	378
1981	99,815	98,481	90,113	198,296	307,203	432	1981	99,373	98,038	89,698	197,411	306,405	471
1982	99,603	98,009	89,641	197,613	306,367	471	1982	99,178	97,584	89,234	196,763	305,741	547
1983	99,372	96,933	88,575	196,305	304,896	575	1983	98,982	96,543	88,185	195,525	304,455	665
1984	99,128	96,379	88,027	195,507	303,828	639	1984	98,779	96,030	87,669	194,808	303,602	725
1985	98,999	96,260	87,911	195,259	303,284	640	1985	98,689	95,950	87,590	194,639	303,284	750
1986	98,865	96,052	87,713	194,917	302,689	615	1986	98,605	95,792	87,428	194,397	302,904	737
1987	98,883	95,669	87,355	194,551	302,129	617	1987	98,679	95,465	87,117	194,144	302,549	747
1988	99,033	96,084	87,785	195,117	302,489	472	1988	98,890	95,940	87,598	194,830	303,104	625

Annex E
Report of the Sub-Committee on North Atlantic Minke Whales

Members: Hammond (Convenor), Allison, A. Arnason, U. Arnason, Arnbom, Bjørge, Borchers, Buckland, Butterworth, Chapman, Cooke, de la Mare, Donovan, Gunnlaugsson, Hester, Hiby, Holt (R.), Holt (S.), Horwood, Ikeda, Inagaki, Joyce, Kasamatsu, Kato, Kirkwood, Lankester, Larsen, Lassen, Le Gall, Magnusson, Misaki, Mizroch, Miyashita, Nakamura, Nakken, Øien, Ohsumi, Øritsland, Palsbøll, Perrin, Sakuramoto, Sigurjónsson, Smith, Tillman, Ulltang, Walløe, Whitehead.

1. ELECTION OF CHAIRMAN

Hammond was elected Chairman.

2. APPOINTMENT OF RAPPORTEUR(S)

The Chairman undertook the duties of rapporteur.

3. ADOPTION OF AGENDA

The adopted Agenda is given in Appendix 1.

4. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS

The following documents contained information of relevance to the work of the sub-committee: SC/40/Mi1, 7, 9, 11, 12, 15, 21, 22, 23, 24; SC/40/O 9, 10, 11, 12, 15, 28, 29, 30, 34, 36, 41; SC/40/SM10; SC/40/ProgRep Denmark, Iceland, Norway.

5. REVIEW OF STOCK BOUNDARIES

At last year's meeting the sub-committee was unable to conclude whether the boundary between the West Greenland and Central stocks at Kap Farvel should be retained and had agreed that future assessments should examine the consequences of this. Some new information was available this year. SC/40/O 34 presented the results of a study in which a human cDNA probe was used to investigate the C4 gene in minke whales. Seven restriction endonucleases were used but no polymorphism was found. The authors concluded that more restriction enzymes needed to be investigated from a larger sample of animals for the potential of this technique to be realised. SC/40/ProgRep Denmark reported that analysis of the variation in DNA from 24 minke whales suggested that animals from the Barents Sea and West Greenland are different. This was a preliminary result from a pilot study and further analysis of a larger sample was needed to confirm it.

The sub-committee discussed the value of the existing catch data and the new sightings data from the 1987 North Atlantic Sightings Survey in illuminating the question of stock identity in the North Atlantic. It was noted that information on distribution from these sources pertained only to the summer feeding areas; knowledge of the distribution of animals in the lower latitudes where they breed is very poor. However, analyses of changes in distribution of catches within seasons may indicate how minke whales segregate by sex and length in time and space on the feeding grounds.

The sub-committee **recommended** that genetic studies, as outlined in Annex J1, and telemetry studies, as outlined in Annex J8, be continued or initiated to try to resolve the question of stock identity in North Atlantic minke whales.

6. ASSESSMENT OF STOCKS

6.1 Assessment methods and available data

6.1.1 Sightings analyses

The sub-committee had before it several papers relating to the North Atlantic Sightings Survey which took place in the summer of 1987 (NASS-87).

The objectives of NASS-87 were to investigate the distribution and estimate the abundance of the three primary target species; fin, minke and pilot whales. SC/40/O 29 described the shipboard surveys undertaken by Iceland. Three vessels (one research and two combined trawler/purse seiners) operated from 24 June – 28 July around Iceland, in the Denmark Strait, north to Jan Mayen, southwest to the Faroes and south to the deep water west of Britain and Ireland. These vessels were modified by installation of communication and navigation systems and by the construction of barrels. They steamed 11,786 n.miles on searching effort realising 1,215 primary sightings. Of these sightings, 264 were fin, 194 minke and 96 pilot whales. In addition, one Faroese combined trawler/purse seiner steamed 5,608 n.miles on effort around the Faroe Islands, east to Norway and south to the north and west of Britain and Ireland, realising 189 primary sightings. Fin whales were seen throughout the areas surveyed, mostly in deep waters. Minke whales were mostly seen in shallower waters closer to shore.

SC/40/O 10 described the aerial survey undertaken in Icelandic waters, 1–20 July. The aircraft used was a *Partenavia P68 observer* with bubble windows. Over 3,550 n.miles were flown on effort but because of poor weather the waters east of Iceland received no coverage. A total of 304 primary sightings were seen on effort, of which 172 were of minke whales.

SC/40/O 9 described the shipboard and aerial surveys undertaken by Norway. Three vessels (two sealers and one small-type whaler) operated for 3 weeks in the Barents, Norwegian and Greenland Seas, north and west of Norway and north of the areas covered by Iceland and the Faroe Islands. These vessels steamed 3,439 n.miles on searching effort. One aircraft, a *Partenvia P68 observer* with bubble windows, flew about 1,600 n.miles on searching effort off the west coast of Svalbard and the north coast of Norway. These surveys realised 364 sightings in total, of which 171 were minke and 58 were fin whales.

SC/40/O 11 described the aerial survey conducted off West Greenland, 28 July – 13 August, using the same aircraft as in the Icelandic survey. The weather was good enough for all blocks to be covered twice. Sightings included 53 fin whales, 38 minke whales and 460 pilot whales during 4,423 n.miles of survey effort. Fin whales were distributed throughout the survey area. Minke whales were mostly found in nearshore waters and were not found north of 69°N.

SC/40/O 15 described the Spanish shipboard survey which took place in the waters northwest of Spain and southwest of Ireland between 6 July and 3 August. The vessel used was a converted tunaboat which had been used on two previous surveys for fin whales. A total of 2,323 n.miles were searched on effort during which time 151 primary sightings were made of which 91 were fin and 11 were pilot whales; no minke whales were seen.

Data from all shipboard surveys were collected according to the procedures used on the Southern Hemisphere minke whale assessment cruises. No experiments to estimate the probability of detecting animals on the track line, g(0), were undertaken. Experiments to estimate surfacing rates of minke whales for use in the cue counting procedures adopted on the aerial surveys were carried out on the Icelandic and Norwegian surveys. These experiments are described in papers SC/40/Mi23 and SC/40/Mi15, respectively. The results are consistent. From the Icelandic vessels 15 experiments, completed mostly in coastal waters, gave an average mean dive time interval of 67.5 seconds which is equivalent to a surfacing rate of 53.3 per hour. From the Norwegian vessels, four completed experiments where no whale reaction was observed gave an average rate of 52.4 surfacings per hour. The sub-committee agreed to use a mean surfacing rate of 53 per hour in analyses of aerial survey data.

It also agreed that these experiments were crucial to the use of cue counting techniques and **recommended** that more data are collected to investigate differences in surfacing rates among areas (e.g. shallow vs deep water), diurnal patterns, differences in behaviour, etc. It noted that such experiments were planned by Iceland and Norway this year. SC/40/SM10 cited Lynas and Sylvestre (1988, *Aquatic Mammals* 14:21–32) as a source of information on variability in dive duration in Gulf of St. Lawrence minke whales.

The sub-committee recognised the large amount of work represented by the planning and execution of NASS-87 and by preliminary analyses of the data. It expressed appreciation to the scientists involved in the survey and to Iceland, Norway, Denmark, the Faroe Islands, Spain, the Nordic Council of Ministers, the USA, Japan and the UK for making the research possible, and it looked forward to the results of further analyses at next year's meeting.

6.1.2 Mark-recapture analyses

There were no recoveries of marks in the North Atlantic and no new analyses were carried out during the last year.

6.1.3 Assessing trends and status

The sub-committee had available to it the computer programs HITTER and FITTER (Annex L) which can fit a population model to estimates of population size and/or CPUE data. Some members felt that the decision on whether or not to apply this method should be made on a stock by stock basis. Other members felt that if it could be validly applied in any one case at this meeting then it would be valid to apply it to all three stocks under consideration. In addition, some members expressed their reservations about the value of using this procedure during this meeting without adequate time to review the input data and to programme an appropriate series of runs.

SC/40/O 41 raised some general problems of using sightings and other estimates of stock size in assessing trends. Several issues were of particular concern. First, estimates of abundance are frequently not calculated for sightings surveys in which few sightings are made because of problems in estimating effective search width from small sets of perpendicular distance data. This could result in a bias if estimates are only accepted if many whales are seen. Second, most surveys do not cover the entire range of a stock; even if they are designed to, poor weather will result in some areas not being covered. The status of such estimates is unclear. Third, there are sources of bias in stock estimates from sighting surveys which often cannot be quantified, e.g. the proportion of animals missed on the transect line. Sigurjónsson noted that an additional problem was how to treat sightings estimates from surveys conducted primarily for another purpose, such as marking or fisheries research. The sub-committee recognised that the presence of a negative bias due to one or more effects does not necessarily mean that the calculated stock size is a minimum estimate.

The sub-committee also recognised that some of these points would need to be addressed in relation to the sightings estimates from NASS-87. Discussion of the wider issue of defining objective criteria for whether or not sightings estimates should be used in stock assessments was deferred to Plenary Agenda Item 6.4.1.

6.1.4 CPUE analyses

The sub-committee agreed that, given the time available and the problems identified by the Committee in dealing with CPUE series, nothing could be done at this meeting to improve the series.

6.2 Northeastern stock

6.2.1 Sightings estimates

SC/40/Mi9 presented preliminary analyses of the data collected on the Norwegian shipboard surveys. As agreed in the joint post-cruise meeting (SC/40/O 28), a hazard rate model was fitted to the perpendicular distance data and estimates were made for both passing and closing mode, where possible. No minke whales were seen on effort in block C2 (Barents Sea). Separate estimates were given for areas covered by aerial survey.

The sub-committee noted the large apparent difference between the distributions of perpendicular distance collected during passing and closing mode. This difference was tested and found not to be significant for the data truncated at 0.5 n.miles; the data were pooled to estimate a single effective search width. There was no significant difference between the sighting rates in closing and passing modes and a single population estimate was calculated for each block using the pooled data. Numbers of animals were apportioned to management stock areas based on the proportion of each block in each stock area as done in SC/40/Mi9. These estimates were accepted by the sub-committee as provisional estimates of the number of whales in each survey block. They are presented in Appendix 2.

This management area also includes the area covered by the Faroese ship survey, provisional results of which are presented in SC/40/O 30 and Appendix 2.

SC/40/O 12 presented an analysis of the aerial survey data. The data were collected according to the cue counting method as described in SC/40/Mi4, SC/40/O 9, 10, 11 and 12. This method calculates the density of cues (surfacings in the case of North Atlantic minke whales) seen in an effective search area estimated from the radial sightings distances. This is then divided by a mean surfacing rate as discussed under Item 6.1.1. The method uses duplicate sightings of the same cue to check the accuracy of the radial distance estimates and to account for whales missed at zero distance. SC/40/O 12 presented a combined estimate of minke whales from both aerial surveys in Norway. This figure was recalculated using a mean surfacing rate of 53 surfacings/hour (see Item 6.1.1) for Svalbard and North Norway separately.

The sub-committee discussed why the effective search area calculated for the Norwegian aerial surveys was so much larger than for the Icelandic and West Greenland survey (see Items 6.3.1 and 6.4.1). The most likely explanation was that the observers on the Norwegian survey had directed their searching effort over a much greater range of distance from the aircraft than the observers on the other surveys. No reason for this difference in searching strategy could be determined.

The sub-committee accepted these aerial estimates of the number of animals in these areas at the time of the survey. They are given in Appendix 2. Members noted that the density in the area west of Svalbard was considerably lower than the density from a shipboard survey conducted in 1985 in the same area (SC/37/Mi3).

The sub-committee agreed that the provisional estimate of total stock size was the sum of the survey blocks using aerial estimates where available. This gives a figure of 19,112 (CV=0.163) animals. There was very little survey effort in the part of block B2 in the Northeastern stock management area (SC/40/Mi9). If block B2 is excluded, the estimate is 17,014 (CV=0.179) animals. These estimates are considered to be provisional because they are based largely on shipboard sightings surveys with a very low coverage and no indication of how many animals were missed on the transect line.

6.2.2 CPUE analyses

At last year's meeting the sub-committee had recommended that new analyses be undertaken which took account of discussions at that meeting (*Rep. int. Whal. Commn* 38: 90). However, no new analyses were presented to this meeting. Further analyses of CPUE series using detailed information available from ship's logbooks might be undertaken as part of the Norwegian five year programme of research. It was noted that Norwegian catch and effort data for the period 1938–1986 had been lodged with the Secretariat as recommended last year (*Rep. int. Whal. Commn* 38: 91) and were thus available according to the normal rules of the Commission. Data on operational details had to be sought in deck-logbooks of individual ships.

Holt asked for clarification regarding some restrictions apparently placed by the Norwegian government on publication of analyses using some of the above data series. Nakken stated that there would be no restriction on the use of these data other than those imposed by Norwegian legislation. This was a question of data availability and the sub-committee referred it to Plenary Agenda Item 11.4.

6.2.3 Stock assessment

The sub-committee had before it SC/40/Mi11, the report of the group of scientists appointed by the Norwegian government to review the basis for Norway's harvesting of minke whales. This report was made available at last year's meeting but had not been a meeting document. SC/40/Mi1, a critique of SC/40/Mi11, had been available to members for several months. SC/40/Mi12 had been submitted by the group of scientists as a reply to SC/40/Mi1. The differences of opinion expressed in these documents, although important for the management of North Atlantic minke whales, as well as to more general questions of whaling management, were not immediately relevant to the work of the sub-committee this year. These differing views were restated briefly and the sub-committee did not discuss the matter further.

The authors of SC/40/Mi11 had recommended a firm commitment to institute a programme of research and monitoring to provide the basis for effective management. The sub-committee noted that SC/40/Mi7, the Norwegian programme to study and monitor Northeastern Atlantic minke whales 1988–1992, had been drawn up largely as a result of SC/40/Mi11, and in consultation between interested laboratories and scientists in Norway.

The sub-committee agreed that it was important to try to assess this stock because the five year programme of research proposed by Norway involved a scientific take, although no indication had been given of when commercial whaling might resume.

However, several reasons for not attempting an assessment at this meeting were put forward; (i) the unresolved problems with CPUE series; (ii) no agreed basis for choosing a range of MSY percents; (iii) the provisional nature of the stock estimate; and (iv) the likelihood of a change in age at recruitment over the period of the catch. Although not all members agreed with all of these reasons, the sub-committee agreed not to attempt an assessment at this meeting.

Management advice

At last year's meeting some members believed that the assessment attempted showed that there was no basis for changing classification of the stock and that it should remain classified as a Protection Stock. Other members believed that there had been no basis for attempting an assessment and that there was consequently no basis for providing advice on the classification of the stock.

This year, in the absence of a new assessment, the sub-committee was unable to provide further advice on classification of the stock.

Horwood noted that if the stock size was about 20,000, as indicated above, then previous modelling (*Rep. int. Whal. Commn* 37: 103) showed that the stock was in the Protected category. Some other members associated themselves with this statement.

6.2.4 Future research

Norwegian Research Programme

Last year, the sub-committee discussed a provisional programme of research proposed by Norway (SC/39/O 11). It recommended that the programme concentrate on three major areas: sightings surveys; provision of data for assessment; and utilisation of non-lethal techniques (*Rep. int. Whal. Commn* 38: 91). This year, the sub-committee received SC/40/Mi7, a revised Norwegian programme to study and monitor Northeastern Atlantic minke whales, 1988–1992.

In presenting a summary of SC/40/Mi7, Nakken noted that the revised proposal had benefited from sub-committee discussions last year and from recommendations from the Walløe report (SC/40/Mi11), and that he would be pleased to receive further comments this year. The revised proposal was much more broadly based than SC/39/O 11, both in the scope of the research and in the organisations involved. Invitations were extended to other workers to submit proposals for co-operative or independent research within the subject area of the programme, including those which required funding. The objectives of the programme were to conduct research leading to identification of stocks, stock assessments and quantifying the role of the minke whale in the environment. To achieve these objectives it was planned to investigate acoustic surveillance, radio-tagging, molecular genetic variation, morphometrics, theoretical and practical aspects of sightings surveys, age determination, reproductive parameters, length estimation, population models, energetics of feeding, body composition and the development of multispecies assessment models. Several of the proposed projects were already underway or about to begin. It is proposed that 35 whales be caught for methodological studies under four projects: feasibility of radio tagging – 5 whales; food selection and intake – 10; food digestion – 10; and body composition – 10.

The five whales to be anaesthetised to investigate the possibility of attaching radio tags to live-captured animals would be released if the technique was successful. The remaining 30 whales would be used in as many studies as possible but each project would have priority on ten whales. The sub-committee agreed that the question of whether or not a scientific permit was required to experiment on live captured animals was beyond the competence of the sub-committee and referred this to the Scientific Committee.

The sub-committee noted that the proposed removal of 30 to 35 whales was for the first year of a five year programme. The sub-committee was only able to consider the effect of a single take of 30–35 whales on the status of the stock. It agreed that the effect would be negligible. The sub-committee stressed, however, that the effect of a small take in a single year would always be negligible.

The sub-committee noted the following statement from SC/40/Mi7:

> 'The need for further catches after 1988 must necessarily be evaluated and decided on the basis of results from the first field season. It is anticipated, however, that continued studies of temporal and spatial food selection and intake may require an annual sampling of even larger numbers throughout the program period, i.e. each of the years from 1989 to 1992'.

Consequently, the sub-committee could not consider the effects of takes associated with the entire five year programme.

The sub-committee requested clarification on how the sample sizes for the methodological studies had been decided and on whether all whales would be utilised in all the studies. The size of the take had been decided via a combination of the number of animals needed to investigate the potential of the methodologies and the operational capabilities of two vessels working for three weeks. No attempt had been made to calculate sample sizes on statistical grounds.

Several points were clarified concerning the proposed studies on age determination, digestion and telemetry. The suggestion that vertebrae should be examined or collected to investigate age at physical maturity was accepted.

Nakken stressed that the work planned for 1988 was not a feasibility study but the introductory phase of a five year programme of research. This work included the projects already started and a major sightings survey in the northeast Atlantic using six ships, one of which would carry a helicopter. The duration of this survey was expected to be five weeks.

The sub-committee discussed the proposed 1988 survey in terms of the research priorities of the Scientific Committee.

Priorities for future research

One such priority, that of estimating absolute abundance could potentially be achieved by such sighting surveys. Last year, the sub-committee recommended that, in the 1987 surveys, direct evidence for whales being missed on the transect line be collected. This could now be addressed by the aerial survey methodology discussed above (Item 6.2.1). It had not been addressed by the 1987 shipboard surveys because the extra personnel necessary to conduct independent observer experiments could not be accommodated.

The sub-committee discussed the feasibility of obtaining acceptable estimates of g(0) from shipboard independent observer experiments in the North Atlantic. It was noted that after several years of data collection from three different experimental designs, the Southern Hemisphere minke sub-committee had still failed to produce a satisfactory estimate of g(0). Three views were expressed. One was that until a suitable methodology had been worked out there may be little point in conducting independent observer experiments in the North Atlantic. Effort could more productively be used in developing such a methodology. A second view was that it was essential to attempt to estimate g(0) for these surveys. The problems encountered in the Southern Hemisphere may not arise in the North Atlantic where there should be fewer problems in identifying duplicate sightings because of lower densities, smaller school sizes and narrower effective search widths. Sample sizes would be smaller in the North Atlantic than in the Southern Hemisphere, but approximately three times as much effort was planned for the northeast Atlantic in 1988 compared with 1987. A third view was that shipboard estimates could be calibrated with aerial estimates (assumed not to be biased), if some surveys took place at the same time in the same place.

The sub-committee noted that plans to develop methodology to estimate g(0) from shipboard surveys were included in SC/40/Mi7 and that such estimates could be applied to earlier survey results. It also noted that more observers for experiments meant less time at sea, for financial reasons. It was planned, however, to cover some areas by ship and helicopter, and independent observer experiments could be attempted on a limited scale in high density areas.

The report of the joint post-cruise meeting of the 1987 North Atlantic Sightings Survey (SC/40/O 28) had recommended that the next coordinated international survey effort be postponed until 1989. The sub-committee welcomed the intentions of Norway, Iceland and Denmark to conduct another such survey at that time because of the importance of obtaining estimates of absolute abundance. It noted that the participation of the Faroe Islands and Spain had greatly increased the value of the 1987 survey and urged participation by these and other countries in 1989. It was highly desirable that methodological problems be resolved before this survey. The sub-committee agreed that planning for a North Atlantic Sightings Survey in 1989 should start as soon as possible. It **recommended** that a working group meet before the end of this year's Scientific Committee meeting.

6.3 Central stock

6.3.1 Sightings estimates

SC/40/O 30 presented preliminary analyses of the data collected on the Icelandic and Faroese shipboard surveys. No information on the proportion of animals missed was available from duplicate sightings, but there were some marked differences among observers suggesting that whales had been missed on the transect line as a result of observer inexperience. A calculation using the surfacing rate information from SC/40/Mi23 estimated that at least 43.9% of minke whales were missed on the transect line because they were underwater. The data had not yet been analysed to account for weather conditions which are likely to have a marked effect on estimates of minke whale abundance. These problems led the authors of SC/40/O 30 to conclude that the estimates of abundance from these surveys were negatively biased.

The sub-committee discussed these sources of negative bias. It noted that two of these biases were expected before the surveys began. First, because the surveys were also for fin whales, part of the searching effort had been conducted in weather conditions unsuitable for sighting minke whales, although it should be possible to account for this in further analyses. In addition, the observers were used to searching out to the horizon for fin whales. Second, no independent observer experiments to estimate g(0) had been planned because the personnel required could not be accommodated on the vessels.

The sub-committee also discussed other possible sources of bias. SC/40/O 30 drew attention to problems in the use of the distance gauges to estimate radial distance on two of the vessels. This was thought to contribute to the greater sightings distances recorded on these two vessels than on the third vessel. SC/40/O 30 showed that most minke whales were seen within a perpendicular distance of 200 metres. The authors reported that this was also true for radial distances. Although no experiments were conducted to calibrate distance (or angle) measurements, the sub-committee agreed that while there could be considerable variability in even such short distance estimates, there was no reason to suspect a bias in either direction.

Attention was drawn to the very spiked nature of the distribution of perpendicular distances. It was noted that this was to be expected because the cue for a North Atlantic minke whale is its back which is difficult to see, especially in poor weather conditions. It was also noted that how spiked a distribution appeared was a question of scale. The sub-committee was informed that the distribution was quite flat out to about 200m. SC/40/O 30 had used an estimate of effective search width of twice the median perpendicular distance which assumed a flat distribution out to that distance. The sub-committee considered that a more appropriate estimator would be the negative exponential. It agreed to adjust the estimates accordingly by multiplying median distances by 2.88 to give these effective search widths. Members noted that there may be bias of unknown direction associated with using the negative exponential on unsmeared data. Because of these problems, the sub-committee then accepted these estimates as provisional estimates of the number of animals in each block. They are given in Appendix 2.

SC/40/O 12 presented two estimates for the Icelandic aerial survey. One was calculated using an unstratified effective search area (esa), the other using an esa stratified by sea state. The sub-committee agreed that the stratified estimate was preferable. The distance data for this survey are distributed differently from those for the other two surveys. Part of this difference between Iceland and West Greenland is accounted for by the weather conditions. A further contributing factor may be the problems one of the observers on the Iceland survey had with recording radial distance. The sub-committee agreed to accept the stratified estimate from the survey, using 53 surfacings/hour as agreed (Item 6.1.1). This estimate is presented in Appendix 2.

Two areas of Icelandic coastal waters were covered by both aerial and shipboard surveys. In one area, the shipboard (block 1) estimate was 3,443 (CV = 0.11) whales and the aerial (block 1) estimate was 2,450 (CV = 0.23) whales. In the other area, the shipboard (block 10) estimate was 1,038 (CV = 0.29) whales and the aerial (block 8) estimate was 957 (CV = 0.37) whales. The CVs do not account for all the variability (see Appendix 2).

The sub-committee noted that these comparisons could not be used in a calibration exercise because of the provisional nature of the shipboard estimates, the unresolved questions concerning the radial distance data in the aerial survey, and the difference in the timing of the surveys.

The sub-committee accepted as a provisional estimate of stock size the sum of the aerial estimate and appropriate shipboard estimates. This figure is 17,091 (CV=0.330) or 19,484 (CV=0.292) if the estimate for the Norwegian shipboard block B2 is included (see Item 6.2.1).

6.3.2 Stock assessment

Some members believed that a stock assessment could not be attempted at this year's meeting for similar reasons to those stated for the northeastern stock; the lack of an acceptable CPUE series and the lack of an agreed basis from which to choose an appropriate range of MSY percents.

Other members believed that an assessment should be attempted in light of the new estimates of abundance from NASS-87. They agreed upon a run of the HITTER program (Annex L) detailed in Table 1.

Table 1

Run of the HITTER program for the Central Stock. MSY level = 60%; natural mortality rate = 0.1; age at recruitment = 4; 1987 stock size = 17,091 (total stock aged 1 and over).

MSY%	A	Total exploitable stock in 1941	Total exploitable stock in 1988	$\frac{\text{1988 stock size}}{\text{1941 stock size}}$
1%	0.135	17,593	12,457	70.8%
2%	0.270	16,531	12,360	74.8%
3%	0.405	15,658	12,286	78.5%
4%	0.539	14,943	12,234	81.9%

Management advice

Those members in favour of the assessment believed that these results showed that the Central Stock, currently unclassified, should be classified as a Sustained Management Stock.

Those members who believed that an assessment should not be attempted at this meeting consequently also believed that no advice on classification of the stock could be given, and that the stock should remain unclassified.

Horwood considered it difficult to interpret the validity of the sightings estimates. The aerial survey estimate has been considered, in some sense, as a 'best' estimate from a part of the stock, whereas the ship surveys have produced 'provisional' estimates. What was meant by 'provisional' was unclear throughout the meeting, and there had been a reluctance to agree that they were 'valid' and could be used to get a best estimate of total stock at this time. Consequently he considered the summed estimates could not be used to infer the status of the stock (as based on the above results). Nevertheless, whilst recognising the variability of the aerial estimate, it is in some sense a 'best' estimate of a component of the stock, and it is known that significant numbers can be found outside of this small region. It can then be considered that the estimated abundance may be above 10,000. In this case, information from modelling studies, (*Rep. int. Whal. Commn* 37: 108), indicates that the stock is unlikely to be in the Protection category.

6.3.3 Results from past research and priorities for future research

SC/40/Mi22 presented biological information on minke whales caught in Icelandic waters. Over 90% of mature females were found to be pregnant and apparent ovulation rate was 0.97. The study indicated that corpora albicantia persist in the ovaries throughout life. Comparison of age readings from ear plugs and tympanic bullae showed that growth layers in bullae were generally lower than in ear plugs. Age at sexual maturity is about 6 growth layers (years) from both bullae and ear plugs in females but from bullae alone is 1–2 years younger in males. Length at which 50% of animals were mature was estimated to be 24.4 ft for females and 22.4 ft for males. The study suggested that age determination from tympanic bullae warrants further examination in minke whales. The sub-committee had insufficient time to discuss this document.

As for the Northeastern stock a priority for future research is the estimation of absolute abundance from sightings surveys. This is discussed fully under Item 6.2.4. The sub-committee noted that Iceland is planning experiments this year to address the question of estimating the proportion of animals missed on the transect line.

6.4 West Greenland stock

6.4.1 Sightings estimates

The sub-committee received an estimate of 1,153 (CV = 0.417) from the West Greenland aerial survey calculated from the number of cues and the coverage probabilities from SC/40/O 11, the effective search areas from SC/40/O 12 and a mean surfacing rate of 53 surfacings/hour (see Item 6.1.1). It noted that the CV did not include a component for variability in mean surfacing rate. Although minke whales were known to occur north of the survey area (north of 71°30'N) and to the west of it (west of 57°W, between 67°N and 69°N), the sub-committee agreed that most of the stock could be expected to be within the survey area. The aerial survey estimate was accepted as an estimate of the number of animals in the management area. The question of whether or not the animals in the management area constituted a separate stock was addressed in Items 5 and 6.4.3.

6.4.2 CPUE data

In response to the recommendation from the CPUE Workshop that such details be made available, SC/40/Mi21 described operational details for the Norwegian small-type whaling vessel *Kato* working off West Greenland during the period 1979–1985. Searching was not at random but was based on information from previous catches and on weather and ice conditions. It was also based on information from other fishing vessels acting effectively as 'scouts' in the area. The sub-committee recalled that it had previously utilised CPUE series when only *Kato* was operating, to try to avoid the problem of 'co-operative fishing'. It was noted in SC/40/Mi21 that *Kato* did not operate south of 64°N because the weather was considered too poor for minke whaling in that area, although catches have been taken off Kap Farvel by other vessels. Data on operational details and time budgets would be provided to the Commission before the end of the year and would be available according to the normal rules of the Commission.

The sub-committee welcomed the information contained in SC/40/Mi21. It was confirmed that *Kato*'s pattern of searching was typical of Norwegian small-type whaling operations. Once a general area had been selected, bottom topography could play an important role in searching within that area. In East Greenland, the ice edge was often followed. The sub-committee recognised that it would be extremely difficult to quantify the effects of this searching strategy, especially as fishing vessels outside the whaling fleet were acting as 'scouts'.

6.4.3 Stock assessment

At the 1985 meeting of the Scientific Committee most members believed that this stock should be classified as a Protection Stock. This was based on the stock assessment presented at that meeting (*Rep. int. Whal. Commn* 36: 43) which indicated a probability of 0.74 that the stock was in the Protection Stock category. Other members, however, had expressed doubts about the validity of this assessment and believed that the stock should remain unclassified. At that meeting, the Scientific Committee recommended that a catch limit of less than 50 whales be set for one year only.

The stock was subsequently classified by the Commission as a Protection Stock, but an aboriginal subsistence catch limit substantially higher than this number was set.

At its 1987 meeting, the Scientific Committee drew to the attention of the Commission that the catch limit recommended in 1985 had not been put into effect (*Rep. int. Whal. Commn* 38: 51). It reminded the Commission of the continuing uncertainties about the identity, current size and replacement yield for the stock.

This year the sub-committee reiterated its concerns expressed in Item 5 about the question of stock identity. There was substantial evidence, relating to the absence of calves and lactating females and the continuing high proportion of females in the catch (SC/37/Mi4 and subsequent Danish Progress Reports), that the minke whales off West Greenland did not constitute a separate biological stock. Resolving this question was of crucial importance to the assessment of minke whales off West Greenland in relation to the provision of advice to the Commission about the aboriginal subsistence take in this area.

Management advice

For the first time, an estimate of the size of the management stock was available. Some members believed that a run of the HITTER program (Annex L) would help them in formulating their advice to the Commission. The parameter values used and the results of the run are given in Table 2.

Table 2

Run of the HITTER program for the West Greenland Stock. MSY level = 60%; natural mortality rate = 0.1; age at maturity = 7; age at recruitment = 5; 1987 stock size = 1,153 (total stock aged 1 and over)

MSY	A	Total exploitable stock in 1948	Total exploitable stock in 1988	$\frac{\text{1988 stock size}}{\text{1948 stock size}}$	1988 RY
1%	0.135	7,100	904	12.7%	–48
2%	0.270	6,809	904	13.3%	–47
3%	0.405	6,549	904	13.8%	–47
4%	0.539	6,315	904	14.3%	–47

The results show that under the range of parameter values chosen, neither the predicted level of depletion nor the 1988 replacement yield was sensitive to this range of values of MSY percent.

Given the problems discussed above, the sub-committee agreed that it was difficult to interpret these runs. Nevertheless, given that the stock (estimated to be 1,153 animals) was smaller than had previously been thought and that the average annual catch during the last 10 years had been 263 animals per year, the sub-committee believed that the stock was severely depleted, below the level believed in 1985. The sub-committee **recommended** that the stock remain a Protection Stock. It agreed that it had no evidence that any catch would allow the stock to move towards its MSY level.

Lassen and Larsen had the opportunity to study the simulations (Appendix 3) in more detail after the discussion in the sub-committee. This revealed a substantial change over time in the predicted sex ratio in the stock which is not reflected in the catches. They found it difficult to imagine a process which would give this result and therefore found the simulations of little value.

6.4.4 Priorities for future research

The sub-committee agreed that two issues were important for the future management of the stock. First, the size of the stock should continue to be monitored. It welcomed the intention of Denmark to conduct an aerial survey off West Greenland in 1988 with twice the survey effort expended in 1987. An aerial survey was also planned for 1989 as part of the proposed international North Atlantic Sightings Survey.

Second, it was important to try to resolve the question of the identity of this stock. The sub-committee welcomed the existence of research programmes in Denmark, Iceland and Norway which were trying to address this issue. It further noted that Danish research in this area includes the use of a large sample of existing tissue from West Greenland. Samples would also be taken from animals taken under aboriginal subsistence whaling from East Greenland where possible. The sub-committee **recommended** that biopsy samples from whales in the Central stock management area be collected as a matter of urgency. It noted that Norway may be able to take biopsy samples from whales encountered during surveys around Jan Mayen if suitable equipment could be provided.

The sub-committee noted that information on the relationship of minke whales off West Greenland to those off eastern Canada is of interest. It **recommended** that the Commission instruct the Secretary to contact the Government of Canada to inform them of the useful work being undertaken in Greenland and Denmark on analysis of genetic material from minke whales found in the Davis Strait, and requesting their cooperation in providing old materials and new biopsy materials from the Canadian east coast stock for comparative studies.

7. PRIORITIES FOR NEXT YEAR

The sub-committee recognised that it may be required to consider assessments for all three stocks next year. Results from further analyses of the 1987 North Atlantic Sightings Survey data and results from the survey efforts in 1988 (including experiments to estimate the proportion of animals seen on the transect line in shipboard surveys) will also be available. These results will also be relevant to the planning of the 1989 North Atlantic Sightings Survey. In addition, there may be results from analyses of CPUE data or genetic studies which the sub-committee would wish to discuss. The sub–committee **recommended** that priority be given to studies relating to the above.

8. DATA PROCESSING AND COMPUTING NEEDS FOR 1988–9

The sub-committee agreed that, if work was done during the year to expand the FITTER program (Annex L) to incorporate the estimation of confidence limits, high priority should be given to the validation by the Secretariat of the expanded program.

9. PUBLICATION OF DOCUMENTS

A list of documents to be considered for publication was submitted to the Editorial Board.

10. OTHER MATTERS ARISING

Øritsland expressed his appreciation to de la Mare for making the HITTER and FITTER programs available to Norwegian scientists.

11. ADOPTION OF REPORT

The report was adopted at 18:30 on 14 May 1988.

Appendix 1

AGENDA

1. Election of Chairman
2. Appointment of Rapporteur(s)
3. Adoption of Agenda
4. Review of available documents and reports
5. Review of stock boundaries
6. Assessment of stocks
    - 6.1 Assessment methods and available data
        - 6.1.1 Sighting analyses
        - 6.1.2 Mark-recapture analyses
        - 6.1.3 Assessing trends and status
        - 6.1.4 CPUE analyses
    - 6.2 Northeastern stock
        - 6.2.1 Sightings estimates
        - 6.2.2 CPUE analyses
        - 6.2.3 Stock assessment
        - 6.2.4 Future research
    - 6.3 Central stock
        - 6.3.1 Sightings estimates
        - 6.3.2 Stock assessment
        - 6.3.3 Results from past research and priorities for future research
    - 6.4 West Greenland stock
        - 6.4.1 Sightings estimates
        - 6.4.2 CPUE data
        - 6.4.3 Stock assessment
        - 6.4.4 Priorities for future research
7. Priorities for next year
8. Data processing and computing needs for 1988–9
9. Publication of documents
10. Other matters arising
11. Adoption of report

Appendix 2

ESTIMATES OF NUMBERS OF MINKE WHALES FROM NASS-87

	Shipboard	Aerial
1. Northeastern stock		
Norwegian survey block A (part)	2,961 (0.287)	
Norwegian survey aerial part of block A	547 (0.287)	244 (0.517)
Norwegian survey block B1	5,787 (0.415)	
Norwegian survey block B2 (part)	2,098 (0.316)	
Norwegian survey block C1	2,625 (0.477)	
Norwegian survey block C2	-	
Norwegian survey Svalbard area	-	787 (0.451)
Faroese survey blocks 11-14	4,610 (0.220)	
Icelandic survey ship block 7	-	
2. Central stock		
Norwegian survey block A (part)	729 (0.287)	-
Norwegian survey block B2 (part)	2,393 (0.316)	-
Icelandic aerial area/ship blocks 1,2,10 form part of this area	6,456 (0.099)	8,645 (0.202)
Iceland survey ship blocks 3-6, 8, 9	7,717 (0.139)	
3. West Greenland stock		
Danish survey		1,153 (0.417)

Notes:

(1) Norwegian shipboard estimates have been recalculated by fitting a hazard rate model to unsmeared data truncated at 0.5 n.miles pooled over both closing and passing mode for all blocks. They have then been assigned to stock area as in SC/40/Mi9.

(2) All aerial estimates are taken from SC/40/0 12 adjusted for a mean surfacing rate of 53hr. The Icelandic estimate uses an effective search area stratified by Beaufort.

(3) Icelandic shipboard estimates are those presented in SC/40/0 30 multiplied by 1.39 to convert the effective search width from twice the median perpendicular distances to that for the negative exponential.

(4) Faroese shipboard estimates are as presented in SC/40/0 30.

(5) CVs for all aerial estimates include components for variability between transects and in effective search area but not in mean surfacing rate.

(6) CVs for Icelandic and Faroese shipboard estimates do not include components for variability in effective search width or mean school size.

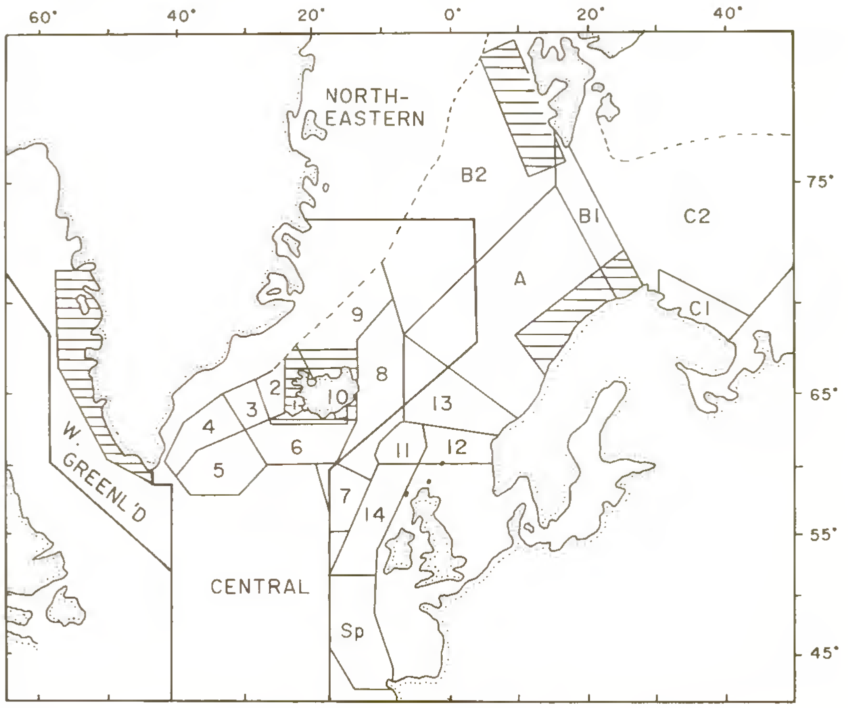


Fig. 1. Map showing the survey blocks from NASS-87 (hatched areas are the aerial survey blocks). Also shown are the IWC stock boundaries (bold lines) and the ice edge (dotted lines).

Appendix 3

RESULTS FROM THE RUN OF THE HITTER PROGRAM FOR THE WEST GREENLAND STOCK [MSY level = 60%, natural mortality rate = 0.1, age at maturity = 7, age at recruitment = 5, 1987 stock size = 1,153 i.e. total stock aged 1 and over)

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY	Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
MSY exploitation rate = 0.01							**MSY exploitation rate = 0.02**						
1948	3,550	3,550	2,907	7,100	10,592	0	1948	3,405	3,405	2,788	6,809	10,158	0
1949	3,549	3,547	2,904	7,096	10,588	0	1949	3,404	3,402	2,785	6,806	10,155	0
1950	3,548	3,544	2,901	7,092	10,583	1	1950	3,403	3,399	2,782	6,802	10,150	1
1951	3,546	3,539	2,896	7,085	10,575	2	1951	3,400	3,394	2,777	6,794	10,141	2
1952	3,542	3,530	2,888	7,072	10,559	3	1952	3,396	3,385	2,769	6,781	10,126	3
1953	3,533	3,512	2,871	7,046	10,528	5	1953	3,388	3,367	2,752	6,755	10,096	5
1954	3,526	3,496	2,854	7,021	10,495	7	1954	3,380	3,350	2,735	6,731	10,066	7
1955	3,522	3,486	2,844	7,008	10,470	8	1955	3,377	3,341	2,725	6,717	10,044	8
1956	3,518	3,476	2,836	6,995	10,444	7	1956	3,373	3,331	2,717	6,705	10,021	8
1957	3,514	3,467	2,828	6,981	10,418	5	1957	3,370	3,323	2,709	6,692	9,999	7
1958	3,508	3,456	2,819	6,964	10,391	3	1958	3,364	3,313	2,701	6,677	9,976	6
1959	3,499	3,441	2,808	6,940	10,359	4	1959	3,356	3,299	2,689	6,655	9,947	6
1960	3,483	3,411	2,781	6,894	10,304	7	1960	3,342	3,269	2,663	6,611	9,897	10
1961	3,469	3,381	2,753	6,850	10,246	10	1961	3,328	3,240	2,636	6,569	9,845	13
1962	3,460	3,367	2,739	6,827	10,204	11	1962	3,321	3,228	2,623	6,548	9,811	14
1963	3,441	3,330	2,706	6,771	10,130	14	1963	3,303	3,192	2,591	6,496	9,744	18
1964	3,395	3,240	2,623	6,634	9,967	23	1964	3,258	3,103	2,509	6,362	9,591	28
1965	3,351	3,158	2,545	6,509	9,800	31	1965	3,216	3,024	2,432	6,240	9,437	36
1966	3,298	3,061	2,454	6,359	9,595	43	1966	3,166	2,929	2,343	6,095	9,248	49
1967	3,241	2,953	2,353	6,195	9,356	54	1967	3,112	2,824	2,243	5,936	9,027	60
1968	3,181	2,841	2,247	6,023	9,092	54	1968	3,055	2,715	2,139	5,770	8,784	64
1969	3,080	2,682	2,104	5,762	8,730	64	1969	2,958	2,560	1,999	5,518	8,446	76
1970	2,900	2,524	1,964	5,425	8,273	80	1970	2,784	2,408	1,861	5,192	8,014	94
1971	2,788	2,409	1,861	5,197	7,910	81	1971	2,678	2,299	1,762	4,977	7,680	96
1972	2,672	2,186	1,670	4,858	7,436	92	1972	2,569	2,083	1,575	4,652	7,234	109
1973	2,613	2,071	1,565	4,685	7,098	77	1973	2,518	1,976	1,476	4,494	6,924	96
1974	2,479	1,825	1,361	4,304	6,562	84	1974	2,392	1,738	1,278	4,131	6,414	105
1975	2,382	1,576	1,145	3,958	6,031	96	1975	2,305	1,498	1,069	3,803	5,908	117
1976	2,311	1,439	1,022	3,750	5,600	69	1976	2,243	1,372	952	3,615	5,498	90
1977	2,216	1,274	893	3,490	5,136	69	1977	2,158	1,216	832	3,373	5,051	89
1978	2,098	1,128	778	3,227	4,665	43	1978	2,049	1,079	725	3,128	4,597	61
1979	2,009	1,026	704	3,035	4,291	5	1979	1,968	985	658	2,953	4,237	20
1980	1,862	883	612	2,745	3,861	1	1980	1,828	849	574	2,676	3,821	15
1981	1,728	718	489	2,445	3,431	–2	1981	1,699	689	457	2,388	3,403	10
1982	1,603	600	396	2,203	3,055	–9	1982	1,580	577	370	2,157	3,037	2
1983	1,456	453	285	1,909	2,633	1	1983	1,437	435	264	1,873	2,623	11
1984	1,305	301	163	1,606	2,190	7	1984	1,292	287	147	1,579	2,184	17
1985	1,171	166	60	1,337	1,770	1	1985	1,162	156	49	1,318	1,765	8
1986	1,035	64	0	1,099	1,386	–1	1986	1,029	66	0	1,095	1,389	4
1987	945	52	0	997	1,153	–22	1987	942	54	0	995	1,153	–19
1988	867	37	0	904	971	–48	1988	865	39	0	904	969	–47

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY	Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
MSY exploitation rate = 0.03							**MSY exploitation rate = 0.04**						
1948	3,275	3,275	2,681	6,549	9,770	0	1948	3,158	3,158	2,585	6,315	9,421	0
1949	3,274	3,272	2,679	6,546	9,767	0	1949	3,157	3,155	2,583	6,312	9,418	0
1950	3,273	3,269	2,675	6,542	9,762	1	1950	3,156	3,152	2,580	6,308	9,413	1
1951	3,270	3,264	2,671	6,534	9,754	2	1951	3,153	3,147	2,575	6,300	9,405	2
1952	3,266	3,255	2,662	6,521	9,740	3	1952	3,149	3,138	2,566	6,287	9,392	3
1953	3,258	3,237	2,645	6,495	9,711	5	1953	3,141	3,120	2,549	6,261	9,364	6
1954	3,250	3,220	2,629	6,471	9,682	8	1954	3,133	3,103	2,533	6,237	9,338	8
1955	3,247	3,211	2,619	6,458	9,663	8	1955	3,130	3,094	2,523	6,224	9,322	9
1956	3,244	3,202	2,610	6,446	9,644	9	1956	3,127	3,085	2,515	6,212	9,306	10
1957	3,240	3,193	2,603	6,434	9,625	8	1957	3,124	3,077	2,507	6,201	9,291	10
1958	3,236	3,184	2,594	6,420	9,606	8	1958	3,120	3,069	2,499	6,189	9,274	10
1959	3,229	3,171	2,583	6,400	9,581	9	1959	3,114	3,057	2,488	6,171	9,253	11
1960	3,215	3,143	2,558	6,358	9,535	12	1960	3,102	3,029	2,463	6,131	9,211	15
1961	3,203	3,115	2,532	6,318	9,489	15	1961	3,091	3,003	2,438	6,094	9,169	18
1962	3,197	3,104	2,520	6,300	9,461	17	1962	3,086	2,993	2,427	6,078	9,148	19
1963	3,181	3,070	2,489	6,250	9,401	21	1963	3,071	2,960	2,397	6,030	9,094	24
1964	3,137	2,982	2,407	6,119	9,256	32	1964	3,028	2,873	2,317	5,902	8,956	35
1965	3,097	2,904	2,331	6,001	9,114	41	1965	2,990	2,797	2,241	5,787	8,825	45
1966	3,049	2,812	2,244	5,861	8,939	54	1966	2,944	2,707	2,155	5,651	8,664	59
1967	2,997	2,709	2,145	5,706	8,737	67	1967	2,894	2,606	2,058	5,500	8,478	72
1968	2,943	2,603	2,043	5,546	8,513	73	1968	2,843	2,502	1,958	5,345	8,272	81
1969	2,850	2,452	1,905	5,302	8,196	87	1969	2,754	2,355	1,821	5,108	7,975	97
1970	2,681	2,305	1,769	4,985	7,787	107	1970	2,588	2,212	1,688	4,801	7,588	118
1971	2,581	2,202	1,674	4,782	7,479	111	1971	2,494	2,115	1,595	4,609	7,303	124
1972	2,478	1,992	1,492	4,470	7,059	125	1972	2,397	1,911	1,418	4,308	6,906	139
1973	2,434	1,892	1,397	4,326	6,774	113	1973	2,360	1,818	1,327	4,178	6,644	129
1974	2,317	1,662	1,206	3,979	6,288	124	1974	2,250	1,595	1,141	3,845	6,177	142
1975	2,238	1,431	1,002	3,669	5,803	136	1975	2,178	1,372	944	3,551	5,711	153
1976	2,185	1,313	892	3,498	5,409	108	1976	2,133	1,262	839	3,395	5,333	125
1977	2,107	1,166	779	3,273	4,978	106	1977	2,063	1,122	733	3,185	4,915	121
1978	2,006	1,037	679	3,043	4,538	77	1978	1,969	1,000	639	2,969	4,486	91
1979	1,933	949	618	2,882	4,190	33	1979	1,902	919	584	2,820	4,150	44
1980	1,798	819	541	2,617	3,787	26	1980	1,773	793	512	2,566	3,757	36
1981	1,675	665	430	2,339	3,380	20	1981	1,653	643	407	2,297	3,360	29
1982	1,561	557	347	2,117	3,023	11	1982	1,543	540	328	2,083	3,011	19
1983	1,422	420	246	1,842	2,615	20	1983	1,408	406	231	1,814	2,610	28
1984	1,280	276	134	1,556	2,181	25	1984	1,270	266	122	1,536	2,178	33
1985	1,154	149	41	1,303	1,762	14	1985	1,148	142	34	1,290	1,759	20
1986	1,024	69	0	1,093	1,391	8	1986	1,020	71	0	1,091	1,393	12
1987	939	56	0	995	1,153	–17	1987	937	57	0	994	1,153	–15
1988	864	40	0	904	968	–47	1988	863	41	0	904	966	–47

A comparison of the percentage females in the catch to those calculated by the HITTER program (above) is given below:

		MSY exploitation rate						MSY exploitation rate			
Year	Catch	1%	2%	3%	4%	Year	Catch	1%	2%	3%	4%
1965–68	65	48	47	47	47	1983	66	24	23	23	22
1970–74	67	45	44	44	44	1984	68	19	18	18	17
1975–79	71	37	36	36	36	1985	63	12	12	11	11
1980	71	32	32	31	31	1986	67	5.8	6.0	6.3	6.5
1981	69	29	29	28	28	1987	67	5.2	5.4	5.6	5.7
1982	66	27	27	26	26						

Annex F

Report of the Sub-Committee on Other Baleen Whales

Members: Tillman (Convenor), Arnason (A.), Arnason (U.), Arnbom, Aurioles, Chapman, Cooke, da Silva, de la Mare, Fleischer, Goncalves, Gunnlaugsson, Holt (S.), Horwood, Ikeda, Inagaki, Jover, Joyce, Kasamatsu, Kasuya, Kato, Lankester, Larsen, Lassen, Lens, Lockyer, Luna, Mae, Magnusson, Martin, Mate, Martin, Misaki, Miyashita, Mizroch, Moore, Morimoto, Nakamura, Nakken, Ohsumi, Øien, Palsboll, Reilly, Sakuramoto, Sanpera, Sigurjónsson, Tanaka, Ulltang, Vidal, Vikingsson, Walløe, Yamamura.

1. ELECTION OF CHAIRMAN

Tillman was elected Chairman.

2. APPOINTMENT OF RAPPORTEUR

Mizroch agreed to serve as Rapporteur.

3. ADOPTION OF AGENDA

The Agenda adopted is given in Appendix 1.

4. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS

The following documents contain information, data or analyses pertaining to this sub-committee: SC/40/Mi16, 17; SC/40/Ba2–13; SC/40/O 8, 15, 29, 30, 33-36, 41; SC/40/ProgReps Iceland, Japan, Spain. Studies on electrophoretic and biochemical techniques were referred to the sub-committee on the Comprehensive Assessment.

5. WESTERN NORTH PACIFIC BRYDE'S WHALE

Stock identity

SC/40/Ba2 presented a comparison of biological data obtained from catches of Bryde's whales taken by land-based fisheries off the Bonin Islands in 1981-1987 with those taken off the Pacific coast of Japan in 1981–1986. In the Bonin sample mean lengths at sexual maturity of males and females were about one foot smaller than those found for the coast of Japan proper, although the difference was not significantly different. The modes of length frequency distributions were similarly one foot less. It was suggested that these differences indicated the possibility that different stocks inhabited the coastal Kuroshio current area and the offshore Kuroshio counter-current area.

During discussion of this paper it was pointed out that a refined statistical analysis was needed for the age at maturity, to ascertain whether the differences found were statistically significant. Taken at face value, it was thought that these findings might provide evidence of segregation in the population (e.g. there was a definite male bias in the Bonin Island catches) but not necessarily of stock separation. The sub-committee noted that bio-chemical analyses were underway which might provide definitive information on genetic differences between Bryde's whales in these two areas and looked forward to receiving these results.

Estimates of abundance

At its last annual meeting, the Scientific Committee had recommended that additional analyses of the 1979–1982 and 1983–1986 sightings data be undertaken, applying the most recent simulation models and sightings methods (e.g., as for IDCR data analyses).

SC/40/Ba3 presented an analysis of the sightings data obtained from 1983 and 1984 summer cruises in the western North Pacific which used the smearing technique and the hazard-rate model fitted to the perpendicular sighting distance distribution (Buckland and Anganuzzi, 1987). Population estimates for the research area west of 170°E, as corrected for animals missed along the track line, were 12,545 in 1983 and 12,258 in 1984. A further correction for divergence from the track line in 1984 gave a revised estimate of 10,875. Adding in the population estimate for the segment east of 170°E derived from 1974–1982 survey data gave a total population size in the research area of 13,000–15,000. Extrapolation of the 1984 estimate to the unsurveyed area of the entire range of the stock gave a total population estimate of 18,000 Bryde's whales. Survey data from 1985–1987 were not used since these cruises were not targeted on Bryde's whales and hence covered only a very small proportion of the total stock area.

SC/40/O 41 provided comments on some of the generic problems associated with population estimates obtained from sightings surveys. From discussion it was thought that among the problems applicable to the above Bryde's whales estimates were the following:

(i) the selection of particular years as a basis for estimating abundance from among a series of annual surveys may introduce bias – hence the selection of 1983 and 1984 may be problematical;

(ii) the 1983 and 1984 surveys failed to cover the entire stock area and biases may arise in selecting and combining data from previous surveys to estimate abundance for the areas missed;

(iii) some areas of the stocks's summer distribution had never been surveyed and it was unclear as to whether or not the estimate for the surveyed areas should be extrapolated to these areas – moreover, it was unclear what the boundaries were for the Bryde's whales' summer distribution and if and how they might vary with environmental variables such as sea surface temperature.

It was also noted that, rather than obtaining a new estimate of the probability of missing animals along the track line, g(0), the estimate obtained by Miyashita and Kasamatsu (*Rep. int. Whal. Commn* 35: 363–8) had been used. Miyashita stated that an Independent Observer experiment had been tried in 1986 in an attempt to estimate g(0), but the ship did not have a suitable platform for an independent observer. He noted that this would be attempted again in future surveys.

The sub-committee agreed that a re-analysis of all available sightings data should be undertaken by 5° square, combining data over all years surveyed. The sub-committee **recommended** that this re-analysis be undertaken as outlined in Appendix 2 before the stock is next assessed.

The sub-committee also **recommended** that all information on the summer distribution of Bryde's whales be synthesised to ascertain the appropriate range for stock estimates and future survey coverage. This synthesis should also examine the factors affecting inter-annual variability of distribution, such as sea surface temperature.

Catch data

At last year's annual meeting, the sub-committee made use of a revised catch data series for Bryde's whales which assumed that certain proportions of the catches recorded as sei whales during 1911–49 were actually Bryde's whales (Wada, *Rep. int. Whal. Commn* 38: 106–8). Further refinement of the assumptions used in this earlier analysis are detailed in Appendix 3, which provides the currently accepted historical catch series for this stock.

6. OKHOTSK SEA-WEST PACIFIC STOCK OF MINKE WHALES

Biological data on size distribution, sexual maturity and apparent pregnancy rate were analysed from catch data collected from 1969–1986 (SC/40/Mi17). These analyses showed marked latitudinal segregation, as has been the case for many other minke whale stocks. It was noted that since the size distribution of the catches varied markedly from area to area, the effect of these differences must be taken into account in relation to assessments, especially when determining recruited stock.

In response to last year's recommendation of the Scientific Committee, SC/40/Mi16 presented abundance estimates based on sightings cruises from 1978–1986. Although minke whales were not the primary species of interest during this series of cruises, records of minke whale sightings were kept. Spatial and temporal distribution were analysed, as well as the effect of sighting conditions by Beaufort Scale. Because the distribution of whales in the area studied is not uniform, the data were stratified two different ways, and estimates of abundance were produced.

These estimates were considered preliminary only, and the sub-committee **recommended** that further studies should include analysis by 5° squares, investigations of the results of seasonal trends in distribution and examination of the stratification boundaries. The sub-committee also requested that the range of sightings surveys be expanded with the cooperation of related nations.

7. EAST GREENLAND-ICELAND FIN WHALES

Biological parameters

Preliminary studies on reproductive data were presented (SC/40/Ba12). The stability in length at maturity was noted, which is corroborated in many other studies. Preliminary studies on the age at sexual maturity were presented that suggested changes were correlated with environmental (and hence feeding) conditions. Other findings of note were the changes in proportion of the catch with a corpus luteum (through which pregnancy can be inferred), which were also correlated with changes in environmental conditions. Data on foetal length indicated a winter calving season.

The sub-committee discussed the data on age at sexual maturity at great length. Some felt that the variations observed, although not significant statistically, showed the effects of environmental variability. Others felt that, due to the lack of a significant trend, the arguments regarding trend and speculations about causes had no substance, there being no evidence for changes at all. It was agreed that in the absence of such evidence, the sub-committee would assume, for the purposes of assessment, a constant age at sexual maturity.

Sigurjónsson noted that SC/40/Ba8 showed that apparent pregnancy rate in recent years had varied considerably, and this was to be studied further in relation to the energetic condition of the animals.

Estimate of abundance

SC/40/O 30 provided a line transect estimate of abundance of 7,527 fin whales based upon sightings data obtained from Icelandic surveys undertaken as part of the 1987 North Atlantic Sightings Survey (NASS-87). Although an analysis of environmental factors affecting sightings had not been carried out, differences between observers and vessels had been examined. Consequently, only the data from one of the two vessels which surveyed fin whales had been used to analyse effective track width by fitting a hazard rate model.

Upon discussing these results, it was noted that a major portion of one of the blocks surveyed by the Icelandic vessels (block 7) actually occurred within the British Isles-Spain and Portugal stock area. A re-analysis omitting this block and accounting for similar small adjustments for blocks 8 and 11 gave an estimate of 5,757 fin whales in the survey area. It was further noted that the Norwegian component of NASS-87 around Jan Mayen provided additional sightings of fin whales which could be included in the estimate for the East-Greenland-Iceland stock area. The Norwegian sightings effort was not available at the meeting to estimate the abundance of this northern sector directly, but the sub-committee agreed to utilise an approximation based on a simple ratio correction to the minke whale estimate for that area, which is further described in Appendix 4. This approach gave an estimate of 6,436 for the stock area which was used for assessment purposes. Noting the preliminary nature of this estimate, however, the sub-committee **recommended** that it be updated prior to the next annual meeting by undertaking an appropriate line transect analysis of the Norwegian data from the Jan Mayen area.

Stock trajectories

SC/40/Ba4 used all available data on fin whale catches taken off Iceland during 1883–1987 to calculate possible population trajectories from an initial 1883 stock size. The

HITTER/FITTER computer program (Annex L), which incorporates a Pella-Tomlinson stock recruitment function, was used to calculate the trajectories with alternative target values of recruited stock size of 3,000 and 5,000 fin whales in 1987. The trajectories obtained were compared with a crude catch per boat (CPB) series available for 1895–1915, and a modern CPUE series for 1962–1987. On comparing the stock trajectories with these two indices of abundance, it was found that if the MSY rate was much lower than 7%, the CPB series overestimated the population decline and the recent CPUE series underestimated the decline. Given the likelihood of a non-linear relationship between CPB and true stock size, and the failure of such indices to detect population declines, it was concluded that the early CPB series was more likely to underestimate any decline than to overestimate it. Consequently, it was suggested that the possibility that the MSY rate for this stock could be higher than 4% could not be ruled out.

Several members of the sub-committee pointed out that the outcome of this interpretation was largely dependent upon the admittedly crude early CPB series, together with the consequences of the variability in the modern series. They indicated that a thorough examination of this early series was needed, including a detailed description and analysis of the methods and strategy of the coastal whaling operation at that time as generally agreed by the Scientific Committee in receiving the report of its CPUE Workshop last year (*Rep. int. Whal. Commn* 38: 35). Until such an analysis was available and its sensitivity to variability in the modern series had been examined, they would be unable to accept these findings as being any more than qualitative speculations.

Magnusson responded that the whole point of the simulations was that, if the stock had collapsed, as was indicated by the CPB series, then the catches which were taken during the modern era could only have been possible if there had been a MSY rate greater than 4%. Several other scientists associated themselves with this view.

S. Holt and others observed that there was no way to discriminate the level to which the population had collapsed in the beginning of the century, and that such discrimination is critical to the evaluation being offered.

Stock assessment

It was proposed by some members that a stock assessment be produced. S. Holt considered that any simulations using the old and/or the recent CPUE series would have no discriminatory power and that therefore there was little purpose on carrying out such simulations at this meeting.

Nevertheless, the sub-committee requested that a small working group compute stock trajectories using the simulation program, HITTER/FITTER (Annex L). The agreed population estimate of 6,436 was used, as well as a selection of CPUE series' (Appendix 4), and the catch series from 1883–1987. Results of this assessment exercise were problematical. One problem was that the estimated MSY rate of 11–13% exceeded the gross recruitment rate values of 4–6% previously estimated from catch curves (*Rep. int. Whal. Commn* 33: 125). Most members agreed that the exercise demonstrated that either there were problems with the model used by HITTER/FITTER, or there were problems with the CPUE series, or that problems with both the model and the CPUE confounded the result. It was pointed out that the inclusion of early CPB series made little difference in the result. S. Holt did not agree that this exercise gave any indication of problems with the HITTER/FITTER procedure. Therefore, the sub-committee **recommended** that more detailed simulation studies be carried out in relation to this model and the CPUE series, and that results be presented with the calculated confidence bounds. The sub-committee agreed that this stock be considered on a priority basis next year.

Effect of research catches

SC/40/O 8 indicated that the Government of Iceland had issued permits for a take of 80 fin whales for scientific purposes during 1988.

Noting the new, provisional stock estimate of 6,436 fin whales, some members of the sub-committee noted that the proposed take represented only 1.2% of the population. They believed that a take of this magnitude would have only a negligible effect upon the population over the two years remaining of the proposed 4-year Icelandic research programme. Furthermore, Nakken expressed the belief that this stock could likely sustain an annual take of 80 whales for a considerably longer period than two years given the following considerations:

(1) the CPUE series indicate there was no significant change in stock size during the past 25 years (1962–1987) (Appendix 4);
(2) the annual catch in that period varied between 310 (1966) and 76 (1986), with the average being 224;
(3) the estimated stock size in 1987 is more than 6,000; and
(4) the corresponding replacement yield will be above 80 for reasonable figures of the biological parameters (SC/40/Ba4).

In relation to Nakken's explanation of his opinion, S. Holt and Lankester affirm that the available data, including CPUE series, in no way exclude replacement yields lower than 80, and further that a wide range of replacement yields is compatible with other sets of reasonable values of biological parameters. Some members expressed the view that without information on net recruitment rates or trends in abundance for this stock, it was inappropriate to comment on the likely effect of a take being continued at the proposed level. They believed that, given the current lack of knowledge, it was entirely possible that such a take could have a significant effect, particularly in the long term.

Sigurjónsson and others expressed the view that the sub-committee's main task was to assess the effects of the remaining two years of the Icelandic research programme, and not the long term consequences of a possible future catch.

8. ICELAND-DENMARK STRAIT SEI WHALES

Estimate of abundance

Information on this stock of sei whales was presented as part of the results of the Icelandic portion of the North Atlantic Sightings Survey (SC/40/O 30). The abundance estimates presented in SC/40/O 30 were described as preliminary in that the data represent only a small portion of the sei whale stock. The sightings surveys were conducted in June and July, the time when fin and minke whales are found in the study area. Sei whales begin to arrive in the area surveyed in larger numbers in August. The sub-committee **recommended** that an estimate of abundance of sei whales appropriate for stock assessment purposes be obtained by extending the survey area, particularly southward along the North Atlantic Ridge. In the absence of an appropriate estimate of abundance, the sub-committee could not assess this stock of sei whales.

Effect of research catches

SC/40/O 8 indicated that the Government of Iceland had issued permits for the take of 20 sei whales for scientific purposes during 1988.

Noting the new, albeit preliminary estimate of 1,243 (CV = 0.32) sei whales in the Icelandic survey area (SC/40/O 30), some members of the sub-committee observed that the proposed take represented only 1.6% of this partial estimate of abundance. Despite the shortcomings of the estimate, they believed that it increased our knowledge sufficiently that they could make the judgement that the proposed take would probably have only a negligible effect upon the total population.

Other members pointed out that the sub-committee had examined the estimate of abundance only preliminarily because the survey had not covered this stock's total summer distribution. Consequently, it was unknown what biases or possible systematic errors may have occurred in obtaining it. They further noted that not only was it an incomplete estimate, but also that it was not an estimate of the exploitable portion within the survey area. They expressed the view that, as a consequence, they had no confidence in the estimate and that it could not be used as a basis for judging the likely effect of the proposed take.

9. RESEARCH RESULTS FROM EXISTING SCIENTIFIC PERMITS

Sigurjónsson introduced SC/40/O 8, a progress report of the research proposed 3 years ago (SC/37/O 20) under Iceland's 4-year research programme. The research programme proposed catches of 80 fin, 40 sei, and 80 minke whales in each of the 1986–1989 seasons. To date, permits have been issued for the take of fin and sei whales, but not for minke whales. The 1986 permits allowed the sampling of 80 fin whales and 40 sei whales, of which 76 fin whales and 40 sei whales were taken. The 1987 permits allowed the catch of 80 fin and 20 or less sei whales, of which 80 fin whales and 20 sei whales were caught (one of the 20 sei whales was lost at sea). The status of the different research projects are reported in SC/40/O 8 and progress on six studies was specifically reported to this sub-committee. Four papers reporting on electrophoretic and biochemical techniques (SC/40/Ba9–11, SC/40/O 34) were referred to the Comprehensive Assessment sub-committee and are discussed in Annex J1.

Studies on growth layer formation in tympanic bullae of fin whales caught during the 1986 and 1987 season were presented (SC/40/Ba5). Preliminary results show a relationship between earplug growth layers and tympanic bullae growth layers for immature animals only.

Preliminary work on chlorophyll and zooplankton densities collected during whaling operations was presented (SC/40/O 33) in an attempt to monitor oceanic conditions on the whaling grounds.

A progress report on sei whale morphometric studies was presented (SC/40/Ba6). Results indicate isometric growth, with a slight tendency towards positive allometry of the head region. Further studies will include a Principal Component Analysis of the measurements, and additional comparative studies with data from sei whales caught in other regions.

A preliminary progress report on energy content of blubber and muscle of fin and sei whales was presented (SC/40/Ba7). It concluded that for fin whales the females had a slightly higher lipid content in 1987 than in 1986, but that the reverse was true for the males. Although the study replicated Lockyer's (1986, *Can. J. Fish. Aquat. Sci.* 43: 142–7) approach which had demonstrated a relationship between reproductive status and energetic status, the sub-committee suggested that the data be analysed in greater detail by sexual and reproductive class.

A progress report on hormonal levels in whales caught in Icelandic waters was presented (SC/40/Ba8). Results confirm that serum progesterone seems to be a good indicator of pregnancy condition in fin whales. There is also a correlation between age and hormonal levels, and for length and hormonal levels in females. There is also an apparent rise in testosterone levels in males during the hunting season, the implications of which will need further examination.

After presentation of these preliminary studies, some members of the sub-committee commented on the difficulties of evaluating the research programme on the basis of the reports presented to this meeting. They expressed the desire that more detailed analyses of the commercial and research data be conducted, and that the existing data be presented in such a way that the contribution of the research data component is clearly shown.

Some members expressed the view that the research results presented to this meeting contributed substantially to our knowledge of this stock.

Other members refrained from commenting on the value of the research on the understanding that this was to be discussed in the full Scientific Committee.

Discussion of the value of the research to the objectives of the Commission and the Comprehensive Assessment has been deferred to the Scientific Committee.

10. INFORMATION ON STOCKS NOT ASSESSED

British Isles-Spain-Portugal stock of fin whales

Results were presented of the Spanish component of NASS-87 (SC/40/Ba13). The area surveyed was similar in scope to areas surveyed in previous years, and the resulting estimate of exploitable population size was 4,127, with a total population size of 4,485 (95% CI: 3,369–5,600) for the area surveyed. The suggestion was made to compare the 1987 results to previous population estimates, and to pool across years if possible. However, it was pointed out that the 1987 survey used a different cruise track design, and, unlike previous years, most of the sightings effort was conducted in passing mode.

The sub-committee also noted that two other vessels conducted surveys in a portion of this stock area. A re-analysis of data presented in SC/40/O 30 (see Annex F) gives a population estimate of 616 for block 14 (covered by the Faroese vessel), and 116 for block 7 (covered by the Icelandic vessel).

11. PRIORITY STOCKS AND AGENDA ITEMS FOR NEXT YEAR

Given the above recommendations for undertaking further analyses prior to the next annual meeting, the sub-committee **recommended** that the following stocks be accorded priority status (not ranked in any order): western North Pacific Bryde's whales, Okhotsk Sea-West Pacific stock of minke whales, East Greenland-Iceland fin whales.

12. COMPUTING AND OTHER NEEDS FOR NEXT YEAR

The sub-committee **recommended** that the IWC computing facility clearly document the programs used for validation of IDCR sightings data in order that they might be used by all members of the Scientific Committee.

13. PUBLICATION OF DOCUMENTS

A list of sub-committee documents to be considered for publication was submitted to the Editorial Board.

14. OTHER MATTERS

No other matters were discussed.

15. ADOPTION OF REPORT

The sub-committee adopted the final draft as amended.

Appendix 1

AGENDA

1. Election of Chairman
2. Appointment of Rapporteur
3. Adoption of Agenda
4. Review of available documents and reports
5. Western North Pacific Bryde's whales
6. Okhotsk Sea – West Pacific stock of minke whales
7. East Greenland – Iceland fin whales
8. Iceland – Denmark Strait sei whales
9. Research results from existing scientific permits
10. Information on stocks not assessed
11. Priority stocks and agenda items for next year
12. Computing and other needs for next year
13. Publication of documents
14. Other matters
15. Adoption of Report

Appendix 2

REPORT OF A SUB-GROUP TO PREPARE RECOMMENDATIONS FOR THE ANALYSIS OF WESTERN NORTH PACIFIC BRYDE'S WHALE SIGHTINGS DATA

Members: Reilly, de la Mare, Miyashita, Cooke.

(1) The group noted that sighting and effort data by 5° square had been presented for the years 1974–82 and 1984, and recommended that 5° square sighting and effort data also be presented for the remaining years (1983 and 1985–87), so that the entire series can be analysed in a common manner.

(2) The group considered the appropriate method of correction for the bias in density estimates arising from deviations from the pre-planned cruise tracks in high density areas, and recommended that the following procedure be applied:

For each survey, the sighting and effort records be compiled by 1° square. Let n_i represent the recorded primary sightings in 1° square i. Let L_i be the recorded effort in square i. Let L_i^* be the length of the intended cruise track in that square (normally a straight line or two line segments). The adjusted number of sightings is $n_i^* = n_i L_i^*/L_i$. The adjusted sighting and effort data, n_i^* and L_i^* are then totalled by 5° square to calculate the indices of abundance.

(3) The group recommended that f(0) estimation (effective strip width estimation) be performed using the hazard rate model by whales with smeared data, as is the current practice in the sub-committee on Southern Hemisphere minke whales. There was some discussion about whether f(0) be estimated separately by year and vessel, or the data be pooled. It was recognised that separate estimation might fail to yield meaningful values in years with very few sightings, but that exclusion of these years would lead to a selection bias. The group reluctantly concluded that the data should be pooled across years and vessels provided that there was no significant evidence of heterogeneity.

Appendix 3

REVISION OF HISTORICAL CATCHES BRYDE'S WHALES

K. Lankester

This revised version was the result of discussions with Dr Miyashita.

In 1987, the Scientific Committee received new information concerning historical catch records of the western North Pacific stock of Bryde's whales (Cooke and Lankester, 1987). Catch records were shown to exist for sei whales since 1899, which were highly likely to include Bryde's whales catches, since the Bryde's whale had only been distinguished as a species since 1949 (Omura, 1950). The catch series presented in 1987 was based on an estimated geographical distribution of the catches, in that sei whales have a more northerly distribution than Bryde's whales. Wada (1988) subsequently presented more detailed information on the catches, which resulted in a revised version of the catch series. He argued that pre-1946 catches in the Bonin Islands were not all Bryde's whales, because catches occurred also in winter and Omura and Fujino (1954) had shown that also sei whales were caught in pre-war years. He also provided some corrections for post-war years.

A further small correction of the estimated catches has been made (Table 1). Kasahara (1950) provides catches of sei whales by whaling ground for 1911-1949, and he also reports the distribution over the season. With the detailed catch information, it appears that 48% of the catches in the Sanriku region were in July and August. Omura and Nemoto (1955) showed that the number of Bryde's whales in the catch has a peak in that period, when 60% of the 'sei' whales caught were recognised as Bryde's whales. Based on the separation by area of catches in Kasahara (1950) (see Fig. 1) and the estimated proportion of Bryde's whales in Omura and Nemoto (1955) by month, it is estimated that in fact 33% of the sei whale catch in the Sanriku grounds were Bryde's whales. Following Wada (1988), the 'sei' whales caught in Chiba/Wakayama, Shikoku/Kyushu and Amani are all taken to be Bryde's whales. For 1915–1918 and 1920, catches in areas VI-IX are not specified by area, and these catches are included here. In all but one of these areas, probably 100% of catches were Bryde's whales. Moreover, the data for other early years suggest that these catches in the late 1910's mainly occurred in area VI. [Note: In Table 2 in *Rep. int. Whal. Commn* 38: p. 107, the catch for 1919 in Area VI should be 90]. Of the pre-1946 catches in Bonin Island, 75% are considered Bryde's whales. Early small Taiwan catch records are included. Data from 1950 onwards are taken from Wada (1988).

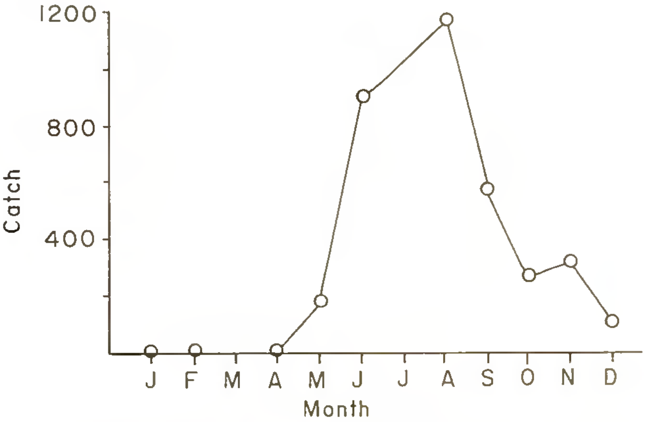


Fig. 1. The monthly distribution in the Sanriku-Fukushima region of 'sei' whale catches, 1911–1949. The numbers estimated from the figure coincided well with the exact numbers, which were not available at the time of making this revised catch-series.

Table 1

Revised catch series for the Bryde's whale of the western North Pacific stock

Year	Total	Year	Total	Year	Total	Year	Total
1899	1	1922	100	1944	169	1966	63
1900	4	1923	93	1945	15	1967	45
1901	5	1924	141	1946	170	1968	171
1902	7	1925	141	1947	207	1969	89
1903	11	1926	167	1948	221	1970	139
1904	34	1927	138	1949	255	1971	919
1905	35	1928	92	1950	243	1972	160
1906	58	1929	72	1951	280	1973	693
1907	86	1930	81	1952	412	1974	1,323
1908	104	1931	155	1953	47	1975	1,433
1909	66	1932	110	1954	2	1976	1,459
1910	48	1933	115	1955	95	1977	946
1911	185	1934	111	1956	27	1978	596
1912	73	1935	109	1957	43	1979	1,028
1913	112	1936	119	1958	300	1980	755
1914	76	1937	192	1959	305	1981	484
1915	214	1938	205	1960	407	1982	482
1916	124	1939	249	1961	172	1983	545
1917	226	1940	62	1962	504	1984	528
1918	183	1941	196	1963	210	1985	357
1919	187	1942	34	1964	74	1986	317
1920	117	1943	68	1965	8	1987	317
1921	112						

REFERENCES

Cooke, J.G. and Lankester, K. 1987. Catch history and current status of the North-West Pacific Bryde's whale (*Balaenoptera edeni*). Paper SC/39/Ba4. 12pp. (unpublished).

Kasahara, T. 1950. Whale resources in adjacent waters of Japan. *Rep. Nippon Suisan Lab.* No.4.

Omura, H. 1950. Whales in the adjacent waters of Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 4:27–113.

Omura, H. and Fujino, K. 1954. Sei whales in the adjacent waters of Japan II. Further studies on the external characters. *Sci. Rep. Whales Res. Inst., Tokyo* 9: 89–103.

Omura, H. and Nemoto, T. 1955. Sei whales in the adjacent waters of Japan III. Relation between movement and water temperature of the sea. *Sci. Rep. Whales Res. Inst., Tokyo* 10: 79–87.

Wada, S. 1988. Report of the Scientific Committee, Annex G, Appendix 7. Correction of the Bryde's whale catch series in SC/39/Ba4. *Rep. int. Whal. Commn* 38: 106–7.

Appendix 4

REPORT OF WORKING GROUP TO COMPUTE EAST GREENLAND – ICELAND FIN WHALE STOCK TRAJECTORIES WITH AVAILABLE CPUE SERIES

Members: Reilly (Convenor), Cooke, Gunnlaugsson, Øien, Sigurjónsson

The group was convened to compute trajectories of population size from the onset of whaling for this stock in 1883 through 1987, with the simulation programs of Cooke and de la Mare (FITTER/HITTER) which utilise information from both CPUE series and catch series. The population model is described in Annex L.

1987 Population estimate

The 1987 population size estimate was made as follows. The estimate for the Iceland ship blocks was given as 5,757.

Øien and Gunnlaugsson provided an estimate for the Norway ship blocks (the Jan Mayen area) utilizing a simple ratio correction to the minke whale estimate for that area. They assume the group size for fins and minkes to be equal (approximately 1.0). From the Icelandic data the ratio of median sighting distances for the two species is 0.09/0.52 = 0.173. The total estimate for minke whales in the Jan Mayen area is 2,564. The ratio of sightings of fin and minke whales is 23/15 = 1.53 (from SC/40/O 9 Figs 4 and 5). The estimate of fin whales in the Jan Mayen area is then

$$2564 \times 0.173 \times 1.53 = 679.$$

The total population estimate for 1987 for this stock is then

$$5,757 + 679 = 6,436.$$

CPUE series

Five CPUE series were available: one each from four whaling ships from 1962 to 1987 (with some variation in exact duration, from *Rep. int. Whal. Commn* 35: 110, 36: 156–7, 37: 169–71, 38: in press, and SC/40/ProgRep Iceland), and a series for 1901 –1915. This later series is from data given by Jonsgard, 1977 (*Rep. int. Whal. Commn* 27:413–26). The 1901 – 1915 CPUE series (listed in the Appendix) was computed as the number caught divided by the Catcher-boat-days. The data from 1883 – 1900 were not used for the CPUE series due to changes in the nature of the fishery around 1900, when most of the whaling activity had moved to the east coast of Iceland.

Catch series

The catch series for 1883 – 1987 was taken from SC/40/Ba4 Table 1. The catches from SC/40/Ba4 were corrected for struck-but-lost whales as described in the text of that document (50% SBL for 1883 – 1886 and 33% during 1887 – 1903).

Biological parameters

A natural mortality rate of 0.04 and an age at recruitment of 3 years were used, being the values used in the last assessment of this stock (*Rep. int. Whal. Commn* 34: 112–13). Ages at 50% and 95% maturity (8.5 and 11.5 years, respectively) were taken from SC/40/Ba12.

Simulation runs

Two model runs were requested by the sub-committee: one including all five CPUE series and one excluding the 1901 – 1915 series. We have conducted these and an additional two. One set of runs was made with CPUE non-linearity factors all set equal to 1.0. Another set was made with the non-linearity factor for the 1901 – 1915 series set at 4, and the other four non-linearity factors set at 2, following the advice of Cooke.

We have used the program HITTER, which is designed to shoot a trajectory exactly through the absolute abundance estimate, for the above four runs.

Table 1 lists the input parameters, catch and CPUE data for the run with five CPUE series. Input for the other runs was the same with the exceptions given above for nonlinearity factors and exclusion of early CPUE data.

Results

Trajectories for the simulation runs with 5 CPUE series and both sets of nonlinearity factors are shown in Figs 1 and 2. The run with 4 CPUE series and non-linearity factors set at 1 is shown in Fig. 3. (The fourth run was not plotted here since it presents no information in addition to the three presented).

Pertinent information from the runs is tabulated below.

Four CPUE Series
Nonlinearity = 1,1,1,1

Year	Population total	RY
1883	6,737	–
1915	2,031	73
1962	6,445	239
1988	6,536	208

A = 4.43 MSY% = 12.8
%1988/1883** = 84.6

Five CPUE Series
Nonlinearity = 1,1,1,1,1

Population total	RY
6,912	–
2,012	70
6,481	228
6,543	207

A = 4.12 MSY% = 11.9
%1988/1883 = 85.0

Four CPUE Series
Nonlinearity = 2,2,2,2

Year	Population total	RY
1883	6,708	–
1915	2,038	73
1962	6,439	240
1988	6,535	208

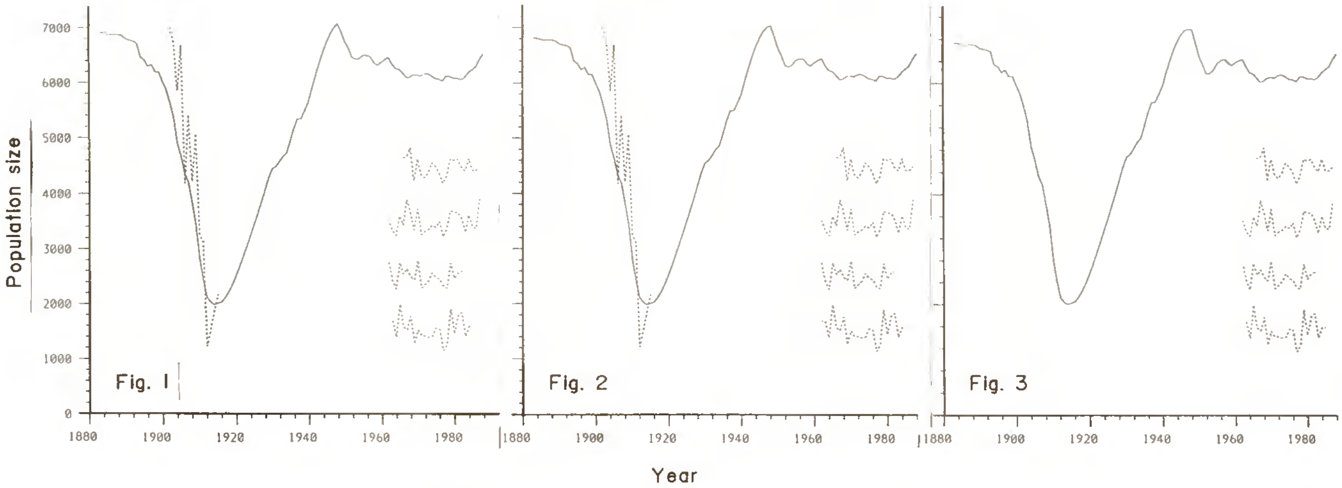
A = 4.48 MSY% = 12.9
%1988/1883 = 82.4

Five CPUE Series
Nonlinearity = 4,2,2,2,2

Population total	RY
6,813	–
2,015	71
6,462	235
6,539	207

A = 4.28 MSY% = 12.3
%1988/1883 = 83.6

Discussion of these results is recorded in the sub-committee report and the full listings of run results are available from the Secretariat.



Figs 1–3. Trajectories for simulation runs (see text).

Table 1

Information on Catch and CPUE data-used and the result of the run with five series (see text). Biological parameters as in text. MSYL = 60% MSYR = 4%

CPUE data						Catches					
Year	1	2	3	4	5	Year	Male	Female	Year	Male	Female
1901	44.15	0.0000	0.0000	0.0000	0.0000	1883	2	4	1938	54	59
1902	43.50	0.0000	0.0000	0.0000	0.0000	1884	10	12	1939	52	57
1903	41.90	0.0000	0.0000	0.0000	0.0000	1885	12	16	1948	92	103
1904	36.40	0.0000	0.0000	0.0000	0.0000	1886	7	9	1949	109	140
1905	41.60	0.0000	0.0000	0.0000	0.0000	1887	15	16	1950	98	128
1906	26.00	0.0000	0.0000	0.0000	0.0000	1888	25	28	1951	122	190
1907	33.70	0.0000	0.0000	0.0000	0.0000	1889	54	61	1952	97	127
1908	26.24	0.0000	0.0000	0.0000	0.0000	1890	55	61	1953	98	109
1909	31.57	0.0000	0.0000	0.0000	0.0000	1891	66	72	1954	69	108
1910	20.28	0.0000	0.0000	0.0000	0.0000	1892	90	97	1955	117	119
1911	19.45	0.0000	0.0000	0.0000	0.0000	1893	213	232	1956	115	150
1912	7.60	0.0000	0.0000	0.0000	0.0000	1894	150	165	1957	149	199
1913	9.54	0.0000	0.0000	0.0000	0.0000	1895	205	223	1958	140	149
1914	11.67	0.0000	0.0000	0.0000	0.0000	1896	129	142	1959	95	82
1915	13.50	0.0000	0.0000	0.0000	0.0000	1897	214	232	1960	81	79
						1898	141	154	1961	65	77
1962	0.00	0.1398	0.1512	0.1048	0.0000	1899	216	237	1962	165	138
1963	0.00	0.1363	0.0841	0.0671	0.0000	1900	198	214	1963	152	131
1964	0.00	0.0770	0.0551	0.0492	0.0000	1901	232	253	1964	109	108
1965	0.00	0.1979	0.1519	0.1204	0.0000	1902	244	267	1965	157	131
1966	0.00	0.1150	0.1083	0.0863	0.1310	1903	336	364	1966	163	147
1967	0.00	0.1040	0.1280	0.1798	0.1350	1904	218	238	1967	110	129
1968	0.00	0.1548	0.0990	0.1314	0.1672	1905	242	263	1968	100	102
1969	0.00	0.0541	0.0880	0.0691	0.0495	1906	164	178	1969	118	133
1970	0.00	0.1040	0.1596	0.1466	0.1282	1907	265	288	1970	140	132
1971	0.00	0.0824	0.0591	0.0523	0.0703	1908	268	291	1971	96	112
1972	0.00	0.0836	0.0718	0.0648	0.0601	1909	363	394	1972	118	120
1973	0.00	0.0785	0.0853	0.0708	0.0791	1910	240	261	1973	132	135
1974	0.00	0.0810	0.1134	0.0861	0.1132	1911	177	193	1974	145	140
1975	0.00	0.1115	0.0958	0.0779	0.1011	1912	58	63	1975	126	119
1976	0.00	0.1067	0.0909	0.0993	0.0779	1913	38	43	1976	132	143
1977	0.00	0.0296	0.0651	0.0443	0.0390	1914	9	11	1977	62	79
1978	0.00	0.0507	0.0583	0.0732	0.0675	1915	21	24	1978	108	128
1979	0.00	0.1817	0.1494	0.1389	0.1276	1929	37	32	1979	126	134
1980	0.00	0.0891	0.0933	0.1317	0.1220	1930	131	79	1980	116	118
1981	0.00	0.1572	0.1134	0.1333	0.1271	1931	89	76	1981	119	135
1982	0.00	0.1677	0.1190	0.1094	0.0974	1932	86	74	1982	96	98
1983	0.00	0.0804	0.0000	0.0597	0.0837	1933	106	92	1983	68	74
1984	0.00	0.1169	0.0000	0.1233	0.1283	1934	24	22	1984	67	99
1985	0.00	0.1170	0.0000	0.0777	0.0857	1935	12	13	1985	74	87
1986	0.00	0.0000	0.0000	0.0744	0.0856	1936	27	45	1986	27	49
1987	0.00	0.0000	0.0000	0.1792	0.0990	1937	137	117	1987	38	42

[continued]

Appendix 4, Table 1 (continued)

Year	Exploitable males	Exploitable females	Mature females	Total exploitable	Total	RY
1883	2,848	2,963	2,385	5,811	6,813	0
1884	2,847	2,959	2,381	5,805	6,807	0
1885	2,837	2,947	2,372	5,784	6,789	1
1886	2,826	2,933	2,359	5,759	6,774	2
1887	2,820	2,925	2,352	5,745	6,781	4
1888	2,807	2,912	2,339	5,719	6,779	9
1889	2,786	2,890	2,317	5,677	6,766	17
1890	2,741	2,841	2,269	5,582	6,711	27
1891	2,699	2,798	2,221	5,497	6,690	38
1892	2,652	2,750	2,166	5,402	6,676	53
1893	2,588	2,685	2,093	5,273	6,644	77
1894	2,416	2,504	1,917	4,919	6,398	114
1895	2,320	2,407	1,799	4,726	6,362	147
1896	2,186	2,271	1,643	4,457	6,239	186
1897	2,144	2,232	1,556	4,376	6,288	229
1898	2,037	2,130	1,415	4,167	6,155	276
1899	2,022	2,127	1,340	4,148	6,161	301
1900	1,950	2,052	1,225	4,003	5,990	317
1901	1,908	2,004	1,140	3,911	5,843	317
1902	1,835	1,915	1,045	3,750	5,610	312
1903	1,751	1,808	954	3,559	5,341	302
1904	1,574	1,603	817	3,177	4,882	299
1905	1,509	1,517	753	3,026	4,644	287
1906	1,415	1,401	678	2,816	4,346	277
1907	1,391	1,363	648	2,753	4,190	258
1908	1,261	1,209	563	2,470	3,826	247
1909	1,123	1,048	473	2,171	3,437	238
1910	889	783	328	1,672	2,833	239
1911	773	648	246	1,421	2,427	228
1912	712	573	195	1,285	2,118	205
1913	756	610	199	1,365	2,031	160
1914	801	641	215	1,442	1,989	111
1915	852	677	251	1,529	2,015	71
1916	871	683	289	1,554	2,037	50
1917	895	707	344	1,602	2,122	44
1918	912	732	401	1,644	2,235	49
1919	929	762	454	1,691	2,376	62
1920	951	799	498	1,750	2,540	80
1921	980	847	532	1,827	2,721	102
1922	1,019	906	560	1,926	2,914	124
1923	1,069	976	585	2,045	3,112	144
1924	1,128	1,055	611	2,183	3,313	158
1925	1,196	1,140	642	2,335	3,517	168
1926	1,269	1,228	678	2,497	3,724	174
1927	1,347	1,318	723	2,665	3,936	178
1928	1,427	1,409	774	2,836	4,155	181
1929	1,508	1,502	833	3,010	4,384	185
1930	1,556	1,565	878	3,121	4,556	192
1931	1,517	1,587	897	3,104	4,600	207
1932	1,526	1,619	918	3,144	4,696	220
1933	1,544	1,658	938	3,202	4,800	232
1934	1,549	1,686	948	3,236	4,868	243
1935	1,639	1,786	999	3,425	5,082	245
1936	1,742	1,894	1,060	3,636	5,314	243
1937	1,831	1,969	1,108	3,800	5,498	241
1938	1,813	1,974	1,117	3,787	5,502	245
1939	1,877	2,037	1,162	3,914	5,646	245
1940	1,943	2,102	1,210	4,045	5,790	244
1941	2,058	2,221	1,294	4,279	6,035	237
1942	2,171	2,336	1,381	4,507	6,265	231
1943	2,281	2,449	1,471	4,729	6,476	224
1944	2,387	2,557	1,563	4,944	6,661	214
1945	2,489	2,661	1,657	5,150	6,815	201
1946	2,586	2,757	1,750	5,343	6,933	183
1947	2,676	2,843	1,843	5,519	7,010	160
1948	2,756	2,917	1,933	5,673	7,044	132
1949	2,736	2,877	1,949	5,613	6,849	108
1950	2,689	2,789	1,931	5,477	6,634	83
1951	2,641	2,699	1,910	5,340	6,495	58
1952	2,558	2,537	1,834	5,095	6,322	54
1953	2,492	2,440	1,792	4,932	6,302	74
1954	2,427	2,378	1,754	4,804	6,336	110
1955	2,402	2,338	1,709	4,740	6,421	153
1956	2,349	2,311	1,651	4,660	6,450	197
1957	2,319	2,277	1,569	4,596	6,452	232
1958	2,275	2,209	1,457	4,484	6,364	256
1959	2,253	2,199	1,389	4,452	6,322	265
1960	2,282	2,255	1,377	4,537	6,374	262
1961	2,325	2,309	1,380	4,634	6,419	251
1962	2,380	2,359	1,398	4,739	6,462	235
1963	2,333	2,341	1,390	4,674	6,333	224
1964	2,294	2,323	1,391	4,617	6,240	210
1965	2,291	2,319	1,408	4,610	6,225	196
1966	2,235	2,287	1,409	4,522	6,149	194
1967	2,170	2,240	1,395	4,410	6,073	202
1968	2,158	2,216	1,388	4,375	6,084	210
1969	2,159	2,224	1,393	4,383	6,135	220
1970	2,147	2,206	1,375	4,353	6,137	234
1971	2,119	2,198	1,355	4,317	6,118	245
1972	2,140	2,213	1,348	4,353	6,161	249
1973	2,142	2,221	1,339	4,363	6,164	250
1974	2,133	2,214	1,323	4,347	6,135	251
1975	2,111	2,203	1,307	4,314	6,086	249
1976	2,108	2,210	1,307	4,318	6,077	245
1977	2,098	2,191	1,295	4,289	6,040	242
1978	2,154	2,232	1,323	4,386	6,133	236
1979	2,161	2,224	1,324	4,385	6,125	235
1980	2,150	2,211	1,320	4,361	6,095	235
1981	2,149	2,213	1,324	4,362	6,093	233
1982	2,145	2,197	1,318	4,342	6,074	232
1983	2,162	2,217	1,333	4,379	6,114	231
1984	2,204	2,259	1,362	4,464	6,201	228
1985	2,246	2,277	1,378	4,523	6,257	227
1986	2,281	2,306	1,401	4,586	6,309	224
1987	2,359	2,370	1,448	4,729	6,436	217
1988	2,423	2,437	1,502	4,860	6,539	207

Annex G

Report of the Sub-Committee on Protected Species and Aboriginal Subsistence Whaling

Members: Albert, Arnason (A.), Aurioles, Bannister, Best, Braham (Convenor), Braund, Breiwick, Broadhead, Brownell, Buckland, Butterworth, Cawthorn, Chapman, Clark, da Silva, Donovan, Fleischer, Goncalves, Hall, Hammond, Hester, Holt (S.), Horwood, Inagaki, Jover, Kasuya, Kato, Kishino, Larsen, Ljungblad, Lockyer, Martin, Mate, Luna, Misaki, Miyashita, Moore, Morimoto, Nakamura, Ohsumi, Øien, Øritsland, Palsboll, Perrin, Puddicombe, Raftery, Reilly, Scott, Sonntag, Swartz, Tarpley, Tillman, Vidal, Vikingsson, Whitehead, Zeh.

1. ELECTION OF CHAIRMAN

Bannister was elected Chairman.

2. APPOINTMENT OF RAPPORTEURS

Best, Cawthorn and Puddicombe assisted the Chairman.

3. SPECIFIC CHARGES FROM THE SCIENTIFIC COMMITTEE

No specific matters were referred under this item.

4. ADOPTION OF AGENDA

The Agenda was adopted without amendment, as in Appendix 1.

5. DOCUMENTS AVAILABLE

The sub-committee had available to it documents SC/40/PS1 to 14. In addition, documents SC/40/O 9, O 11, O 29, O 37 were relevant, as were SC/A88/ID2, 4, 5, 16, 17, 31 and 35. Certain national Progress Reports also contained relevant information.

6. PRIORITY ASSESSMENTS UNDER ABORIGINAL WHALING SCHEME

6.1 Bering – Chukchi – Beaufort Sea stock of bowhead whales

6.1.1 Catch limits and catches, 1987 and 1988

Final details of 1987 catches and initial catch figures for spring 1988 were presented to the sub-committee and are summarised in Table 1. In 1987, 31 strikes were taken of the allowed quota of 32. As at 2 May 1988, 18 strikes had been taken from the available 35 strikes for 1988. Ten of the 22 whales landed in 1987 (45%) were over 13m in length. The sub-committee noted that the mean length of whales landed in 1987 was 12.4m (n = 22), and that adult females comprised 31.8% of the landed catch. These values were slightly higher than the average figures of 11.8m and 25% for the periods 1981–86 and 1978–86 respectively.

The bisexual animal noted in Table 1 is the third record of a sexually aberrant animal of 81 animals examined since 1981. Two animals were genetically male while the exact status of the other has not yet been determined. While males affected by this condition cannot reproduce, the trait is carried by the female without altering her ability to produce offspring.

Table 1

Catch data for the bowhead whale harvest, 1987 (complete) and 1988 (to May 2, 1988)

	Landed catch							
	Landed	Imm. (< 13m)	M	F	Struck/ lost	Assumed dead	Total strikes	Annual strike limit
1987								
Spring	19[1]	11	6	12	8	6	27	
Fall	3	1	1	2	1	1	4	
Total	22	12	7	14[2]	9	7	31	32
1988								
Spring	15[3]	10	6	7[4]	3	-	18	35

[1] Whale landed May 28 at Pt. Hope reported to have both male and female reproductive organs.

[2] Two foetuses found: a 4.0m foetus (sex unknown) from a 15.7m female landed June 15 at Barrow; and a 1.5m foetus (sex unknown) from a 15.2m female landed October 5 at Nuiqsut.

[3] Length and sex of one whale (Wainwright, April 26), and sex of another whale (Pt. Hope, April 30) unknown.

[4] A 4.3m foetus (sex unknown) was aborted when a 15.5m female was struck and landed (Gambell, April 16).

6.1.2 Struck and lost rates

In 1987, 22 whales were landed and nine were struck and lost. The sub–committee noted that the struck and lost rate of 29% was the same as in 1986 which had continued the decreasing trend of earlier years. The fate of the nine animals was assessed to be three dead, four with a poor chance of survival and two with a good chance of survival.

To 2 May 1988, 15 whales had been landed and 3 had been struck and lost.

Albert reported that a Norwegian, E. Øen, had been developing a penthrite bomb with the AEWC which is expected to be more reliable and powerful than the existing bombs. It had not been possible to use it in 1987 but four small whales have been killed with it this year.

Albert also reported on SC/40/PS9 which detailed the use of radio telemetry to aid in the recovery of struck but lost whales. Since 1983 at Kaktovik and since 1986 at Nuiqsut a total of eleven whales have been struck where the floats were radio-instrumented. Six of these were retrieved without need of the radio location device. One which would have otherwise been lost was relocated by virtue of the radio location device. The use of the device was thought worthwhile in situations where open water is likely to occur and allows the float to surface and thereby allows transmission of the signal. Such environmental conditions are associated with fall whaling in Kaktovik, Nuiqsut and Barrow and to some extent St. Lawrence Island in the spring. The AEWC is continuing evaluation of the radio instrumented float programme. Sonic devices attached to the harpoon are again being considered for possible use in areas where floats with transmitters are unsuitable.

6.1.3 Stock identity

The sub-committee had no new information on this item.

6.1.4 Biological information and distribution

The sub-committee reviewed documents describing the bowhead's digestive system and reproductive biology. SC/40/PS7 presented information on the gastric and duodenal structure of the bowhead whale. The narrow diameter of the connecting channel (third chamber) could lead to blockages if objects such as tarballs, e.g. associated with an oil spill, or still other pollutants, e.g. discarded plastics, were ingested.

SC/40/PS8 provided information on reproductive morphology of female bowhead whales. Major findings of this work included: a suggested female body length at sexual maturity of 13–14m; the possibility that spontaneous ovulation occurs, a possible gestation period of 12–16 months with the most likely period being 13–14 months; conceptions in late winter to spring with births likely in late spring and early summer with a 1cm/day foetal growth rate; and a crude calving interval estimate of four (3–5) years. The reliability of estimates is hampered by a sample size of only 15 sexually mature females and the physical restraints on performing the work. Given the presence of very large corpora in the apparent absence of lactation or a foetus in four of the females examined, the sub-committee noted the low likelihood of finding foetuses less than one metre in length in the absence of biologists or technicians, particularly as technicians are no longer present in each of the villages. Tarpley felt that under most field conditions trained personnel could detect foetuses as small as 13cm while smaller foetuses, particularly those in the embryonic phase, could be overlooked.

Ovaries of ten bowhead whales had been examined for corpora. SC/40/PS8 demonstrated that corpora 1–2cm in diameter were found with greatest frequency and could eventually be useful in an estimation of ovulation rate given that (1) corpora can be realistically differentiated into 'young', 'medium' and 'old' categories; and (2) corpora can be shown to persist. It was noted in SC/40/PS8 that the decline in observed numbers of the very smallest corpora could result either from a tendency for corpora to persist or, alternatively, from an accelerated rate of resorption at the smaller diameters. The sub-committee noted that the size distribution of corpora suggested that the smallest of them may have been missed by the researchers. The poor correlation between body length and corpora number suggested that either body length had no strict relationship to the rate of corpora accumulation or that corpora do not persist. However, Tarpley felt that since the smallest corpora in the longest whales easily exceeded the diameter of visual detectability, the poor correlation cannot be used to support the lack of corpora persistence.

It was agreed that an independent age determinant such as earplug laminations was required, but bowhead earplugs are unreadable. Age determination using the baleen is not yet considered reliable and routine examination of epiphyseal closure of the backbone or flipper is impractical. As an alternative in the long term, natural marking data could be used to provide age-specific reproductive information, particularly given that 1,400 animals had so far been individually identified in a twelve year period. The sub-committee noted with concern that continuation of the photo-identification programme was dependent on available research funds in 1989 and beyond.

The sub-committee strongly **recommended** that the morphological analyses be continued, despite the practical difficulties and limitations, as the bowhead harvest provides a valuable and unique opportunity for such work on a little studied and still relatively rare species. The sub-committee also strongly **recommended** the resumption of aerial photo-identification surveys in the 1989 spring, based on the work already done and given the potential for further work to estimate reproductive parameters unambiguously. The sub-committee noted that each of the projects had the potential to enhance the findings of the other.

A preliminary report, based on photogrammetry of the spring migration in 1987, indicated that calf recruitment was only 1.1% in 1987, compared with 12.8% in 1986 and 1.2% in 1985. However, the 1987 estimate was based on only 50 – 60% of the season. The sub-committee noted that the photogrammetry flights, if continued, could provide good information on calving interval.

The sub-committee then considered bowhead distribution. SC/40/PS2 reviewed results of aerial surveys conducted from the eastern Alaskan and western Canadian Beaufort Sea in August to mid-September 1979 to 1986. Bowheads consistently occurred near the US/Canadian border and from 50 – 150km north of Barter Island, Alaska, with an indication that they left the study area in the second half of August. Their use of shallow water (<50m) increased from late August (21%) to early September (60%). Mean swimming direction in August was northwest, swimming alternating with bouts of feeding, milling or resting throughout August and early September. Whales were most commonly seen feeding in shallow (<20m) coastal water east of the US/Canadian border.

Large-scale surveys are now being curtailed and conducted directly by the agency that leases offshore tracts for oil development. The sub-committee noted that it was unfortunate that survey effort was decreasing, as large-scale monitoring surveys remain the best method of detecting cumulative effects of industrial activities over a number of years. The sub-committee therefore strongly **recommended** that large-scale surveys be continued to provide objective determination of any future impacts.

The use of passive acoustics in 1986 and 1987 to monitor the autumn (September-October) migration of bowheads was described in SC/40/PS3. Effort was greater in 1986 than in 1987. Call rates were reported to be significantly correlated with aerial survey sighting rates, but the correlation of results may have been an artifact given that the outcome would be greatly affected by the removal of two data points. The sub-committee recognised that acoustic monitoring can be conducted when visual census is impossible, e.g. darkness and bad weather, and **recommended** that acoustic monitoring continue to be used to supplement aerial surveys rather than to replace them.

SC/40/PS11 reported on aerial surveys flown near Point Barrow, Alaska in each spring from 1984 to 1986 to determine the offshore distribution of migrating bowheads. They were designed to provide information on the proportion of whales missed by the shore based census and thus improve population estimates. Results from transect surveys flown irregularly since 1978 have estimated that between 6% and 58% of whales migrate beyond the ice-based observers' maximum visual range of around 5km. However, SC/40/PS11 reported that photogrammetric surveys found only 3% in 1985 and 42% in 1986 beyond 5km compared with 58% in both 1985 and 1986 from the transect flights. The transect flight estimates were believed to be hampered to some degree by relatively low sample size and more reliance was therefore placed by the authors on the photogrammetry data. Another result of the surveys was the observation in 1986 that immature whales occurred further offshore than other whales.

The sub-committee recognised the difficulties inherent in both transect and photogrammetry flights. Photogrammetry data are biased through concentration of effort in inshore areas; the programme was also performed away from the area of shore-based surveys. Transect surveys are extremely useful for verifying acoustic data but are hampered when ice cover shields the whales from view. (Assumptions that the degree of ice cover does not affect bowhead migration could be partly answered through acoustic techniques). It was noted that the inshore bias of photogrammetry effort could be evaluated by transect flights. In summary the sub-committee **recommended** that both photogrammetric and transect survey flights continue, and that ice cover should be constantly monitored on the flights.

6.1.5 Stock size

Initial

SC/40/PS10 was a compilation of data relating to shore-based bowhead whaling by Alaskan Eskimos. The work validated and extended the earlier work of Marquette and Bockstoce (1980, *Mar. Fish. Rev.* 42(9–10):5–19) through a more detailed literature search and interviews with Eskimo people, and added 285 landed whales to the earlier study; 157 were landed between 1816 and 1977. The sub-committee agreed that this new information should be added to the existing data set used in estimating historical population size, but it had no new independent information available on initial stock size.

Current

The spring 1988 visual census and acoustic location efforts off Point Barrow began on 17 and 18 April, respectively, and are still under way. By 6 May, 1,044 'new' whales had been seen and 12,981 bowhead calls field-tallied.

SC/40/PS4 reported the results of acoustic surveys performed at Point Barrow, Alaska in 1986. Acoustic analysis of 233 hours of multi-channel recordings resulted in 4,636 acoustic locations. Those locations were analysed by the tracking algorithm and five correction factors were applied: geometric correction for whales up to 4.5 km offshore which are under-sampled in the '120° sector'; distance correction – for missed whales further than 10km offshore; pairs correction – for animals swimming within several body lengths of at least one other whale; non-segment correction – for periods of time when recordings were made but not analysed; non-monitored correction – for unmonitored time (220 out of 1,102 hours). The final estimate for the total numbers of vocalising bowhead whales in 1986 was 5,633.

The sub-committee accepted the use of the correction factors described. It noted that while the total number of vocalising whales differed from last year's estimate based on 1986 data, this difference resulted from more data being analysed and the use of a geometric correction factor based on empirical data.

The sub-committee noted that in contrast to the need to blow regularly, bowheads may not call regularly, so it is possible that the acoustic survey only monitors a segment of the population. The author of SC/40/PS4 agreed that call rate varies considerably and is not predictable, based on ice-based visual sighting data.

Appendix 2 presented some preliminary analysis of bowhead swimming tracks based on the acoustic characteristics of calls, since it appears that some whales will produce predictable call types as they migrate. The objective is to plot these call tracks and compute swimming parameters from these tracks which are independent of visual observations. Since the tracking algorithm results are particularly sensitive to the input parameters for minimum swimming speed and deviation from migration direction, the independent data from call tracks should improve the confidence in the choice of input parameters and ultimately reduce the variance in the population estimates. Calling serves to coordinate the movements of groups of whales and as a navigation tool when swimming through the unpredictable Arctic environment. By listening to the characteristics of call echoes off the ice the animals can determine the distances to heavy ice floes and avoid areas of deep-keeled ice (Ellison, Clark and Bishop, 1987, *Rep. int. Whal. Commn* 37:329–32). In addition, whales could interpret changes in the properties of the predictable calls from other whales to assess changes in their environment.

Estimation of current stock size was addressed in two papers, each using different methodology but working from the same database. SC/40/PS5 presented a new mark-recapture estimate of population size based on the 1986 visual and acoustic data. The methodology was based on that of Zeh, Turet, Gentleman and Raftery (1988, *Rep. int. Whal. Commn* 38: 349–64) with the following innovations:

(1) instead of estimating visual and acoustic detection probabilities independently at specific times through the season, the probabilities were estimated as functions of visibility, acoustic condition and distance offshore using the entire season's data;

(2) the estimate P3 of the proportion of whales passing within 3km of observation points was computed from distributions of estimated whale numbers obtained

using the detection functions of (1) rather than from adjusted acoustic locations;

(3) unmonitored time, effectively accounted for by adjacent monitored periods, was estimated;

(4) a single set of tracking parameters was used throughout the season – a jack-knife variance estimate reflected variability due to the choice of tracking parameters, as well as other sources of variability;

(5) the correction factor for whales travelling close together was not included.

The sub-committee believed that the correction for whales travelling together should be included. The estimate recomputed with this correction, as detailed in Appendix 3, was 8,200 with a standard error of 2,000. A weighted average of this estimate and the estimate of the 1985 population obtained last year (*Rep. int. Whal. Commn* 38, p.49) was 7,800.

A new method for estimating the bowhead population (SC/40/PS6) using the Bayes empirical Bayes methodology together with the adjustment described in Appendix 3 gave 95% confidence limits of 5,700 –10,600. A preliminary version of this methodology was presented in Raftery, Turet and Zeh (1988, *Rep. int. Whal. Commn* 38: 377–88).

The Bayes empirical Bayes approach is based on an explicit scientific model of the census process and of whale behaviour. It yields a full, asymmetric probability distribution of the numbers of whales given the 1985 and 1986 combined visual and acoustic censuses off Point Barrow, Alaska. It takes account of current gaps in scientific knowledge, of errors made by the tracking algorithm used, and of uncertainty in the tracking algorithm parameters.

The sub-committee noted that the confidence intervals in SC/40/PS6 take account of the main sources of variability, namely (1) missed acoustic time due to environmental conditions; (2) the fact that many acoustic locations from the very large data set were not computed; and (3) the uncertainty about the tracking algorithm parameters due to the lack of information about small–scale movements. It noted that the wide confidence intervals are also due partially to errors in acoustic locations, changes in direction, alterations in ice geography and swimming speed, and other factors. The sub-committee agreed that the posterior distribution technique employed in SC/40/PS6 is a preferable method for obtaining population estimates. Developments in research as outlined in Appendix 2 will permit refinement of the parameters of the tracking algorithm.

The sub-committee agreed, using as its rationale the information in Appendix 3, to accept the weighted average point estimate of 7,800 whales with an adjusted 95% confidence interval of 5,700 to 10,600.

6.1.6 Effects of industrial development

The sub-committee had no further results nor comments to make on the effects of industrial development on bowhead whale populations.

The sub-committee was informed that the report of the two year bowhead whale feeding study pertaining to the importance of the eastern Alaskan Beaufort Sea (noted in *Rep. int. Whal. Commn* 38, p.111) was now available. The report concluded that the area does not contribute significantly to the annual energy needs of the stock. A peer review under the auspices of the Science Advisory Committee of the North Slope Borough found that the data presented do not support such a conclusion. Such marked disparity in interpreting the data argues that additional study and/or data analysis are warranted and that such large studies should be designed and conducted in such a manner that data produced are useful for habitat management.

6.1.7 Management advice

As last year, population trajectories were simulated using the model described in Annex H, Appendix 4 (*Rep. int. Whal. Commn* 38, p.116). The same input parameter values were used as last year (age at first parturition = 10 years, age at recruitment constant throughout the fishery = 4 years, natural mortality rate, both juvenile and adult = 0.05) but with a catch series incorporating the new data provided in SC/40/PS10, as described in Appendix 4.

Appendix 5, Table 1, gives the calculated replacement yields (RYs) for MSY rates ranging from 1–5%, using the agreed weighted average point estimate of population size of 7,800 and the agreed range (5,700 – 10,600). The calculated replacement yields for the different stock sizes and MSY rates are as follows:

	MSY rate				
Population estimate	1%	2%	3%	4%	5%
5,700	43	77	107	132	155
7,800	56	99	135	165	192
10,600	71	119	153	178	196

The sub-committee accepted the results of the simulation as the basis for a recommendation on classification of the stock, although it recognised that the sensitivity tests recommended last year (*Rep. int. Whal. Commn* 38, p. 50) had not been carried out because the model had only recently been validated. In most instances the simulation indicates classification as a Protection Stock. The sub-committee therefore **recommended** that this stock remain a Protection Stock.

The sub-committee noted that the simulation indicated that the population had, for all values of an acceptable parameter range, increased under an estimated average annual removal since 1910 of 27 animals. However it had no evidence on the rate of increase and therefore which MSY rate to use. It agreed that the most appropriate values of RY are those associated with the weighted average point estimate of population size i.e. 7,800. It **recommended** that sensitivity tests be performed on the model and also **recommended** that, since population estimates are now available from a 10-year period, efforts be made to determine any trends in population levels since 1978 to assist the sub-committee in developing future management advice for this stock.

The sub-committee noted that under the provisions of the Aboriginal Whaling Scheme (Schedule Para. 13a) only a proportion of RY should be permitted to be taken, to allow the stock to move to MSY level, and that the smaller the proportion taken, the greater the rate of population increase.

While noting that benefits to the stock may only be marginal, the sub-committee again **recommended** that any catch should be directed to smaller (<13m) animals.

6.2 Other species/stocks subject to whaling

6.2.1 Eastern North Pacific gray whales

The sub-committee noted that 158 gray whales were reported taken (154 landed) during the 1987 Soviet season. The catch, below quota, was restricted by bad weather conditions and a delay in the start of the season (SC/40/ProgRep USSR).

The sub-committee reviewed the results of the most recent census of this stock (SC/40/PS12). The census attempted to address three questions: offshore distribution; missed whales; and estimation of the tails of the migratory distribution. Two independent observation posts were manned to give a mark-recapture correction factor and aerial surveys were used to accurately determine the offshore distribution of whales. A Hermite polynomial model was used in analysis of data resulting in a population estimate of 21,113 with standard error 688. The small standard error raised questions in the sub-committee about assumptions of day/night passage rates. However, previous radio-tagging had shown little significant difference between day and night rates of travel (Swartz *et al.*, 1987, *Rep. int. Whal. Commn* 37: 295–9). The sub-committee concluded this was a well-planned and conducted systematic study and accepted the point estimate of 21,113 gray whales.

The sub-committee also noted that there have been fluctuations in arrival times of gray whales in northern Mexican waters. It would welcome receiving results of current research in Mexico.

The sub-committee considered that the 1987/88 estimate of population size was not directly comparable with any of the previous series of population estimates for two main reasons. Firstly, a different model (the Hermite polynomial rather than the gamma distribution) was used to fit the daily counts to estimate the number of pods passing during the night, in poor visibility, and before and after the census periods.

Secondly, a correction factor for whales missed based on a mark-recapture type estimate was available for 1987/88 but not for previous years.

The sub-committee believed that while the 1987/88 estimate of 21,113 represents a considerable improvement in the estimation of absolute abundance of this stock, it is important to attempt to link the 1987/88 estimate (and those for 1984/85 and 1985/86) with the earlier continuous series of estimates from 1967/68 to 1979/80 (Reilly *et al.*, 1983, *Fish. Bull., US* 81: 267–81) so that more recent trends in the population can be examined. To make the estimates comparable, however, would require examination of the earlier data to see if they can be analysed in a similar way to 1987/88, or a reanalysis of the 1987/88 estimate using the gamma distribution model of earlier years and data from only one of the two observation posts.

Approximate offshore distance correction factors would also have to be developed for the 1984/85 and 1985/86 censuses to make them comparable with the earlier and later data. These analyses could clearly not be done at this meeting, but the sub-committee **recommended** that they should be carried out before the next annual meeting.

Because this stock is likely to be near its original abundance, the sub-committee recognised the importance of continuing the shore censuses. In the absence of other information it believed that such censuses should be carried out annually. However it is possible that the frequency of such censuses could be reduced, depending on the rate of population change expected and the accuracy of monitoring required. If such a reduction could be achieved without a significant loss of statistical precision, it might release resources for other research on gray whales (see below).

The sub-committee therefore **recommended** that an analysis of the survey frequency requirement be carried out before the next annual meeting.

The sub-committee also believed that it is important to obtain information on the demographic parameters of the gray whale population as it nears carrying capacity. Two sources of information are available, the Soviet aboriginal catch and photoidentification research carried out in Mexican, US and Canadian waters. The Soviet aboriginal catch is limited in size, with a sex-ratio biassed in favour of females, but the information potentially available is important.

The sub-committee felt that photo-identification of gray whales on their breeding grounds in Mexican waters is potentially a very powerful technique for obtaining data on calving intervals, age at first parturition, and juvenile and adult survival rates. It noted that research by Swartz and others between 1977 and 1982 (Jones and Swartz, 1984, pp.309–74 *In*: Jones *et al.* (eds) *The Gray Whale* Eschrichtius robustus. Academic Press, Fla) had been continued in two lagoons by Mexico, but a comparison of photo-collections between all groups concerned had not yet taken place.

The sub-committee therefore **recommended** that all groups currently and previously involved in gray whale photo-identification work should be contacted to evaluate the status of their photo-collections, and to investigate what information might already be available. A working group determined that there were two existing collections of photographs from systematic programs, and that some additional photographs may exist that could be solicited from individuals that were not involved in systematic programs. Jones and Swartz possess a collection of approximately 500 identified individual whales from Laguna San Ignacio obtained during the period 1977 to 1982, which has been partially sorted and analysed. Fleischer has a collection from Bahia Magdalena (Boca de Soledad) of approximately 100 photographs including identified individuals from the period 1983 to the present. This collection represents a continuous time series, but it has not been compared with any other collections.

The sub-committee agreed that while the existing data would not be suitable for population estimates, the photographs could be useful in estimating age at first reproduction, calving interval, and perhaps age specific survivorship. To do this, Fleischer and Swartz will solicit photographs from colleagues in Mexico and the USA, and under the guidance of Hammond, conduct an initial analysis of the data by the next fall.

The sub-committee **recommended** that the Magdalena Bay study continue, as this represents a continuous time series that, if uninterrupted, would yield valuable estimates of reproductive parameters and survivorship.

It also discussed additional research to provide estimates of juvenile survivorship (calf survivorship). Because gray whale females with calves congregate within the four major breeding lagoons of Baja California, and because their northward spring migration brings them very close to shore (within photographic range) near Piedras Blancas in central California, a mark-recapture experiment could be conducted. An effort should be made to photograph females with calves in as many lagoon areas as possible during the period when the female-calf pair populations are greatest (early February) to obtain an initial sample of calf production. This should be followed by an effort to recapture female-calf pairs as they migrate north past Pt.

Piedras Blancas during their spring migration. Comparison of females observed with calves in the breeding lagoons with the same females with or without their calves during the spring migration would provide the basis for an estimation of calf survival for comparison with previous studies.

Management advice

The sub-committee strongly believes that the eastern North Pacific stock of gray whales is a stock of special interest and importance to the IWC, in that it is the only one that has demonstrably recovered to a level approaching its original abundance, and for which a great deal of information on stock identity, population size and trends in abundance is available. It therefore feels that this stock could form the basis of a broad, in-depth assessment by 1990.

The sub-committee agreed that this stock is well above its minimum population size, as specified by the aboriginal/whaling management scheme. Classification of the stock would have to await the broad, in-depth assessment mentioned above, but the sub-committee noted that the population had increased at about 2.5% a year between 1967/68 and 1979/80, despite an annual catch of about 179 animals. This catch comprised only 0.8% of the best estimate of current population size.

Pending the broad, in-depth assessment mentioned above, the sub-committee **recommended** no change in the catch limit for this stock in 1988.

6.2.2 West Greenland fin whales

The sub-committee received information on a stock estimate from the North Atlantic Minke Whale sub-committee, as follows. Information on the number of cues seen and coverage probabilities during an aerial survey of the West Greenland coast in July/August 1987 (SC/40/O 11) was combined with information on effective search areas calculated from radial distance data (SC/40/O 12) to produce a population estimate of 1,693 whales. Although analysis of duplicate sightings seen by two independent observers showed that all cues on the track line were seen, the coefficient of variation for the estimate was large (0.47). This was due to inter-transect variation in cue sighting rate and to variability in the estimated effective search area. In addition, the population estimate was based on a mean surfacing rate for fin whales of 36 per hour, calculated from a small data base that did not originate from experiments designed to estimate surfacing rate. Because of the unknown reliability of the mean surfacing rate estimate, no component of variability had been calculated for it. If better information on this parameter becomes available, it can readily be incorporated into the population estimate.

The survey was considered to cover most of the summer range of this fin whale stock. The discreteness of the population, however, was uncertain, and there was some discussion of whether a link existed with the stock off Newfoundland (which some evidence suggested had declined in recent years). There was also no information available on the status of the stock. The sub-committee recognised, however, that the population estimate obtained this year, despite its large associated CV, was a considerable improvement on the information previously available. Nevertheless, until there is a more robust estimate, and more information on stock identity and status, it is difficult to predict the long-term effect of an aboriginal take of 10 whales as permitted in 1987.

The sub-committee **recommended** that aerial surveys of this stock continue, and that experiments designed to estimate surfacing rate for this fin whale population (of which radio-tagging might be one) should be carried out. It also **recommended** photo-identification studies of the West Greenland fin whales, for comparison with the catalogue of identified individuals already available for other areas in the northwestern Atlantic.

The sub-committee was pleased to learn that planned aerial survey efforts off West Greenland this year will be double that of 1987, and that photo-identification work by Danish scientists will commence this year.

6.2.3 Western North Atlantic humpback whales

The sub-committee noted that new estimates for the population size of northwest Atlantic humpback whales had been provided in a paper to the Workshop on Individual Recognition and the Estimation of Cetacean Population Parameters (Katona and Beard, SC/A88/ID2). Mark-recapture estimates using Bailey's modification of the Petersen method were undertaken with the number of photographically identified individuals on the feeding grounds in one year as n_1, the number of identified individuals on the breeding grounds the following winter as n_2, and the number of individuals identified in both samples as m_2. A variance-weighted estimate based on all photographs from the northern areas was considered the best estimate for the total population i.e. 5,505 ± 2,617 (95% CI), for the years 1979–1986. A separate estimate based on the rate of discovery of new individuals was 6,570 ± 148 (SE).

Least-squares regressions using the natural logarithms of annual population estimates with lowest variances from the mark-recapture model yielded slopes for population increase of 9.4% (95% CI: –12% to 30%, not significantly different from zero) and 10.3% (95% CI: 2% to 23%) for estimates based on all northern photographs (1979–86) and Gulf of Maine photographs (1981–1986) respectively.

The sub-committee noted the stranding of 15 dead humpback whales off Cape Cod and New York in late 1987, including several individuals previously photo-identified. The reason for this mortality was believed to be the ingestion of mackerel tainted with biotoxins from 'red tide' (SC/40/ProgRep USA). It was reported that four dead humpback whales also washed ashore in the Dominican Republic. Further animals might have died at sea, but the degree of mortality reported in the northeastern USA alone represented 6.25% of the estimated size (240 ± 95% Cl 93) of the Gulf of Maine feeding aggregation from SC/A88/ID2, although SC/A88/ID4 suggested that that stock size is an underestimate.

No official information on the take of humpback whales in Bequia or St. Vincent in 1987 was available to the sub-committee, although it believed that two (including one calf) had been taken.

7. INFORMATION ON OTHER STOCKS

7.0 Information on other stocks

The following was extracted from documents available at the meeting.

7.1 Right whales

(a) *North Atlantic*
Six sightings, five off Florida and one off North Carolina, were reported from the United States east coast between January and April 1987 (SC/40/ProgRep USA). One animal was seen west of Iceland in July (SC/40/O 29).

(b) *North Pacific*
No right whales were sighted by Japanese research vessels in the North Pacific either *en route* for the Antarctic or in Japanese coastal waters during 1987/88, or by operating catcher boats (SC/40/ProgRep Japan).

(c) *Southern Hemisphere*
One right whale was sighted on the IDCR cruise, in Area III (SC/40/ProgRep Japan). Off Western Australia the largest number seen on an individual survey flight in 1987 was 79, including 13 calves (SC/40/ProgRep Australia). Since 1977, that stock has increased at an annual average rate of 10% (5.2–16.2%: SC/A88/ID17). There were 57 sightings, including 16 calves, off South Australia; average swimming speeds of 1.25–2 knots were recorded. Calving was recorded off New South Wales in September, and for the first time in recent years off Tasmania, where there were more than 40 sightings between June and October (SC/40/ProgRep Australia).

The population size for mature females off South Africa has been estimated as 289 (279–302). It has increased exponentially since 1971 at 6.8% ± 1% annually (SC/A88/ID16).

A total of 452 right whales was seen at Campbell Island and around New Zealand between January 1986 and December 1987. Some seen north of the Auckland Islands were reported as mating (SC/40/ProgRep New Zealand).

Blue whales

(a) *North Atlantic*
Two animals were sighted off Godthåb, West Greenland, during aerial surveys in July and August 1987 (SC/40/O 11). Eighty blue whales were seen from whaling vessels on the Icelandic whaling grounds and 40 on sightings surveys in that area in 1987 (SC/40/ProgRep Iceland). One blue whale was seen off Svalbard (SC/40/ProgRep Norway).

(b) *North Pacific*
Based on sightings reports, blue whales are present seasonally in some areas of the Gulf of California, possibly correlated with availability of food (SC/40/ProgRep Mexico). No calves have been seen in sightings surveys undertaken since 1983.

Two blue whales were recorded from Japanese research vessels between 40°–50°N, 170°E–170°W (SC/40/ProgRep Japan).

(c) *Southern Hemisphere*
A blue whale was reported off Kangaroo Island, South Australia, in April 1987 (SC/40/ProgRep Australia).

Nine blue whales were seen on the 1987/88 IDCR cruise, 6 in Area III (SC/40/ProgRep Japan). Off New Zealand, there were six sightings in 1986 and 13 in 1987. One animal was recorded stranded in March 1988 (SC/40/ProgRep New Zealand).

Humpback whales

(a) *North Atlantic*
A total of 143 humpbacks was recorded during shipboard surveys and 159 from whaling vessels on the whaling grounds, off Iceland in 1987 (SC/40/ProgRep Iceland). Fourteen animals were seen in aerial surveys off Svalbard (SC/40/Progrep Norway) in July-August. Three sightings were made off Svalbard and one off Finnmark from Norwegian sightings vessels in July (SC/40/O 9).

(b) *North Pacific*
Strandings of three humpbacks were reported, two from Hawaii, one from Alaska, as well as the incidental catch of one animal off Alaska, in 1987 (SC/40/ProgRep USA).

Three animals were sighted off the coast of Japan from whaling vessels in 1987/88 (SC/40/ProgRep Japan). Forty-four were seen on a joint Soviet-USA cruise in October-November 1987, one in the South Okhotsk Sea, the remainder off the Kodiak Islands (SC/40/O 37).

(c) *Southern Hemisphere*
A total of 39 humpbacks was seen on the 1987/88 IDCR cruise, mostly in Area III, south of 60°S (SC/40/ProgRep Japan). Around New Zealand, 120 animals were seen in 1986, 64 in 1987 and 26 so far in 1988. They have not been reported from Cook Strait or Foveaux Strait, two of their major migratory routes, for over ten years (SC/40/ProgRep New Zealand). A total of 302 humpbacks was recorded in shore-based studies off eastern Australia. The best estimate for annual net increase between 1982 and 1987 is 13.9%, confirming the large increase seen in recent years. A total of 352 animals was individually identified from fluke photographs in 1987 bringing the total number of individuals identified since 1984 to approximately 415 (SC/40/ProgRep Australia).

8. SPECIAL PERMITS AND RESEARCH PROPOSALS

Two proposals that had been subjected to the normal review process were submitted to the sub-committee for consideration. In addition, two proposals were forwarded to the sub-committee via the Comprehensive Assessment sub-committee.

SC/40/RP1 was a proposal by Best and Ruther seeking £11,907 for aerial surveys of southern right whales off the south African coast. The main objective of the study is to clarify aspects of right whale biology to facilitate an understanding of its population dynamics and interpretation of survey data. The survey also expects to continue to monitor the rate of population change through aerial surveys. Funding was sought from the IWC for this continuing project to bridge a one year interval between other grants.

This proposal had been discussed in SC/40/Rep1 and had been strongly supported there. The sub-committee also considered the proposal to be very worthwhile and Best to have proven research ability. As such the sub-committee strongly **recommended** IWC funding for the proposal as submitted.

SC/40/RP2 was a proposal by Swartz and Wells seeking £6,000 to assess the retention and performance of sub-dermal VHF-radio tags with blue, fin and humpback whales off the US West coast. The same proposal had been supported last year but it had only been partly implemented. The sub-committee considered the proposal to be well conceived and the proposers to be conscientious, professional and likely to succeed. In addition it was felt that the results of the survey would have considerable application to a number of other studies. One anonymous reviewer had queried the proposal's intention not to double tag animals. Swartz explained that individually identifiable whales were to be tagged, making double tagging unnecessary. In clarification of the scheduling of survey flights, Swartz explained that tag loss is expected to be highest in the first month following tagging, accordingly flights would be more frequent in that period. After that time flights would be structured to some extent based on the results of flights up to that time. The sub-committee accepted these explanations and **recommended** that funding for the survey be provided.

The sub-committee examined Annex I1 of SC/40/Rep1 which was a proposal for further development and initial compilation of a North Atlantic fin whale catalogue. An amount of £9,000 was requested to further develop and implement methods to photographically identify North Atlantic fin whales.

The sub-committee considered that compilation of such a catalogue would be very useful. However, as its priority was the West Greenland stock of fin whales it felt that the work should be expanded to include as many fin whales as possible, including those from the Gulf of St Lawrence. It agreed that any formal proposal, prepared according to IWC guidelines for this work and submitted next year, should be sympathetically considered.

The sub-committee considered Appendix 6 which was a proposal by Glockner-Ferrari, Ferrari and Mizroch seeking £10,000 for analysis and encoding of North Pacific humpback whale fluke photographs which would lead to a direct estimate of calf mortality. By identifying mothers with calves in southern waters and determining whether the same adult females still had their calves in northern waters, an estimate of calf mortality could be determined.

The sub-committee considered the chances of the study leading to a valid estimate of calf mortality, and whether access to the data would be available should IWC funds be used to sponsor the work. It agreed that the work was worthwhile and **recommended** that the proposal should be funded in full by the IWC.

The sub-committee considered priorities in relation to the three projects for which funding was recommended. Based on the priorities of the Commission, particularly in relation to the Comprehensive Assessment, and the desirability of continuity in ongoing projects, the sub-committee gives first priority to the proposal by Best and Ruther, second priority to the proposal by Swartz and Wells and third priority to the proposal of Glockner-Ferrari, Ferrari and Mizroch.

9. OTHER BUSINESS

The sub-committee proposes no future meetings, special studies, data processing or funding apart from those already recommended in previous sections.

10. PRIORITY STOCKS AND ISSUES FOR NEXT MEETING

The sub-committee **recommended** that, should the Commission set a one year catch limit for bowheads this year, priority should continue to be given to the Bering-Chukchi-Beaufort Seas stock. If it sets a catch limit for more than one year, special consideration next year, in addition to the broad in-depth assessment of gray whales (see Item 6.2.1), should be given to reviews of right whale stocks and other stocks of humpback whales, including studies of population dynamics and results of surveys. These could be expected to give information relevant to the Comprehensive Assessment.

11. PUBLICATION OF DOCUMENTS

A list of meeting documents to be considered for publication was submitted to the Editorial Board.

12. ADOPTION OF REPORT

The sub-committee adopted the final draft as amended.

Appendix 1

AGENDA

1. Election of Chairman
2. Appointment of Rapporteurs
3. Specific charges from the Scientific Committee
4. Adoption of Agenda
5. Documents available
6. Priority assessments under aboriginal whaling scheme
    - 6.1 Bering-Chukchi-Beaufort Sea stock of bowhead whales
        - 6.1.1 Catch limits and catches, 1987 and 1988.
        - 6.1.2 Struck and lost rates
        - 6.1.3 Stock identity
        - 6.1.4 Biological information and distribution
        - 6.1.5 Stock sizes – initial and current
        - 6.1.6 Effects of industrial development
        - 6.1.7 Management advice
    - 6.2 Other species/stocks subject to whaling
        - 6.2.1 Eastern North Pacific gray whales
        - 6.2.2 West Greenland fin whales
        - 6.2.3 Western North Atlantic humpback whales
7. Information on Other Stocks
8. Special permits and review research proposals
9. Other business
    - 9.1 Future meetings
    - 9.2 Special studies
    - 9.3 Data processing and computing needs
    - 9.4 Funding requirements
10. Priority stocks and issues for next meeting
11. Publication of documents
12. Adoption of report.

Appendix 2

THE USE OF BOWHEAD WHALE CALL TRACKS BASED ON CALL CHARACTERISTICS AS AN INDEPENDENT MEANS OF DETERMINING TRACKING PARAMETERS

Christopher W. Clark

The calls of bowhead whales during their spring migration have been used since 1984 as a means of determining the offshore component of the migration relative to ice-based visual observation sites. For 1985 and 1986 the acoustic location data have been combined with visual sighting data to calculate population estimates (SC/40/PS5; SC/40/PS6; Zeh *et al.*, 1988, *Rep. int. Whal. Commn* 38: 349–64)

As part of the methodology for computing numbers of whales, a tracking program (Sonntag *et al.*, 1986, *Rep. int. Whal. Commn* 36: 299–310; Sonntag *et al.*, 1988, *Rep. int. Whal. Commn* 38: 337–47) has been developed and utilised. This program requires a set of parameters that describe a set of swimming characteristics and consolidation thresholds. Analysis has shown that results of the tracking algorithm are particularly sensitive to two input parameters, minimum swimming speed and deviation from the path of migration. Presently, these parameters are selected based on a combination of visual sighting data and the results of the tracking analysis. The method of selecting these parameters could be improved if there were data on whale swimming behavior which were independent of visual observations.

With this in mind, the acoustic location data from 1985 and 1986 are being closely examined with the intention of determining tracks based on the acoustic characteristics of the calls. Such tracks are referred to as *call tracks*. This notion evolved over the past several years of intensive acoustic analysis as we became increasingly aware of cases where very similar sounding calls were heard over the course of several hours and the calls progressed from left to right in a direction similar to the procession of the migration.

At present we have scrutinised 153 hours of tapes for call tracks. Call tracks are recognised by the following procedure. All cassette tapes from an array period have been converted into continuous, hardcopy representations referred to as stereograms. The whale calls on a stereogram which has already been analysed for acoustic locations are carefully studied for cases where calls with very similar acoustic characteristics occur. When a consistently unique call type is identified and the bearings progress from low to high (representing movement from southwest to northeast, the migration direction), then that sequence of calls is considered a potential call track. The location data for that call track are processed by the tracking algorithm, and the results compared to a plot of the call track.

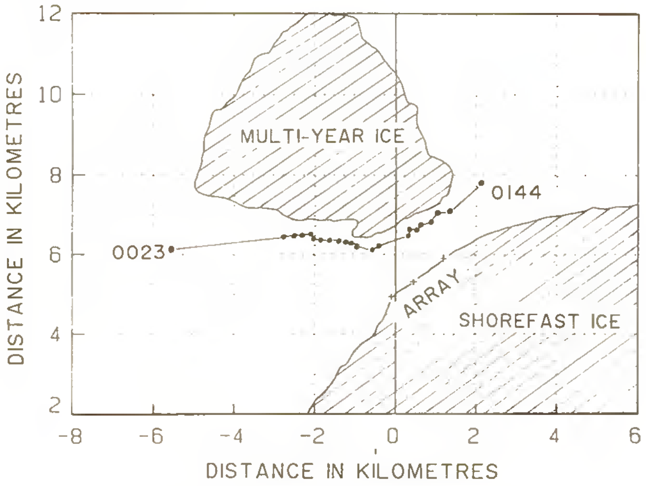
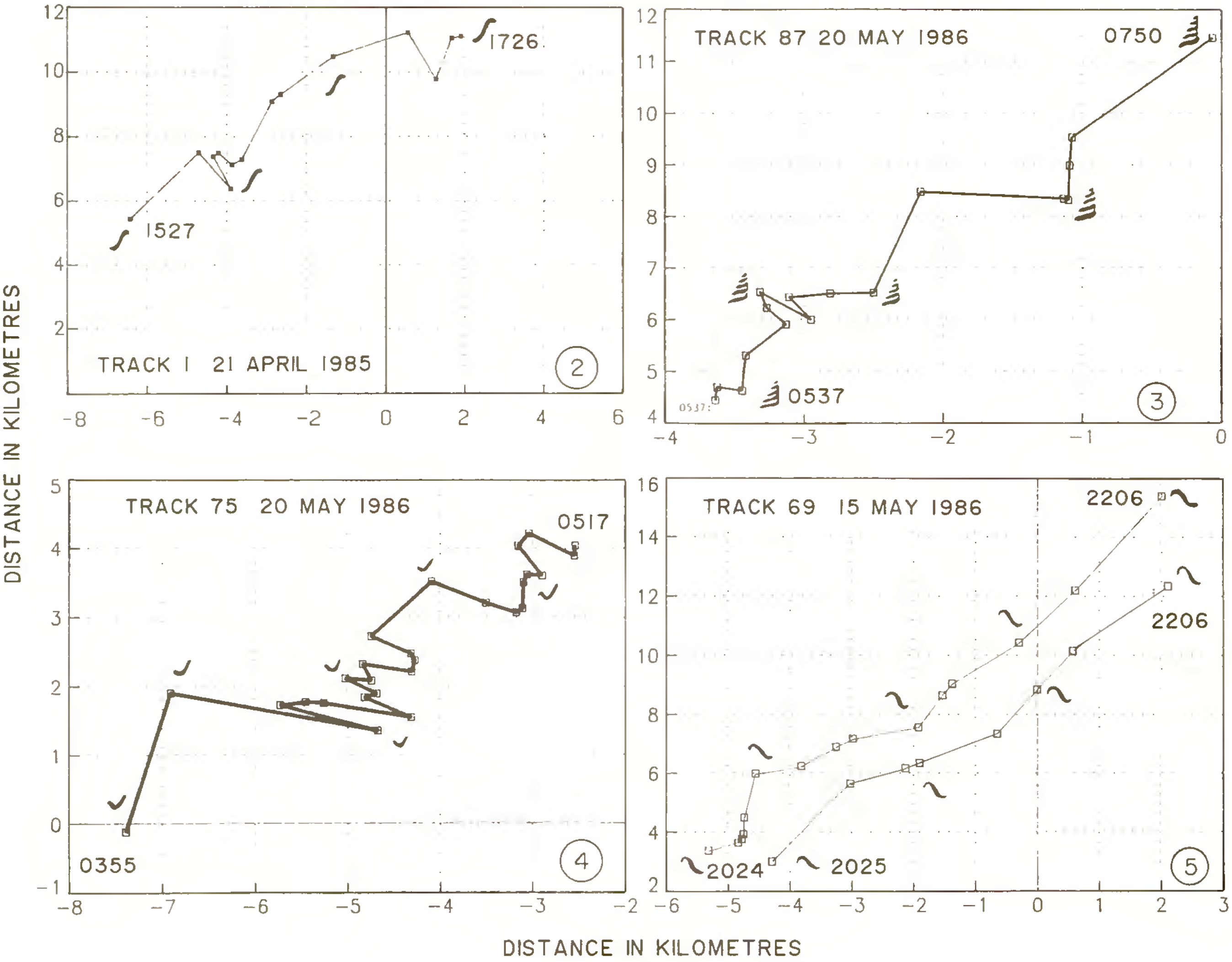


Fig. 1. Call track for a singing bowhead whale.

The outcomes from this call track analysis are proving to be very interesting, not only from what they show us about the tracking algorithm, but from what they tell us about the



Figs 2—5. Call tracks for bowhead whales based on call characteristics.

acoustic behaviour of bowhead whales. So far we have identified 106 potential call tracks but only several dozen of these have been studied in detail. Figs 1–5 are some examples of call tracks. Fig. 1 shows the track of a singer in 1985 as it swam inshore of a large multi-year ice floe. Singers by far present the clearest cases of call tracks since the whale is usually producing song notes continuously, which makes the track easy to construct. Figs 2–4 illustrate single tracks of whales, each producing a different call type (not song). In each figure an icon representing a tracing of the original spectrogram of the call has been placed near several of the acoustic locations in order to show the consistency in the call characteristics over time. For the sake of not cluttering the figures, icons are not given for each of the calls in a track although all calls in a track look and sound identical. Fig. 5 shows the case of two whales swimming in parallel with both animals producing a nearly identical call type. In this case calls are often produced antiphonally such that when one animal calls, the other responds with a call in a matter of seconds. There are also cases, not illustrated here, where groups of whales, on the order of 3–5 animals, move together as a unit with each group member producing a unique call type or all members producing a similar call type.

These initial results on the acoustic behaviour of migrating bowheads have implications for population estimate computations as well as providing insights into what the whales are actually doing acoustically. At present none of the call tracks have been similar to the tracks derived by the application of the tracking algorithm to these same acoustic location data. This is to say, the results from the tracking algorithm do not yield swimming tracks which are similar to any of the call tracks; a fact that has been known since the algorithm was first used and was discussed in Gentleman and Zeh (1987, *Rep. int. Whal. Commn* 37: 313–27). This does not invalidate the use of the tracking algorithm but merely emphasises that its results, as far as swimming tracks are concerned, do not represent what whales are actually doing. The new approach of Raftery *et al.* (SC/40/PS6) does take into account the characteristic of the tracking algorithm to break and join real tracks, and the data from the call tracks provide an empirical means of quantifying the extent of these tracking algorithm effects.

Of even greater importance is the fact that the call tracks provide an independent means of calculating swimming speeds and deviations in the migratory direction. At present, call track results indicate that swimming speeds are between 2.5 – 6.5 km/h and that deviations in migration direction are variable but range between ± 30°.

The immediate benefit of call track analysis, in terms of population estimates, is that we now have an independent means of specifying parameters for the tracking algorithm. The net result of this will be to improve the confidence limits of the population estimate distribution as presented by Raftery *et al.* (SC/40/PS6) by improving the confidence in the parameters for minimum swimming speed and deviation in migration direction.

In terms of acoustic behaviour, we now have some fairly specific data demonstrating that calling serves to coordinate the movements of groups of whales during the migration and serves as a navigation tool when swimming through the unpredictable Arctic environment (Ellison, Clark and Bishop, 1987, *Rep. int. Whal. Commn* 37: 329–32). It now appears that the whales not only use their calls to communicate directly with each other, but that they use call degradation and echoes from calls as a means of assessing the environment. By producing regular, predictable sound patterns (as demonstrated in Figs 2–5) whales can relate changes in the quality of the predictable sounds from another whale to changes in the environment, such as intervening ice floes of varying shapes and sizes. By listening to the characteristics of the call echoes off the ice the animals can determine the distance to heavy ice floes and thereby actively use their vocalisations as a means of navigating in the ice.

Appendix 3

1986 AND COMBINED BOWHEAD POPULATION ESTIMATES

Judith E. Zeh and Adrian E. Raftery

In response to comments from members of the Committee, we have recomputed the 1986 population size estimate of SC/40/PS5 to include the correction factor for whales travelling close together described in Zeh, Turet, Gentleman and Raftery (1988). This correction changes the estimate from 7,000 to 8,200 and the standard error from 1,700 to 2,000.

A weighted average of this 1986 estimate and the 1985 estimate of Zeh, Reilly and Sonntag (1988) is 7,800 with a standard error of 1,500. An approximate normal theory 95% confidence interval is 4,800 to 10,800.

The estimates contained in SC/40/PS6 are based on a range of values for the minimum swimming speed in the tracking algorithm of 1 to 3km/hr. The estimate in SC/40/PS5 is based on a single minimum swimming speed of 1km/hr for reasons explained therein. It is our opinion, based on the sensitivity analysis in Appendix 4 of SC/40/PS6, that if the range of minimum swimming speeds in that paper was changed so as to be centred at 1km/hr, then the posterior mode based on the combined 1985 and 1986 distributions would be about 8,200.

Thus the combined 1985 and 1986 estimates produced by the mark-recapture and Bayes empirical Bayes approaches are quite similar, although the asymmetric posterior distribution obtained using the latter approach determines more realistic confidence intervals than the normal theory interval computed above. The Bayes empirical Bayes approach yields a 95% confidence interval of approximately [6,100, 11,000]. If this were shifted to correspond to a point estimate of 7,800, the resulting 95% confidence interval would be roughly [5,700, 10,600].

REFERENCES

Zeh, J., Reilly, S. and Sonntag, R. 1988. Bowhead population estimate and variance. *Rep. int. Whal. Commn* 38: 115–16.

Zeh, J.E., Turet, P., Gentleman, R. and Raftery, A.E. 1988. Population size estimation for the bowhead whale, *Balaena mysticetus*, based on 1985 visual and acoustic data. *Rep. int. Whal. Commn* 38: 349–64.

Appendix 4

DOCUMENTATION FOR REVISED BOWHEAD WHALE CATCH DATA (1948–1987)

Ron M. Sonntag and Gordon C. Broadhead

At the request of the sub-committee, the bowhead whale catch data, presented by Breiwick, Eberhardt and Braham (1984, *Can. J. Fish. Aquat. Sci.* 41:484–96), was updated to reflect recent additions in the historic catch data on shore based bowhead whaling in Alaska (Braund *et al.*, SC/40/PS10). The following paragraphs explain the procedures used to generate a new set of yearly bowhead whale catch data (Table 1 opposite) for use by the HITTER and FITTER population models used in presenting replacement yield at different MSY rates and population estimates.

Data presented in Appendix 1 (Braund) were organised by location by year. The relevant data for catch are found in the columns labeled 'landed', 'killed but lost', and 'struck and lost'. These data were entered into a database and reorganised so as to present a summary of catch by year by location. The numbers for 'landed' and 'killed but lost' were summed and then compared to the numbers under 'Alaskan' and 'Canadian shore kill' in Table 1 of Breiwick *et al.*

Since Appendix 1 of Braund *et al.*, does not include 'Canadian landings', they were removed from the Breiwick *et al.*, table in order to make the comparisons. The yearly 'Canadian landings' numbers were obtained from Table 5, Marquette and Bockstoce (1980, *Mar. Fish. Rev.* 42:5–19).

These data, corrected for 'Canadian landings', were compared, on a year by year basis, to the reorganised data from Braund *et al.* Many years were identical. In a few cases, the Braund *et al.*, yearly totals were lower than the corrected numbers in Breiwick *et al.* But for all other differences, the totals were higher, reflecting the added numbers from Braund's new research. The final totals for 'Alaska shore kill', presented in the attached summary, were taken from Braund *et al.*

'Total shore kill' includes the revised 'Alaskan shore kill' plus 'Canadian shore kill' (Marquette and Bockstoce), plus 'Soviet shore kill' (Breiwick *et al.*).

Following the methodology in Breiwick *et al.*, struck and loss was computed as 50% of the 'total shore kill' for each year through 1969. For years 1970 – 1981, the 'struck and loss' values were taken from Breiwick *et al.* For years 1982 – 1987, the 'struck and loss' numbers were obtained from the appropriate sub-committee reports.

The same methodology as used by Breiwick *et al.*, was used to estimate mortality of 'struck and lost', which was then included in the 'total kill'. For years prior to 1970, the columns 'total shore kill' plus 'adjusted shore kill' plus 'Pelagic kill' do sum to the 'total kill' (because 100% mortality was assumed for 'struck and lost'). However, a percentage mortality of 50% was used for years 1970 – 1977 and 75% for years 1978 – 1987, and therefore the 'total kill' may not be computed by simply adding the other columns together without first adjusting the 'struck and lost' numbers by the appropriate mortality percentages.

Appendix 5

RESULTS OF RUNS USING THE HITTER/FITTER PROGRAM

Trend simulations were run using the validated HITTER program and the revised bowhead whale catch data reflecting the additions of SC/40/PS10. Test runs using the target values of Table 1, Appendix 4, Annex H of *Rep. int. Whal. Commn* (1988) gave differences of 1% or less in 1848 and 1987 population sizes. The results of runs using the agreed parameter values and the revised catch data are given in Table 1.

Table 1 (right)

Summary of the results of runs using the validated HITTER/FITTER program (see Annex L) for three target population values and MSY rates of 1–5%. The revised catch data from Appendix 4, Table 1 (p. 115) were used.

	1%	2%	3%	4%	5%
Target 5,700					
1848	21,012	17,650	15,706	14,417	13,480
1912	4,580	2,988	2,111	1,595	1,273
1986	5,700	5,700	5,700	5,700	5,702
1988	5,743	5,826	5,899	5,964	6,025
% 1988	27.3	33.0	37.6	41.4	44.7
RY (1988)	43	77	107	132	155
	PS	PS	PS	PS	PS
Target 7,800					
1848	21,836	17,982	15,848	14,482	13,511
1912	5,770	3,705	2,561	1,886	1,468
1986	7,800	7,800	7,800	7,800	7,800
1988	7,874	7,977	8,064	8,137	8,203
%	36.1	44.4	50.9	56.2	59.4
RY (1988)	56	99	135	165	192
	PS	PS	PS	SMS	SMS
Target 10,600					
1848	23,023	18,500	16,083	14,595	13,569
1912	7,452	4,795	3,293	2,391	1,826
1986	10,600	10,600	10,600	10,600	10,600
1988	10,707	10,820	10,897	10,947	10,976
%	46.5	58.5	67.8	75.0	80.9
RY (1988)	71	119	153	178	196
	PS	SMS	SMS	IMS	IMS

Table 1

Catch totals by year from 1848–1987 (see text)

Year	Total pelagic kill	Alaska shore kill	Canadian shore kill	Soviet shore kill	Total shore kill	Adjusted shore kill struck + lost	Total kill
1848	18	0	0	0	0	0	18
1849	571	0	0	1	1	1	573
1850	2,067	0	0	0	0	0	2,067
1851	896	0	0	1	1	1	898
1852	2,682	17	0	1	18	9	2,709
1853	796	7	0	0	7	4	807
1854	130	24	0	0	24	12	166
1855	2	0	0	0	0	0	2
1856	0	0	0	0	0	0	0
1857	78	0	0	0	0	0	78
1858	459	1	0	0	1	1	461
1859	366	0	0	4	4	2	372
1860	221	0	0	0	0	0	221
1861	306	0	0	0	0	0	306
1862	157	0	0	0	0	0	157
1863	303	0	0	0	0	0	303
1864	434	0	0	0	0	0	434
1865	588	0	0	1	1	1	590
1866	540	0	0	9	9	5	554
1867	599	0	0	0	0	0	599
1868	516	0	0	0	0	0	516
1869	370	5	1	2	8	4	382
1870	620	5	0	6	11	6	637
1871	133	0	0	3	3	2	138
1872	194	4	0	0	4	2	200
1873	147	0	0	0	0	0	147
1874	95	0	0	0	0	0	95
1875	200	0	0	0	0	0	200
1876	76	0	0	0	0	0	76
1877	262	0	0	5	5	3	270
1878	80	0	0	0	0	0	80
1879	261	3	0	0	3	2	266
1880	460	12	0	1	13	7	480
1881	418	11	0	0	11	6	435
1882	240	1	0	0	1	1	242
1883	39	2	0	0	2	1	42
1884	133	13	0	5	18	9	160
1885	287	41	0	19	60	30	377
1886	133	13	0	10	23	12	168
1887	204	23	0	1	24	12	240
1888	133	17	1	0	18	9	160
1889	53	49	0	0	49	25	127
1890	127	6	0	0	6	3	136
1891	234	33	0	0	33	17	284
1892	317	19	0	0	19	10	346
1893	141	26	0	0	26	13	180
1894	151	52	0	3	55	28	234
1895	94	10	0	5	15	8	117
1896	58	40	0	0	40	20	118
1897	73	38	0	0	38	19	130
1898	228	44	1	9	54	27	309
1899	208	14	0	3	17	9	234
1900	112	21	0	3	24	12	148
1901	29	17	0	0	17	9	55
1902	132	18	0	2	20	10	62
1903	95	13	0	1	14	7	116
1904	74	8	0	0	8	4	86
1905	93	8	0	0	8	4	105
1906	36	19	0	3	22	11	69
1907	70	15	0	2	17	9	96
1908	33	49	0	11	60	30	123
1909	10	28	0	6	34	17	61
1910	16	14	0	0	14	7	37
1911	30	12	0	0	12	6	48
1912	0	26	0	0	26	13	39
1913	0	15	0	0	15	8	23
1914	40	14	0	0	14	7	61
1915	0	14	1	0	15	8	23
1916	0	15	0	0	15	8	23
1917	0	23	0	0	23	12	35
1918	0	17	1	0	18	9	27
1919	16	11	0	0	11	6	33
1920	0	17	0	5	22	11	33
1921	0	6	0	0	6	3	9
1922	0	25	1	0	26	13	39
1923	0	7	0	1	8	4	12
1924	0	25	0	2	27	14	41
1925	0	33	0	2	35	18	53
1926	0	21	0	2	23	12	35
1927	0	7	0	2	9	5	14
1928	0	16	0	4	20	10	30
1929	0	17	0	3	20	10	30
1930	0	8	0	3	11	6	17
1931	0	19	0	2	21	11	32
1932	0	9	0	9	18	9	27
1933	0	5	0	9	14	7	21
1934	0	6	0	8	14	7	21
1935	0	8	0	2	10	5	15
1936	0	11	0	5	16	8	24
1937	0	32	0	3	35	18	53
1938	0	22	0	2	24	12	36
1939	0	12	0	0	12	6	18
1940	0	13	0	0	13	7	20
1941	0	23	0	2	25	13	38
1942	0	14	0	3	17	9	26
1943	0	7	0	2	9	5	14
1944	0	5	0	0	5	3	8
1945	0	12	0	3	15	8	23
1946	0	12	0	1	13	7	20
1947	0	14	0	0	14	7	21
1948	0	5	0	0	5	3	8
1949	0	7	0	0	7	4	11
1950	0	15	0	0	15	8	23
1951	0	15	0	0	15	8	23
1952	0	7	0	0	7	4	11
1953	0	27	0	0	27	14	41
1954	0	6	0	0	6	3	9
1955	0	24	0	0	24	12	36
1956	0	7	0	0	7	4	11
1957	0	3	0	0	3	2	5
1958	0	2	0	1	3	2	5
1959	0	1	0	0	1	1	2
1960	0	22	0	0	22	11	33
1961	0	11	0	0	11	6	17
1962	0	13	0	0	13	7	20
1963	0	10	0	0	10	5	15
1964	0	16	0	0	16	8	24
1965	0	9	0	0	9	5	14
1966	0	16	0	0	16	8	24
1967	0	8	0	0	8	4	12
1968	0	18	0	0	18	9	27
1969	0	21	0	0	21	11	32
1970	0	29	0	0	29	37	48
1971	0	23	0	0	23	3	25
1972	0	41	0	1	42	3	44
1973	0	40	0	2	42	15	50
1974	0	23	0	3	26	28	40
1975	0	17	0	2	19	26	32
1976	0	57	0	0	57	35	75
1977	0	32	0	0	32	79	72
1978	0	12	0	0	12	5	16
1979	0	12	0	0	12	15	23
1980	0	15	0	0	15	15	26
1981	0	17	0	0	17	9	24
1982	0	8	0	0	8	11	16
1983	0	9	0	0	9	9	16
1984	0	12	0	0	12	13	22
1985	0	11	0	0	11	6	16
1986	0	20	0	0	20	8	26
1987	0	20	0	0	20	9	27
Total	18,684	1,954	6	201	2,161	1,231	21,842

Appendix 6

PROPOSAL FOR INITIAL WORK TOWARDS ESTIMATION OF JUVENILE MORTALITY RATE IN NORTH PACIFIC HUMPBACK WHALES

Although it is assumed that juvenile mortality rate is higher than adult mortality rate in cetaceans, there are no reliable estimates of the parameter for any large whales species. The proposal below describes initial work needed for obtaining a direct estimate of calving mortality for North Pacific humpback whales. It originally appeared in SC/40/Rep1 Annex I.3.

Over 580 adults and 260 humpback whale calves have now been identified on the breeding grounds in Hawaii from 1975 to 1988, on the basis of underwater photographs of body patterns. Most workers in the North Pacific use fluke photographs to identify individual whales and the major research groups on both the breeding and feeding grounds have contributed their fluke photographs to the US Marine Mammal Laboratory (NMML) centralised fluke photograph collection (SC/A88/ID11).

Although fluke photographs exist for many of the cows and calves identified from their body patterns, these have not yet been analysed and cross-correlated, apart from the two years 1984 and 1985.

If these data can be worked up and included in the NMML system, then a direct estimate of mortality in about the first six months of life (i.e. up to weaning) should be obtainable by comparing information from the breeding and feeding grounds. Problems of changing fluke patterns in the first two years of life (SC/A88/ID35) may preclude estimation of later juvenile mortality. The major objective of this proposal is to enable a large additional set of cow/calf data to be encoded into the NMML system for future analysis.

Although this proposal concerns the major body of cow/calf data from the breeding grounds, it will not in itself allow estimation of calf mortality. The overall success of the study is dependent on the synthesis of data from the many contributors to the NMML system, and the collaborative analysis of data from the breeding and feeding areas. It is expected that the collaborative work could be organised within eight months after completion of this preliminary work. It should also be remembered that the working up and coding of these data onto the NMML system will allow further collaborative work on the estimation of other parameters than calf mortality (e.g. calving interval, age at first parturition).

Researchers

(a) Analysis of photographs

D. Glockner-Ferrari and M. Ferrari – Center for Whale Studies, 1728 Osan Luis Road, Walnut Creek, CA 94596, USA.

(b) Encoding of photographs onto the MML System

S. Mizroch, National Marine Mammal Laboratory, Seattle, WA 98115, USA.

Work Programme

(a) First month

Preparation and processing of photographs from the years 1975–83 and 1986–88.

(b) Next six months

(i) Analyse available underwater and fluke photographs to identify individual animals, concentrating on cow/calf pairs.
(ii) Cross-correlate body pattern and fluke photographic collections.
(iii) Tabulate resighting histories.
(iv) Submit photographs to the NMML.

(c) Final 4 months

Encoding photographs on the NMML computerised matching system. Cross-matching new fluke photographs to those already in the system.

Budget

Steps (a) and (b) combined will cost £7,500 and step (c) £2,500, bringing the total cost to £10,000.

Annex H
Report of the Sub-Committee on Small Cetaceans

Members: Amos, Anganuzzi, Aurioles, Balcomb, Bannister, Best, Bjørge, Broadhead, Brownell, Buckland, Cawthorn, Collet, da Silva, DeMaster, Goodall, Hall, Hammond, Heyning, Holt (R.), Holt (S.), Hoelzel, Horwood, Inagaki, Jones, Joyce, Kasuya, Kato, Leatherwood, Lens, Lockyer, Martin, Mate, Mead, Misaki, Miyashita, Moore, Morimoto, Nakamura (T.), Pallsbøl, Perrin (Convenor), Pitman, Puddicombe, Reilly, Sanpera, Scott (G.), Scott (M.), Smith, Swartz, Vidal, Vikingsson, Whitehead.

1. ELECTION OF CHAIRMAN

Perrin was elected Chairman.

2. APPOINTMENT OF RAPPORTEURS

Balcomb, Heyning and Mead acted as rapporteurs for the sessions on beaked whales. Buckland, Reilly, Collet and G. Scott also served as rapporteurs.

3. ADOPTION OF AGENDA

The Agenda adopted is given in Appendix 1.

4. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS

The sub-committee considered documents SC/40/SM1–23 and the national progress reports. SC/40/O 9–13, 15, 16, 21, 22, 28–31, 37–39 and SC/40/Mi18 also contained information on small cetaceans.

5. REVIEW OF POPULATION BIOLOGY AND EXPLOITATION OF BEAKED WHALES, ZIPHIIDAE

5.1 Berardius bairdii

5.1.1 Distribution and stock identity

The overall distribution of Baird's beaked whale is limited to the North Pacific Ocean and adjacent seas. Kasuya (SC/40/SM8) reported on the distribution of Baird's beaked whales in the western North Pacific, Sea of Japan and the Sea of Okhotsk as determined from whale sighting cruises made during 1982–1987. Each of these areas is probably inhabited by a separate stock or population, as the whales occur concurrently in summer and autumn months along the Pacific coast of Japan (Jun-Sep: Omura *et al.*, 1955; SC/40/SM8), in the Sea of Japan (Jun-Aug: Omura *et al.*, 1955; Oct: Nishimura, 1970) and near ice floes in Soviet waters of the Okhotsk Sea (April/May, Dec: Fedoseev, 1985). The whales are not known to transit the relatively shallow straits between the regions or to enter the East China Sea (Yang, 1976; Zhou, 1986). The Pacific coast stock probably inhabits continental slope waters between the fronts of the Kuroshio and Oyashio Currents, north of about 34°N. The mid-winter distribution of the putative stocks is unknown.

There is no recent information available about Baird's beaked whales around the Kurile Islands, but Sleptsov (1955) reported the species from the Kamchatka Peninsula and the western Bering Sea along the ice edge as far north as Cape Navarin (65°N) in summer months. Strandings have been reported from the Commander Islands and St. Matthew Island in the Bering Sea as well as the Aleutian Islands and Siberia (SC/40/SM21). The whales from this region may represent yet another stock or population.

The eastern North Pacific stock (or stocks) of this species occurs in summer and autumn from Alaska (SC/40/SM21) and Vancouver Island to as far south as the tip of Baja California (23°N) (SC/40/SM13; SC/40/SM14).

Ohsumi (1983) mapped the distribution of Baird's beaked whales across the mid–latitudes of the entire North Pacific Ocean (with notable densities near the Emperor Seamount Chain and north of Hawaii) from sightings reports of Japanese whale scouting ships. However, accuracy of the identifications has been called into question and there is no way to confirm them. Kasuya reported that the Japan Fisheries Agency will send four vessels to the North Pacific for two months this summer (1988), to survey for all marine mammals between 3°N and 45°N across the entire ocean from Japan to North America. The sub–committee looks forward to seeing the report of these surveys, to resolve, in part, whether Baird's beaked whales are in fact distributed in oceanic waters far offshore.

The distributional evidence to date indicates that *Berardius bairdii* is a cold-water deep-diving species that has good potential for separate stocks and populations in the regions mentioned. Amos and Hoelzel noted that if so, recently developed molecular methods may shed light on stock identity.

5.1.2 Abundance

Miyashita (1985) calculated an abundance estimate of 4,220 for the western North Pacific population of Baird's beaked whale from sightings data. The CPUE data do not show a clear annual trend from 1947 to 1983 (SC/36/SM14), so it is not known if the population is diminishing or stable. Kasuya noted that in addition to the expanded general surveys for marine mammals mentioned in 5.1.1, there will be another vessel conducting dedicated surveys for Baird's beaked whales and pilot whales in Japanese coastal waters this summer (1988). The sub-committee looks forward to receiving the results of those surveys at its next meeting, to re-examine population size of the western North Pacific stock. There are insufficient data available for any of the other putative stocks to allow estimation of abundance.

5.1.3 Migration

SC/40/SM8 stated that the results of sightings cruises made during 1982–87 supported the conclusions of Omura *et al.* (1955) that Baird's beaked whales leave the Pacific coast of Japan in winter months. The Sea of Japan stock may possibly remain isolated there during all seasons. The Okhotsk Sea stock apparently inhabits waters near Hokkaido in late spring and fall and retreats to the north during the summer months. Its winter distribution is unknown, but Kasuya noted that some of these whales may migrate to the east of the Kuril Islands in winter when the southern Okhotsk Sea is filled with ice. As noted by Fedoseev (1985), others may remain in small open leads in the northwestern Okhotsk Sea in winter months. Dohl (1983) reported from aerial surveys along the California coast that Baird's beaked whales were present along the continental slope in summer and fall but absent in winter, a seasonal pattern which is similar to that found in the western Pacific.

5.1.4 Life history

SC/40/SM7 reported on the biological examinations of 135 Baird's beaked whales taken in 1975 and 1985–1987 in a fishery on the Pacific coast of Japan. As Omura *et al.* (1955) and Nishiwaki and Oguro (1971) had noted, the catches are primarily of sexually mature males. From examination of layers in the tooth cementum, it was determined that males attain sexual maturity at 6–10 GLGs (growth layer groups – Perrin and Myrick, 1980) at a length of about 9.1 to 9.7m, and females attain sexual maturity at 10–14 GLGs at a length of 9.8 to 10.6m. One GLG likely equals one year (Kasuya, 1977). The sex ratio of juvenile whales in the catch is approximately 1:1, but for whales with over 20 GLGs it is strongly biased toward males. There does not seem to be obvious differential catchability of males and females that could explain this imbalance in catch, although it could be due to behavioural factors, such as adult males swimming peripherally in the school. The oldest female had 54 GLGs and the oldest male 84, with a correspondingly unusual age distribution suggesting a significantly higher mortality rate in females. The sub-committee discussed the significance of a higher female mortality rate for this species and was unable to explain it, while noting that SC/40/SM22 reported a similar situation in *Ziphius cavirostris* from stranded specimens. Aurioles (1987) reported a similar distribution in a mass stranding of seven Baird's beaked whales near La Paz, B.C., Mexico. The annual pregnancy rate for adult females has been estimated at 0.30, and the ovulation rate at 0.47.

Prey items include benthic fishes (Moridae and Macrouridae) and cephalopods (Omura *et al.*, 1955; Nishiwaki and Oguro, 1971; and SC/40/SM16), which indicates deep-water feeding in the western Pacific. Rice (1963) reported macrourid fish from *B. bairdii* taken off central California. The diet of these whales in the shallow waters of the northwest Okhotsk Sea is not known. Baird's beaked whales are heavily parasitised internally in the stomach, liver, blubber and kidney with extensive tissue pathology noted in the latter due to the nematode *Crassicauda giliakiana* (SC/40/SM15).

5.1.5 Exploitation

See Table 1 for Japanese catches. Small numbers were also taken at various land stations along the US and Canadian coast in the eastern Pacific.

Table 1

Catches of Baird's beaked whales by small-type whaling off Japan (*Rep. int. Whal. Commn* 33: 633 and ProgReps Japan)

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1948	76	1958	229	1968	117	1978	36
1949	95	1959	186	1969	138	1979	28
1950	197	1960	147	1970	113	1980	31
1951	242	1961	133	1971	118	1981	39
1952	322	1962	145	1972	86	1982	60
1953	270	1963	160	1973	32	1983	37
1954	230	1964	189	1974	32	1984	38
1955	258	1965	172	1975	46	1985	40
1956	297	1966	171	1976	13	1986	40
1957	186	1967	107	1977	44	1987	40

5.1.6 Status

The CPUE data for the Western Pacific do not show a clear annual trend from 1947 to 1983 (SC/36/SM14), so it is not known if that population is diminishing or stable. The Government of Japan sets an annual national quota on the harvest of this species of 40. The whaling industry has divided this into 35 in the western Pacific and 5 in the Okhotsk Sea.

5.2 Berardius arnuxii

5.2.1 Distribution and stock identity

Joyce reported on sightings of Arnoux's beaked whales during IDCR cruises in Antarctic waters from 1978/9–1987/8. This species was seen in Antarctic Areas II, IV, V and VI, but it was noted that in earlier cruises some sightings may have been simply logged as 'unidentified ziphiid' or not logged at all. Balcomb noted that he had plotted sightings in Southern Hemisphere waters from logbook entries of Japanese whale scouting ships before 1975 (kindly provided by Ohsumi); but, as with the sightings data for the species' North Pacific congener, there may be some question as to the accuracy of some of the identifications. Goodall and SC/40/SM23 provided data on strandings of Arnoux's beaked whale from all southern continents, noting that they have tended to cluster around New Zealand (perhaps reflecting effort). The conclusion from sightings and strandings is that the species is circumpolar in distribution, occurring throughout the Southern Hemisphere in cool temperate, sub-Antarctic and Antarctic waters. The northernmost stranding was at 34°S in South Africa, and the southernmost was at 64°S on the Antarctic Peninsula (Godoy and Goodall, pers. comm.). Sightings of these whales have been made very near the ice edge and amongst ice floes in the Antarctic pack. Some have been known to become entrapped in pack ice (Taylor, 1957).

The largest male reported was 960cm long and the largest female of confirmed length 885cm. Both were mature and smaller than typical specimens of mature *B. bairdii* (SC/40/SM23). It has been suggested that this species is conspecific with *B. bairdii* (McLachlan *et al.*, 1966; Ross, 1984).

5.2.2 Abundance

Nothing is known about the absolute abundance of Arnoux's beaked whales, but Kasamatsu *et al.* (1988) noted that they are significantly less common than southern bottlenose whales (*Hyperoodon planifrons*).

5.2.3 Migration
Nothing is known about migration.

5.2.4 Life history
Nothing is known about the life history of Arnoux's beaked whales. Kasamatsu *et al.* (1988) and Balcomb reported that the species is often gregarious and has been seen in groups numbering up to about 80 individuals. There was a mass stranding of four animals in Hawke's Bay, New Zealand. According to SC/40/SM23, most strandings have been in summer. The life history of this species is presumably similar to that of *B. bairdii*, taking into account its smaller size (Mead, 1984).

5.2.5 Exploitation
Arnoux's beaked whales are not presently commercially taken in any directed fisheries, nor have they ever been taken in any significant numbers (Brownell, 1974).

5.2.6 Status
No information.

5.3 Hyperoodon ampullatus

Unless otherwise referenced, the information below for *Hyperoodon* spp. is abstracted from Mead (in press).

5.3.1 Distribution
Northern bottlenose whales are distributed in the North Atlantic from Nova Scotia to about 70°N in Davis Strait, along the east coast of Greenland to 77°N and from England to the west coast of Spitzbergen. There is a single record from the White Sea. In the North Sea, strandings have been reported from Belgium, Denmark, France and England. There are a few records from the Mediterranean. In the western Atlantic, there are two main centres of distribution, one in the area called 'The Gully' just north of Sable Island, Nova Scotia and the other in Davis Strait off northern Labrador. Strandings have been reported from as far south as Rhode Island. This is a deep-water animal, usually inhabiting waters more than 2,000m deep.

Sightings from the North Atlantic are presented in SC/40/O 9, 11, 15 and 29.

5.3.2 Abundance
A recent line-transect survey yielded preliminary estimates of 3,142 bottlenose whales off Iceland and 287 off the Faroe Islands (SC/40/O 30). Vikingsson reported that allowance was not made in the survey for animals missed due to long dives.

5.3.3 Migration
There is evidence from the distribution of catches that a northward migration occurs in the eastern Atlantic in April-July. The southward migration begins in July and continues to September.

5.3.4 Life history
Length at birth is about 350cm. Asymptotic length in males of about 850–900cm is reached at about 20 GLGs and in females of about 750cm at about 12 GLGs. One GLG is assumed to correspond to one year in this species. Fifty-three females from Labrador ranged in age from 1 to 50 GLGs; 75 males ranged from 1 to 37 GLGs. Modal age in adults was 12 GLGs for females and 16 for males. Maximum recorded age is 27 (?) GLGs for females and 37 for males.

Minimum lengths of sexually mature animals (n=5,224) were 600cm for females and 730cm for males. Mean length at attainment of sexual maturity was 690cm in females and 750cm in males. Minimum age at sexual maturation has been estimated at 7 GLGs in both sexes, with the average at 11 GLGs in females and 7–11 GLGs in males. Average mature testis weight is about 600g; the maximum recorded was 2,600g for both testes combined.

Gestation is estimated at 12 months. Lactation is estimated to last at least one year. The mean calving interval is estimated to be two years. The largest recorded foetus was 360cm long and the smallest calf 350cm. Calving takes place in the spring.

The bottlenose whale feeds on deep-living squids and fishes; an extensive list of taxa recorded from stomach contents is given in Mead (in press).

5.3.5 Exploitation
The Norwegian fishery can be divided into two periods: 1882 to 1920s, and 1930s to 1973. The catches during the first period have been estimated at 72,000. When the modern period began, a government licence was required, and more exact records were kept; a total of 5,043 whales were taken during the period 1938–1969. The fishery closed in 1973 when only 3 whales were caught. The peak annual catch during the modern period was 700. A small fishery operated out of Nova Scotia and took 87 whales in 'The Gully' during the period 1962–67.

5.3.6 Status
The minimum initial population has been estimated at about 28,000. The consensus is that the aggregate North Atlantic population is depleted, but there is disagreement about the degree of depletion (Holt, 1977). The stock(s) were classified as a provisional Protected Stock in 1977. The species is currently classified as 'Vulnerable' by the IUCN.

5.4 Hyperoodon planifrons

5.4.1 Distribution
The southern bottlenose whale has a wider distribution than that of *H. ampullatus*; it occurs in the entire Southern Ocean and north to about 30° S. It is possible that some sighting records involve misidentifications, as it is difficult for non-experts to distinguish between this species and *Berardius arnuxii*. R. Best *et al.* (1986) recently reported a sighting in November of 5 animals which they referred to the species at 5°42'S and 34°1'W (off northeast Brazil). Due to the extremely low latitude of this sighting, particularly when compared to the next most northerly record (the type specimen, at 20°S), there is some doubt about the identification.

SC/40/O 22 reported 10 sightings of 35 individuals in the area bounded by 30-40°S and 70–100°E from February to March, 1988. Joyce presented a summary of 407 sightings from IDCR cruises in 1978–1987. Goodall reported several new stranding records for South America.

5.4.2 Abundance
There is no population estimate. Joyce reported that it was the ziphiid most often sighted during the IDCR cruises. It was sighted about as often as Gray's beaked whale, *Mesoplodon grayi*, in the Indian Ocean north of 40°N (SC/40/O 22).

5.4.3 Migration

No information.

5.4.4 Life history

The maximum size reported in the literature for males is 694cm and for females 745cm. Goodall reported larger specimens of both sexes: a 714cm male with 50+ GLGs and a female of 750cm. She also reported an age of 37 GLGs for a 576cm female. A 780cm female contained a 185cm fetus (Baker, 1983). A 570cm female was lactating (Zemskii and Budylenko, 1970). A calf of 291cm had fetal folds (Ross, 1984).

Stomach contents of nine specimens included remains of squid of several families (Clarke, 1986) and krill (which may have been eaten by the squid).

5.4.5 Exploitation

Although there has been no fishery for the southern bottlenose whale, a few have been taken by pelagic whalers for research purposes (Tomilin and Latyshev, 1967; Zemskii and Budylenko, 1970).

5.4.6 Status

No information.

5.5 ? Hyperoodon sp.

Evidence has grown concerning the existence in the tropical Pacific of a beaked whale of unknown identity that is likely to prove to be a species of *Hyperoodon* (Leatherwood *et al.*, 1982). Two papers presented at this meeting dealt with this problem: SC/40/SM9 and SC/40/SM14. The consensus of the members of the sub-committee is that the whale is *H. planifrons* or may prove to be a new species. The records of *H. planifrons* from northwestern Australia (Flower, 1882) and from Brazil (Gianuca and Castello, 1976) make it plausible that the unidentified whale in the tropical Pacific could be of this species. However, considering that this is either a most remarkable range extension for a reputedly antitropical genus or even possibly an undescribed species of ziphiid of a different group, the sub-committee **recommended** that an attempt be made to collect two adult specimens (a male and a female) in the western Pacific. The possibility of collecting biopsy materials for molecular studies was also raised, but there would likely be difficulty in collecting a sufficient number of samples from both the Antarctic and the western Pacific to resolve the identity of these whales. If such studies suggested differences, specimens would still be needed for taxonomic analysis and type material.

5.5.1 Distribution

SC/40/SM9 reported eight sightings of a total of about 280 individuals on the equator at 166°W (central tropical Pacific) and in the western North Pacific in the area bounded by 130–142°E and 20–34°N. SC/40/SM14 reported 7 sightings in the area bounded by 80–170°W and 5°N – 15°S, with a concentration in the area 90–120°W and 5–15°N during 1965–88.

5.5.2 Abundance

SC/40/SM9 did not give numerical relative abundance of this species but implied that it was relatively rare. SC/40/SM14 reported that the species is rare, being involved in only 7 of 946 sightings of ziphiids.

5.5.3 - 5.5.6

There is nothing known concerning migrations, life history, exploitation or status.

5.6 Ziphius cavirostris

5.6.1 Distribution and stock identity

Cuvier's beaked whale is known from strandings along most coasts and many oceanic islands within all ocean basins (Heyning, in press). Strandings occur from tropical to sub-polar waters. Sightings data from the eastern tropical Pacific (SC/40/SM14) indicate that the species is found offshore to beyond the continental slope in this region.

Due to the wide geographical range and extreme sexual dimorphism in the skulls of *Z. cavirostris*, there are numerous synonyms in the literature (Hershkovitz, 1966; Heyning, in press). Although most of the variation observed in skulls is regarded as sexual dimorphism and/or individual variation, no comprehensive study has been done. Mitchell (1968) examined skeletal material from the northeast Pacific and believed that there are no separate stocks in that region.

5.6.2 Abundance

There are no abundance estimates for any region. Stranding data from the Northern Hemisphere indicate that strandings of *Z. cavirostris* are about as frequent as the strandings of all other ziphiid species combined (SC/40/SM21). Data from the eastern tropical Pacific (SC/40/SM14) suggest that sightings of *Z. cavirostris* are about as frequent as sightings of all species of *Mesoplodon* combined in that region. *Z. cavirostris* is the most frequently sighted medium-size cetacean within this region.

5.6.3 Migration

There is no information on migration for this species. Stranding and sighting data should be further analysed for seasonal trends in geographical distribution.

5.6.4 Life history

Life history data for this species are discussed in SC/40/SM22 and SM23. The maximum lengths recorded from precisely measured specimens are a 660cm female (Nicol, 1987) and a 693cm male. Contrary to prior published reports (Omura *et al.*, 1955), there seems to be no significant sexual dimorphism in adult size for this species (Heyning, in press).

Based on limited data, males seem to become sexually mature at about 11 GLGs in the dentine. The shortest sexually mature specimen was 526cm long and was also physically mature. The testes of sexually mature males are about 20cm in length and weigh from 150 to 372g each. The testis weights reported by Omura *et al.* (1955) seem an order of magnitude too large when compared to other data from *Z. cavirostris* and other ziphiid species of similar size. There is less reproductive information for females. The shortest sexually mature female was 512cm long. Males reach an age of up to 47 GLGs, but females attain an age of only 28 GLGs. The difference is not due to readability of layers. This vast difference in age between males and females cannot be easily explained, but the phenomenon also occurs in *Hyperoodon ampullatus* (Benjaminsen and Christensen, 1979) and in *Berardius bairdii* (SC/40/SM7). Additional specimens of *Ziphius* need to be aged to determine if the great difference in ages of males and females is general.

In the eastern tropical Pacific, pods range in size from one to seven individuals, with most sightings of four or fewer individuals; there are two records of mass strandings for this species (Heyning, in press).

5.6.5 Exploitation

The Japanese formerly took *Z. cavirostris* in small-type whaling (Omura *et al.*, 1955; Nishiwaki and Oguro, 1972). This take has largely ceased, but Kasuya reported that an occasional animal may be taken. A few *Z. cavirostris* were taken in the former small cetacean fishery off the Lesser Antilles island of St Vincent (Caldwell *et al.*, 1971). There is no systematic direct take of *Z. cavirostris* at this time. Animals may be taken incidentally in offshore fisheries, but there are no data for this.

5.6.6 Status

No information.

5.7 Mesoplodon spp.

It was suggested that species within this group be discussed in a comparative manner because there are few data on any one species and because such factors as taxonomy and pigmentation (SC/40/SM6) are more usefully covered in an overall review. Review of most of the current knowledge regarding biology can be found in Mead (1984) and Ross (1984). The species *M. pacificus* is herein retained in the genus *Mesoplodon*, not separated into the monotypic genus *Indopacetus* Moore, 1968. It is felt that until the entire genus is reviewed, no single species should be removed.

5.7.1 Distribution and stock identity

The distributions of various species of *Mesoplodon* are summarised for the Northern Hemisphere in SC/40/SM21 and for the Southern Hemisphere in SC/40/SM23. Identification of *Mesoplodon* to species at sea is difficult and seldom made, especially in the Northern Hemisphere, because the pigmentation patterns are less distinctive than for many Southern Hemisphere species. Therefore, the known distributions of the species are based almost exclusively on stranding records.

M. bidens – Sowerby's beaked whale is endemic to the North Atlantic, with the majority of strandings occurring around the British Isles. A few records are available from the northwestern Atlantic that might be records of strays, and one record from the Gulf of Mexico clearly is of a stray individual.

M. bowdoini – Andrew's beaked whale is known from about twenty specimens from the Southern Hemisphere, primarily from strandings in Australia and New Zealand. The species may be conspecific with *M. carlhubbsi*, which would give the species an antitropical distribution.

M. carlhubbsi – If Hubbs' beaked whale is distinct from *M. bowdoini*, then it is endemic to the North Pacific, with the majority of strandings occurring from British Columbia to southern California.

M. densirostris – Blainville's beaked whale seems to be distributed in tropical and warm temperate waters of all oceans. Strandings are most frequently recorded along the east coast of the United States, but stranding collection effort is also high in this region. *M. densirostris* is occasionally sighted in the eastern tropical Pacific (SC/40/SM14).

M. europaeus – Although the type specimen of Gervais' beaked whale was recorded from the English Channel, the overwhelming number of strandings are from the southeastern United States and the Caribbean region. There are records of three specimens from the Ascension Islands in the South Atlantic.

M. ginkgodens – This relatively rare species of *Mesoplodon* is known from nine strandings in the North Pacific in warm temperate and tropical waters and one stranding in the South Pacific in the Chatham Islands. Three specimens of the ginkgo-tooth beaked whale were also taken in Chinese waters (Nishiwaki *et al.*, 1972).

M. grayi – Gray's beaked whale has a circumpolar Southern Hemisphere distribution that ranges from 30° to at least 53°S. Approximately half of the recorded strandings were along the coast of New Zealand. There is one record of a *M. grayi* stranded on the coast of the Netherlands.

M. hectori – Most of the strandings of Hector's beaked whale have occurred in cold-water regions of the Southern Hemisphere (Mead and Baker, 1987), but four strandings occurred along southern California beaches in the late 1970s (Mead, 1981) and may represent a small stray group. Some additional information on recent strandings, including a mass stranding of four animals, was presented (SC/40/SM18).

M. layardii – The strap-toothed whale has a distribution in cooler waters of the Southern Hemisphere that resembles the distribution of *M. grayi*. It is the most commonly stranded species of *Mesoplodon* in the Southern Hemisphere and second only to *M. bidens* worldwide. In Tierra del Fuego, strandings of *M. layardii* consist primarily of adults, whereas strandings of *M. grayi* include young animals (SC/40/SM19).

M. mirus – True's beaked whale was previously believed to be endemic to the North Atlantic, but is now known from several strandings in the Southern Hemisphere. In the western North Atlantic, this species ranges from the Bahamas to Nova Scotia. In the northeast Atlantic most strandings occur along the British Isles and in the Bay of Biscay. Southern Hemisphere strandings include specimens from South Africa, Australia and New Zealand. Slight cranial and pigmentation differences between the North Atlantic and Southern Hemisphere specimens have been documented and discussed by Ross (1984). These differences suggest that the two groups are distinct breeding populations.

M. pacificus – Longman's beaked whale is known from two skulls, one from Australia and one from Somalia. Based on this, an Indopacific distribution is suggested.

M. stejnegeri – Stejneger's beaked whale is endemic to the North Pacific and is recorded from the Sea of Japan and along the Aleutian Islands to the coast of North America from Alaska south to southern California. The majority of strandings occur in the northern part of the range where it is not sympatric with *M. carlhubbsi*.

The unidentified species of *Mesoplodon* that has been sighted in the eastern tropical Pacific (Pitman *et al.*, 1987; SC/40/SM13 and 14) was discussed in detail. It was suggested that the basic colour pattern is similar to that of *M. layardii* (SC/40/SM21). Photographs of the unidentified species were compared with those of known *M. layardii* specimens from the Southern Hemisphere. It was concluded that although the basic pattern was similar, the differences are too great to consider the unidentified species to be *M. layardii*. The colour pattern of the unidentified species is not identical to that of any known species of ziphiid for which the colour pattern is known (the external appearance of *M. pacificus* is unknown).

5.7.2 Abundance

There are no data on absolute abundance for any species of *Mesoplodon*. The little relative abundance data available have been discussed in the above distribution section.

5.7.3 Migration

There is little or no good information to support or refute any migration pattern for any species of *Mesoplodon*.

5.7.4 Life history

There is very little life history information for any species of *Mesoplodon*. Most of the current information was summarised by Mead (1984) for all species and by Ross (1984) for those occurring in South African waters. The most information for any one species is for *M. carlhubbsi* (Mead *et al.*, 1982). Unless otherwise stated, all information in this section is from these papers.

M. bidens – Adult males may attain a length up to 550cm and females 505cm. The length at birth is about 240cm.

M. bowdoini – The largest specimens were a 457cm female and a 467cm adult male (SC/40/SM23).

M. carlhubbsi – The largest specimens of both sexes were 532cm in length. Calves are about 250cm long at birth, and the calving season is early summer (Mead *et al.*, 1982; Heyning, unpublished data). The mean testis weight of a 496cm sexually mature male was 250g.

M. densirostris – The maximum lengths recorded are for a 473cm male and a 471cm female. Calves are probably less than 240cm long at birth. The oldest physically immature male had 7 GLGs. The youngest physically mature female had 10 or 11 GLGs.

M. europaeus – The largest male was 520cm long and the largest female 456cm. Calves are about 210cm long at birth. The known maximum age for this species is 27 GLGs (Perrin and Myrick, 1980).

M. gingkodens – The maximum length reported for a female is 490cm and for a male 477cm. The maximum testis weight for a mature male was 140g (Nishiwaki *et al.*, 1972).

M. grayi – The largest female recorded was 533cm long and the largest male 564cm long. The shortest calf was 237cm long (Goodall and Baker, pers. comm.).

M. hectori – The largest male was 430cm long and the largest female 443cm. The shortest calf measured 210cm. The weight of a testis from a mature male was 116g. Two physically mature specimens (a male and a female) had nine GLGs in their teeth.

M. layardii – This is the largest known species of *Mesoplodon*. The males attain lengths up to 584cm and females 615cm. The shortest recorded calf was 250cm long (SC/40/SM20). McCann (1964) provided details on the reproductive tract of one female.

M. mirus – Females reach 510cm in length and males 533cm. Calves are about 233cm long at birth. The testis of a mature male weighed 170g. One South African female had 7 corpora in the right ovary and 6 in the left (Ross, 1984).

M. pacificus – This species is known from two skulls; thus there is no life history information available.

M. stejnegeri – The largest specimens of both sexes measured 525cm. The three known calves averaged about 245cm in length; they stranded at the southern edge of the range, two in California and one in Oregon (Heyning, unpublished data).

5.7.5 Exploitation

There are no known direct fisheries on any species of *Mesoplodon*. Rarely, some animals have been taken in small-type whaling (e.g. Nishiwaki and Oguro, 1972; Nishiwaki *et al.*, 1972). Some animals are incidentally taken in gillnet fisheries (Nishimura and Nishiwaki, 1964; Diamond *et al.*, 1987). The magnitude of this problem is unknown at this time.

5.7.6 Status

There are no data on the status of any species of *Mesoplodon*.

5.8 Tasmacetus shepherdi

5.8.1 Distribution and stock identity

Shepherd's beaked whale is found only in the Southern Hemisphere and seems to be associated with cooler waters from 33° to 50°S (SC/40/SM19 and 23). Best reported that there are now some specimens in South African museums.

5.8.2 Abundance

There is no information on abundance. However, because this species is only known from about twenty strandings and a few sightings (SC/40/SM23), it may be less abundant than some species of *Mesoplodon*.

5.8.3 Migration

There are no data on migration.

5.8.4 Life history

The largest female was 660cm long and the largest male 700cm (Mead, 1984). The female was sexually mature.

5.8.5 Exploitation

There are no records of direct or incidental takes.

5.8.6 Status

No information.

5.9 General recommendations

1. *Non-lethal research.* The sub-committee **recommended** that the new techniques for studying living cetaceans, such as individual indentification using natural marks, which have proven successful for larger whales, be encouraged for application to the beaked whales, particularly where there are reasonably consistent concentrations of a well-marked species for which concern exists about population size and stock identity (e.g. the northern bottlenose whale, *Hyperoodon ampullatus* in the North Atlantic). Whitehead reported that such studies of the species will begin soon in 'The Gully' off Nova Scotia.
2. *Effects of gillnets.* The sub-committee **recommended** that offshore gillnet fisheries should be monitored to determine the nature and extent of impact on beaked whales.
3. *Sampling catches.* The sub-committee **recommended** that, when possible, beaked whales taken in direct fisheries be examined thoroughly by biologists to collect data and samples that can be used to estimate life history parameters.
4. *Strandings.* Because information on life history is so sparse for most of the beaked whales, the sub-committee **recommended** that efforts be made to collect full suites of data and specimens for all stranded animals.

6. NEW INFORMATION ON OTHER STOCKS

6.1 Dolphins associated with tuna in the eastern tropical Pacific (ETP)

The Committee last year noted recent increases in levels of incidental mortality in the international tuna purse-seine fishery in the eastern Pacific and expressed concern over estimated substantial decline in stocks of three species that may have occurred in the period 1975 to the early 1980s (*Rep. int. Whal. Commn* 38: 51). The sub-committee recommended that detailed analyses of possible sources of bias in the abundance estimates based on data collected aboard commercial seiners be carried out and that indices of abundance based on US research-vessel surveys be reported to the Committee this year (*Rep. int. Whal. Commn* 38: 121). The sub-committee noted that documents submitted this year do address these questions and wishes to thank the members involved for this response. The sub-committee received the documents and discussed them briefly but did not conduct a substantive review of the issue. It **recommended** that such a review be carried out at a future meeting.

6.1.1 Estimates of mortality

SC/40/SM2 gave estimates of total incidental kill of dolphins for 1987. The total estimate based on kill-per-ton was 115,000. These levels are high, although they represent a 12–20% reduction over the previous year (*Rep. int. Whal. Commn* 38: 51). The number of sets on dolphins was 35% higher than in 1986, so that the kill-per-set declined. Reasons for this reduction are (1) there were lower average catches of tuna per dolphin set in 1987; (2) sets were slightly shorter on average; (3) the proportion of sets on common dolphins was smaller; (4) the percentage of night sets was down; (5) the proportion of sets with zero mortality was higher; (6) the average number of animals left in the net after backdown was smaller; and (7) the average group size encircled by the net was smaller.

It was noted that international participation in the observer programme operated by the IATTC has increased markedly. Observers were placed on board 45% of trips by fleets of all flags in 1987. The US policy was to attempt coverage of all US trips in 1987. The coverage of the US trips in the analysis was 86%; the final figure will be about 95%. The next highest was Mexico at 28%. During the first few months of 1988, observers were placed on 43% of both Mexican and US trips.

Hall suggested that mortality might be reduced substantially through better application of existing rescue gear and techniques. Further reduction of the kill would probably require development of new technology, and he expressed the hope that such research initiatives would be launched. The sub-committee **recommended** that such research be undertaken.

Concern was expressed about the comparability of mortality estimates over years. Estimates in recent years have been generated by three different methods, dictated by the data available. As coverage of the international fleet has improved, it has been possible to use more sophisticated methods. R. Holt reported plans to examine the different methods by subsampling the 1987 database, which covers almost all of the US trips.

It was also noted that kill estimates would be most useful for purposes of comparisons with estimates of abundance if they were calculated on a stock-by–stock basis. For example, the IATTC estimates for the offshore spotted dolphin are not stratified into estimates for the northern and southern stock units used in management and in estimation of abundance. The sub-committee **recommended** that the estimates be stratified by stock.

SC/40/SM1 tabulated the sex, length and reproductive condition of the dolphins examined by observers aboard the seiners. Only about one quarter of the observed kill was sampled. It was noted that several kills of over 50 animals occurred in single sets and that complete suites of life history from such large series would be extremely valuable in population analysis. The authors explained the logistical difficulties involved in dealing with such large samples. The sub-committee **recommended** that the level of biological sampling be increased, possibly by allocation of funds for returning the carcasses from large-kill sets to research facilities and for subsequent processing.

6.1.3 US sightings surveys

SC/40/SM12 presented relative abundance indices by stock based on a 1987 survey. R. Holt also provided a table of estimates from 1986.

The estimates were generated under a number of options. Some of these are expected to result in biased estimates of absolute abundance but may yield more reliable estimates of trends. Large differences were noted between estimates for the two years (e.g., under one set of assumptions, 1,257,300 offshore spotted dolphins in 1986 and 2,070,000 in 1987, a change much larger than could be accounted for by biological increase). R. Holt suggested possible explanations but considered them to be unsatisfactory. The group noted a reciprocal relationship between the estimates for spotted dolphins (given above) and those for common dolphins: 1.8 million in 1986 and 0.6 million in 1987. This may indicate that sampling offshore-spotted-dolphin habitat changed relative to the sampling of common-dolphin habitat in 1987. The tracklines were nearly the same in the two years, but the habitats may have shifted.

Pooled estimates, as defined in SC/40/SM12, appeared more stable than weighted estimates. The large differences noted may be a result of variances being underestimated, for example if dolphin schools occur in concentrations. It is possible that survey tracklines tend to hit or miss ridges of density, leading to correspondingly high or low estimates. It is also possible that many animals that are within the survey region in one season are outside in another, since in some years the tropical habitat is larger than in others due to temporary global climatic shifts.

If problems with the estimates are a result of forming of local concentrations of schools, greater sighting effort should solve the difficulty. For example, the southern region might be ignored, and more effort distributed over the northern region. However, the argument that animals may move between south and north seasonally would not then be adequately considered. Stratification by oceanographic features was discussed, but it was not considered feasible at present, especially on the micro-scale that may be required. Another possibility might be to have larger surveys in alternate years. A possible source of bias might be the use of better observers, on average, with more experience available in the second survey relative to the first. R. Holt noted that further investigative analysis would be carried out to assess the impact of factors such as this, sea state, etc. on the abundance estimates.

6.1.4 Indices of abundance from data collected on tuna seiners

SC/40/SM3 is a revision and update of Buckland and Anganuzzi (1988) which was reviewed last year. The study differs from the previous paper in that stratification procedures were introduced in the estimation of two additional parameters: average school size and f(0). In a manner similar to stratification of encounter rates (which was not changed from last year), school size estimates were computed for 1° squares and pooled into strata of similar magnitude. The overall estimates of average school size were made as weighted averages of the within-strata estimates.

The estimation of f(0) included consideration of three variables likely to have an effect on the detection function: fishing mode (dolphin or non-dolphin fishing); use of birds as cues; and use of helicopters to make initial sighting. These variables were combined by computing principal components from data pooled by 1° squares; component scores were assigned to each square. The stratification scheme was then applied to the component scores.

Two alternative area specifications were used: the areas defined in Buckland and Anganuzzi (1988) and somewhat smaller areas proposed by Au, Perryman and Perrin (1979 – also used in SC/40/SM12).

In general, the results are similar to those presented in Buckland and Anganuzzi (1988). Estimates for most stocks were slightly lower, with fewer significant trends indicated. The estimates were presented as provisional by the authors, pending computation of complete bootstrap standard errors and inclusion of additional data for 1987.

It was noted that inclusion of information regarding fishing mode, use of helicopters in searching and birds as sighting cues resulted in a marginal improvement in the reliability of the estimates and alleviated some of the concerns about bias expressed by the sub-committee last year.

There was discussion about relative differences and similarities between the results of this study and those of SC/40/SM12. It was noted that estimates for all stocks except northern offshore spotted dolphins were comparable, and in the tuna vessel estimates it is this stock for which the 1983 (El Niño) estimate is anomalously low. Estimates for eastern spinner dolphins, whose range is entirely contained within the survey areas in all analyses in all years, were least variable and showed no anomalous dip in 1983. There was consensus that environmental variation was the likely cause of the variation in estimates. Pitman noted that the 1983 El Niño resulted in the death of 15 million sea birds in the ETP and that birds of these species are frequently used as sighting cues. This could explain in part the lower sighting rate of 1983.

It was also suggested that redistribution of dolphins could be responsible for part of the inter-annual variation observed, both in the estimates in this study and the research vessel estimates reported in SC/40/SM12. Redistribution within the ETP was considered more likely than major shifts to areas outside of the known historical range.

6.1.5 Recommendation

The sub-committee was concerned that the mortality of dolphins of the three major species remains high when compared with the most recent estimates of absolute abundance (Holt and Powers, 1982) and **recommended** that every effort be made to bring it down and to assess its impacts on the stocks. An attempt should be made to produce updated estimates of absolute abundance.

6.1.6 UNEP/IATTC courses in Latin America

Hall reported that courses in marine mammal biology and assessment have been given in several countries in Latin America. The courses were directed at graduate students and others involved or likely to be involved in future in marine mammal research and management, including acting as scientific observers aboard commercial seiners in the tuna fishery. The IATTC organised the courses; funding was provided by UNEP. Several members of the sub-committee were involved as instructors or students; they stressed the high quality of the educational programme and its potential value to future conservation and management of dolphins and other marine mammals. The sub–committee endorses the effort and hopes that it will continue.

6.2 Other cetacean/fishery interactions

Da Silva reported that the Brazilian Foundation for the Conservation of Nature (FBCN) with funding from WWF-US carried out a survey of incidental catches in an artisanal gillnet fishery in Atafona in northern Rio de Janeiro State. The fishing grounds extend for some 80km along the coast in waters usually less than 16km from shore. The fleet comprises 91 boats crewed by 280 fishermen and fishes gillnets 4–13m deep × 110–2740m long with 14cm mesh. From June 1987 to April 1988, 55 dolphins of 5 species were caught: *Sotalia fluviatilis*, *Pontoporia blainvillei*, *Steno bredanensis*, *Delphinus delphis* and *Stenella* sp. The dolphins were used as bait in a longline fishery. The research was carried out by L. Lodi and L. Capistrano of FBCN.

6.3 Putative occurrence of Burmeister's porpoise in the Indian Ocean

A specimen of *Phocoena spinipinnis* reported from Heard Island in the subantarctic Indian Ocean is actually a specimen of the spectacled porpoise, *Australophocaena dioptrica* (SC/40/SM17); several members of the sub-committee have examined large series of both species, and the revised identification is certain. Thus *P. spinipinnis* remains a species endemic to coastal waters of southern South America (Brazil [SC/40/ProgRep Brazil], Argentina, Uruguay, Peru and Chile). The occurrence of *A. dioptrica* at Heard Island fits in well with its previously known broad distribution in sub-Antarctic and southern cold temperate waters.

6.4 Harbour porpoise

SC/40/SM5 reported the results of experimental line-transect surveys of harbour porpoises in an area of high density in the Bay of Fundy. Simultaneous surveys conducted by teams of observers on top of the pilot house and in the crow's nest yielded different results. Some possible causes are the greater area searched from the crow's nest, avoidance of the vessel by the porpoises, better sightability of porpoises viewed from the higher elevation, and differential distribution of sighting effort relative to the vessel's course. Hohn noted that harbour porpoises in the eastern North Pacific did not avoid survey vessels except at very close range. Suggestions from the group for improving survey methods included larger observer teams and assigned sighting sectors. The point was made that the situation in the Bay of Fundy offers a good opportunity for experimental development of line-transect methodology because of the very high density of harbour porpoises, which allows fitting of a density function to the data from a relatively short survey or survey leg. The sub-committee **recommended** that the possibilities for such work be considered by those involved in development and design of the IDCR minke whale surveys.

Bjørge reported that a programme of research on the harbour porpoise has been initiated in Norway this year. The three-year research programme is in cooperation with scientists from Sweden (SC/40/ProgRep Sweden), Denmark and the Federal Republic of Germany (SC/40/ProgRep FRG). The primary objectives of the Norwegian programme are to study reproduction and feeding habits. Stock identity will also be investigated. Samples will be collected from incidental gillnet kills and from strandings. A similar programme is under way in the Netherlands (SC/40/ProgRep Netherlands). Sightings of harbour porpoises in the North Atlantic were reported in SC/40/O 9 and 10, SC/40/O 29 and SC/40/ProgRep Netherlands. A pilot survey of harbour porpoises was conducted along the English North Sea coast in 1988 (SC/40/ProgRep UK).

6.5 White whales and narwhals

SC/40/SM10 dealt primarily with line-transect theory. While the group believes that the paper does not contain information on line-transect methodology that is not available elsewhere, they believe that the data on duration of dive in the white whale contained in the paper are new and valuable.

SC/40/SM4 discusses recent harvests of white whales in Alaska and contains data and assessments that the Committee has repeatedly recommended be provided (e.g. *Rep. int. Whal. Commn* 32: 59, 31: 67). The sub-committee concurred with the recommendation of the authors' that the estimates of abundance and harvests be refined and further work carried out on stock identity; the estimated removals of up to 6.7% are large enough to cause concern about their sustainability.

Sightings of white whales in the North Atlantic were reported in SC/40/O 9.

6.6 Pilot whales

SC/40/O 42 reported on the satellite tracking of a pilot whale re-introduced into the wild. The whale was located 479 times over a period of 95 days during which it travelled over 7,500km; time and depth data were collected for over 192,000 dives. The very large quantity of data collected provide an opportunity for modelling experimental design for tracking other small cetaceans and the large whales.

Sightings of pilot whales in the North Atlantic were reported in SC/40/O 9, 10, 11, 15, 29 and 39 and in SC/40/ProgRep Denmark.

6.7 Other species

New information was also received on a mass stranding of melon-headed whales, *Peponocephala electra*, in Brazil (SC/40/SM11); on sightings of North Atlantic killer whales (SC/40/O 9, 10, 15, 29, 30), whitebeaked dolphins (SC/40/O 9, 10), white-sided dolphins (SC/40/O 10, 29), common dolphins (SC/40/O 15, 29, 39), bottlenose dolphins (SC/40/O 15, 29, 39), Risso's dolphins and false killer whales (SC/40/O 39), and *Stenella spp.* (SC/40/O 15, 29, 39); on eastern North Pacific killer whales (SC/40/O 31); on sightings of Dall's porpoise (SC/40/O 37; on molecular genetics of several small cetaceans (SC/40/O 40); on the possible causes of mass strandings (SC/40/O 13); on sightings, strandings and exploitation of several small cetaceans in South America (SC/40/ProgReps Argentina and Brazil). Much additional information on sightings and strandings of small cetaceans and on national research programmes was included in the various national progress reports (see Item 4). A great increase (two-or threefold) in the incidence of strandings, mostly of common dolphins, was reported for the French coast (SC/40/ProgRep France). The causes of this are unknown. An unexplained mass mortality of over 700 bottlenose dolphins occurred along the US east coast (SC/40/ProgRep US); the cause is under study.

7. OTHER BUSINESS

7.1 Takes of small cetaceans in 1987

Takes are summarised in Appendix 3.

7.2 UNEP meeting on small cetaceans

A small working group was set up to consider the UNEP meeting. The sub–committee received the group's report (Appendix 2) and **recommended** that the IWC cooperate in organising and conducting the meeting.

7.3 Nomenclature

The sub-committee notes the general acceptance in the taxonomic community of the change from *Globicephala melaena* to *Globicephala melas* (*Rep. int. Whal. Commn* 39: 117) and the placement of *Phocoena dioptrica* in a new genus *Australophocaena* (*Rep. int. Whal. Commn* 39: 122) and **recommended** that the Committee's 'List of Recognised Species and Common Names' be amended accordingly.

7.4 ICES

Bjørge reported that the ICES Marine Mammals Committee recently discussed the benefits of all member nations collecting and reporting data on strandings and incidental takes of small cetaceans.

7.5 Publication of documents

The following documents are recommended for possible publication in a special volume on beaked whales: SC/40/SM6, 7, 8, 9, 13 (possibly partially combined with 14 and/or 21), 14, 15, 16, 18 (in part), 19, 20, 21, 22 and 23. Other papers developed from working papers of the meeting will be included in the volume. Additional papers on life history, status and exploitation of the northern bottlenose whale will be solicited from I. Christensen, E.D. Mitchell and R. Reeves. A list of other papers recommended for publication in *Rep. int. Whal. Commn* 39 was submitted to the Editorial Board.

7.6 Priority topics for 1989 meeting

The sub-committee proposed to review the biology and status of phocoenid populations in 1989. The group will also note and discuss briefly new information on other exploited stocks and species.

REFERENCES

Au, D.W.K., Perryman, W.L., and Perrin, W. 1979. Dolphin distribution and the relationship to environmental features in the eastern tropical Pacific. Southwest Fish. Cent. Admin. Rep. LJ-79-43, 59pp.

Aurioles, D. 1987. Stranding of seven Baird's beaked whales in the southeastern Gulf of California. Abstract, Seventh Biennial Conference on the Biology of Marine Mammals, 5–9 December 1987, Miami, Florida, USA.

Baker, A.N. 1983. *Whales and Dolphins of New Zealand and Australia. An identification guide.* Victoria University Press, Wellington. 133pp.

Benjaminsen, T. and Christensen, I. 1979. The natural history of the bottlenose whale, *Hyperoodon ampullatus* Forster. pp. 143–64 *In:* H.E. Winn E. and B. L. Olla (eds). *Behavior of Marine Mammals.* Plenum Press, New York. xix + 438 pp.

Best, R.C., da Rocha, J.M. and da Silva, V.M.F. 1986. Registro de pequenos cetaceos na costa nordeste Brasiliera. Actas, Primera Reunion de Trabajo de Expertos en Mamíferos Acuáticos de América del Sur, pp. 23–32.

Brownell, R. L. 1974. Small odontocetes of the Antarctic. pp. 13–19, pls. 8,9,11. *In*: S. G. Brown, R. L. Brownell, A. W. Erickson, R. J. Hofman, G. A. Llano and N. A. Mackintosh (eds). *Antarctic Mammals, Folio 18, Antartic Map Folio Series.* American Geographic Society, 19 pp., 11 pls.

Buckland, S.T. and Anganuzzi, A.A. 1988. Estimated trends in abundance of dolphins associated with tuna in the eastern tropical Pacific. *Rep. int. Whal. Commn* 38: 411–37.

Caldwell, D.K., Caldwell, M.C., Rathjen, W.F. and Sullivan, P. 1971. Cetaceans from the Lesser Antillean Island of St. Vincent. *Fish. Bull. US* 69: 303–12.

Clarke, M. R. 1986. Cephalopods in the diet of odontocetes. pp. 281–321 *In*: M.M. Bryden and R. Harrison (eds). *Research on Dolphins* Oxford University Press, Oxford. xiv + 478pp.

Diamond, S.L., Scholl, J.P. and Hanan, D.A. 1987. Drift gill net observations for the 1985–86 fishing season. NOAA/NMFS Admin. Rept. SWR87-4:1–21.

Dohl, P.D., Guess, R.C., Duman, M.L., and Helm, R.C. 1983. Cetaceans of central and northern California 1980–1983: Status, abundance, and distribution. Report prepared for Minerals Management Service, Contract 14-12-0001-29090, 284pp.

Fedoseev, G.A. 1985. Records of whales in ice conditions of the Okhotsk Sea. Paper SC/37/O 4 presented to the IWC Scientific Committee, June 1985 (unpublished). 8pp.

Flower, W.H. 1882. On the cranium of a new species of *Hyperoodon* from the Australian seas. *Proc. Zool. Soc., Lond.* 1882: 392–6.

Gianuca, N.M., and Castello, H.P. 1976. First record of the southern bottlenose whale, *Hyperoodon planifrons*, from Brazil. *Sci. Rep. Whales Res. Inst., Tokyo* 28: 119–26.

Hershkovitz, P. 1966. Catalog of living whales. *Bull. US Nat. Mus.* 246: 1–259.

Heyning, J.E. In press. Cuvier's beaked whale, *Ziphius cavirostris* Cuvier 1823. *In*: S.H. Ridgeway and R.J.H. Harrison (eds). *Handbook of Marine Mammals.* Vol. 4, Academic Press.

Holt, R.S. and Powers, J.E. 1982. Abundance estimation of dolphin stocks in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys in 1979. US Dept. Commer. NOAA-TM-NMFS-SWFC-23, 95pp.

Holt, S.J. 1977. Does the bottlenose whale necessarily have a sustainable yield, and if so is it worth taking? *Rep. int. Whal. Commn* 27: 206–8.

Kasamatsu, F., Hembree, D., Joyce, G., Tsunoda, L., Rowlett R. and Nakano, T. 1988. Distribution of cetacean sightings in the Antarctic: results obtained from the IWC/IDCR minke whale assessment cruises, 1978/79 to 1983/84. *Rep. int. Whal. Commn* 38: 449–87.

Kasuya, T. 1977. Age determination and growth of the Baird's beaked whale with a comment on the fetal growth rate. *Sci. Rep. Whales Res. Inst., Tokyo* 29: 1–20.

Leatherwood, J.S., Reeves, R.R., Perrin, W.F. and Evans, W.E. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters. *NOAA Technical Report NMFS Circular 444*, v + 245 pp.

McLachlan, G.R., Liversidge, R. and Teitz, R.M. 1966. A record of *B. arnouxi* from the southeast coast of South Africa. *Ann. Cape Prov. Mus. (Nat. Hist.)* 5: 91–100.

Mead, J.G. 1981. First records of *Mesoplodon hectori* (Ziphiidae) from the Northern Hemisphere and a description of the adult male. *J. Mamm.* 62: 430–2.

Mead, J.G. 1984. Survey of reproductive data for the beaked whales (Ziphiidae). *Rep. int. Whal. Commn* (special issue 6): 91–6.

Mead, J.G. In press. Bottlenose whales, *Hyperoodon ampullatus* and *H. planifrons*. *In*: S.H. Ridgeway and R.J.H. Harrison (eds). *Handbook of Marine Mammals.* Vol. 4, Academic Press.

Mead, J.G. and Baker, A.N. 1987. Notes on the rare beaked whale *Mesoplodon hectori* (Gray). *J. Roy. Soc. New Zealand* 17: 303–12.

Mead, J.G., Walker, W.G. and Houck, W.J. 1982. Biological observations on *Mesoplodon carlhubbsi* (Cetacea: Ziphiidae). *Smiths. Contrib. Zool.* 344, 25pp.

Miyashita, T. 1985. Abundance of Baird's beaked whales off the Pacific coast of Japan. *Rep. int. Whal. Commn* 36: 383–6.

Nicol, D.J. 1987. A review and update of the Tasmanian cetacean stranding record to the end of February 1986. University of Tasmania Environmental Studies Working Paper 21, 93pp.

Nishimura, S. 1970. Recent records of Baird's beaked whale in the Japan Sea. *Publ. Seto. Mar. Biol Lab.* 18(1): 61–8.

Nishimura, S. and Nishiwaki, M. 1964. Records of the beaked whales, *Mesoplodon*, from the Japan Sea. *Publ. Seto Mar. Biol. Lab.* 12: 323–34.

Nishiwaki, M. and Oguro, N. 1972. Catch of Cuvier's beaked whales off Japan in recent years. *Sci. Rep. Whales Res. Inst., Tokyo* 24: 35–41.

Nishiwaki, M., Kasuya, T., Keruha, K. and Oguro, N. 1972. Further comments on *Mesoplodon gingkodens*. *Sci. Rep. Whales Res. Inst., Tokyo* 24: 43–56+10 plates.

Omura, H., Fujino, K. and Kimura, S. 1955. Beaked whale *Berardius bairdi*, of Japan, with notes on *Ziphius cavirostris*. *Sci. Rep. Whales Res. Inst., Tokyo* 10: 89–132.

Oshumi, S. 1983. Population assessment of Baird's beaked whales in the waters adjacent to Japan. *Rep. int. Whal. Commn* 33: 633–41.

Perrin, W.F., and Myrick, A.C. (eds). 1980. Age determination of toothed whales and sirenians. *Rep. int. Whal. Commn* (special issue 3), vii+229pp.

Pitman, R.L., Aguyao, A. and Urban, J. 1987. Observations of an unidentified beaked whale (*Mesoplodon* sp.) in the eastern tropical Pacific. *Mar. Mamm. Sci.* 3: 345–52.

Rice, D.W. 1963. Progress report on biological studies of the larger Cetacea in the waters off California. *Norsk Hvalfangstid.* 52: 181–7.

Ross, G.J.B. 1984. The smaller cetaceans of the south east coast of southern Africa. *Ann. Cape Prov. Mus. (Nat. Hist.)* 15(2): 173–411.

Sleptsov, N. 1955. *Cetacea. Part III.* Trans. Inst. Oceanology, Acad. Sci. USSR, Moscow, Vol. 14.

Taylor, R.J.S. 1957. An unusual record of three species of whale being restricted to pools in Atlantic sea ice. Proc. *Zool. Soc.*, Lond. 129: 325–31 + 7 plates.

Tomilin, A.G. and Latyshev, V.M. 1967. Novye dannye ploskolobom butylkonose - *Hyperoodon planifrons* Flower 1882 [New data on the flat-fronted bottlenose - *Hyperoodon planifrons* Flower, 1882]. Moskovskava Obshchestba Ispytately Prirody, Byulleten, Otdel Biolologicheskii, 72(3): 119–122. [In Russian]

Yang, H. 1976. Studies on the whales, porpoises and dolphins of Taiwan. *Ann. Sci. Taiwan Mus.* 19: 131–78. [In Chinese]

Zemskii, V.A. and Budylenko, G.A. 1970. Ploskolobye butylkonosy iz Antarktiki [the flat-headed bottlenose in the Antarctic]. pp. 193–202. *In:* Zemskii, V. A. (ed.) *Kity Iuzhnovo Polushariia (Biologiia i Morphologiia)* [Whales of the Southern Hemisphere (Biology and Morphology)], Tr. AtlantNIRO, number 29, 234 pp.

Zhou, K. 1986. An outline of marine mammalogical research in China. *Acta Theriol. Sinica* 6(3): 219–32. [In Chinese with English summary]

Appendix 1

AGENDA

1. Election of Chairman
2. Appointment of rapporteurs
3. Adoption of agenda
4. Review of available documents
5. Review of population biology and exploitation of beaked whales, Ziphiidae
    - 5.1 *Berardius bairdii* (sub-items repeated for each species below)
        - 5.1.1 Distribution and stock identity
        - 5.1.2 Abundance
        - 5.1.3 Migration
        - 5.1.4 Life history
        - 5.1.5 Exploitation
        - 5.1.6 Status
    - 5.2 *Berardius arnuxii*
    - 5.3 *Hyperoodon ampullatus*
    - 5.4 *Hyperoodon planifrons*
    - 5.5 *?Hyperoodon* sp.
    - 5.6 *Ziphius cavirostris*
    - 5.7 *Mesoplodon* spp.
    - 5.8 *Tasmacetus shepherdi*
6. New information on other stocks
7. Other business
    - 7.1 Takes of small cetaceans in 1971
    - 7.2 UNEP meeting on small cetaceans
    - 7.3 Nomenclature
    - 7.4 ICES
    - 7.5 Publication of documents
    - 7.6 Priority topics for 1989 meeting

Appendix 2

RECOMMENDATIONS ON ORGANISATIONAL ASPECTS OF UNEP'S PROPOSED MEETING ON THE STATUS AND PROBLEMS OF SMALL CETACEANS

A small group of participants in the small cetaceans sub-committee reviewed the proposal for this meeting (IWC/40/10 D) to determine the importance of its goals and the suitability of the proposed approach. It was agreed that the topics proposed to be addressed were both important and timely; the scope of the proposed topics was very broad, but that the breadth appeared to be important to meet the goal of providing a basis for developing an action plan that is global in scope.

There are several documents that address many aspects of the topics proposed for this meeting, but many are in need of updating. A useful approach for this meeting might be to have consultants prepare updated material for several of these existing documents, perhaps on a regional basis, in advance of the meeting. Such updates could be finalised during the meeting, especially with any additional information that participants might bring.

The identification of institutions that would be able to provide training opportunities for scientists from developing countries would be be met by identifying individuals in potential institutions early in preparation for the meeting, and inviting their participation. Participants from areas where problems have been identified, or where they are anticipated, should be identified so that the most current information is available, and so interest in these problems is developed.

Several of the fisheries where small cetaceans are taken incidentally may be subject to technological improvements to reduce kill levels. Other fisheries may require management. The meeting should attempt to identify technical and management approaches, and those problems that appear to require additional technical expertise.

The meeting should schedule sufficient time to determine priorities for actions on small cetacean problems on a global basis, and within the regional scopes used in reviewing the status of the populations.

The proposed meeting appears to be an important step towards improving our understanding of small cetacean problems, and toward developing approaches to their solution. The group noted that scientists involved in the IWC have considerable expertise in the topics proposed to be addressed, and in the problems involved in convening such a meeting, and recommends that the IWC cooperate in planning and conducting the meeting.

Based on this discussion, the group recommends the following agenda to be considered:

1. Review status of small cetacean populations globally
  — Develop regional status reports in advance
1.1 Evaluate effect of habitat degradation
— Review ICES IOC Unit organochlorides report and other reports
— Review information on other factors
— Add information from participants
1.2 Directed fisheries
— Review Reeves and Brownell report on harvested marine mammals not under international control
— Add information from participants
1.3 Incidental kill in fisheries
— Update Northridge FAO/UNEP report on fishery/marine mammal interactions
— Review results of proposed IWC gillnet workshop
— Add information from participants
2. Review technological and management needs
2.1 Review outlook for technological solutions
2.2 Review effectiveness of different management approaches
3. Develop global action plan to address identified problem
3.1 Identify priorities for regional problems
3.2 Identify priorities that relate to global problems
3.3 Identify approaches for training needed
— Institutions to provide training
— Methods to identify individuals who would benefit from training

Appendix 3

REPORTED CATCHES OF SMALL CETACEANS IN 1987

		Argentina[1]	Australia[2]	Canada[3]	Denmark[4]	France[5]	Iceland[6]	Japan[7]	Netherlands[8]	New Zealand[9]	Norway[10]	Sweden[11]	UK[12]	USA[13]	USSR[14]	Other	Total[15]
Baird's beaked whale, *Berardius bairdii*	D	–	–	–	–	–	–	40	–	–	–	–	–	–	–	–	40
Narwhal, *Monodon monoceros*	D	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–	x
White whale, *Delphinapterus leucas*	D	–	–	–	x	–	–	–	–	–	–	–	–	–	34	–	34+x
False killer whale, *Pseudorca crassidens*	D	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	2
Killer whale, *Orcinus orca*	D	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	3
	L	1	–	–	–	–	4	–	–	–	–	–	–	–	–	–	5
Pygmy or dwarf sperm whale, *Kogia* spp.	I	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Long-finned pilot whale, *Globicephalus melas*	D	–	–	–	1,422	–	–	–	–	–	–	–	–	–	–	–	1,422
	I	–	–	–	–	1	–	–	–	–	–	–	2	x	–	–	3+x
Short-finned pilot whale, *G. macrorhynchus*	D	–	–	–	–	–	–	386	–	–	–	–	–	–	–	–	386
	I	–	–	–	–	–	–	9+x	–	–	–	–	–	–	–	–	9+x
Dusky dolphin, *Lagenorhynchus obscurus*	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16,17]	x
	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16,17]	x
Pacific white-sided d. *L. obliquidens*	D	–	–	–	–	–	–	16	–	–	–	–	–	–	–	–	16
	I	–	–	–	–	–	–	189+x	–	–	–	–	–	5+x	–	–	194+x
Atlantic white-sided dolphin, *L. acutus*	D	–	–	–	76	–	–	–	–	–	–	–	–	–	–	–	76
White-beaked dolphin, *L. albirostris*	I	–	–	–	–	–	–	–	–	–	–	–	2+x	–	–	–	2+x
Peale's dolphin, *L. australis*	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16]	x
	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3+x[16]	3+x
Bottlenose dolphin, *Tursiops truncatus*	D	–	–	–	1	–	–	1,812	–	–	–	–	–	–	–	–	1,813
	I	–	3	–	–	–	–	4+x	–	–	–	–	–	38–52+x	–	–	44–59+x
	L	–	–	–	–	–	–	–	–	–	–	–	–	24	–	–	24
Spotted dolphin, *Stenella attenuata*	I	–	–	–	–	–	–	–	–	–	–	–	–	5,031–8,598+x	–	57,544–63,510[18]	57,544–63,510
Spinner dolphin, *S. longirostris*	I	–	–	–	–	–	–	–	–	–	–	–	–	2,226–3,546+x	–	22,135–25,072[18]	22,135–25,072
Striped dolphin, *S. coeruleoalba*	D	–	–	–	–	3	–	2,173	–	–	–	–	–	–	–	–	2,176
	I	–	–	–	–	–	–	76+x	–	–	–	–	–	3–8+x	–	3,401–3,789[18]	3,477–3,865+x
	L	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Stenella spp.	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[19]	x
Common dolphin, *Delphinus delphis*	D	–	1	–	–	2	–	6	–	–	–	–	–	–	–	–	9
	I	–	–	–	–	1+x	–	34+x	–	1+x	–	–	–	246–1,525+x	–	19,324–22,463+x[18,19]	19,360–22,499+x
Northern right whale d. *Lissodelphis borealis*	I	–	–	–	–	–	–	261+x	–	–	–	–	–	–	–	–	261+x
Hector's dolphin, *Cephalorhynchus hectori*	I	–	–	–	–	–	–	–	–	8+x	–	–	–	–	–	–	8+x
Commerson's dolphin, *C. commersonii*	I	20+x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20+x
Black dolphin, *C. eutropia*	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16]	x
	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16]	x
Risso's dolphin, *Grampus griseus*	D	–	–	–	–	1	–	3	–	–	–	–	–	–	–	–	4
Franciscana, *Pontoporia blainvillei*	I	x	–	–	–	–	–	–	–	–	–	–	–	–	–	x[19]	x
Tucuxi, *Sotalia fluviatilis*	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[19]	x
Rough-toothed dolphin, *Steno bredanensis*	D	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
	I	–	–	–	–	–	–	–	–	–	–	–	–	8–24+x	–	x[19]	8–24+x
Harbour porpoise, *Phocoena phocoena*	D	–	–	–	1	–	–	8	–	–	–	–	–	–	–	–	9
	I	–	–	–	x	–	–	21	7+x	–	3	17–140	85+x	200–300	–	13+x[20]	346–569+x
Burmeister's porpoise, *P. spinipinnis*	D	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16]	x
	I	3+x	–	–	–	–	–	–	–	–	–	–	–	–	–	x[16]	3+x
Spectacled porpoise, *Australophocoena dioptrica*	I	3+x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3+x
Dall's porpoise, *Phocoenoides dalli*	D	–	–	–	–	–	–	13,406	–	–	–	–	–	–	–	–	13,406
	I	–	–	–	–	–	–	816+x	–	–	–	–	–	–	–	–	816+x
Unidentified species	D	–	–	–	–	–	–	667	–	–	–	–	–	319–	–	–	667
	I	x	15+x	–	–	–	–	294+x	–	–	–	–	2+x	392+x	–	x[19]	630–730+x
Sub-total	D	x	1	x	1,500+x	6	–	18,523	–	–	–	–	–	–	34	x[19]	20,064+x
	I	26+x	18+x	–	x	2+x	–	1,705+x	7+x	9+x	3	17–140	91+x	8,076–14,450+x	–	102,417–114,847	104,297–116,850+x
	L	1	–	–	–	1	4	–	–	–	–	–	–	24	–	–	30
Total		27+x	19+x	x	1,500+x	9+x	4	20,228+x	7+x	9+x	3	17–140	91+x	8,100–14,474+x	34	102,417–114,847	124,391–136,944+x

Notes to the Table

* Official statistics have been taken to be those provided in National Progress Reports or official catch records submitted to the Secretariat. Values given in scientific papers to the Committee are provided for information only and their sources indicated; these are given under the heading 'Other'. Catches have been presented by nation, rather than ocean area, except in the case of the data submitted by the IATTC for the eastern Tropical Pacific. In this case, the submitted estimated catches are not broken down by country but a summed total incidental catch for the following countries is given: Costa Rica, Ecuador, El Salvador, Mexico, Panama, Spain, USA, Vanuatu and Venezuela.

Key: D = direct take; I = incidental capture; L = live capture; x = catches known to occur but no current information available on levels.

Footnotes: (1) SC/40/ProgRep Argentina. (2) SC/40/ProgRep Australia. (3) SC/40/O 31. (4) SC/40/ProgRep Denmark, SC/40/O 31 and SC/40/BIWS. (5) SC/39/ProgRep France, SC/40/ProgRep France and Collet (pers. comm.). (6) SC/40/ProgRep Iceland. (7) SC/40/ProgRep Japan and SC/40/BIWS. (8) SC/40/ProgRep Netherlands. (9) SC/40/ProgRep New Zealand. (10) SC/40/ProgRep Norway. (11) SC/40/ProgRep Sweden: 17 reported and estimation of 75 to 140 per year. (12) SC/40/ProgRep UK. (13) SC/40/ProgRep USA and SC/40/SM1. (14) SC/40/ProgRep USSR and SC/40/BIWS. (15) The totals do not take into account the USA catches in the ETP for *S. attenuata, S. longirostris, S. coeruleoalba and D. delphis*, as those are included in the estimates for the whole ETP. (16) Goodall (pers. comm.). (17) Progress Report to IUCN by Gaskin *et al.*, 1987. (18) SC/40/SM2. (19) Da Silva (pers. comm.). (20) Deimer (pers. comm.).

Annex I
Report of the Working Group on Progress Reports

Members: Donovan, Horwood, Holt, Tillman, Chapman, Kasuya, Braham, Ivashin*

The Working Group met under the terms of reference described in Item 4.2 of the main Committee Report.

BACKGROUND

National Progress Reports have been submitted to the Committee since the mid-1950s, but it was not until 1961 that specific guidelines on presentation were drawn up (*Rep. int. Whal. Commn* 12: 144) and 1976 that submission of such reports was formalised in Rule of Procedure E1 (*Rep. int. Whal. Commn* 27: 55):

> Progress Reports. Each nation having information on the biology of cetaceans, cetacean research, the taking of cetaceans, or other matters it deems appropriate should prepare a brief progress report in the format already used by the Committee summarising these matters for consideration by the Committee.

Although not specifying Progress Reports as such, their submission seems to have been in response to Article VIII para. 3 of the Convention:

> Each Contracting Government shall transmit to such body as may be designated by the Commission, in so far as practicable, and at intervals of not more than one year, scientific information available to that Government with respect to whales and whaling, including the results of research conducted pursuant to paragraph 1 of this Article and to Article IV.

In 1981 the Commission endorsed an Australian proposal that, in addition to the usual information included in Progress Reports, for both nationally and internationally (e.g. WWF, FAO and UNEP) funded research, the following information should be appended: title of project, duration and completion date; aims of project; addresses to write for further information and/or a final report (*Rep. int. Whal. Commn* 32: 28). The Committee had noted that this would be difficult for countries which fund large numbers of projects and in 1983 the Committee recommended and the Commission agreed that as there had been few requests for these Appendices and as they duplicated much of the information already included in the Progress Reports, the procedure be discontinued (*Rep. int. Whal. Commn* 34: 63).

In the following year, in an attempt to encourage nations to submit reports (each year since 1983, the Committee has expressed concern at the number of nations failing to submit such reports) as well as to improve the quality and consistency of submitted reports, the Committee revised the 1961 Guidelines. The new Guidelines were endorsed by the Commission and published in *Rep. int. Whal. Commn* 35: 144.

SUGGESTED REVISED GUIDELINES

The aim of Progress Reports is to present a brief and concise summary of the year's research, not a lengthy essay suited to publication elsewhere. The report should be arranged under the headings given below.

Preamble. This should indicate the organisations/agencies/laboratories to which the progress report refers.

(1) **Species and stocks studied.**
(2) **Field observations and collections.** This should include a summary of the amount of biological material collected during the year. If catch data for large whales are included under this item, this does *not* fulfil the obligation to supply data to the Commission as specified in the Schedule.
(3) **Marking.** A summary of releases and returns of artificial (e.g. Discovery) marks should be given. This section may also include information on species and agencies/focal points concerned with natural marking studies; data should not be included.
(4) **Laboratory work.** Age reading, reproduction studies, etc.
(5) **Development of techniques.** Field, laboratory and analytical.
(6) **Research results.** This should, as far as possible, **at least** include all government sponsored research.
(7) **Sightings data.** This should include a summary of results and/or an indication of where these can be found.
(8) **Strandings.** If included, this section should only provide information on focal institution/individuals who can be contacted. Data should not be included (although they may be submitted as a separate paper).
(9) **Pollution studies** (including a summary of results and/or an indication of where these can be found).
(10) **Statistics and data for small cetaceans.** These may include catch statistics detailing species, number, locality and where possible, biological data for animals taken incidentally as well as directly and in live-capture fisheries as agreed by the Commission in 1976 (*Rep. int. Whal. Commn* 27: 31). Catch data must be presented by calendar year.
(11) **Publications** (full references to all publications on small and large cetaceans should be included, excluding those published in IWC volumes).

OTHER MATTERS

The Working Group **recommends** that Progress Reports continue to be published in the proceedings volumes if the compilers wish and if the above guidelines are adhered to.

The Working Group considered the problem of countries which do not submit Progress Reports. While it recognised that not all of these may have cetacean research programmes, it agreed that the Committee should continue to recommend that the Commission should urge all countries to submit Progress Reports.

---

*Written contribution only.

Annex J
Matters Concerning the Comprehensive Assessment

Annex J1. REPORT OF THE WORKING GROUP ON GENETICS

Members: Dizon (Convenor), Amos, Arnason (A.), Arnason (U.), Hoelzel, Palsboll.

1. Introduction
This group was convened (see Appendix 1 for the Agenda) to review the application of molecular genetic techniques for the identification of stocks and individuals, to discuss useful new methodologies and to make recommendations for future studies and initiatives to the Comprehensive Assessment sub-committee. The primary goals of the working group were to review the progress of the IWC contract study on the use of DNA probes for stock identity as formalised last year (*Rep. int. Whal. Commn* 38: 130–31) and to provide recommendations on a proposed workshop on the genetic and biochemical analysis of tissue samples collected by biopsy sampling and other means (given as Annex J2).

2. Progress report on contract study
Amos presented his paper SC/40/O 38. In summary, contacts were made for the procurement of samples for population screening while preparatory work on the development of probes was conducted. A 14 kilobase (kb) segment of the rDNA gene family repeat sequence from *Orcinus orca* was cloned and mtDNA from *O. orca* was isolated for sub-cloning and mapped by Hoelzel; and a mini-satellite locus from *Globicephala melas* was cloned by Amos. Additional work was conducted on the development of sample preservation techniques, the screening of various cetacean species for variation (especially at the mini-satellite loci), and the possible application of more highly conserved minisatellite loci for the identification of stocks. Further, a number of uncharacterised gene families were cloned by Amos from *G. melas* for possible use in stock assessment. The report was unanimously accepted by the group.

3. Stock identification
The application of various techniques to the problem of defining genetic stocks was discussed. It was agreed that a high level of resolution is required, although too much variation is difficult to interpret at the population level. It was recognised that a large body of data is available on isozyme studies, and the comparison of these data with other studies will be useful. Preliminary studies on mtDNA variation suggest that there is substantial variation within and between proposed stocks for some species.

Several meeting papers were discussed (SC/40/Ba9–11, SC/40/ProgRep Denmark). The Danish study indicates significant genetic differences between the West Greenland and Northeast Atlantic putative stocks of minke whales based on the rDNA gene family. The results, however, are based on few individuals and require verification from a larger sample, which is expected within the year. In SC/40/Ba9, a simple isoenzyme system (carbonic anhydrase) was reported to demonstrate that the fin whales caught off Iceland belong to a breeding unit in Hardy-Weinberg equilibrium with some young males coming from other units some years. This report covers the years 1971, 1981–1987. SC/40/Ba10 describes a study of 33 enzyme loci, of which 7 were polymorphic. These, however, did not show differences between fin whales caught off Iceland and Spain. SC/40/O 34 reports polymorphisms of C4 genes in fin and sei whales using a human cDNA probe; data on mother-foetus pairs demonstrates simple allele transmission. The fact that human C4 probe hybridises with cetacean DNA demonstrates that it is possible to use human probes under some conditions. Species-specific patterns were noted as well as polymorphic patterns within fin and sei whales. Ongoing studies were summarised of mtDNA of Dall's porpoise (Jones) and spinner dolphin (Dizon); these studies (as yet unpublished) did not demonstrate genetic stock differentiation of the sampled putative populations. U. Arnason described studies with a cloned mtDNA probe made from fin whale. This probe revealed three different fragment morphs in 16 sperm whale DNA samples. An unpublished manuscript (Arnason, U. and Ledje, C.) was provided to the working group.*

Theoretically, an investigation of variation in gene families such as rDNA is especially appropriate to the description of genetic stocks due to the homogenisation of such sequences (creating relative uniformity) within reproductive populations. The use of mini-satellite sequences at the population level is currently an untested possibility. It was suggested that the variable major histocompatibility complex and complement genes should also be investigated. The work of A. Arnason was discussed in this context (SC/40/O 34).

4. Other applications
One small sample (e.g. 8mm dia. skin biopsy extending into blubber) provides sufficient genetic material for numerous investigations. Useful possibilities include the determination of sex by karyotyping or probing for the

---

* Arnason, U. and Ledje, C. Southern blot hybridization to DNA of fin, sei, and sperm whales using a 3.5 kb portion of fin whale mtDNA as a labeled probe.

Testes Determining Factor (TDF) on the Y-chromosome, the description of social structure by extending genealogies with paternity testing (using mini-satellite DNA) or kinship estimation, and the estimation of effective population size (cf. SC/40/Rep1). Sample preservation techniques were discussed and a preliminary guide was prepared (Appendix 3).

5. Recommendations

5.1 Continuation of funding

Funds for the contract study on the use of DNA probes for stock and individual identity to Dr Gabriel Dover (Dept of Genetics, Cambridge University) should be continued for the second cycle of the two-year project. The Working Group feels that substantial progress has been made since its initiation. The preliminary steps necessary to achieve the specific goals outlined in Annex M have been accomplished. The Working Group feels that the outlined goals will have a high probability of being met during the second year of the contract.

5.2 Tissue sampling

The Working Group recommends that the IWC Secretariat establish or fund establishment of a database containing information on the availability of existing, preserved cetacean tissue samples. This information, stored in some standardised format, would be available to investigators requiring tissue samples. The investigators would then make their own arrangements with the caretakers of the samples.

The Working Group encourages the sub-committee to, in turn, influence individual investigators and research institutions to collect and archive tissue samples from available harvested, beachcast or biopsied cetaceans and to make that information available to the IWC and those tissues available, when requested, to interested researchers. Towards that end, the Working Group has provided a preliminary guide for collecting, transporting and storing cetacean tissue samples (Appendix 2).

The Working Group requests the IWC Secretariat to approach the Secretariat of CITES to see if the necessary permit process may be simplified to promote exchanges of cetacean tissue between scientific institutions.

5.3 Workshop

As proposed in Annex J2, the Working Group proposes that the IWC fund a workshop on the genetic and biochemical analysis of tissue samples collected by biopsy sampling and other means. The 3–4 day workshop for 15–20 participants will meet, possibly just prior to the next IWC Scientific Committee meeting, to discuss and report details of sample collection (projector, projectile and retrieval), sample preservation or fixation, tissue culture, sample storage, genetic analysis and interpretation. The findings of the workshop will be published as an IWC Special Issue and will contain, among others, specific guidelines on sample preservation to replace the preliminary ones in Appendix 2. The cost of the workshop is estimated to be from £10,000 to £15,000.

Appendix 1

1. Appointment of Rapporteur and Election of Chairman
2. Adoption of Agenda
3. Review available documents
4. ID of individuals
    - 4.1 Hypervariable mini satellites
5. Stock identification
    - 5.1 Isozyme studies
    - 5.2 mtDNA
    - 5.3 Gene families (e.g. rDNA)
    - 5.4 Mini-satellites
    - 5.5 Other
6. Other applications of general analyses
    - 6.1 Sex Determination
    - 6.2 Social Structure
    - 6.3 Assessment of Ne
    - 6.4 Other
7. Proposed workshop-genetic and biochemical analysis of biopsy samples
8. Recommendations

Appendix 2

Outlined below is an interim scheme for the opportunistic sampling of cetacean tissues for genetic analysis, pending the outcome of the workshop on genetic and biochemical analysis of tissue samples (Annex J2). This appendix is designed as a guide to the collection of useful samples and the concomitant data that should be noted.

(1) Sample collection

(a) For protein electrophoresis: samples should be frozen; a temperature of —70°C or below is preferable, however, –20°C can be used for periods of weeks prior to permanent storage at the lower temperature. Where blood is available (within 1 day of death) it should be stored at 4°C.

(b) For cell culture: cell culture can expand the range of genetic techniques applicable to biopsy samples. In view of the cost of sampling, it has been suggested that this method should be tried where feasible. Samples should be placed in a suitable medium supplemented with antibiotics and stored at 8°C until a laboratory is reached. Success rates depend on the length of storage time (90%+ for fresh, falling to 30% or so after one week).

(c) For DNA preservation: DNA is best preserved by freezing at –20°C or below. In the absence of refrigeration adequate preservation may be achieved by immersing the sample in 3 or more volumes of saturated table salt (NaCl) 20% DMSO solution. This will preserve the sample for at least one month at room temperature, though any cooling will be beneficial.

For all techniques the methods are primarily aimed at skin samples from biopsy darts (esp. 1b & 1c where freshness is more important) or stranded material. In all instances where freezing is suggested freeze:thaw cycles should be avoided.

(2) **Data collection**
The following is a preliminary list of data that will be useful in the construction of tissue banks for genetic analysis. The projected workshop aims to produce a complete data form applicable to all potential cetacean samples.

Location collected:
Date:
Ambient temperature:
Sample type:
Tissue type:
Quantity taken:
Time post mortem:
Species:
Size:
Age:
Sex:
Other sampling data:
Other samples available:
Collected by:
Contact address:

Annex J2. IWC WORKSHOP ON THE GENETIC AND BIOCHEMICAL ANALYSIS OF TISSUE SAMPLES COLLECTED BY BIOPSY SAMPLING AND OTHER MEANS

1. Introduction

It is proposed that a 3–4 day workshop for 15–20 participants be sponsored by the IWC on the collection of tissue samples from cetaceans and the subsequent analysis of those samples. The areas of expertise represented by participants should include, the collection of tissue samples in the field, the preservation and transport of tissue for various types of analyses, recombinant DNA analysis of samples, and the interpretation of genetic variation for the conservation of populations. It is estimated that the workshop would cost between £10,000 and £15,000.

2. Sample collection

There are three essential components to the apparatus used for the remote collection of biopsy samples (collection device, projection and retrieval), and numerous designs have been suggested for each.

(2a) *Collection device*
Various devices have been tested or proposed. Most designs are cylindrical core samplers, sharpened at the leading edge and including internal barbs or other devices for sample retention. Experience to date suggests that the best design will depend on application and the subject species. The design of appropriate apparatus for the various applications will greatly benefit from discussions among those experienced in their use. It will be useful to further integrate these discussions with participants who have experience with the preservation, required quantity and type of tissue needed for subsequent analyses.

(2b) *Projection device*
Projection equipment has included modified harpoon guns, spearguns and various types of bows. The choice of equipment is usually dependent on required range, accuracy and the effectiveness of dart deflection. Further considerations for future designs should include portability and adjustable projection velocity.

(2c) *Retrieval*
Existing retrieval systems include a line tether and fishing reel, and independent flotation. These systems could be optimised to minimise the risk of entanglement and loss of sample.

Further discussion on sample collection could include methods for sampling entrapped animals and the preferred tissues to sample from stranded animals.

3. Sample preservation

The preservation of tissue for DNA analysis will require different and less stringent conditions than the preservation of live tissue for tissue culture. Both techniques are presently being perfected in various labs. Further, different types of DNA analysis optimally require different levels of stringency. The success rate for the storage and transportation of tissue samples to a lab for tissue culture is currently fairly low. A discussion of techniques used in different labs and under different field conditions would be very useful.

4. Genetic analysis

There are currently numerous labs investigating various genomic regions for their structure and variability. These genomic components include ribosomal DNA which has been suggested to be useful for stock identification, mini-satellite regions which are useful at least for the identification of individuals, kinship and paternity, and mitochondrial DNA which can trace the movements of females and estimate genetic distance between populations. These components have been discussed in a report submitted to the IWC (Hoelzel and Dover). It is clear, however, that there are numerous additional possibilities being developed in other labs, and that a discussion of the possible application of various techniques would be extremely useful. This would be especially true for special applications, for example when only very little or very degraded material was available. Further, other kinds of information, for example sex, may now be able to be determined by similar analyses of the same tissue samples.

5. Storage and interpretation

The appropriate methodology for the long-term storage of samples including extracted DNA and tissue cultures should be discussed. Methods will vary to some extent with the analytical techniques used. If possible a technique should be developed that incorporates sufficient stringency to be adequate for all proposed analyses.

The interpretation of data is expected to be a major item for consideration. This would hopefully include an agreement on what kinds of information can be interpreted from various types of results and how results could be effectively compared between labs.

Annex J3. RECOMMENDATIONS FROM THE WORKSHOP ON INDIVIDUAL RECOGNITION AND THE ESTIMATION OF CETACEAN POPULATION PARAMETERS

The Working Group established to review the recommendations in Section 11 of SC/40/Rep1 (Bannister, Hammond, Donovan, Mizroch, Harwood) considered the eight recommendations of special interest to the Commission and **recommends** as follows:

Workshop Recommendation	*Working Group View*
SC/40/Rep1, p. 19: Item 11, Preamble. Requests for assistance with funding for long-term photo-id studies where data are in jeopardy through discontinuity in funding.	*Endorse* the Workshop's strong recommendation that the Scientific Committee give highest priority to funding such studies, on the understanding that the study is an existing long-term one from which promising results have already been obtained, that the situation is an emergency, and that funding will be considered for one year only.
11.1 *Catalogues and Photographic Collections.* Creation of central catalogues for each species: North Atlantic fin whales, SC/40/Repl, Annex I-1: £9,000.	*Refer to Protected Species sub-committee* for recommendation to Scientific Committee, particularly in the context of the animals' possible relationship with the West Greenland stock of fin whales.
11.1 *Protection from chance destruction or damage.* Archiving of collections through NMML video-disc system; storage of copy-discs and updating to be undertaken at IWC: £4,000.	*Endorse concept but reject proposal* for support because data cannot under the current proposal be made readily available to Scientific Committee members, and financial commitment is for more than one year.
11.3 *Biopsy sampling proposal.* Workshop on current studies, collection methodology, and end uses: Annex I-2.	Concept exactly similar to that already discussed in C.A. sub-committee. Recommend *adoption* of proposal as already described in 5.3 (Appendix 2), but with addition of consideration of effect of biopsy sampling on animals (SC/40/Repl item 11.5).
11.6 *Estimation of Juvenile Mortality.* North Pacific humpback calf mortality: Partial support for analysis and collection integration into NMML system: Annex I-3.	*Refer* to Protected Species sub-committee. Revised proposal to be submitted direct.
11.7 *Computer Assisted Matching.* Feasibility study for applicability of digitising technique of SC/A88/ID9 to whales: Annex I-4.	*Refer* revised proposal (Appendix 1) to C.A. sub-committee.
11.8 *Photogrammetry.* Workshop to facilitate exchange of information on field methods, laboratory technique and analysis: £20,000.	*Endorse* workshop concept given that methodology could be important, e.g., estimating length of S. Hemisphere minke whales, but more details should be prepared. *Refer* to C.A. sub-committee for decision.
11.9 *Extension of field studies.* Photo-id of S. Hemisphere minke whales: 1–2 day feasibility study on a forthcoming IDCR cruise.	Already discussed in S.H. minke sub-committee. *Refer* to that sub-committee for recommendation.

Appendix 1

Research proposal for the development of a computer-aided matching procedure for photographs of cetacean natural markings

Submitted by P. Lovell, Conservation Research Group, PO Box 114, Cambridge CB4 1YJ, UK, in collaboration with A.R. Hiby, Sea Mammal Research Unit, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

Description of project

The application of capture-recapture estimation procedures to multiple sightings of individually-recognisable animals has already provided useful assessments for North Atlantic humpback whales. The same technique holds great promise for a number of other whale stocks which the Scientific Committee has found difficult to assess (see SC/40/Rep1). However, it is substantially more difficult to identify individuals from the photographs which can be taken of these species. This is because they do not offer a plane, well-marked surface (like the underside of a humpback's tail fluke) for photography. Instead, the angle at which the animal is photographed will affect the appearance of any distinctive patterns. A computer-aided system which corrects for these differences and calculates the quality of the match between two photographs has been successfully developed for grey seals *Halichoerus grypus* (SC/A88/ID9).

This is a proposal to develop a similar, generalised system for large whales. Such a system should permit the application of capture-recapture techniques based on individual recognition to a wide range of stocks which will be considered as part of the Comprehensive Assessment.

Requirements for resources

The system will be developed for two stocks for which a substantial catalogue of suitable photographs already exists. They are: blue whales in the northeast Atlantic (Sears, 1984); and southern right whales (Payne *et al.*, 1983). The project will make use of a low-cost digitising system designed for use with an IBM-AT, or equivalent, and all programs will be written to run on such a machine. The Sea Mammal Research Unit will provide access to specialist computing and electronics facilities, and secretarial support.

Budget

	£
Salaries and wages (1 researcher for 5 months including overheads for supplies and report preparation)	8,000
Travel (for visits to researchers in USA)	750
TOTAL FUNDS REQUESTED	8,750

Work Schedule

1–15 December 1988	– Preliminary visits to researchers to determine extent and quality of available photographs.
16 Dec. 1988–15 Feb. 1989	– Preliminary development of computer models and matching procedures.
16 February – 2 March 1989	– Follow-up visits to researchers to assess model development.
3 March – 1 May 1989	– Further development of models and programs. Preparation of progress report for presentation at 1989 Scientific Committee.

Annex J4. WORKSHOP ON THE FEEDING ECOLOGY OF SOUTHERN BALEEN WHALES

Background

At its 1987 meeting, the Scientific Committee of the IWC (*Rep. int. Whal. Commn 38:* 134) drew up the objectives and a list of topics to be addressed by the Workshop. A budgetary allocation of £13,500 was made and a further contribution of US $15,000 was offered by the US National Marine Mammal Laboratory.

Subsequently, the CCAMLR Scientific Committee agreed (SC-CAMLR-VI/7, Paras 7.45–7.47) that it would be important to refine further the objectives of the Workshop. The Committee recognised that the identification of valuable data on krill (*Euphausia superba* Dana) distribution and abundance was important in order to complement existing whale data. Accordingly, it was agreed that a small joint Steering Committee of representatives from both the IWC and CCAMLR should be formed to organise the Workshop. This Committee met in conjunction with the IWC Scientific Committee on 9 and 10 May, 1988.

Objective

To review and evaluate current knowledge and data on the relationship between southern baleen whales and their food.

Terms of reference

The terms of reference of the Workshop are to:

(1) assess the current status of knowledge on the seasonal distribution and density of southern baleen (particularly minke) whales;

(2) assess the current status of knowledge on the diet and feeding behaviour of southern baleen whales;

(3) assess to what extent data on the seasonal distribution, density and feeding of southern baleen whales can be reconciled with available information on krill distribution and swarming behaviour (this would include an assessment of the implications of krill fishing activities);

(4) identify biological parameters of baleen whales which might be affected by changes in the availability of krill;

(5) determine whether currently available information can be used to estimate these parameters sufficiently reliably, that they can be used to reflect changes in the availability and nutritive value of krill;

(6) determine to what extent abiotic factors may affect the relationship(s) between whale feeding and krill availability at various scales;

(7) report to the Scientific Committees of the IWC and CCAMLR on the results of the Workshop, and its recommendations for future work.

Proposed Workshop topics and pre-Workshop tasks

In order to fulfil these terms of reference, the Steering Committee recommended that information on as many of the following topics as possible should be available at the Workshop. Although the Workshop will be primarily concerned with southern baleen whale feeding ecology in the Antarctic, the Steering Committee agreed that it would be useful to consider case studies from other areas. Such consideration would be particularly important given the lack of information on certain aspects of baleen whale feeding ecology in the Antarctic.

Preparation of review papers and analyses

(a) Estimates of abundance for blue, humpback, fin and minke whales from IDCR cruises by the most detailed geographical breakdown possible.

(b) Review of available information on southern baleen whale diet including prey species and size composition by month and year and locality, stomach fullness and nutritive value of prey where possible.

(c) Analysis of new information on diet and feeding rates of minke whales.

(d) Review of morphological feeding adaptations in baleen whales.

(e) Review of feeding strategies in baleen whales particularly energetic implications of food-gathering (schooling behaviour, rates of feeding, migration etc.)

(f) Review of available knowledge on summer krill distribution in the Antarctic, including diurnal movements and swarming behaviour.

(g) Review of distribution of commercial krill fishing activities and catches within the Antarctic.

(h) Analysis of body condition (blubber thickness, girth, carcass lipid content) of baleen whales in relation to food availability.

(i) Review of annual trends in growth and reproductive rates of Antarctic baleen whales.

(j) Analysis of variations in oil yields from commercial whaling operations in the Antarctic.

(k) Analysis of IDCR data on school size, diving/feeding behaviour of minke whales in relation to abiotic factors (e.g. proximity of ice edge, sea surface temperature, whale abundance, etc.).

Workshop facilities

Although the Steering Committee felt that it would not be necessary to have substantial computing facilities available during the Workshop, it agreed that it would be essential to have the ability to produce plots such as:

(a) Whale catches from BIWS tape records by species, by month, and by 1° square (1946-present).

(b) Whale sightings from IDCR cruises by month and by 1° square (1978/79 – present).

(c) Krill fishery activities and catches on as fine a geographical scale as possible and by month, by season or seasons (1972-present) combined.

(d) Distribution of krill swarms from scientific surveys, incidental observations, etc. (Discovery data? BIOMASS data?).

(e) Plots of ice edge by Summer season (1946-present).

(f) Plots of sea surface temperature by month by year.

Proposed budget

No alteration is proposed for the currently allocated IWC budget. The Steering Committee recognised that budgetary implications as far as CCAMLR is concerned will have to be discussed at the next meeting of the CCAMLR Scientific Committee.

Arrangements for the Workshop

The Steering Committee recommends that co-convenors for the workshop should be appointed as soon as possible from the Scientific Committee of the IWC and CCAMLR respectively.

It would be desirable that the workshop is held at a laboratory which has access to as much of the data and necessary plotting facilities as possible.

As the completion of the required tasks will take some time, the Steering Committee felt that the earliest time that the Workshop could be held would be the austral spring of 1989/1990. In the interim, the convenors should solicit appropriate analyses and reviews (as listed above). Progress reports should be presented at the 1989 meetings of the IWC and CCAMLR Scientific Committees.

Annex J5. WORKING GROUP TO DEVELOP A PROTOCOL FOR THE EVALUATION OF PROCEDURES TO ESTIMATE POPULATION DYNAMICS PARAMETERS FROM AGE DATA

Members: Butterworth, Cooke (convenor), Lassen, de la Mare, Nakamura, Sakuramoto, Tanaka.

The group noted that discussions in the Scientific Committee at recent meetings had failed to reach definitive conclusions on the feasibility or otherwise of estimating various population dynamics parameters from catch at age data (either alone or in combination with other types of data), and that this was partly due to the lack of clearly defined criteria for the evaluation of estimation techniques.

The group considered that the techniques are aimed at estimating the net recruitment rate and the natural mortality rate. The aspect of the performance of the different techniques that is of greatest relevance to the work of the Scientific Committee is their power to discriminate between values of these parameters which are within the ranges that are realistic for whale populations. A draft protocol was elaborated for the evaluation of this aspect of the different techniques (Appendix 1).

The group believed that a protocol along these lines would in principle be the most appropriate way to evaluate estimation techniques when they had reached a sufficient stage of development. However, the estimation techniques which have been proposed to date are still under development. Consequently, the group considered that the application of the draft protocol to the current versions of the available estimation techniques as they now stand would not be an effective use of time. Nevertheless, the group believed that the draft protocol provides a useful guideline for the developers of the estimation techniques. The implementation of a final agreed protocol should be discussed again at the next Scientific Committee meeting if progress with the development of the techniques in the interim warrants this.

Appendix 1

Suggested protocol for the evaluation of estimators of natural mortality rate and net recruitment rate from catch at age data

Procedures for the estimation of biological parameters from catch at age data are to be evaluated using simulation trials. Hypothetical catch age distributions are to be generated from simulated populations with various values of the biological parameters under different sampling regimes. These data sets can then be input into the estimation procedures in order to evaluate their potential to estimate the 'true' parameter values used to generate the data sets.

The true population dynamics are as follows. The true parameters of the generated population are to lie within the ranges specified.

Notation

N(a,t)	numbers of animals of age a at beginning of year t
C(a,t)	catch of animals age a during year t
q(a)	selectivity of age class a
M(a)	natural mortality rate at age a

True population parameters

(a) *Population size*: total (age 1+) population at start of significant exploitation (1970) shall range from 50,000 to 150,000.

(b) *Age at maturity*: 7 years.

(c) *Recruitment*: no. of 1-year olds is proportional to the mature population size in the previous year;

$$N(1,t) = R \,.\, \sum_{a=7}^{60} N(a,t-1)$$

where $R = 0.25$ is a constant.

(d) *Age-specific selectivity*:
Historical catch (1970–87): $q(a) = 1$ $(a >= 7)$ $q(a) = 0$ $(a < 7)$
Research catch (1988 onwards): $q(a) = 1$ $(a >= 1)$

(e) *Natural mortality*
At age 1: range 0.05 to 0.15.
At age 40: range 0.05 to 0.15.
At other ages: linearly changing from age 1 to age 40, constant from age 40 onwards. Constant over time.

The natural mortality at age a is:

$$M(a) = M(1) + (M(40) - M(1))(a-1)/39 \quad (1 < a < 40)$$
$$M(a) = M(40) \quad (a > 40)$$

(f) *Dynamics*:

$$N(a+1, t+1) = (N(a.t) - C(a,t)) \exp(-M(a))$$

$$N(1,t) = R \,.\, \sum_{a=7}^{60} N(a,t-1)$$

In each case, the initial population has the stable age distribution implied by these mortality and recruitment rates.

(g) *Historical catches*: total recorded of minke whales in Antarctic Area IV 1970–87 (sexes combined).

Research catch: 825, 825, 0, 0, 825, 825, 0, 0, 825, 825, 0, 0, etc., for 26 years beginning in 1988.

Catch at age data

The entire research catch in each year is assumed to be aged. It is assumed to be a random sample of the 1+ population with multinomial sampling.

Auxiliary data

It is not yet known what kinds of auxiliary data will be required by the final forms of the different estimation techniques. The alternatives given here are examples of how different types of auxiliary information may be specified.

(A) For those techniques requiring them (e.g. SC/40/O 23), sampling effort data for research catch, are given as a random variable which is log-normally distributed with CV 0.2 and expected value proportional to the actual fishing mortality rate in each year.

(B) For those techniques which require it, a single unbiassed, lognormally distributed population estimate (e.g. from sightings or other data) is available in 1988 with a CV of 0.2

(C) For those techniques requiring them, annual unbiassed, lognormally distributed population estimates (e.g. from sightings or other data) with a CVof 0.2 are available for each year with a research catch.

Output

For each hypothetical data set, estimates shall be provided for (i) mean M (ii) mean net recruitment rate.

For this purpose, mean M is defined as:

$$\overline{M} = \frac{\sum_{a=1}^{60} (1 - \exp(-M(a))) \exp(-\sum_{i=1}^{a-1} M(i))}{\sum_{a=1}^{60} \exp(-\sum_{i=1}^{a-1} M(i))}$$

The net recruitment rate (NRR) in a given year is defined as:

NRR(t) = (recruits – natural deaths)/(population size)

$$= \frac{N(1,t) - \sum_{a=1}^{60} N(a,t-1).(1 - \exp(-M(a)))}{\sum_{a=1}^{60} N(a,t)}$$

The mean net recruitment rate in 26 years is defined as:

$$\overline{NRR} = (1/26) \sum_t NRR(t)$$

Implementation

The group did not reach agreement on the details of the implementation of a protocol of the above type at this stage, but some members believed that a procedure along the following lines would be appropriate.

A number (preferably at least 50) sets of catch at age data are to be generated for each of the cases (A-C) above (or such other cases as may later be relevant) from simulations of the population with the above dynamics. For each trial, the true population parameters are to be generated randomly from uniform distributions across the ranges specified above. These data sets are to be sent to the authors of the estimation techniques. The programme used to generate the data sets will be sent to the Secretariat for verification.

The authors of each estimation technique would send their estimates of (i) mean M and (ii) mean net recruitment rate from each of the 50 data sets to the Secretariat. These estimates would then be plotted against the true parameter values used to generate the data sets. The trials would be done blind in the sense that the estimators do not know the true parameter values before they make their estimates.

Annex J6. ON THE ESTIMATION OF AGE-DEPENDENT NATURAL MORTALITY

K. Sakuramoto and S. Tanaka

This Annex shows the results of simulation responding to the comments related to SC/40/O 23 by Horwood. That is, the simulations were conducted under the condition that the recruitment of population had been increasing at 5% per year since 1940 and it did not stop at the year of 1970. The increase had continued up to present. Natural mortality at age M_a was assumed to be constant at 0.12. It was assumed that the commercial whaling did not operate before the research take (f_t=0.0).

10-year-old and older whales were assumed to be randomly sampled ($q = 0.0$ for $a<10$, $q_a=1.0$ for ≥ 10). Sampling size was assumed either to be 1,650 in year one and five or 825 in each of year one and two and five and six. Simulations were conducted 100 times for each case and apparent increasing trends of M_a were measured by the regression slope b (See SC/40/O 23 for details).

		Apparent trend estimated	
Way of sampling		$M_{10} - M_{25}$	$M_{10} - M_{30}$
1650, 0, 0, 0, 1650	b (average)	0.0004	0.0008
	SD of b	0.0027	0.0025
825, 825, 0, 0, 825, 825	b (average)	0.0000	0.0003
	SD of b	0.0026	0.0023

The results show that the increase of recruitment does not produce the apparent increasing trend of age-dependent natural mortality as we mentioned in SC/40/O 23.

Annex J7. A NOTE ON NECESSARY CONDITIONS TO OBTAIN INFORMATION ON STOCK ABUNDANCE/RECRUITMENT TRENDS FROM CATCH-AT-AGE DATA

D.S. Butterworth

In the absence of auxiliary information, catch-at-age data alone provide no information on stock abundance and/or recruitment trends (see, e.g., SC/D87/32). Further to this, suggestions have been made that no information on such trends can be obtained without, say, a time series of a relative abundance index (see paragraph 3 of letter from Holt in SC/40/O 5). The purpose of this note is to illustrate by means of a counter-example that this is not necessarily the case, i.e., the provision of a relative abundance time series may comprise part of a sufficient set of conditions to obtain such trend information, but it is not necessarily (depending on the precision required) a necessary condition, and a much weaker condition regarding necessary auxiliary information may suffice.

The appendix following comprises extracts from an article on the application of Virtual Population Analysis (VPA) to the Namibian horse mackerel stock. The resource in question is not of immediate relevance here (for the moment), rather only the fact that any assessment method using age-structure data is essentially isomorphic to VPA.

The purpose of Figs 1–4 of the appendix is to illustrate that VPA using age-structure data alone (Fig. 1) indeed cannot estimate stock trends, and can provide only a lower bound for an abundance (or recruitment) time-series. Auxiliary information must be introduced, and one method to effect this is the so-called '*ad hoc* tuning' technique. This technique is used to fix the terminal fishing mortalities, which are generally sufficient to define the VPA solution uniquely. The appendix details one particular application of such techniques, using the assumption of asymptotically flat age-specific selectivity to tune the oldest-age terminal fishing mortalities ($F_{y,m}$), and effort data to tune the most-recent-year fishing mortalities ($F_{n,a}$). The latter is essentially equivalent to incorporating the information content of a relative abundance time series (under the assumption that CPUE is proportional to abundance).

Attention is drawn to Fig. 3 of the appendix, which shows the effects of tuning the oldest-age terminal fishing mortalities, but *NOT* the most-recent-year mortalities (i.e. *NOT* using relative abundance information). A range of [0, ∞] for the latter mortalities will again allow any possible abundance trend, excepting only the area excluded by the abundance lower bound corresponding to $F_{n,a} = \infty$. Note, however, the upper bound shown in Figure 3 corresponding to $F_{n,a} = 0.01$ (an unrealistically low value for this particular resource). Over the range $F_{n,a}$ from [0.01, ∞] *the abundance trend is very precisely determined for the earlier years of the fishery DESPITE the absence of information from a relative abundance time series.* (This is a manifestation of the well known backward convergence property of VPA.) Setting a lower limit on $F_{n,a}$ corresponds *ONLY* to the much weaker condition of providing an upper bound for the current population level, whose effect on abundances and their trends in the early years of the time series is manifest only in a weak and very non-linear fashion.

The implications of the above for analysis of whale stock catch-at-age data are given below.

(1) Relative abundance time series data are not necessarily a necessary requirement for the assessment of abundance (or recruitment) trends from age structure data.

(2) As a corollary, age-structure data may usefully augment relative abundance times series in the assessment of stock abundance trends. (If relative abundance data are available only for later years, age-structure data for the complete period allows the relative trend to be extrapolated to cover the earlier period as well.)

(3) Care should be taken in drawing conclusions as to what can be assessed from age-structure data, from analyses using the $F \rightarrow 0$ ($C << N$) limit (as, e.g., in SC/40/O 1); it is the very fact that catches ARE finite and NOT infinitesimal which gives rise to non-linear terms in the VPA equations which may allow effects otherwise confounded to be distinguished.

(4) The analyses of SC/40/O 1 and SC/D87/32 are NOT sufficient to exclude the possibility that the method suggested by Tanaka to estimate the parameter $\bar{R}$ (see *Rep. int. Whal. Commn* 38: 141) is under-determined.

Naturally, questions of estimation precision relating to the above points can only be assessed by consideration of data-parameter-space examples more pertinent to whale populations than the region of such space encompassed by the attached Namibian horse mackerel example.

Appendix

This appendix contains extracts from the following article:

Butterworth, D.S., Hughes, G. and Strumpfer, F. VPA with *ad hoc* tuning: implementation for disaggregated fleet data, variance estimation, and application to the horse mackerel stock in Divisions 1.3 + 1.4 + 1.5. *Select. Pap. ICSEAF.* (Submitted).

The extracts have been confined to certain Figures and the associated captions, as these alone provide sufficient basis to illustrate the contentions above.

[*Appendix figures overleaf*]

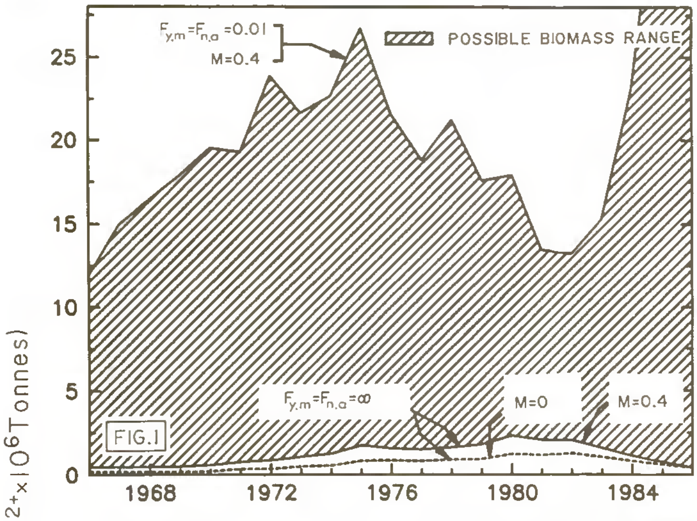


Fig. 1. The shaded area shows the range within which possible historic biomass (B^{2+}) trends for the Namibian horse mackerel stock could lie. The upper and lower bounds correspond to fixed terminal F values of 0.01 and ∞ (i.e. no tuning whatsoever). The ultimate lower limit which corresponds to $M = 0$ is shown by the dashed line.

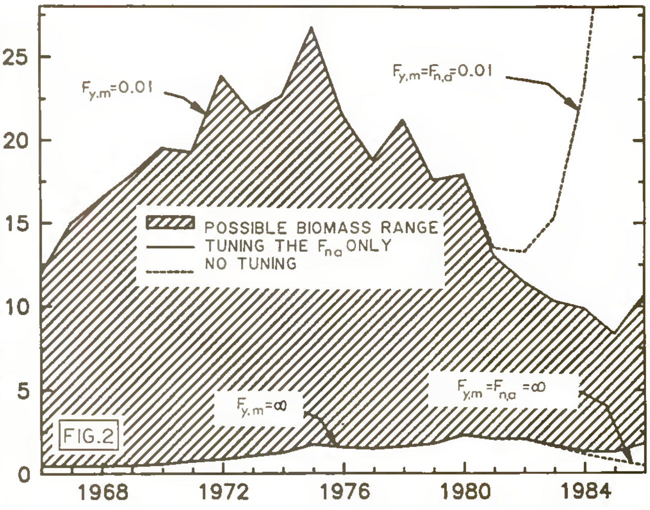


Fig. 2. The shaded area shows the range within which possible historic biomass (B^{2+}) trends for the Namibian horse mackerel stock could lie, when the terminal $F_{n,a}$ values for the most recent year are tuned using equation (6), but the oldest age fishing mortalities $F_{y,m}$ are unspecified. The bounds correspond to values of 0.01 and ∞ for $F_{y,m}$. The dashed lines are the Fig. 1 bounds for no tuning at all.

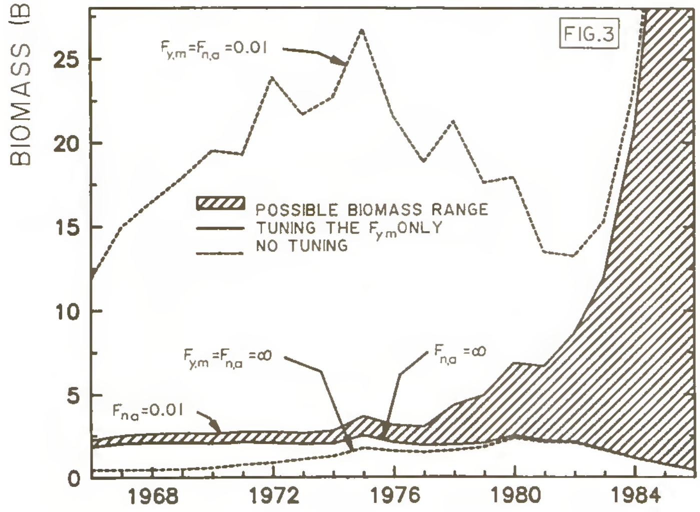


Fig. 3. The shaded area shows the range within which possible historic biomass (B^{2+}) trends for the Namibian horse mackerel stock could lie, when the terminal $F_{y,m}$ values for the oldest age are tuned using equation (9), but the most recent year fishing mortalities $F_{n,a}$ are unspecified. The bounds correspond to values of 0.01 and ∞ for $F_{n,a}$. The dashed lines are the Fig. 1 bounds for no tuning at all.

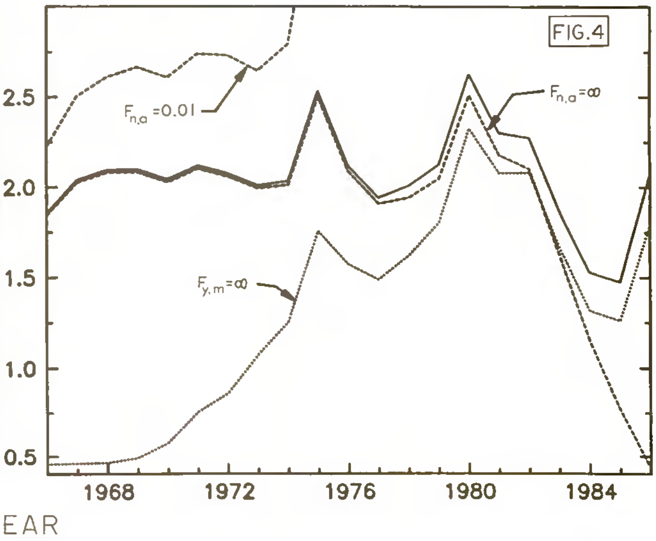


Fig. 4. The historic biomass (B^{2+}) trend for the Namibian horse mackerel stock when both the $F_{n,a}$ and $F_{y,m}$ are tuned is shown by the solid line. The dashed lines show the upper and lower bounds when only the $F_{y,m}$ are tuned; the dotted line is the lower bound when only the $F_{n,a}$ are tuned.

Annex J8. REPORT OF STEERING GROUP ON DEVELOPMENT OF MANAGEMENT PROCEDURES

Members: Kirkwood (Convenor), Allison, Butterworth, Cooke, de la Mare, Magnusson, Sakuramoto

Background

At the Workshop on management procedures held in Reykjavik in 1987 (*Rep. int. Whal. Commn* 38: 163–70), a process for developing and evaluating the performance of proposed new management procedures was developed. This involved a two-stage screening process, the first of which was to be carried out by the proposers of the procedures, and the second by the IWC Secretariat. A detailed protocol for first stage screening was developed by the Workshop and subsequently endorsed by the Committee at its 1987 Annual Meeting.

During the current Scientific Committee meeting, results of first stage screening were available for the management procedures proposed by Cooke (SC/40/O 41), de la Mare (SC/40/O 19), Punt and Butterworth (SC/40/O 26) and Sakuramoto, Tanaka and Miyashita (SC/40/O 24). During Committee discussions, it was established that first stage screening for each of these had either been completed, or very substantial progress had been made towards completion.

Magnusson informed the Steering Group that other committments in the past year had prevented him from carrying out further development of his procedure, but that he did intend to commence work on this after the current meeting. Despite the substantial progress achieved with the other procedures, all of the authors indicated that they felt further work was necessary before their procedures would be ready for second stage screening.

It was agreed that the full Committee was not an appropriate forum for the necessary detailed technical discussions of the results presented and for planning further work. Accordingly, the Steering Group was charged with the task of developing recommendations for facilitating further progress, including planning of a Workshop to be held during the intersessional period, as envisaged last year (*Rep. int. Whal. Commn* 38, p.40).

Proposed Workshop

The Steering Group **recommends** that a Workshop be held in the coming year to address the following items:

(1) detailed review of first stage screening results presented at this Scientific Committee meeting and further screening tests carried out after this meeting;
(2) develop a comprehensive protocol for second stage screening;
(3) develop procedures and mechanisms whereby the second stage screening can be efficiently carried out by the computing section of the IWC Secretariat.

The Steering Group **recommends** that this Workshop should be convened by Kirkwood and be held over a period of five days early in 1989. This timing should allow the required further work to be completed, but yet still leave time for some progress towards second stage screening to be made by the Secretariat prior to the 1989 Annual Meeting. Failing an invitation to host the Workshop elsewhere, the most appropriate venue would be Cambridge. The precise dates for the Workshop depend both on the venue and on the availability of the proposers of the management procedures. These will be agreed by correspondence between members of the Steering Group soon after this Annual Meeting; it is essential that all members concerned are able to attend the Workshop. The budget required for the Workshop is estimated to be £15,000, including provisions for invited participants with expertise in development of optimal management procedures in fisheries. No computing will be required during the Workshop.

Preparatory work before the Workshop

For the Workshop to be successful, it is essential that certain preparatory work be completed prior to the Workshop. Accordingly, the Steering Group **recommends** that the work listed below be completed.

(1) Further development of the procedures be conducted prior to the Workshop, to the extent that the procedures are deemed by their proposers to be as ready as possible for second stage screening. Papers describing these developments should be circulated amongst members of the Steering Group prior to the Workshop where possible.

(2) Properly documented and fully operational computer programs implementing the procedures and first stage screening should be brought to the Workshop. These should be written in a sufficiently modular form that it would be possible to interchange modules implementing the different procedures.

(3) Immediately after this meeting, each author of a management procedure should send to Allison a documented FORTRAN version of a program implementing first stage screening on his management procedure. Using these programs as a basis, Allison should attempt to develop a master program, into which the various management modules could be fitted, initially including modules implementing the scenarios outlined for the first stage screening protocol.

Annex J9. TELEMETRY AND REMOTE SENSING WORKING GROUP REPORT

Members: Albert, Braham, DeMaster, Hohn, Joyce, Kasamatsu, Le Gall, Ljungblad, Lockyer, Martin (Convenor), Mate, Moore, Scott, Swartz.

Terms of reference

The working group agreed to direct its comments and discussions with reference to the Scientific Committee's definition of the Comprehensive Assessment. Thus, while recognising that telemetry and remote sensing have uses in many fields of cetacean biology, this report covers only those topics of relevance to determining the status of large whale stocks in the light of management objectives and procedures.

Scope of the discussions

The group briefly considered remote sensing other than radio telemetry, but concluded that relatively little of relevance in the current context could be gained from the use of such tools as satellite imagery. Indirect advantages include a better understanding of oceanographic dynamics which might help to explain whale distribution, and more efficient and accurate surveying by allowing the simultaneous monitoring of environmental conditions. We acknowledge the role of photogrammetry in some aspects of assessing whale stocks and feel that the subject was adequately considered at the recent Workshop on Individual Recognition and the Estimation of Cetacean Population Parameters (see SC/40/Rep1).

Remote sensing in general was considered in more detail by a workshop sponsored by the US Marine Mammal Commission in March 1987 at the Northwest and Alaska Fisheries Center, Seattle (Montgomery, 1987*). The Seattle workshop reached a similar conclusion to this working group and interested parties should refer to the report of the workshop for a comprehensive overview. The remainder of this report will thus be focused on uses of radio telemetry in the pursuit of information on the status of stocks. The term 'conventional telemetry' will be used for shorter range VHF and HF transmitters, and 'satellite telemetry' for UHF transmitters relaying signals via satellites.

On what topics related to management could telemetry provide information, either now or in the foreseeable future?

Four topics were identified as being of greatest importance in addressing the Comprehensive Assessment: stock identity; population size; population trends; and RY or MSY.

Stock identity (stock boundaries)

This is the one topic on which new, direct information can be expected from the use of telemetry in the short and medium term. Some work has already been done using conventional systems, but the very nature of the task requires data on numbers of scattered animals over a period of months or years, and this could only be accomplished using satellite-linked tracking. The group considered that the newly-acquired information may force a reappraisal of stock delineation as the spatial dynamics of whale groups become clearer and strict geographical limits become inappropriate.

Population size, population trends and RY or MSY

There seems little hope that telemetry can be expected to provide direct evidence on any of these topics. Nevertheless, telemetry could usefully be employed to provide information which indirectly improves our knowledge of one or more of these parameters, e.g.:

(1) Sighting cues. Radio transmitters allow the determination of dive times, blow rates and surfacing rates. These are required as parameters in the analysis of survey data.
(2) Rates and diurnal patterns of migration. Conventional telemetry can be easier and cheaper for short-term near-shore migrations, while satellite tags can be employed to look at both near-shore and offshore stocks in the long-term.
(3) Immigration/emigration. Capture-recapture experiments can be assessed much more accurately if the rates of immigration to and emigration from the sampling area is known. Again, tracking by satellite is more cost effective for long-term studies.
(4) Geographical distribution. Both aerial and ship surveys can be better planned and more accurate if areas of high and low whale density and the limit of distribution are known beforehand. Assessment of birth rates may be improved if aggregations of cow-calf pairs can be located. Tracking by satellite required.

Differences between species in amenability to telemetry; general considerations

Information on the status of stocks can be gained in the short or medium term using opportunistic tagging, but larger numbers of animals must be taggable before the management of whale stocks can benefit significantly from telemetry studies. The achievement of this aim is dependent largely on transmitter design (size, attachment and delivery systems) and on the ease with which particular species of whale can be approached to within taggable distance and the instrument attached correctly.

Developments in electronics design and construction have resulted in the production of radio transmitters small enough to be attached even to dolphins. The two major problems now are the delivery system to be used and long-term retention of the transmitter once it has been placed. Retention will be improved if the device can be attached at close range. Remote delivery is facilitated by a close approach and a long surface-time between dives.

In general, results might first be expected from catchable small cetaceans and slower-swimming, approachable large whales such as the right whales and sperm whale. Data from tagged rorquals will probably not be consistently recovered until a delivery system is developed for unrestrained animals, e.g. by crossbow or gun.

Results to date in cetacean telemetry studies

So far, studies of large whales resulting in more than just a few days of signals have used conventional telemetry. They include: fin whales off Iceland; gray whales off Baja California and several sites off the US west coast; and humpback whales off Canada and southeast Alaska.

---

* Montgomery, S. 1987. Report on the 24–26 February 1987 workshop to assess possible systems for tracing large cetaceans. Report no. mms 87-0029 of the Marine Mammal Commission, Washington DC, USA.

Although first successfully demonstrated on cetaceans only five years ago, satellite telemetry has already achieved short-term results on large whales, e.g. humpback and sperm whales, and tracks of up to 35 days on bottlenose dolphins and 95 days on a pilot whale (SC/40/O 42).

Results anticipated by 1990

The large amount of development and testing followed by complex logistical planning required for telemetric studies necessitates a long lead-time for any project. It is thus unlikely that any work not already begun will produce results of use before the 1990 target of the Comprehensive Assessment. Apart from a project on right whales, no large-scale studies using satellite telemetry on large cetaceans are likely to come to fruition in the period, but experimental work is anticipated on humpback, minke, gray, and sperm whales. Conventional telemetry, more likely to produce short-term quantitative results, is expected on minke, blue, fin, humpback and possibly gray whales.

Anticipated progress in the next 10 years

Three problems have adversely affected the development of this technique:

(1) a lack of consistency in year-to-year availability of funds;
(2) reliable attachment mechanisms;
(3) sufficiently miniature electronics and energy efficiency.

Great progress has been made on the third area but problem number (1) has had a negative impact on problem number (2). We feel that if funding is consistent and constant over several years, then the next 10 years will see the fulfillment of much of the promise of this technique.

The working group considered that recent advances in materials, electronic design and attachment devices will be continued to the point where a satellite-linked transmitter will be small enough to implant in the same way as today's VHF 'capsule tag'. Improved biocompatibility may be expected to increase tag retention to perhaps a year, but a totally implantable transmitter may not be possible because UHF signals as used by the current satellite system are absorbed by animal tissue.

New or improved satellite systems may become available, giving potential benefits of smaller transmitter power requirements, location from a single message (rather than the current two or more messages) and locations during a greater proportion of the day.

In the short-term, the speed of development of telemetry for all cetaceans is likely to be enhanced if work is first carried out on smaller cetaceans. A shorter period is possible between tests of design iterations, and animals can be held in captivity so behaviour and tissue reaction can be observed.

Thus, in general, transmitters can be expected to become smaller, lighter, longer-lasting (though not immortal) and more easily attached. Unit prices of satellite tags are likely to diminish, perhaps to around $1,000, when large numbers can be ordered. The group thus felt that the medium-term prospects for the successful use of radio telemetry is excellent and that it is likely to be routinely producing results of value to the Commission within the next decade.

Requirements for the orderly development of telemetry on cetaceans

(1) *Regular meetings*. Experience has shown that much time and money can be wasted, and progress hindered, if groups work in isolation. Provision of a regular forum at which to discuss ideas and results would be beneficial to all.
(2) *Peer review*. There should be comprehensive review of all tagging proposals with careful consideration of all potential implications of the research.
(3) *Improvement of sampling strategy*. Due to the large amounts of data resulting from satellite studies, consideration of sampling (transmission) strategies need to be worked out at the study design phase. Analysis of current examples will be helpful in planning future tagging efforts.

Recommendations

(1) The Working Group **recommends** that the Commission requests the Secretary to write to Service Argos, NOAA and NASA urging them to implement the concept of a dual beam interferometer on future satellites to provide locations from single messages. These letters should communicate the Working Group's belief that satellite telemetry will become increasingly important in its work and that the ability to locate cetaceans from a single transmission would be advantageous.
(2) The Working Group believes that telemetry, particularly using satellite–linked transmitters, provides and will increasingly provide valuable information of use in the assessment of the status of whale stocks in relation to management. It **recommends** that member governments provide adequate funding to allow the development and use of telemetry to progress rapidly, and further **recommends** that such funding be of several years continuous duration in recognition of the special requirements of this work.

Annex J10. A NOTE ON THE CONSIDERATION OF THE MSY% IN THE COMPREHENSIVE ASSESSMENT

D.S. Butterworth

Abstract

The matter of MSY% estimation is important and merits more attention. It is suggested that:

(1) sources of existing estimates (or opinions) should be listed;
(2) the methods used and assumptions made in reaching these estimates should be critically reviewed, in part because some may no longer be considered to be acceptable;
(3) future research priorities, particularly as regards the development of (absolute or relative) abundance time-series from direct surveys, should be specified.

Introduction

Much of the attention and resources in the IDCR and, more recently, the Comprehensive Assessment have been focussed on the estimation of the sizes of a number of whale populations, in particular by use of sighting surveys. Estimates have been forthcoming with CVs of perhaps 20% (though admittedly also with some conceivably larger systematic errors due to incomplete area coverage and assuming g(0) = 1 to obtain final abundance estimates).

Without detracting from the value of these initiatives, it is important not to forget that scientific advice for management authorities regarding catches (whether for potential commercial, aboriginal or experimental-permit whaling) is equally dependent on the estimation of net recruitment rates. It seems probable that the Scientific Committee will continue (at least in the short to medium term) to place some import on the estimation of MSY% (the ratio of MSY to MSYL expressed as a percentage, where MSYL is the population size at which MSY is achieved) for whale populations for guidance as regards possible values of net recruitment rates. This appears to be likely notwithstanding reservations which have been advanced (Chapman, 1987) concerning inference by analogy (use of an MSY% estimate for one population for a different stock of the same species, or for a different species), and also notwithstanding the possibility that management procedures of an empirical feedback type which do not require explicit estimation of net recruitment rates may be considered.

The wide divergence of opinions in the Scientific Committee about appropriate values for MSY% for baleen whales seems at present to be conventionally encompassed by the range 1%-4%. This represents a level of uncertainty that could be said to be some three-fold larger than that for typical population size estimates. It thus seems important that more attention in the Comprehensive Assessment be focussed on the matter of MSY%. The author suggests that this might be done under the following three headings.

(1) Listing the sources of existing estimates for (or opinions concerning) MSY%

For example, this list might include:

(1) Reilly (1984, 1987) – Northeastern Pacific Gray whale stock: an annual growth rate estimate of about 2.5% from shore-based censuses coupled with an annual harvest of about 1% suggests an MSY% in the vicinity of 3.5%.
(2) Best (1985) – South African Right whales, and Whitehead, Payne and Payne (1986) – Argentinian Right whales: annual growth rate estimates of about 7% from direct surveys and natural-mark-recapture observations respectively (the latter estimate being very imprecise) for very depleted stocks; Fowler's (1981, 1984, 1988) hypothesis of convexity in net growth rate as a function of stock size implies that MSY% must be minimally 50% of this figure (assuming transient age structure effect are not substantial), i.e. minimally some 3.5%.
(3) Clark (1982) – Antarctic fin whales: declines (in contrast to anticipated compensation effects) in gross recruitment rates during the period of exploitation suggest that MSY% is very low (<1%?).

These examples are intended to be illustrative only; the list does not pretend to be exhaustive, nor do the details given pretend to be complete. However, the author suspects that the total list would (embarrassingly) prove to be not very long, and hence that it could readily be compiled by an ad hoc sub-committee (should that be deemed appropriate) during this Scientific Committee Meeting.

[Appendix 1 contains an initial attempt made by the author during the meeting to develop such a list.]

(2) Critical review of the methods used and assumptions made in obtaining the 'estimates' of MSY% listed under (1)

In view of the importance of the value of MSY%, and particularly since some of the sources that might be listed under (1) are not that recent, it would seem desirable that the methods used and assumptions made in estimating or reaching an opinion concerning MSY% should be stated and critically reviewed. It may be that while the result of an earlier analysis continues to be cited, the methods or assumptions on which it was based would no longer be (as) acceptable to the Scientific Committee in the light of more recent appraisals of these methods or assumptions.

For example, Clark's (1982) analysis of the Antarctic fin whale catch-at-age data used De Lury (CPUE-based) estimates of total population size for the final years of the periods considered, and further allowed for possible age–dependent M effects in a very limited fashion only. Recently views have been expressed in the Scientific Committee that CPUE is 'not suitable as a primary means of assessing stocks........ except...... where a precise relationship (between changes in CPUE and changes in abundance) had been identified' (IWC, 1988), and further that 'it is not possible to obtain unique estimates of recruitment.... from catch-at-age data alone' (IWC, 1989). Does it follow from these views that the conclusion of Clark (1982) can no longer be regarded as well founded (without, perhaps, further analysis at least); or, more broadly, are estimates of MSY% based on catch statistics (CPUE and/or catch-at-age data) only no longer acceptable?

The assumptions underlying the conclusions drawn from the census time-series for various stocks also merit close scrutiny. For example, is there satisfactory evidence that the South African right whale increase rate referenced above is entirely a reflection of a population increase without a substantial immigration component?

It may not be feasible to complete an all-embracing review of such factors during this Scientific Committee Meeting, but it should perhaps be possible to make a start and to identify the more serious concerns at least.

(3) Specification of future research priorities

Attention needs to be given here to what further research would be most likely to resolve the questions that may be raised in the review suggested above. Can critical field experiments be designed to distinguish alternative interpretations of existing data such as the census time-series; or would further analysis of existing data remove (some) uncertainties? For example, would it be desirable to recommend repeating Clark's (1982) Antarctic fin whale assessment under different assumptions for terminal population sizes and age-dependent natural mortality schedules? (Clark (1984) suggests that his results are insensitive to modifications of these assumptions, but without quantified specification of the range of modifications examined.)

There seems to be consensus in the Scientific Committee that the most reliable basis for estimating net recruitment rates (and hence, eventually, MSY%) will be provided in the future by time-series of relative (if not absolute) stock abundance estimates obtained probably from scientifically designed surveys which are independent of the biases that may arise for normal fishing operations. Given that resources to fund such surveys will always be limited, there may be merit in giving attention to relative priorities in this regard. Questions that might profitably be addressed include:

(i) which stocks would provide the best practical prospects for such surveys?

(ii) should limited resources be used to attempt to monitor many of these stocks, or rather to concentrate only on a few?

(iii) should higher priority be given to continuing existing longish time-series, or to developing shortish or new series for other stocks?

Again, it would seem neither unfeasible nor undesirable for this Scientific Committee Meeting to consider giving at least initial attention to these questions.

REFERENCES

Best, P.B. 1985. The recovery of right whales off South Africa. Paper SC/37/PS28, presented to the IWC Scientific Committee meeting, June 1985 (unpublished).

Clark, W.G. 1982. Historical rates of recruitment to Southern Hemisphere fin whale stocks. *Rep. int. Whal. Commn* 32: 305–24.

Clark, W.G. 1984. Recruitment rates of Antarctic fin whales, *Balaenoptera physalus*, inferred from cohort analysis. *Rep. int. Whal. Commn* (special issue 6): 411–5.

Chapman, D.G. 1987. Southern Hemisphere minke whale recruitment rate. *Rep. int. Whal. Commn* 37: 79–80.

Fowler, C.W. 1981. Density dependence as related to life history strategies. *Ecology* 62(3): 602–10.

Fowler, C.W. 1984. Density dependence in cetacean populations. *Rep. int. Whal. Commn* (special issue 6): 373–9.

Fowler, C.W. 1988. Population dynamics as related to rate of increase per generation. *Evolutionary Ecology*. (In press).

International Whaling Commission. 1988. Report of the Scientific Committee, *Rep. int. Whal. Commn* 38: 32–155.

International Whaling Commission. 1989. Report of the Special Meeting of the Scientific Committee to consider the Japanese research permit (feasibility study), Cambridge, UK, December 1987. (Published in this volume.)

Reilly, S.B. 1984. Observed and maximum rates of increase in gray whales, *Eschrichtius robustus*. *Rep. int. Whal. Commn* (special issue 6): 389–99.

Reilly, S.B. 1987. Reanalysis of rate of change in the California-Chuckotka gray whale stock, 1967/68 – 1979/80. *Rep. int. Whal. Commn* 37: 347–9.

Whitehead, H., Payne, R. and Payne, M. 1986. Population estimate for the right whales off Peninsula Valdes, Argentina, 1971–76. *Rep. int. Whal. Commn* (special issue 10): 169–71.

Appendix 1

A suggested list of desirable contributions for presentation at the next meeting to aid a review of MSY%

For the purpose of critically reviewing the evidence for estimates of (or opinions concerning the likely range of) MSY%, or estimates of net recruitment rate from which inferences about MSY% might be drawn, it would be useful if *analyses* or *succinct summaries of existing literature* could be provided to the next meeting on the following topics (and any others that may have relevance). Such summaries or analyses should include estimates with their associated estimation precision (where relevant), and also a critical discussion of the assumptions made in obtaining the estimates and relating them to MSY% (or net recruitment rate).

(I) *Increase rates from direct surveys*

(a) Gray whales:		E N Pacific
(b) Humpback whales:	(i)	NW Atlantic
	(ii)	Areas IV and V (Australia)
(c) Right whales:	(i)	Argentina
	(ii)	Australia
	(iii)	South Africa

(II) *Change in biological parameters*

(a) Fin whales:	(i)	Antarctic
	(ii)	Iceland
(b) Sei whales:		Antarctic
(c) Minke whales:	(i)	Antarctic
	(ii)	NW Pacific

(d) Potential net recruitment rates as functions of biological parameters values and their changes.

(III) *Analysis of catch-at-age data*

(a) Fin whales:	Antarctic
(b) Minke whales:	Antarctic

(IV) *Fits of population models*

(a) Bowhead whales:	B-C-B sea stock
(b) Fin whales:	Iceland

(c) Potential precision from fitting models to absolute estimate(s) and/or relative abundance time series.

Annex J11. GALAPAGOS SPERM WHALE STUDY – SUMMARY

SC/40/Sp1 gives details of two single sperm whales tracked using passive acoustics off Nova Scotia for 12.5 and 7 hours respectively. During these periods their sounds were recorded continuously. Of the results presented, those of most relevance to the Committee were the distribution of time periods spent at the surface and vocalising (SC/40/Sp1, Figs 3 and 5). Data of this type are necessary if visual or acoustic censuses are to be calibrated in order to obtain estimates of absolute abundance.

SC/40/Sp2, Sp3 and Sp4 presented results of studies of sperm whales off the Galapagos Islands carried out between late February and late April 1985 and early January and late June 1987. The latter study was partially funded by the Commission.

SC/40/Sp2 presented results concerning the seasonal cycle of sperm whales off the Galapagos during the study periods. Both visual and acoustic data showed that the proportion of large mature males in the population reached a maximum (2–3% of the population) in April and May, although large males were present in all the months that studies were carried out. The mean duration of interactions between mature males and groups of females was longer, but not significantly so, in April. No very small calves were sighted before the end of April. One recently born animal was seen in late April, and several during June. Other calves measured during April-June were approximately 6m long, or one year old. These results suggest that the sperm whales observed off the Galapagos mate in April-May and calve in June-July, a 'Northern Hemisphere' reproductive schedule. The geographical distribution of sperm whales around the Galapagos changed with season, but there were no significant seasonal changes in abundance.

SC/40/Sp3 presented results on the social organisation and population size of the sperm whales off the Galapagos. Most results are from individual identifications: 224 females or immatures were identified in 1985 and 389 in 1987 from photographs of high quality. Seven large mature males were identified in 1985 and six in 1987. The females/immatures were allocated to groups and the groups were tested for closure using average linkage cluster analysis and likelihood ratio tests (Whitehead and Arnbom, 1987. Social organisation of sperm whales off the Galapagos Islands, February-April 1985. *Can. J. Zool.* 65(4): 913–9). Most of the 12 groups identified in 1985, and 23 in 1987, probably closely correspond to actual groups with almost closed membership. However, there are problems with the clustering process in some cases: a very few 'transient' whales moved between groups, there may be a small number of mis-identifications, and groups associated on occasion confusing the clustering. Three groups maintained much of their identity over the two years between the two studies, identified calves were found to remain within identified groups, and there were morphological similarities within groups. The mean estimated group size was 21 individuals.

Maximum likelihood methods were used to fit models of geographical population structure to the identification histories of the groups. The data were consistent with either: groups from a much larger North Pacific population moving into and out of the Galapagos area, or groups moving into and out of the Galapagos area from a surrounding stock of about 76 groups. The data fit these models significantly better than one of a closed Galapagos population. 'Best fits' of these models suggest that there are about 15–22 groups off the Galapagos at any time, with immigration and emigration rates of about 1–3.5 groups per month.

The groups of females were attended by large mature males (12.8 – 16.4m) about 12–16% of the time, although this varied seasonally. No large males were individually identified in both 1985 and 1987.

SC/40/Sp4 compared results from the 1985 (a 'cool', normal year) and 1987 (an 'El Niño' year) studies. The distribution, abundance and diet of the sperm whales appeared similar in the two years, but whales dived to shallower and more variable depths in 1987, and the rate at which faeces were observed was significantly less than in 1985. Excretion rates were negatively related to sea surface temperatures.

Annex J12. COMMENTS ON SC/40/Ba1 RE: SOUTHERN HEMISPHERE FIN WHALE PREGNANCY RATES

Kirkwood presented the analysis undertaken in SC/40/Ba1, which examined pregnancy rate versus length, season (year), month, area and expedition (factory ship) in Southern Hemisphere stocks of fin whales. A 3-parameter (logistic) model for the relationship between fraction of females pregnant and length was postulated. Only the factors expedition and season were required to account for the observed variability in the data. Other factors were not distinguishable from sampling error. For a significant majority of the expeditions there was an increase with season in the maximum pregnancy rate parameter and the parameter for the length at which animals obtain half the maximum pregnancy rate. The author concluded that the results were consistent with the hypothesis that reproductive rates in southern stocks of fin whales had increased in a density-dependent manner in response to increased exploitation of baleen whales.

Cooke felt that the results were broadly consistent with previous studies where the major factor contributing to variability was expedition. This implies that expeditions were not consistent in the way pregnant females were reported. Thus, calculated trends in pregnancy rates as calculated in this paper may not accurately reflect a real trend. Holt suggested the introduction of an additional factor (the size of the foetus) in any future analysis.

Horwood considered that the approach adopted to remove the effect of length was productive, but noted that comprehension of details of such a complex and large analysis was difficult, and presentation of all details could not be expected. However, he expressed surprise that 'month' had not emerged as a significant factor. This would be expected to be a major effect given our knowledge of the weaning process and many previous studies by biologists (e.g. the Discovery Reports). He considered that the factor could be imposed as a necessary parameter. Two other aspects were raised; first, that apparent rates had been interpreted as true rates for the purpose of calculating calving interval; and second, attention was drawn to additional previous studies that indicated increase in pregnancy rates with year (Horwood, Donovan and Gambell, 1980, *Rep. int. Whal. Commn* 30: 531–5).

Mizroch noted that the analysis presented in SC/40/Ba1 was an interesting extension of her previous work with York (Mizroch and York, 1984). She also pointed out that 'month' was a significant factor in each of her previous studies on Southern Hemisphere baleen whale pregnancy rates (Mizroch, 1980, *Rep. int. Whal. Commn* 30: 561–74; 1981, *Ibid* 31: 629–33).

Chapman noted that as a foetus grows larger the apparent pregnancy rate is likely to increase, due to increased likelihood of detection of foetuses. On the other hand, diminished protection of females with calves through the season would tend to reduce the apparent pregnancy rate. It is unclear to what extent these two effects would tend to cancel.

The analysis in SC/40/Ba1 also showed a significant reduction in the mean length at sexual maturity in the time series. This is not in conformity with biological samples which show no change (Gambell, 1973, *J. Reprod. Fert.* Suppl. 19: 531–51).

Best, in SC/40/O 20, reported on his experiences as a biologist on board a factory ship as well as at a land station. He observed inconsistent reporting of the presence of foetuses and considered that pregnancy rates determined from official statistics were unreliable. Bannister also considered that foetus information derived from the official statistics is unreliable.

The sub-committee agreed that the data are sufficiently flawed that further analyses are not called for. Kirkwood agreed to convey the sub-committee's comments to the author.

Annex K

Ad Hoc Working Group on a 1988/89 IWC/IDCR Southern Hemisphere Sightings Cruise

Members: Best, Borchers, Butterworth, Cawthorn, Harwood (Convenor), Joyce, Kasamatsu, Kasuya, Kato, Kirkwood, Kishino, de la Mare, da Rocha, da Silva

INTRODUCTION

The Working Group was established to discuss the offer from the Government of Japan to provide two research vessels for an Antarctic sightings cruise in 1988/89. The Scientific Committee had recommended that such a cruise should take place as part of the IWC/IDCR. The Working Group was asked to recommend the most appropriate Area, or Areas, in which to conduct the survey, and to provide information on the logistic details and budget for such a cruise.

CHOICE OF SURVEY AREA

The Working Group reviewed the criteria which had been established last year for the choice of a survey Area (*Rep. int. Whal. Commn* 38: 135). It concluded that these were no longer appropriate in the light of more recent discussions in the Southern Hemisphere Minke Whale sub-committee and in the Scientific Committee.

The Working Group agreed that it was important to continue the programme of repeat surveys of Areas using a consistent methodology. Three areas have been surveyed only once: Areas I, IVE, and VI. The Group noted that if Area I or VI was chosen, relatively little time would be available for survey in those Areas because of the long transit time from Japan. In addition, the low density which had been recorded in these Areas on previous cruises and the fact that only two vessels (rather than the three which had been used on previous surveys) were available, implied that estimates of abundance from a cruise in Area I or VI would have poor precision. The Group therefore considered that priority should be given to a second survey in Area IVE.

The Group concluded that it would be valuable to carry out a survey of a complete 60° sector and therefore discussed whether the rest of the survey should be in Area IVW or in Area VW. It noted that the Southern Hemisphere Minke Whale sub-committee had commented on the marked difference in abundance between Areas IV and V indicated by previous surveys. It was suggested that a survey in Area VW might provide some information on the segregation of stocks and on local movements in this region. However, it was not clear whether there actually was a difference in density between Area IVE and Area VW. In addition, it was not obvious how to interpret any differences in density which might be observed.

The Group therefore **recommended** that the 1988/89 Survey should be conducted in Area IV. The 1984/85 Passing Mode surveys of Area IVW had not used an IO and so was not strictly compatible with the results from the most recent surveys in Areas II, III and V. A complete survey of Area IV using the currently accepted methodology would therefore provide an assessment which was consistent with these other surveys.

The Group noted that a Brazilian vessel might be available in 1989 for a sightings cruise in the northern waters of Area II. It **recommended** that, if a Brazilian vessel is available consideration should be given to carrying out an IDCR cruise in this region in 1989/90 which would allow a comparison of skin samples taken with biopsy darts and photo-identification data collected from high and low latitudes in the same season.

SURVEY METHODS AND EXPERIMENTS

The Working Group noted that an effective survey protocol had now been developed and implemented on the three most recent IWC/IDCR cruises. It **recommended** that the 1988/89 cruise should be conducted using this same protocol with the minimum of modification. The Working Group endorsed the Scientific Committee's recommendation that the pre-cruise planning meeting should consider carrying out cue counting and line transect sampling simultaneously on one of the vessels. If this was decided, blow rate measurements should be conducted at regular intervals during the cruise. Experimentation should be limited to testing of biopsy dart equipment in areas of high minke whale density and, in periods of poor weather, incidental collection of individual identification photographs.

It **recommended** that the Government of Australia should be approached as soon as possible to determine if the research vessels will be allowed to berth in Fremantle if they will be carrying out biopsy dart sampling. If permission is not granted in time for the pre-cruise planning meeting, then biopsy dart sampling should not be conducted on the cruise.

CRUISE DETAILS

The *Shonan Maru* and *Shonan Maru 2* will be available. Both have a cruising range of 60 days so that refueling will not be necessary. The home port will be Fremantle (Australia). Timing of the cruise should be as close to the 1978/79 cruise as possible, i.e. from about 25 December to 1 March.

Table 1

Budget for the 1988/89 IDCR cruise (including associated meetings)

(1) Costs of cruise

A. Participants

	Grant	Travel	Per diem	In-port	Insurance	Bank charges	Other
USA	3,200	2,000	500	600	200	80	200
USA	3,200	2,000	500	600	200	80	200
New Zealand	3,200	1,000	500	600	200	80	200
Brazil	3,200	1,800	500	600	200	80	200
Another	3,200	2,000	500	600	200	80	200
Totals	16,000	8,800	2,500	3,000	1,000	400	1,000

sub-total £32,700

B. Equipment and Sundries

Development and purchase of biopsy darts and bow	1,000
Shipping of biopsy samples	200
Communication costs (ice-edge data)	1,000
Software development	1,000
Photocopying	50
Airfreight of data	300
Cue counting equipment	500

sub-total £4,050

(2) Costs of specialist/planning meeting

Travel and per diem for 6 days attendance by 6 participants including senior scientist and cruise leader — sub-total £8,500

GRAND TOTAL £45,250

A total of 7 researchers will be required if cue counting is conducted. Japan will supply 2 scientists, including the cruise leader (Kasamatsu). Other participants may come from the USA, New Zealand and Brazil. Participants will be chosen on a competitive basis. The Working Group noted that it would be desirable to include observers who may participate in the 1989 North Atlantic Sightings Surveys (NASS-89). The senior scientist for the second vessel will be selected in advance of the planning meeting after consultation between the overall organisers and the convenor of the planning meeting.

On board costs will be US $15.00 per researcher per day on each vessel. Total costs associated with the cruise, including meetings, are given in Table 1.

EXPERIMENTS PLANNED FOR THE CRUISE – BUDGETARY CONSIDERATIONS

None of the experiments planned for the cruise involves major expenditure. However, suitable biopsy darts will need to be developed and manufactured and it may be necessary to build some specialised equipment for the cue counting.

In addition, some specific software must be written for use with the on-board computers.

SPECIALIST/PLANNING MEETING

It was agreed that such a meeting should be held in Japan in September or October. It was recommended that the cruise leader, the other senior scientist and 5 selected experts should attend. IWC funds for 6 participants are therefore requested. The meeting should last 6 days.

ALLOCATION OF RESPONSIBILITIES

Overall organisation will be coordinated by Gambell and Kasuya, logistic arrangements will be made by Kasamatsu.

Harwood will convene the specialist/planning meeting with Kasuya and Kasamatsu responsible for local arrangements. Bannister will be asked to handle arrangements in Fremantle.

Annex L
The Model Used in the Hitter and Fitter Programs (Program: Fitter. SC40)

W.K. de la Mare

The population model used is an age structured model in which the proportion in the recruited population is specified by a logistic function:

$$\alpha_a = \frac{1}{1 + \exp[-k_r(a - r_{50})]}$$

with the restrictions

$$\alpha_1 = 0 \text{ and } \alpha_{max} = \alpha_{max - 1} = 1$$

where r_{50} is the age at 50% recruitment, a is the age, max is the oldest age class used, and k_r is a constant. The value of k_r is calculated by the programs from a value for the age at 95% recruitment, i.e.:

$$k_r = \frac{+\ln(19)}{(r_{95} - r_{50})}$$

where r_{95} is the age of 95% recruitment.

Similarly, the proportion mature at each age is given by:

$$\beta_a = \frac{1}{1 + \exp[-k_m(a - m_{50})]}$$

where m_{50} is the age at 50% maturity and

$$k_m = \frac{+\ln(19)}{(m_{95} - m_{50})}$$

where m_{95} is the age at 95% maturity. It should be noted that for females, 'maturity' actually means 'having reached the age of first parturition'.

In the programs, knife-edged recruitment or maturity is used if:

$$r_{95} \leq r_{50} \text{ or } m_{95} \leq m_{50}$$

The initial population age structure is set up separately for each sex from the following generic expressions for recruited population:

$$n_a = 0 \qquad a = 1$$

$$n_a = \alpha_a \exp[-\sum_{j=1}^{a-1} M_j] \qquad 1 < a < max$$

$$n_a = \frac{\alpha_a \exp[-\sum_{j=1}^{max-1} M_j]}{1 - \exp[-M_a]} \qquad a = max$$

where n_a is the relative number of animals of age a and M_a is the natural mortality rate from age a to a+1. Natural mortality is assumed to be independent of age for age classes max and older.

For the unrecruited population:

$$u_1 = 1 \qquad a = 1$$

$$u_a = (1 - \alpha_a) \exp[-\sum_{j=1}^{a-1} M_j] \qquad 1 < a < max$$

The mature female population in the initial population is:

$$f_m = \sum_{a=1}^{max} \beta_a (n_a + u_a)$$

The combined birthrate and juvenile survival rate to age 1 is given by:

$$B_0 = \frac{1}{f_m}$$

The initial population structure is multiplicatively adjusted to the appropriate recruited population for the initial year by the hitting or fitting search process. Catches are removed from the model population as it is advanced each year. The catches can be removed from the overall recruited population or from the mature segment of the recruited population only. The transition for each age and sex (in generic terms) is:

$$N_{a+1,t+1} = \exp[-M_a]N_{a,t} [F_{r,t} - \beta_a F_{m,t}] + U_a \gamma_{a+1}$$

where $N_{a,t}$ is the recruited number of age a in year t, $F_{r,t}$ is the survivorship after catching from the recruited stock, given by:

$$F_{r,t} = 1 - \frac{C_{r,t}}{\sum_{a=1}^{max} N_{a,t}}$$

where $C_{r,t}$ is the catch from the recruited population in year t. These catches include both mature and immature animals, and they are removed unselectively with respect to maturity. $F_{m,t}$ is the proportion of the mature segment of the population caught given by:

$$F_{m,t} = 1 - \frac{C_{m,t}}{\sum_{a=1}^{max} N_{a,t} \beta_a}$$

where $C_{m,t}$ is the catch from the mature segment of the recruited population. The catches are dealt with in this way to allow for situations where two ages at recruitment apply through the existence of different size limits for coastal and pelagic fisheries. In the former, size limits allow the catches of some immature animals, whereas in the latter the mature and pelagic recruited populations will be very similar. In other situations it is sufficient to specify the catch for the recruited population only; specifying zero catches from the mature population does *not* mean that no part of the catch is considered to be mature. U_a is the number of animals not recruited at age a and γ_{a+1} is the proportion of the U_a which recruit at age a+1, and is given by:

$$\gamma_{a+1} = \frac{\beta_{a+1} - \beta_a}{1 - \beta_a}$$

The transitions for the unrecruited segment of each age class are given by:

$$U_{a+1,t+1} = U_{a,t} \exp[-M_a] \, (1 - \gamma_{a+1})$$

The first age class is all unrecruited and is given by the following density dependent function:

$$U_{1,t+1} = P_t B_0 [1 + A\{1 - (N_t/N_0)^z\}]$$

This assumes that the sex ratio is 1:1 at age 1, P_t is the total mature female population in year t and is given by:

$$P_t = \sum_{a=1}^{max} (N_{a,t} + U_{a,t}) \beta_a.$$

N_t is the (exploitable) total population and N_0 the (exploitable) carrying capacity. N_t is given by:

$$N_t = \sum_{♂+♀} \sum_{a=1}^{max} N_{a,t}$$

The parameters A and z are the resilience and degree of compensation respectively. Their values are determined by the specified MSY rate and MSYL. No general closed form expression exists for determining z and the programs use a numerical method to fix this parameter.

The parameters needed to run the program are given in Fig. 1.

There are two versions of the program, called HITTER and FITTER. HITTER shoots a population trajectory through a population estimate in a specified year. It can simultaneously estimate the A (resilience) fitting to CPUE data.

HITTER can be used to shoot through an estimate without fitting to CPUE data by setting the step length for the resilience search to zero.

```
MSY LEVEL                                0.6
MSY EXPLOITATION RATE                    0.04
MAXIMUM AGE CLASS                        20

AGE SPECIFIC MORTALITY RATES
(11F6.4)
0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10
0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10

FEMALE AGE AT 50% MATURITY               6.0
FEMALE AGE AT 95% MATURITY               9.0
FEMALE AGE AT 50% RECRUITMENT            4.0
FEMALE AGE AT 95% RECRUITMENT            6.0
MALE AGE AT 50% RECRUITMENT              4.0
MALE AGE AT 95% RECRUITMENT              6.0
FIRST YEAR OF SIMULATION                 1950
LAST YEAR OF SIMULATION                  1980
NUMBER OF SEPARATE CPUE SERIES           1
NONLINEARITY FACTOR  (Series 1)          1
COMPONENT OF POPULATION (Series 1)       EXPLOITABLE
INITIAL POPULATION SEARCH LEVEL          2000
INITIAL POPULATION SEARCH STEP SIZE      500
STEP SIZE FOR RESILIENCE SEARCH          0.1
MAXIMUM NUMBER OF FUNCTION CALLS         400
MINIMUM REPORTING FREQUENCY              01
STOPPING CRITERIA                        0.0001
FREQUENCY FOR CONVERGENCE TESTING        05
FIT QUADRATIC SURFACE                    0
SIMPLEX EXPANSION COEFFICIENT            1.0
S.D. OF ABUNDANCE ESTIMATES KNOWN 1=Yes  1
MINIMISATION (1=Yes, 0=Simulation only)  1

ABSOLUTE ABUNDANCE ESTIMATES (specify 'TOTAL', 'EXPLOITABLE' or 'MATURE')

EXPLOITABLE
 (I5, 2G12.6)
 1978    2000     100
   :      [Data as required, any year not specified is not used for fitting]
  -1                                 (End of data)

CPUE DATA
 (I5, G12.6)
 1979    5.4
 1971    3.6
   :      [Data as required, any year not specified is not used for fitting]
   :
 1979    2.2
 1980    1.6
  -1                                 (End of data)

CATCHES   EXPLOIT. MALES   EXPLOIT. FEMALES   MATURE MALES   MATURE FEMALES
 (I5, 4F16.0)
 1970          100              100              100            100
 1971          100              100              100            100
   :      [Data as required, any year not specified is not used for fitting]
   :
 1979          100              100              100            100
 1980          100              100              100            100
  -1
```

Fig. 1. Sample data input file used by the HITTER/FITTER programs.

FITTER can use a CPUE series and population estimates in a number of years with associated variance estimates to estimate population size and resilience.

Note: all runs of the program (Fitter. SC40) made during this meeting used a recruited catch data set only i.e. $C_{m,t} = 0$.

Annex M
Report of the *ad hoc* Sub-Group on Sensitivity Tests for Modelling of the Bowhead Population

Members: Horwood, Magnusson, Lassen, Zeh, Sonntag, Butterworth, Breiwick, Lankester.

The group considered two largely independent elements.

1. SENSITIVITY

The sensitivity of the 1848 and 1912 population sizes and estimates of replacement yield are required for ranges of the following parameters in the HITTER program:

(a) 1986 population sizes of 7,800 5,700 10,600
(b) MSY% of 0, 1, 3, 5
(c) MSYL of 40%, 60%, 80%
(d) M of 0.025, 0.05, 0.075
(e) age at maturity: x, y, z* (knife-edge)
(f) age at recruitment: x, y, z* (knife-edge)
(g) not more than three feasible historic catch series: S_1, S_2, S_3

Advice will be sought from the US NMML regarding a realistic range of possibilities for the catch series (point g).

The sensitivity is to be assessed as follows:

(1) Run HITTER for every combination of 1986 population size in a) and MSY% in b) for MSYL=60%, M=0.5, age at maturity =y, age at recruitment =y and historic catch series S_2 (12 runs).
(2) Repeat (1) for MSYL=40% and MSYL=80%, keeping the other parameters of d) to g) fixed as in (1). (24 runs).
(3) Repeat (1) for M=.025 and M=.075, keeping (c) and (e) -(g) fixed as in (1). (24 runs).
(4) Repeat similarly to (2) and (3), but using upper and lower values for age at recruitment (24 runs).
(5) Repeat similarly to (2) and (3), but using upper and lower values for age at recruitment (24 runs).
(6) Repeat similarly to (2) and (3) but using historic catch series S_2 (24 runs).
(Total of 132 runs)

It is **recommended** that this work be done by the IWC Secretariat

2. RECONCILIATION OF CURRENT ESTIMATES OF POPULATION SIZE AND MODELLING RESULTS, WITH ESTIMATES OF INITIAL SIZE DERIVED FROM INDEPENDENT CPUE INFORMATION (e.g. *Rep. int. Whal. Commn* (special issue 5), p.107, p.143)

It is **recommended** that the US produce a review (brief if necessary), on the compatibility of current modelling with estimates of recent population size, and previous independent estimates of initial population size.

In addition to the above, it was noted that the model used by the HITTER procedure was structured by age, and that any age-specific information could be incorporated, although model parameters must remain fixed with time.

The group also considered the problems of assessing the effects on estimates, of variability in recruitment and in other processes. It considered that such effects would have to be investigated independently from the above sensitivity tests.

Annex N
Proposed Meeting on Mortality of Cetaceans in Fishing Nets and Traps

W.F. Perrin and R.L. Brownell, Jr

BACKGROUND

The Scientific Committee in 1985 recommended that a workshop be convened to examine the question of incidental take of cetaceans in gillnet and other static-net fisheries (*Rep. int. Whal. Commn* 36: 37). It was noted that such takes include species of special concern to the Commission such as gray whales, humpbacks and right whales. The meeting was not held in 1986 because of a lack of funding. At the 1987 meeting, the Committee again recommended that the workshop take place (*Rep. int. Whal. Commn* 37: 34). An offer to host the meeting by the Southwest Fisheries Center in La Jolla, California, was accepted in principle, and Perrin was appointed Convenor. Perrin agreed to prepare draft terms of reference for the meeting and to submit them to the 1988 meeting of the Committee.

TERMS OF REFERENCE

It was stressed by the Committee that the meeting's scope should be limited to scientific and technical matters related to cetacean entanglement in gillnets and other static fishing gear. The main charges will be:

(1) to identify and describe new and expanding net and trap fisheries which take cetaceans;
(2) to investigate how and why entanglement occurs;
(3) to the extent possible, estimate mortality and assess its impact on cetacean populations; and
(4) to consider possible ways of reducing levels of net-caused mortality of cetaceans.

The products will include a report to the next meeting of the Committee containing the following:

(1) a list and summary descriptions of gillnet and trap fisheries that take or potentially could take cetaceans, with lists of the species involved;
(2) a species-by-species summary, listing cetacean takes by population and fishery and assessing the impacts of the takes;
(3) an analysis of the causes of entanglement and assessment of technology and alternatives for reducing the incidental takes;
(4) recommendations for (a) documentation of takes, (b) research to develop methods for reducing takes and (c) management actions.

STRUCTURE AND TIMING OF THE MEETING

The meeting will be modelled on the IWC-sponsored conferences on age determination [1978, *Rep. int. Whal. Commn* (special issue 3), reproduction (1981, *Rep. int. Whal. Commn* (special issue 6) and non-lethal assessment techniques (held immediately before this meeting)]. Invited and selected unsolicited papers will be presented at a two-day open symposium. The symposium will be followed by a three– or four-day workshop involving 30–40 invited participants and interested members of the Scientific Committee. The participants in the workshop will be asked to contribute working papers on assigned topics. Subgroups will be convened during the workshop to consider topics such as net characteristics, population impacts, previously undocumented fisheries, etc.

The meeting will be held in late 1988 or early 1989, with enough lead time before the 1989 meeting of the Committee to allow the workshop report to be finalised.

STEERING GROUP

A Steering Group consisting of members of the Committee will be established at this meeting. A provisional local organising committee consists of Perrin, Brownell, L. Jones, D.P. DeMaster, J.S. Leatherwood and J. Barlow. The Steering Group will develop an agenda, select participants and develop a list of invited symposium papers and working papers for the workshop. Members of the Group will edit the symposium papers, workshop report and working papers for publication in a proceedings volume.

PARTICIPANTS

The Committee has recommended participation of a behavioural scientist, a sensory physiologist, a fisheries development officer (from FAO or another international organisation) and a gear expert. These individuals will be identified by the Steering Group. Participation will also be solicited from UNEP, IUCN and regional fisheries organisations.

BUDGET

The total budget for the meeting is estimated at £30,000 (approximately £1,500 each for 20 participants, including those from developing nations without travel funds and the recommended experts on behaviour, physiology and gear). In-kind support will be provided by the US National Marine Fisheries Service (Southwest Fisheries Center) for preparation and mailing of announcements and for local logistical support (local transportation, typing the draft report, photocopying, etc). It is recommended that the Commission commit the funds for the meeting but that UNEP also be approached for assistance in defraying the funding of participants from developing nations.

Annex O
Review of Scientific Permits

The Proposal: 'A statement as to whether the permit proposal adequately specifies the four sets of information required under paragraph 30 of the Schedule.' (*Rep. int. Whal. Commn* 36: 133).

1 'Objectives of the research;' (Sched. Para. 30)
2. 'Number, sex, size and stock of the animals to be taken;' (Sched. Para. 30)
3. 'Opportunities for participation in the research by scientists of other nations; and' (Sched. Para. 30)
4. 'Possible effect on conservation of the stock.' (Sched. Para. 30)

Objectives: The objectives of the proposal as specified by the proposer should first be given; the Committee will then comment on the following:

1. 'Comments on the objectives of the research to be carried out under the proposed scientific permit, including in particular how they might relate to research needs identified by the Scientific Committee.' (*Rep. int. Whal. Commn* 36: 133)
2. 'The proposed research is intended, and structured accordingly to contribute information essential for rational management of the stock;' (*Rep. int. Whal. Commn* 37: 25)
3. 'The research addresses a question or questions that should be answered in order to conduct the comprehensive assessment or to meet other critically important research needs;' (*Rep. int. Whal. Commn* 38: 27–28)

Methodology: A brief summary of the methodology as specified by the proposer should first be given, followed by the Committee's comments on:

1. 'Comments on the methodology of the proposed research and an evaluation of the likelihood that the methodology will lead to achievement of the scientific objectives. These comments may also include evaluation of the methodology in terms of current scientific knowledge.' (*Rep. int. Whal. Commn* 36: 133)
2. 'The objectives of the research are not practically and scientifically feasible through non-lethal research techniques;' (*Rep. int. Whal. Commn* 37: 25)
3. 'The research addresses a question or questions that cannot be answered by analysis of existing data and/or use of non-lethal research techniques; and' (*Rep. int. Whal. Commn* 38: 27–28)
4. 'The number, age and sex of whales to be taken are necessary to complete the research and will facilitate the conduct of the comprehensive assessment;' (*Rep. int. Whal. Commn* 37: 25)
5. 'Whales will be killed in a manner consistent with the provisions of Section III of the Schedule, due regard being had to whether there are compelling scientific reasons to the contrary.' (*Rep. int. Whal. Commn* 37: 25)

   This was later clarified by the Commission to refer to the use of non-explosive harpoons (*Rep. int. Whal. Commn* 38: 12)
6. '...that maximum scientific information be obtained from any whales taken under special permits for scientific research.' (*Rep. int. Whal. Commn* 37: 25)
7. 'The research is likely to yield results leading to reliable answers to the question or questions being addressed.' (*Rep. int. Whal. Commn* 38: 27–28)

Effect of catches on the 'stock': A summary of the proposer's view should first be given followed by the Committees views on:

1. 'A review of the most recent information on the stock or stocks concerned, including information on any exploitation, stock analysis and recommendations by the Scientific Committee to date (including, where appropriate, alternative analyses and conclusions and points of controversy).' (*Rep. int. Whal. Commn* 36: 133)
2. 'An evaluation of the specification in the permit proposal of 'possible effect on conservation of the stock'. As appropriate, the Scientific Committee may carry out its own analysis of the possible effects. (*Rep. int. Whal. Commn* 36: 133)
3. 'The research can be conducted without adversely affecting the overall status and trends of the stock in question or the success of the comprehensive assessment of such stocks;' (*Rep. int. Whal. Commn* 38: 27–28)

Research co-operation: A brief summary of the arrangements made by the proposer should first be given followed by the Committee's views on:

1. 'Comments on the adequacy and implications of specified arrangements for participation by scientist of other nations.' (*Rep. int. Whal. Commn* 36: 133)

Annex P
Matters Concerning Data Availability

Annex P1. PROPOSED REVISION OF THE SCIENTIFIC COMMITTEE RULES OF PROCEDURE: APPENDIX 1, GUIDELINES FOR AVAILABILITY OF DATA HELD BY THE IWC

[alternative wording in square brackets]

1.* Information identified in Section VI of the Schedule that shall be notified or forwarded to the IWC or other body designated under Article VII of the Convention

This information is available on request through the Secretariat to any interested persons with a legitimate claim relative to the aims and purposes of the Convention.

2. Information and reports provided where possible under Section VI of the Schedule

When such information is forwarded to the IWC, a covering letter should make it clear that the information or report is being made available, and it should identify the pertinent Schedule paragraph under which the information or report is being submitted.

Information made available to the IWC under this provision is accessible to [any interested persons under the same conditions as the information and reports referred to in paragraph 1 above] [accredited persons as defined below] [accredited persons as defined below, and additionally to other interested persons subject to the agreement of the government submitting the information or report].

Such information already held by the Commission is not regarded as having been forwarded until clarification of its status is received from the government concerned.

3. Information neither required or requested under the Schedule but which has been or might be made available to the Commission on a voluntary basis

from the previous two types. It can be further divided into two categories:

(a) Information collected under International Schemes

(i) Data from the IDCR projects.
(ii) Data from the International Marking Scheme.
(iii) Data obtained from international collaborative activities which are offered by the sponsors and accepted as contributions to the Comprehensive Assessment, or proposed by the Scientific Committee itself.

Information collected as the result of IWC sponsored activities and/or on a collaborative basis with other organisations, governments, institutions or individuals is available within those contributing bodies, [and more widely (as in paragraph 1 above)] either immediately, or after mutual agreement between the IWC and the relevant body/person, after a suitable time interval to allow 'first use' rights to the primary contributors.

(b) Information collected under national programmes, or other than in (a)

Information in this category is likely to be provided by governments under specified conditions and would hence be subject to some degree of restriction of access. This information can only be held under the following conditions.

(i) A minimum level of access should be that such data could be used by accredited persons (as defined below) during the Scientific Committee meetings using validated techniques or methods agreed by the Scientific Committee. After the meeting, at the request of the Scientific Committee, such data could be accessed by the Secretariat for use with previously specified techniques or validated programs. Information thus made available to accredited persons should not be passed on to third parties but governments might be asked to consider making such records more widely available or accessible.
(ii) The restrictions should be specified at the time the information is provided and these should be the only restrictions.
(iii) Restrictions on access should not discriminate among accredited persons.
(iv) All information held should be documented (i.e. described) so that accredited persons know what is held, along with stated restrictions on the access to it and the procedures needed to obtain permission for access.

Accredited persons

Accredited persons are those scientists defined under sections A.1, 2, 3 and 6 of the Rules of Procedure of the Scientific Committee. Invited participants are also considered as 'accredited' during the intersessional period following the meeting which they attend.

---

* The Government of Norway notes that for reasons of domestic legislation it is only able to agree that data it provides under this paragraph is made available to accredited persons.

Annex P2. DATA AVAILABILITY

(1) Soviet Union

(a) Biological data submitted by the USSR to the IWC Secretariat in accordance with Paragraph 29 of the Schedule become available to all accredited IWC scientists five years after they are received by the Secretariat.

(b) In other cases (i.e. before the above five-year period has passed) biological data are not available for use without permission from the USSR.

(c) The above principles do not cover cases when joint investigations have been carried out with scientists from other countries participating, if help has been provided in material collection and if joint information has been prepared during current work or special sessions of the Scientific Committee.

(2) Japan

(a) All biological data submitted by the Japanese Government as a requirement of Article 29 under the Schedule (e.g. information relating to age and reproductive status) become available to all accredited IWC scientists five years after they are received by the Secretariat (not five years after the collection of the samples).

(b) Biological data submitted as a requirement under Article 29 but before the above five years time period has passed, data collected before any requirement under the Schedule, and data not required by the Schedule are not available for use without permission from the Government of Japan.

(c) Irrespective of the above principles the Japanese Government agrees access of all accredited IWC scientists to the stomach content data of whales taken by Japanese whaling vessels and kept by IWC Secretariat. This will apply to such stomach contents data that have been reported to BIWS and now have been transferred to IWC and those that will continue to be submitted to IWC by the Government of Japan.

(d) Irrespective of the above principles, data are available to scientists under the following cases:

(i) Cooperative studies between Japanese and other interested scientists.
(ii) scientists who helped collect the data, and
(iii) for the preparation of a working paper during the annual or special Scientific Committee meetings using a method or theory published in the field of cetacean biology and under the instruction of the Chairman of the Scientific Committee, sub-committee Chairmen, or Chairmen of special meetings.

(3) Norway

Norwegian catch and effort data are submitted under a special exemption from national data-legislation; available only for scientific research purposes to accredited persons. The data cannot be published in their present format.

Annex Q
Minority Statements

STATEMENTS ON ITEM 2 – ADOPTION OF AGENDA

Statement of the Mexican delegation concerning small cetaceans
With respect to the activities and recommendations on 'small cetaceans', the position of the Mexican delegation is well known and remains unchanged.

Mexico considers that the Commission should confine its activities to the cetacean species listed on the Nomenclature of the International Whaling Conference. It also supports the view that the lack of consensus among the IWC member states, regarding the Commission's competence on small cetaceans, is resulting in an unnecessary dispersion of efforts in the Scientific Committee and in the resources of the Commission, which should be used in the identified priorities and mandates, such as the Comprehensive Assessment. Mexico reiterates its political will to preserve the species which requires protection through its normal efforts and programs, as well as its willingness to cooperate with competent international or regional organizations.

Based on this principle, Mexico reserves its position on the Recommendations derived by the Small Cetaceans Group referred in the Scientific Committee Report.

Statement of the Japanese delegation concerning small cetaceans
The position of the Government of Japan, as stated in the report of the 39th Annual Meeting of the Scientific Committee Annex V, has not changed on the matter of small cetaceans. That is, the activities of the Commission with the population management of whales should be limited to the matters concerning whales listed on the Nomenclature of the International Whaling Conference Final Act (1946).

However, we can support the Resolution adopted by the IWC in its 32nd Annual Meeting in 1980 that the Scientific Committee of the IWC is recommended to consider the status of small cetaceans and provide such scientific advice as may be warranted to Contracting Government.

STATEMENT REGARDING ITEM 4.2

Statement of the Mexican delegation
In regard to the recommendation related to point 4.2 of the Scientific Committee Report, Mexico recognizes and supports the general point of recommending to the Commission to urge the participation of all member states and to ensure the submission of their national Progress Report; However, it wishes to record its reservation regarding the requested information in the guidelines, which is neither requested, nor required by the Schedule and which has been considered when provided as voluntary, but not as mandatory.

Report of the Special Meeting of the Scientific Committee to Consider the Japanese Research Permit (Feasibility Study)

The meeting was held at New Hall, Cambridge, from 15–17 December 1987 under the Chairmanship of R.L. Brownell Jr (USA). A list of participants is given in Annex A.

1. CHAIRMAN'S WELCOME AND OPENING REMARKS

The meeting was called after the Chairman of the Commission had agreed to a request from the Government of Japan that a Special Meeting be held to discuss the feasibility study it had proposed which involves a catch of up to 300 minke whales in Antarctic Area IV under Article VIII of the Convention (SC/D87/1). This study had originally been circulated on 20 October 1987 for written comments by Committee members and the comments received are included in the list of documents (Annex C). The *Note Verbal* requesting that a meeting be held had specified that the meeting be convened to 'sort out the views ... submitted by the members of the Scientific Committee'.

The Committee operated under the new Rule B.3 of the Commission's Rules of Procedure with respect to the requirements for credentials (*Rep. int. Whal. Commn* 38: 31). It agreed to allow two members from Norway and one from the UK to participate in the meeting on the basis that the credentials were expected. In due course the credentials did so arrive.

2. ADOPTION OF AGENDA

After considerable discussion as to the appropriateness of Item 4, the Committee agreed to the Agenda given in Annex B, noting that only a limited time would be allocated to that Item. A minority statement concerning this is given in Annex D.

3. ARRANGEMENTS FOR MEETING

3.1 Appointment of rapporteurs

It was agreed that Donovan, R. Holt and Harwood would act as rapporteurs.

3.2 Meeting time schedule

The Committee agreed to the schedule suggested by the Chairman. It was agreed that in order to have an adopted report available at the end of the meeting, all substantive discussion should be completed by the night of 16 December.

4. CLARIFICATION OF PURPOSE AND PROCEDURE

4.1 Quorum

This Item was included on the Agenda in response to comments made by S. Holt in SC/D87/17. He noted that in view of the short notice of the meeting it was possible that attendance would be sparse. Although this did not turn out to be the case (scientists from 15 countries of the 21 who indicated that they wished to participate in the Scientific Committee attended), the Committee draws the attention of the Commission to potential problems which may arise out of the fact that the Committee's Rules do not specify a quorum. It was recognised that a rigid rule might be inappropriate for special meetings on specialised subjects, where only a small proportion of the Committee may possess the required expertise and thus wish to attend. It was agreed to recommend that the matter be discussed at the next Annual Meeting. It was agreed that the meeting was a properly constituted meeting of the Scientific Committee.

4.2 Formulation of advice, including voting

This Item was also included on the Agenda in response to comments made by S. Holt in SC/D87/17. He noted that recent experience indicated that the Committee was unlikely to achieve consensus on all issues and he believed that current reporting procedures frequently did not provide unequivocal advice to Commissioners. Ohsumi stated the nature of science is incompatible with a procedure which resolves the problems of divergent views with majority votes. Unlike the Commission, whose function is to make restrictive decisions over the conduct of the contracting parties, the Scientific Committee does not have to force its members to unify their advice to the Commission by majority votes. In discussion, the Committee agreed that it wished to continue in its deliberations to avoid voting. However, it noted the comments from the Technical Committee on the matter of interpretation of the Scientific Committee Report (*Rep. int. Whal. Commn* 38: 23–4) and agreed that, at least for this meeting, where there was not consensus in the report, members with various views would be identified. S. Holt indicated that with this understanding he would refrain from calling for indicative roll-call votes on any substantial matters of disagreement. The matter should be reviewed at the next Annual Meeting.

4.3 Status of the Report

The Secretary noted that this Report of a Special Meeting of the Scientific Committee on a special permit is under the Commission's 1987 resolution, a report to the Commission and will be sent to Commissioners, Contracting Governments and Scientific Committee members who did not attend the meeting, the day after the meeting is finished. It was agreed that the special circumstances of the meeting warranted extraordinary measures to ensure that the report reached Contracting Governments as quickly as possible. The Committee *recommends* that the Secretary sends the report by special delivery or similar priority post to the London Diplomatic Missions of Contracting Governments or direct to the Commissioners, as appropriate.

At Annual Meetings, the Report of the Scientific Committee is considered to be publicly available as from the opening of the Commission meeting. In this instance, the Committee believes the Report of the Special Meeting should be considered to be available on 21 December, i.e. after the Report will have been received by the Commissioners.

5. CONSIDERATION OF FEASIBILITY STUDY ON SOUTHERN HEMISPHERE MINKE WHALE RESEARCH PLAN

At last year's Scientific Committee meeting, the Scientific Committee reviewed a Japanese Scientific Permit proposal (SC/39/O 4) entitled 'The programme for research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic'. With respect to minke whales, the aim of the programme was to obtain estimates of the biological parameters required for stock management, principally age-specific natural mortality rates. It was also intended to obtain estimates of various reproductive parameters (e.g. pregnancy rate, age at sexual maturity, etc.), stock size and the distribution and behaviour of whales. The discussion of the minke whale aspects of the programme in the Committee was reported under four main topics:

(1) Was it true that the main reason for the Committee's inability to provide useful management advice to the Commission was because it did not have a reliable estimate of the natural mortality rate (M)?
(2) Was it possible to distinguish between the effects of variations in recruitment, past fishing mortality and M on the population's age structure?
(3) Would the programme lead to reliable estimates of age-specific M as it intended?
(4) Did the advances in the development of alternative management procedures remove the need for improved estimates of M?

The Committee's 1987 Annual Meeting discussion of these four questions is given in *Rep. int. Whal. Commn* 38:55–7.

5.1 Presentation of Japanese research plan

The following is a summary of SC/D87/1. The reader is referred to that document and SC/D87/35 for further details.

The feasibility study was developed subsequent to discussions in the Scientific Committee and in the light of the decision to provide two vessels for the IDCR Southern Hemisphere minke whale assessment cruise. The aims of the research are:

(1) to examine whether the collection of a representative sample of a minke whale population is possible (and within the operational constraints of the programme);
(2) to examine the technical problems which may be encountered by using sampling vessels to concurrently carry out the sightings survey;
(3) to examine possible segregation by age, sex, reproductive state, etc., particularly by latitude;
(4) to investigate possible differences in school structure with school size;
(5) to survey minke whales in lower latitudinal waters to provide information on stock identity, reproductive parameters, migration, etc.

In addition to the above it is proposed to carry out some preliminary studies on the use of biopsy darts to obtain samples and how these samples can be analysed, and also to maximise the biological information to be obtained from each animal.

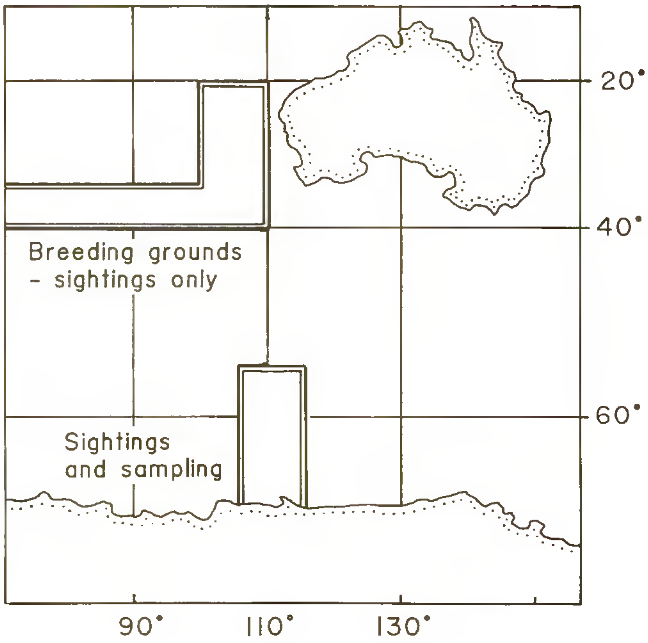


Fig. 1. Areas where preliminary research will take place.

It is intended that the research be carried out in the area shown in Fig. 1. Research will thus be conducted within and in more northerly areas than in the recent IDCR sightings cruises.

In view of the aim of the feasibility study, the question of the sampling scheme was considered particularly important. The survey area has been divided into two areas: the storm zone (55°-60°S) and the area south of 60°S. The paper and SC/D87/35 give details of the cruise tracks and procedures to be followed on encountering ice and poor weather. These aim to ensure that searching effort is randomly distributed in time and space.

All schools observed as primary sightings within 3 n.miles will be subject to sampling. Schools of one or two animals will be completely sampled. For schools of three or more, two animals, randomly chosen (SC/D87/35), will be taken. After sampling, the vessels will return to the original position at which they left the trackline and resume searching effort.

A list of all biological data and samples to be collected under the programme is given in Appendix 1 of SC/D87/35.

5.2 Consideration of written comments received on the feasibility study

These comments (SC/D87/2–31) were available to the meeting and are referred to in the report where appropriate.

5.3 Consideration of other documents received

At its 39th meeting some members of the Scientific Committee had expressed doubts about the ability of the analytical methodology described in the original Japanese proposal to distinguish the effects of variation in recruitment from those of natural mortality (M) or the population's age structure. In SC/D87/39, de la Mare demonstrated that it is not possible to obtain unique estimates of recruitment and age-dependent mortality from catch–at-age data alone. He also showed that specifying trends in population size or recruitment could lead to estimates of age-dependent mortality rates and *vice versa*. However, it was also shown that the solution obtained was sensitive to bias in the specification of the external parameters. Butterworth in SC/D87/32 confirmed that estimation was only possible if additional information was available.

Nakamura in SC/D87/36 described a method for separating the effects of age, year and cohort using the prior information on the successive differences in these effect parameters. Akaike's Bayesian information criterion, ABIC, is used to select the optimal model. It is intended that this method, as it is or when refined, is used to analyse the age-structure data collected during the feasibility study and from the originally planned research.

Some members (Chapman, Arnbom, Cooke, Deimer, Holt, Horwood, Lankester, Lyrholm, de la Mare, Payne and Tillman) noted that the doubts about the estimation of M from age composition data had not been reduced by the introduction of the procedure described in SC/D87/36, particularly in light of de la Mare's results in SC/D87/39. Catch-at-age data do not uniquely determine the parameters of interest and no statistical procedure can overcome this fundamental aspect of the problem. They further noted that any estimates obtained from the procedure outlined in SC/D87/36 by Nakamura are entirely determined by the choice of the prior assumed distributions of the parameters. In effect, this means that the procedure could obtain any arbitrarily given value for the natural mortality or recruitment rate from any data set. Since there is no valid basis for selecting any particular estimate, the procedure proposed by Nakamura contributes no new information. While information on trends in population size or recruitment could provide estimates of age-specific mortality, this additional information could be used to estimate net recruitment rates directly without any necessity to analyse age structure. Further they noted it was lack of reliable estimates of net recruitment rates that had made it impossible for the Scientific Committee to provide useful advice to the Commission on replacement yields and the effects of continuing catches for these stocks.

They further stated that there are limits on the feasible range for levels of and trends in mortality and recruitment and that some indication of the latter might be obtained by assuming ranges in pregnancy rates and age at first pregnancy. The implications of sampling error in catch-at-age and in population estimates for the estimates of natural mortality rates so obtained indicate that confidence intervals would be wide.

Magnusson, Ohsumi and Horwood stated that the method described in SC/D87/36 showed considerable promise.

Gunnlaugsson noted that limits on the feasible range for levels and trends might be narrowed by new unbiased biological material and that there was no reason to believe that age data could not be used in this case, as in most of fisheries science, to enhance the precision in estimates of recruitment. Furthermore, he noted that the suggested new management procedures could not alone locate the MSY level unless the stock was first reduced significantly below that level and then allowed to fluctuate around it.

Nakamura responded that he considered the criticism above by Chapman and others that information on trend in population size was still required for this method was based on a misunderstanding of Nakamura's model. He further stated that the model does not need actual values of trends in recruitment as prior information. Ikeda and Magnusson believed the simulation study in SC/D87/36 had indicated that reliable estimates of age-specific mortality and trends in recruitment can be obtained from catch-at-age data if it is correctly assumed that successive differences of effect parameters are small and change gradually. Ikeda further pointed out that, in view of the results of Nakamura's work, there had been no need to modify the original programme (SC/39/O 4).

6. REVIEW OF JAPANESE PROPOSAL UNDER THE CRITERIA SPECIFIED IN RESOLUTIONS ON SPECIAL PERMITS FOR SCIENTIFIC RESEARCH ADOPTED IN 1986 AND 1987 BY THE COMMISSION, AND THE SCIENTIFIC COMMITTEE'S GUIDELINES FOR REVIEW OF SCIENTIFIC PERMITS

The Committee agreed that its primary task was to review the feasibility study in the light of its own guidelines (Item 6.1) and the resolutions passed by the Commission at its 38th (Item 6.2) and its 39th (Item 6.3) meetings. It noted that in commenting on the feasibility study, it was inevitable that reference would also be made to the original proposal. The Committee was informed that there had been no changes to the original programme (SC/39/O 4).

S. Holt, Lankester, Lyrholm, de la Mare and Payne observed that paragraph 30 of the Schedule requires that special permit proposals be provided 'in sufficient time ...' and that the relatively few comments received from scientists, other than those from the proposing country, and the late arrival of others, showed that in this case insufficient time had been provided.

In response, Ohsumi stated that this feasibility research plan was circulated to the members of the Scientific Committee from the Secretariat on 20 October and he considers this to be sufficient time. In addition, he noted that many responses from other than the proposing country were received.

6.1 Annex L – Proposed guidelines for review of scientific permits (*Rep. int. Whal. Commn* 36: 133)

6.1.1 A statement as to whether the permit proposal adequately specifies the four sets of information required under Paragraph 30 of the Schedule

The Committee noted that: (a) the objectives of the research are stated; (b) the number and stock of the animals to be taken is stated – their size and sex cannot be determined in advance; (c) foreign scientists can participate; and (d) the proposal does take some account of the possible effect of the proposed catches on conservation of the stock, but see section 6.1.3 for a more detailed discussion.

6.1.2 Comments on the objectives of the research to be carried out under the proposed scientific permit, including in particular how they might relate to research needs identified by the Scientific Committee

In SC/D87/1 it was stated that the general purpose of the feasibility study will be to determine whether collection of samples fully reflecting the Southern Hemisphere minke whale population is possible.

Some members (Horwood, Arnbom, Chapman, Deimer, de la Mare, S. Holt, Lankester, Lyrholm, Payne, Tillman) noted that as the feasibility study is a precursor to the original programme, then unresolved problems with the original programme cast doubts on the necessity of the feasibility study. In this connection, they believed that since the main objective of the original programme to determine age-specific natural mortality could not be achieved with the proposed methods, even if random samples could be collected, the objectives in the feasibility study to investigate whether representative samples can be collected are not relevant.

In response, other members (Ikeda, Ohsumi, Kasuya, Nagasaki, Yamamura) noted that the original proposal had been prepared to provide necessary information for the assessment and management of stocks and that the feasibility study was an essential pre-requisite of this. Magnusson and Gunnlaugsson concurred with this view.

Five detailed objectives were given in SC/D87/1 of which the first four require a special permit. These are listed below.

(1) The feasibility study of the newly refined sampling scheme designed for stochastic sampling in the original programme (e.g. whether the required number of samples can be collected by the designated method within the given period).
(2) The feasibility study on the technical problems encountered in the survey by the sampling vessels which collect sighting data and whale samples concurrently.
(3) Investigation on the extent of segregation by age, sex, reproductive condition, etc. in the distribution of the Southern Hemisphere minke whale, from samples collected from an area extending widely north and south.
(4) Investigation on the uniformity or non-uniformity of the biological characteristics according to school size.

Some members (Arnbom, Chapman, Cooke, Deimer, de la Mare, S. Holt, Lankester, Lyrholm, Newman, Payne, Tillman) commented that the first objective could be investigated by an examination of existing data from sightings surveys and operational records (see Item 6.2.1); the problems to be resolved under objective 2 were not specified in the proposal (these were brought out in the discussion of Item 6.2.1); and that objectives 3 and 4 did not fulfill priority needs of the Scientific Committee although they might be of biological interest.

Other members (Gunnlaugsson, Magnusson, Øritsland, Sigurjónsson, Ikeda, Kasuya, Mae, Nagasaki, Ohsumi, Yamamura) noted that the Scientific Committee had frequently commented on the non-random nature of samples taken from the commercial catch. Therefore, the study's objective of collecting a representative sample would be of value to the Committee. While agreeing that research addressing this objective might be of value, Tillman expressed his view that it was not of high priority to the Committee.

6.1.3 A review of the most recent information on the stock or stocks concerned, including information on any exploitation, stock analysis and recommendations by the Scientific Committee to date (including, where appropriate, alternative analyses and conclusions and points of controversy)

No new information was available since the review conducted by the Scientific Committee at its last meeting. It was agreed that this item had been covered by the Scientific Committee in its comments of the original proposal last June (*Rep. int. Whal. Commn* 38: 55–7).

6.1.4 Comments on the methodology of the proposed research and an evaluation of the likelihood that the methodology will lead to achievement of the scientific objectives. These comments may also include evaluation of the methodology in terms of current scientific knowledge

Some members (Tillman, Arnbom, Chapman, Cooke, Deimer, de la Mare, R. Holt, S. Holt, Lankester, Lyrholm, Newman, Payne) commented that there were many unresolved methodological problems in the proposal, in particular they were not convinced that a representative sample of the population would in fact be obtained. In any case, the representativeness of the sample could not be verified. Although biases due to the selectivity of the whalers would probably be reduced there were other sources of bias which had not been addressed: no whales would be taken north of 55°S; changes in the shape and distribution of the ice edge might lead to non-uniform coverage of this area; taking all schools sighted within 3 n.miles of the trackline could lead to large schools being over-represented in the sample; taking a maximum of two whales from each school could lead to unrepresentative sampling of large schools; and problems in the readability of earplugs from younger animals could bias the observed age distribution.

Magnusson noted that the representativeness of a sample could, in general, never be verified, so this was not a problem specific to the Japanese study. The aim should be to try to identify, and eliminate or minimise any possible causes for bias and the study attempts to do just that.

Other members (Ikeda, Mae, Nagasaki, Ohsumi, Yamamura) responded that if the sampling procedure described in SC/D87/35 proved practicable, a random sample of the population would be obtained. In addition, they pointed out that the research vessels would only approach the ice edge on four occasions so that changes in its distribution would have little effect. Although it would be preferable to take all individuals from every school encountered there were logistic constraints on the numbers that could actually be taken. Ikeda believed that if the sampling technique described in SC/D87/35 (which had been designed to remove the question of human selection and account, as far as possible, for our current knowledge of whale distribution and behaviour) prove practical, it would be possible, in conjunction with an examination of data from the commercial catch, to ascertain whether the sample was representative.

There was considerable discussion of improvements which had been made in age-determination techniques for minke whales. For approximately 20% of the whales an age determination was not made, but this was usually because the plug was not collected or was damaged. A high proportion of the unreadable plugs came from animals less than 15 years old. In an attempt to avoid these problems both earplugs would be collected from each animal, and tympanic bullae would be collected from younger animals to aid in their ageing. The image-analysis system described by Kato *et al.* (*Rep. int. Whal. Commn* 38: 269–72) would be used to improve the objectivity of layer counts.

Some members (Tillman, Arnbom, Chapman, Cooke, Deimer, de la Mare, R. Holt, S. Holt, Lankester, Lyrholm, Newman, Payne) indicated that, although these developments were commendable, they were not sufficiently advanced to allay their present concerns about possible biases, particularly in the determination of the age of younger animals.

6.1.5 Comments on the adequacy and implications of specified arrangements for participation by scientists of other nations

It was clear to the Committee that Japan would welcome the participation of foreign scientists in the study. However, S. Holt, de la Mare and Payne noted that the timing of the decision to conduct the feasibility study had left insufficient time for some foreign scientists to make arrangements to participate, or for Governments to provide funding for them.

6.1.6 An evaluation of the specification in the permit proposal of 'possible effect on conservation of the stock'. As appropriate, the Scientific Committee may carry out its own analysis of the possible effects

When the Scientific Committee reviewed the original proposal no agreement could be reached on the status of the Area IV stock. However, a simulation study by Cooke (SC/39/Mi21) had indicated that current replacement yields might be between 466 and 1,106 whales of commercially takeable size (>27ft), and that the stock may be below MSYL. The Committee had recognised that this simulation study represented a useful general approach but recommended that it should be used with agreed estimates of abundance (for details see *Rep. int. Whal. Commn* 38: 55–7). Nevertheless, with the estimate for 'current' population size used in these simulations, the proposed catch of 300 whales is below the lowest estimate of current replacement yield from the simulations.

Some members (Horwood, Gunnlaugsson, Ikeda, Magnusson, Nagasaki, Newman, Ohsumi, Øritsland, Sigurjónsson Tillman, Yamamura) considered that a take of 300 whales in one year will not affect the status of the stock. However, Tillman, Horwood and Newman introduced three points of concern. First is the uncertainty over the status of the stock, second is the uncertainty over the identity of the stock, and third is that the proposed take is from only one sixth of the area of the putative stock, and may cause some local decline in density.

While agreeing with the above concerns, Holt, Chapman, Cooke, de la Mare and Payne noted that, because the biological identity of the population of whales in the sampling area is not known and its state is uncertain, this matter cannot be evaluated.

6.2 Resolution on special permits for scientific research from the 38th Annual Meeting (*Rep. int. Whal. Commn* 37: 25)

6.2.1 the objectives of the research are not practically and scientifically feasible through non-lethal research techniques

Some members (Holt, Arnbom, Chapman, Cooke, Deimer, de la Mare, Lankester, Lyrholm, Newman, Payne, Tillman) commented that the aims (listed in Item 6.1.2) could be met by a combination of the analysis of already available time budget, segregation and school structure data from the commercial catch, previous sightings data, and the implementation of the feasibility study without the final harpooning of the animal. They also noted that aspects of schooling behaviour and segregation by reproductive condition (e.g. sightings of cow/calf pairs) might be addressed using direct observational techniques.

Other members (Ohsumi, Ikeda, Kasuya, Nagasaki, Yamamura) responded that non-lethal techniques would not enable these aims to be met. They noted that the sampling strategy was quite different to that of the commercial operations. In particular the random catching strategy required the taking of specific whales, rather than the nearest or easiest to catch whale; this might result in considerably extended chasing times. They also noted that sampling in the 'storm zone' may result in extended catching times, even though the proposed strategy to steam to the southern zone in poor weather may alleviate this somewhat. Extended catching times would reduce the time available for the sightings part of the survey and hence the precision of the resultant estimates.

These members, as well as Sigurjónsson, Øritsland and Magnusson, did not believe that currently available non-lethal techniques would enable the required biological information (sex, length, age, etc) to be obtained for minke whales.

Cooke noted that it was important not to forget the feasibility study should be considered in the context of the original proposal. He believed that the earlier discussion concerning the likelihood of being able to estimate M (see Item 5.1) meant that the primary objective of estimating M could not be met using either lethal or non-lethal techniques. Arnbom, Chapman, de la Mare, Harwood, S. Holt, Lankester, Lyrholm, Payne, Tillman concurred with this view.

6.2.2 the proposed research is intended, and structured accordingly to contribute information essential for rational management of the stock

Some members (Cooke, Arnbom, Chapman, Deimer, de la Mare, S. Holt, Lyrholm, Lankester, Payne, Tillman) believed that this item was best considered in the context of the original proposal. While it was intended to contribute information essential for rational management of the stock, they noted the impracticability of obtaining reliable estimates of M and they believed that M was not essential for management (discussed under Item 5.3). Therefore they concluded that the original proposal, and thus its feasibility study, is not structured to contribute information essential for the rational management of the stock.

While Horwood concurred with this view, he and Kasuya believed that incidental aspects of the programme will contribute new information about minke whales, and that this may prove to be of significance for our overall understanding of the biology of minke whales and the broader and long-term aspects of whale management.

Other members (Ikeda, Nagasaki, Ohsumi) responded that the estimation of M was both possible and essential for management (see Item 5.3) and thus that the proposed research is intended and structured accordingly to contribute information essential for rational management of the stock. Gunnlaugsson associated himself with this view.

6.2.3 the number, age and sex of whales to be taken are necessary to complete the research and will facilitate the conduct of the comprehensive assessment

Those members who believed that the feasibility study could be achieved by non-lethal means (Item 6.2.1) noted that this meant that no whales need be taken.

Holt noted that some Contracting Governments believed that the Comprehensive Assessment should be completed by 1990. In this case he believed the results of the feasibility study and subsequent programme, if successful, would of necessity not be available by 1990 and thus could not facilitate the conduct of the Comprehensive Assessment. Other members (de la Mare, Arnbom, Chapman, Cooke, Lankester, Lyrholm, Payne, Tillman) considered that even if the results could be obtained in time they would not facilitate the Comprehensive Assessment.

Other members (Ikeda, Kasuya, Nagasaki, Ohsumi) responded that the number, age and sex of whales to be taken are necessary to complete the research and will facilitate the conduct of the Comprehensive Assessment.

6.2.4 whales will be killed in a manner consistent with the provisions of Section III [Para. 6] of the Schedule, due regard being had to whether there are compelling scientific reasons to the contrary*

In response to a question from S. Holt, Kasuya confirmed that all whales to be taken under the sampling scheme (including cows and accompanying calves if encountered) would be killed using explosive grenade harpoons. Kasuya believed that results from past sighting cruises suggest that sightings of mother-calf pairs will be rare, if they occur at all in the sampling area at that time of year.

6.3 Resolution on scientific research programmes from the 39th Annual Meeting (Chairman's Report of the 39th Annual Meeting)

6.3.1 The research addresses a question or questions that should be answered in order to conduct the comprehensive assessment or to meet other critically important research needs

Some members (Tillman, Arnbom, Chapman, Cooke, Deimer, de la Mare, S. Holt, Lankester, Lyrholm) commented that broad-spectrum research of the kind proposed in the feasibility study and the original proposal would not advance the Comprehensive Assessment. They believed that the Comprehensive Assessment would be best achieved by research addressed to specific issues, such as the estimation of net recruitment rates. None of the specific high priority aims of the feasibility study addressed issues which were of critical importance to the Scientific Committee deliberations.

Other members (Ikeda, Kasuya, Mae, Nagasaki, Ohsumi, Yamamura) responded that the wide-ranging studies described in the feasibility study and the original proposal would significantly increase knowledge of minke whale biology and would thus contribute to the Comprehensive Assessment. Gunnlaugsson, Magnusson, Øritsland and Sigurjónsson associated themselves with this view.

6.3.2 The research can be conducted without adversely affecting the overall status and trends of the stock in question or the success of the comprehensive assessment of such stock

Many members noted that its discussions under Item 6.1.6 had indicated that the take of 300 whales for one year would be unlikely to adversely affect the overall status and trends in the stock or the success of the Comprehensive Assessment. However, some members (Chapman, Arnbom, Cooke, de la Mare, S. Holt, Lankester, Lyrholm, Payne, Tillman) noted that the same assurance could not be given for the original programme, where larger catches will be taken over an extended period.

6.3.3 The research addresses a question or questions that cannot be answered by analysis of existing data and/or use of non-lethal research techniques

This point was discussed in considerable detail under Item 6.2.1. Some members (S. Holt, Arnbom, Chapman, Cooke, Deimer, de la Mare, Lankester, Lyrholm, Newman, Payne, Tillman) believed that the main aims of the feasibility study could be achieved through the analysis of existing data and the application of non-lethal methods. Others (Ikdea, Kasuya, Nagasaki, Ohsumi, Yamamura) responded that the aims could only be met by actually catching whales.

6.3.4 The research is likely to yield results leading to reliable answers to the question or questions being addressed

The Committee agreed that the study would demonstrate whether it is feasible to catch 300 whales with the sampling scheme proposed. However, some members (Cooke, Arnbom, de la Mare, S. Holt, Horwood, Lankester, Lyrholm, Payne, Tillman), referring to the discussion of the estimation of M (Item 5.3), believed that since the original proposal would not lead to reliable answers to the primary question it addressed in the long term, neither would the feasibility study.

In response, other members (Ikeda, Mae, Nagasaki, Ohsumi, Yamamura) repeated their belief that M could be obtained and thus that the long term study would provide reliable answers to the questions addressed in the proposal.

7. ADOPTION OF REPORT

The Committee wished to thank the Secretariat for its hard work during the meeting.

---

* See *Rep. int. Whal. Commn* 38: 13

Annex A
List of Participants

ANTIGUA & BARBUDA
R. S. Payne

AUSTRALIA
W.K. de la Mare

DENMARK
F. Larsen

GERMANY, FEDERAL REPUBLIC OF
P. Deimer
J. Ploetz

FRANCE
J.-L. Durand

ICELAND
T. Gunnlaugsson
K. Magnusson
J. Sigurjónsson

JAPAN
K. Fukushima
I. Ikeda
T. Kasuya
A. Mae
S. Misaki (Interpreter)
F. Nagasaki
T. Nakamura
S. Ohsumi
K. Seki
K. Shima
K. Yamamura

NETHERLANDS
K. Lankester

NEW ZEALAND
F. Newman

NORWAY
N. Øien
T. Øritsland

SEYCHELLES
S.J. Holt

SPAIN
L.G. de Sola
S. Lens
H. Quiroga

SWEDEN
T. Arnbom
T. Lyrholm

UNITED KINGDOM
P.S. Hammond
J. Harwood
J.W. Horwood
M. Klinowska

UNITED STATES OF AMERICA
R.L. Brownell Jr (Chairman)
D.G. Chapman
R. Holt
D. McGovern
M.F. Tillman

INVITED PARTICIPANT
J.G. Cooke

IWC
G.P. Donovan
R. Gambell

Annex B
Agenda

1. Chairman's welcome and opening remarks
2. Adoption of Agenda
3. Arrangements for meeting
    - 3.1 Appointment of rapporteurs
    - 3.2 Meeting time schedule
4. Clarification of purpose and procedure
    - 4.1 Quorum
    - 4.2 Formulation of advice, including voting
    - 4.3 Status of report
5. Consideration of Feasibility Study on Southern Hemisphere Minke Whale Research Plan
    - 5.1 Presentation of Japanese research plan
    - 5.2 Consideration of written comments received on the Feasibility Study
    - 5.3 Consideration of any other documents received
6. Review of Japanese proposal under the criteria specified in Resolutions on Special Permits for Scientific Research adopted in 1986 and 1987 by the Commission, and the Scientific Committee's guidelines for review of Scientific Permits
7. Adoption of Report

Annex C
List of Documents

SC/D87/

1 Government of Japan – The Research Plan for the Feasibility Study on 'The Program for Research on the Southern Hemisphere Minke Whale and for Preliminary Research on the Marine Ecosystem in the Antarctic'

Comments submitted by:

2 D. Goodman (USA)
3 M. Nerini (USA)
4 F. Nagasaki (Japan)
5 J. Horwood (UK)
Appendix
6 K. Lankester (Netherlands)
7 W.K. de la Mare (Australia)
8 T. Kasuya (Japan)
9 S. Ohsumi (Japan)
10 T. Smith and T. Polacheck (USA)
11 S.A. Mizroch (USA)
12 D.G. Chapman (USA)
13 T. Miyashita (Japan)
14 S.J. Holt (Seychelles)
15 M.F. Tillman (USA)
16 S. Wada (Japan)
17 S.J. Holt (Seychelles)
18 H. Kato (Japan)
19 P.B. Best (Invited Participant)
20 I. Ikeda (Japan)
21 F. Kasamatsu (Japan)
22 H. Kishino (Japan)
23 S.J. Holt (Seychelles)
24 R. Payne (Antigua & Barbuda)
25 M. Ivashin and R. Borodin (USSR)
26 J.M. Breiwick and L. Tsunoda (USA)
27 S. Reilly (USA)
28 J. Sigurjónsson (Iceland)
29 W.F. Perrin (USA)
30 T. Lyrholm (Sweden)
31 M. Cawthorn (New Zealand)
32 D.S. Butterworth – On the information content of catch-at-age data and some associated implications for Southern Hemisphere minke whales
33 D.S. Butterworth – IWC Scientific Committee Correspondence Group regarding the analysis of catch curve data
34 D.S. Butterworth (Invited Participant)
35 (Japan) Instruction note for researchers and crew on the implementation of research in the 1987/88 preliminary research plan
36 T. Nakamura – A Bayesian cohort model for catch-at-age data
37 J.G. Cooke (Invited Participant)
38 T. Gunnlaugsson and K.G. Magnusson (Iceland)
39 W.K. de la Mare – On the simultaneous estimation of natural mortality rate and population trend from catch-at-age data (SC/40/O 1)
40 Y. Gong (Republic of Korea)

Documents also available:

Commission Resolutions 1986 and 1987 and Scientific Committee Guidelines for Review of Scientific Permits
Extracts from the Report of Scientific Committee 1987 (Item 11.3.3; Annex R)

Annex D
Statement on Procedures Adopted During the Meeting

During the discussion of the Draft Agenda, Sigurjónsson expressed the view that it was not within the scope of the Committee's task at this special meeting to revise or make drastic changes to its procedures. He further felt it was inappropriate to spend the Committee's limited time at this meeting on such items as a quorum or voting procedures and had proposed, supported by Ohsumi, that these items be deleted from the Draft Agenda. On the Chairman's ruling that this Agenda Item should be retained, albeit with a time restraint, and the subsequent adoption of meeting procedures that he felt were equivalent to voting, Sigurjónsson had reserved his right to comment on this.

Furthermore, Sigurjónsson and Magnusson felt that the report should accurately reflect the discussion which took place and that it was unnatural that members who did not speak during the debate, or in some cases were not even present, should attach themselves during discussion of the Report to the various views expressed. They also believed that the procedure of calling for names to be associated with various views put unprecedented pressure on individual scientists.

National Progress Reports

ARGENTINA. PROGRESS REPORT ON CETACEAN RESEARCH, MAY 1987 TO APRIL 1988

Alfredo A. Lichter

Grupo Cetáceos, Fundación Vida Silvestre Argentina, Defensa 245 1075 Buenos Aires, Argentina

and

R. Natalie P. Goodall

Programa Cetáceos Australes, Sarmiento 44, 9410 Ushuaia, Tierra del Fuego, Argentina

This report refers to work conducted by the Museo Argentino de Ciencias Naturales, Buenos Aires (MACN-BA); Grupo Cetáceos-Fundación Vida Silvestre Argentina (GC-FVSA); Instituto Nacional de Investigación y Desarrollo Pesquero, Mar del Plata (INIDEP); Centro Nacional Patagónico (CNP); Universidad Nacional de Buenos Aires (UNBA); Programa Cetáceos Australes of the Centro Austral de Investigación Científica, Ushuaia (PCA-CADIC); Fundación Australis, Buenos Aires (FA) and by private researchers in Argentina.

Species and stocks studied

Sighting and stranding programs covered all species found along the Argentinian coasts. Specific studies were carried out on the following species in the following areas:

Southern right whale *Eubalaena australis* – Provinces of Buenos Aires and Chubut.
Killer whale *Orcinus orca* – Province of Chubut.
Dusky dolphin *Lagenorhynchus obscurus* – Province of Chubut.
Bottlenose dolphin *Tursiops truncatus* – Province of Buenos Aires.
Commerson's dolphin *Cephalorhynchus commersonii* – Provinces of Santa Cruz and Territory of Tierra del Fuego.
Spectacled porpoise *Australophocaena dioptrica* – Tierra del Fuego.
Franciscana dolphin *Pontoporia blainvillei* – Province of Buenos Aires.

Field observations and collections

Sighting and stranding networks

Since their inception in 1985, the *Red Nacional de Avistajes y Varamientos de Cetáceos* (National Network of Cetacean Sightings and Strandings – ReNAV) and the *Red Sudamericana de Ballena Franca* (South American Southern Right Whale Network – RSBF) have continued their development, coordinated by A.A. Lichter (GC-FVSA). Likewise, the *Programa Cetáceos Australes* (Southern Cetacean Program) (PCA-CADIC), developed in 1976, has continued beach surveys for stranded animals and has gathered data on opportunistic sightings. For more information see the sections on sightings and strandings below.

Sightings

R. Bastida (INIDEP) and his team continued observations of *T. truncatus* and *E. australis* off the Province of Buenos Aires and Península Valdés, Chubut, completing, in the latter case, seven general censuses. With the assistance of O. Mandó, A. Roux and D. Rodriguez, Bastida has completed three years of study on the respiration and diving techniques of *E. australis*. He also has continued with the development of an identification catalogue for these whales.

G. Harris continued with the observations and censuses of *E. australis* at Golfo San José, Chubut. Other cetacean observations in this area included *O. orca, L. obscurus, T. truncatus* and *Phocoena spinipinnis*. R. Payne continued his long term behavioural studies of *E. australis* in the Península Valdés area. A. Arias, G. Alvarez Colombo and D. Garciarena (under R. Payne's supervision) continued with a study of the comparison of the behaviour of the southern right whale at Golfo Nuevo, Chubut, where there are interactions between the whales and tourist vessels, and at Golfo San José. V. Rowntree continued her observations on the interactions between lactating female southern right whales.

R. Hoelzel, with the assistance of M. Iniguez, moved ahead with his project of observations of *O. orca* at Punta Norte, Península Valdés. He and A.A. Lichter analysed the movements of an identified group of killer whales in this area.

Mundo Marino Aquarium, San Clemente del Tuyú, Province of Buenos Aires, recorded sightings of *E. australis, O. orca, T. truncatus* and *P. blainvillei*.

M. Iniguez carried out shore observations and censuses of *C. commersonii* at Puerto Deseado, Santa Cruz, during the summer 1987–88. He also joined Dr. Alan Baker aboard the yacht *Southern Cross*, sailing between Mar del Plata, Argentina, and Punta Arenas, Chile. They made several sightings of *C. commersonii* and *L. obscurus*.

A.A. Lichter and H.P. Castello, with the active participation of Mundo Marino Aquarium, have begun a behavioural and population study of *T. truncatus* in the area of Bahía de Samborombón, Province of Buenos Aires.

The opportunistic sightings gathered by PCA-CADIC for this period have not yet been compiled, but included a southern right whale in the eastern Canal Beagle, Tierra del Fuego, in late April 1988. Sightings were also made by the team or reported for *C. commersonii, L. australis, O. orca, Globicephala melaena* and *Australophocaena dioptrica*.

Marking

No marking of animals using artificial tags has been carried out in coastal Argentinian waters. Studies involving natural markings are referred to elsewhere in this Report.

Laboratory work

G. Harris, a group of biology students from the University of Puerto Madryn and a member of the Oceanographic Museum of Puerto Madryn, found and recovered a stranded specimen of *E. australis* in 1985. The skeleton was cleaned for local exhibition. This is the first complete skeleton of a southern right whale in any North or South American collection.

G. Perez Macri analysed the stomach contents of specimens of *P. blainvillei* and *T. truncatus*. She also worked on the determination of age by examining growth-layer-groups in teeth.

The program in Tierra del Fuego continued with the cleaning and curating of skeletal material of 12 species, preparation of annotated bibliographies, and measurement of specimens of ziphiid whales. In November, 1987, W.F. Perrin, R.N.P. Goodall and M. Cozzuol began a study of osteological variation in specimens of *A. dioptrica*.

Many of the young researchers working in Argentina attended an intensive course on marine mammals sponsored by UNEP and IATTC, held in Ushuaia in November, 1987.

Research results

Partial results for the period of this report are given in the papers and documents cited below; other papers are in preparation.

Strandings

Strandings surveys were made by A.A. Lichter, H. Castello, M. Iniguez and F. Fraga (GC-FVSA and MACN-BA) in coastal areas of the Province of Buenos Aires.

G. Perez Macri (UNBA) developed a study on the feeding habits and mortality of *P. blainvillei* on the coasts of the Province of Buenos Aires, examining animals stranded or taken incidentally for stomach contents and parasites.

Table 1

Strandings or incidental capture specimens on the coasts of Tierra del Fuego, Argentina, May 1987–May 1988. Data of collection can also mean date of first discovery (*). There were no new mass strandings; several animals for one area usually represent net entanglements. All specimens are in the RNP collection in Ushuaia. No. = number of carcasses

No.	Date of stranding	Date of collection	Locality/Details
Balaenoptera acutorostrata			
1	–	25 Oct 87	Península Páramo; decomposed
1	13 Apr 88	15 Apr 88	Canal Beagle; fresh, floating, female
Physeter macrocephalus			
1	Jun 87	Feb 88	Estancia Moat; live stranding
Mesoplodon layardii			
1	–	24 Mar 88	Ea. Las Violetas; decomposing
Mesoplodon grayi			
1	–	24 Mar 88	Estancia Sara; beach-worn mandible, teeth
Ziphius cavirostris			
1	–	24 Mar 88	Estancia Sara; beach skull, young
1	–	12 Mar 88*	Cabo San Pablo; not collected
Hyperoodon planifrons			
2	–	25 Mar 88	Ea. Las Violetas; two beach-worn mandibles
Orcinus orca			
1	–	30 Oct 87*	Bahía San Sebastían; mummified whole
Globicephala melas			
7	pre-1982	11 Mar 88	Estancia Fueguina; decomposed
6	pre-1980	12 Mar 88	Estancia Pirinaica; decomposed
1	–	25 Mar 88	Estancia Sara; decomposed
Grampus griseus			
1	–	11 Mar 88	Ea. Fueguina N; vertebrae
3	–	25 Oct 87*	San Sebastián/Páramo; decomposing, not collected
Cephalorhynchus commersonii			
6	Summer 87/8	22 Mar 88	San Sebastián/Páramo; caught in nets
11	"	9-24 Mar 88	Northeast coast; caught in nets
Phocoena spinipinnis			
1	–	24 Mar 88	Ea. Las Violetas N; decomposed
Australophocaena dioptrica			
2	–	26 Oct 87	San Sebastián/C. Domingo; decomposed
5	–	3-25 Mar 88	Ea. Sara to Punta María; decomposed

All the investigators who are working with *E. australis* in the Península Valdés continued to register strandings in this area.

The PCA in Tierra del Fuego was hindered by lack of assistants, but made several beach surveys to collect specimens and made observations on several other strandings. The Government of the Territory of Tierra del Fuego provided a helicopter on 15 April 1988 to closely survey the beaches from Ushuaia, on the Canal Beagle, to Bahía Sloggett.

The PCA of Ushuaia carried out only four coastal stranding surveys during this period, but a great deal of stranded or incidentally captured material was collected or observed, all on the Argentinian coasts of Tierra del Fuego. Only one animal, a female minke whale, was fresh. It was found floating in the Canal Beagle in April 1988 and taken to Isla Gable by a pilot boat, where it was examined. All specimens are held in the collection of the second author in Ushuaia. Information on all strandings is available from the authors.

Statistics and data for small cetaceans

Direct take

We have not heard of any direct exploitation of small cetaceans in Argentinian waters, although fishermen (both Argentinian and Chilean) may harpoon dolphins in the Canal Beagle for bait for southern king crab (*Lithodes antarctica*) traps.

Incidental take

Incidental exploitation was recorded only for Tierra del Fuego and the data there are incomplete. The Goodall team talked to fishermen at six shore sites along the northeast coast. The results of the conversations and specimens collected are listed below (Table 2). Actual incidental take was probably much higher, as we visited the area only twice, in October 1987 and March 1988, and did not talk to all fishermen.

Table 2

Incidental exploitation in nets set for fish in northeastern Tierra del Fuego

Species	Animals reported caught in nets	Specimens collected by PCA	Specimens coll. by PCA which probably died in nets	
C. commersonii	14	8	6	
L. australis	1	–	–	
P. spinipinnis	1	–	1	
A. dioptrica	–	–	6	
Total	16	8	13	= 37

At three sites, fishermen said dolphins (*C. commersonii*) had become trapped in nets, but were released. At Paso de la Cholgas, 'several' were released alive; at Puesto 17 a small one was caught and taken to the sea; at the Páramo, a large and a small dolphin were caught together on 20 March 1988 and taken out over the mud flat to water.

Live-captures

A male killer whale calf which stranded alive near the Mundo Marino Aquarium was recovered by the aquarium and is exhibited along with a previously stranded killer whale, which has been at the aquarium several years.

Publications

Bastida, R. 1987. La ballena franca austral: un recurso turístico peculiar. *Revista Patagónica* 6(29): 24–8.

Castello, H. and Diaz, G. 1987. La colección de mamíferos marinos del Museo Argentina de Ciencias Naturales: una revisión crítica. p. 108. *In*: S. Siciliano and B. Fiori (eds.) *Anais da 2a. reuniao de Trabalho de especialistas en mamíferos aquáticos da América do Sul*. FBCN, Río de Janeiro. 119pp.

Delhon, G.A., Crespo, E. and Pagnoni, G. 1987. Stranding of a specimen of Gray's beaked whale at Puerto Pirámides (Chubut, Argentina) and its gonadal appraisal. *Sci. Rep. Whales Res. Inst. Tokyo* 38: 107–15.

Goodall, R.N.P. 1987a. Identity of *Tursio chiloensis* Philippi 1900. *Abstract, National Geographic Research* 3(1): 258.

Goodall, R.N.P. 1987b. Small cetaceans of the South American sector of the Antarctic and Subantarctic. pp. 148–50. *In*: D.W. Reed (ed.) *Spirit of Enterprise, the 1987 Rolex Awards*. Van Nostrand Reinhold Co. Ltd, Wokingham. 460 pp.

Goodall, R.N.P. and Galeazzi, A.R. 1987a. Strandings on the coasts of the province of Santa Cruz, Argentina – a preliminary look. *Abstracts, Seventh Biennial Conference on the Biology of Marine Mammals*. p.26.

Goodall, R.N.P. and Schiavini, A.C.M. 1987. Focas antárticas halladas en las costas de Tierra del Fuego. pp. 57–9. *In*: S. Siciliano and B. Fiori (eds.) *Anais da 2a, reuniao de trabalho de especialistas en mamíferos aquáticos da América do Sul*. FCBN, Río de Janeiro. 119pp.

Hoelzel, A.R. 1987. Killer whale social group dynamics and associations behaviour during travel and foraging. *Abstracts, Seventh Biennial Conference on the Biology of Marine Mammals*. p.32.

Lichter, A.A. 1987. A preliminary analysis of the Argentine sighting and stranding network. *Abstracts, Seventh Biennial Conference on the Biology of Marine Mammals*. p.40

Loureiro, J. 1987. Recuperación de una orca varada. pp. 71–3. *In*: S. Siciliano and B. Fiori (eds.) *Anais da 2a. Reuniao de Trabalho de Especialistas en Mamíferos Aquáticos da América do Sul*. FBCN, Río de Janeiro. 119pp.

Malaret, A., Bastida, R., Bertolotti, M., Bezzi, S., Brunetti, J., Ciechonski, J., Gregorio, C., Otero, H., Perez Comas, J. and Prenski, B. 1987. Impacto ecológico y econónico de las capturas alrededor de Malvinas después de 1982. *Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Contribuciones* 513. 115pp.

Mendez, J.D. and Mendez de Cabrera, G. 1987. Sobre la construcción de un centro de rehabilitación de mamíferos marinos en Argentina. p. 74. *In*: Siciliano and B. Fiori (eds.) *Anais da 2a. Reuniao de Trabalho de Especialistas en Mamíferos Aquáticos da América do Sul*. FBCN, Río de Janeiro. 119pp.

Rowntree, V. 1987. Interactions between lactacting female southern right whale (*Eubalaena australis*) on their calving grounds. *Abstracts, Seventh Biennial Conference on the Biology of Marine Mammals*. p. 59.

AUSTRALIA. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO APRIL 1988

Australian National Parks and Wildlife Service, GPO Box 636, Canberra, ACT, Australia, 2601

This report refers to work involving: the Australian National Parks and Wildlife Service (ANPWS), Canberra, Australian Capital Territory; New South Wales National Parks and Wildlife Service, Sydney, New South Wales; Queensland National Parks and Wildlife Service, North Quay, Queensland; South Australian National Parks and Wildlife Service, Adelaide, South Australia; Department of Conservation, Forests and Lands, Melbourne, Victoria; Department of Lands, Parks and Wildlife, Hobart, Tasmania; Department of Conservation and Land Management, Como, Western Australia; University of Sydney, Sydney, New South Wales; James Cook University of North Queensland, Townsville, Queensland; University of Tasmania, Hobart, Tasmania; Australian Museum, Sydney, New South Wales; South Australian Museum, Adelaide, South Australia; Queensland Boating and Fisheries Patrol, Brisbane, Queensland; Department of Industries and Development, Darwin, Northern Territory; Department of Agriculture, Ulladulla, New South Wales; Tribond Developments Pty Ltd, West Beach, South Australia; Project Jonah, North Quay, Queensland; ORRCA, Sydney, New South Wales; Pacific Whale Foundation, Maui, Hawaii; and a number of unaffiliated individuals. This report was compiled by R.A. Puddicombe, ANPWS.

Species and stocks studied

(i) Southern right whale *Eubalaena australis* – southern coast of Australia.
(ii) Humpback whale *Megaptera novaeangliae* – east coast of Australia.
(iii) Bottlenose dolphin *Tursiops* sp. and Indo-Pacific humpbacked dolphin *Sousa chinensis* – southeast Queensland.
(iv) Several small cetacean species accidentally captured in the now-ended Taiwanese gillnet fishery in northern Australian waters between 1984 and 1986, including the bottlenose dolphin, spinner dolphin *Stenella longirostris*, spotted dolphin *Stenella attenuata*, Indo-Pacific humpbacked dolphin and the false killer whale *Pseudorca crassidens*.
(v) Various species sighted or stranded around the Australian coast.

Field observations and collections

Autopsy

A recently dead bottlenose dolphin *T. truncatus* was snagged on a fishing line in the Port River (34°50′S, 138°30′E) on 23 December 1987. Being fresh, it was collected by the South Australian Museum, frozen and a post-mortem examination was carried out on 8 January 1988. It was found to be an old, arthritic female, blind or partially blind in one eye and with lymph node abscesses and nodular lungs.

Stranded specimens

The South Australian Museum is continuing to recover and treat all outstanding material from strandings including several specimens from Kangaroo Island (35°40′S, 137°00′E). The South Australian Museum has recently reorganised its cetacean collections so that all material is easily accessible for study and all records are now computerised. Identifications and collection data were corrected and verified. Some specimens still require further study.

H. Burton of the Antarctic Division reports that two more cetacean skulls have been recovered from Heard Island (53°05′S, 73°30′E). They are as yet unidentified but one is a small baleen whale, the other a dolphin (possibly the hourglass dolphin, *Lagenorhynchus cruciger*.

Marking

Artificial markings

Two male common dolphins *Delphinus delphis* stranded in separate incidents in August 1987 at Glenelg Beach (34°59′S, 138°31′E) and Torrens Outlet, Henley (34°56′S, 138°30′E), South Australia. They were taken to Marineland and rehabilitated there and were freeze branded with the numbers 1 and 2 respectively on their dorsal fins. They were released together at sea on 16 September 1987. A female bottlenose dolphin (2.03m, 111.4kg) swam upriver through a lock system at Patawalonga River (34°59′S, 138°31′E). She was captured on 6 January and rehabilitated at Marineland and was freeze branded on the dorsal fin with the number 3. She was released at sea on 22 January 1988 and has been resighted on nine occasions, at times in the company of other *Tursiops*.

Natural markings

A large number of studies in Australian waters now make use of natural markings for individual identification of animals. Progress on many of these is discussed under the 'Research results' section below. Further information may be obtained from ANPWS.

Laboratory work

H. Marsh of the James Cook University of North Queensland, under ANPWS funding, has conducted analyses of reproductive material obtained from dolphins killed in the now-closed northern gillnet fishery. Age determination of the same animals will be made in the near future through analysis of tooth sections.

R. Paterson is conducting a review of beaked whale material held in the Queensland Museum and is also examining the osteology of Bryde's whale *Balaenoptera edeni* from eastern Australia.

Development of techniques

The conservation group ORRCA has developed techniques and expertise towards more effective management of mass strandings. The group holds training weekends in conjunction with national parks officers and members of the public to pass on information and to train people in actions to be taken during the rescue of stranded cetaceans.

Research results

The Pacific Whale Foundation collected photographs of humpback whales for individual identification, mainly at North Stradbroke Island, Queensland (27°27′S, 153°33′E), with additional photographs collected in Hervey Bay, Queensland (25°00′S, 153°00′E). In addition to displaying distinctive fluke patterns, these humpback whales were found to exhibit wide variation in the extent of lateral body pigmentation. Using fluke and lateral body pigmentation patterns 352 humpback whales were identified in 1987. During the course of this study, from 1984–1987, 722 east Australian (Area V) humpback whales have been photographically identified. Excluding resights, this represents approximately 415 individuals. Resight analysis for the 1987 season is still in progress, but to date 82 animals have been resighted off the east coast using fluke and lateral body pigmentation patterns. Table 1 outlines research vessel effort in 1987.

Table 1

Research vessel effort in 1987

Location	Dates	Water days	Whales observed	Whales identified
N. Stradbroke	20 Jun - 31 Sep	43	122	119
N. Stradbroke	1 Sep - 25 Oct	29	169	158
Hervey Bay	4 Sep - 6 Oct	11	78	75

Recordings were made of humpback whale songs near North Stradbroke Island on both northward and southward migrations, and at Hervey Bay, Queensland. Songs collected along the east coast of Australia (1984–1987) are presently being analysed for seasonal changes and compared to songs collected in Western Australia, Tonga and Hawaii.

Queensland National Parks and Wildlife Service (QNPWS) Maritime Estate staff based in Gladstone have continued to collect photographs of tail flukes of humpback whales to facilitate identification of individuals. This project on migration patterns in the southern Great Barrier Reef is being conducted in close collaboration with the Pacific Whale Foundation. The work has led to a significant proportion of resightings of individuals in successive years. Humpback whale songs have also been recorded by QNPWS staff in the southern Great Barrier Reef during 1987.

Work is also proceeding on the identification of areas of importance to humpback calving and mating in the southern Great Barrier Reef through opportunistic interviews with charter boat operators. The need for appropriate management of these areas is being taken into account during ongoing marine park declaration and zoning in Queensland coastal waters.

In association with S. Van Dyck of the Queensland Museum, R. Paterson has reviewed the occurrence and some aspects of behaviour of Bryde's whale *B. edeni* in the coastal waters of eastern Australia.

M.M. Bryden and P.J. Corkeron completed their field research on two species of inshore dolphins (*Tursiops sp.* and *S. chinensis*) in the Moreton Bay region (27°25′S, 153°20′E). Extensive analysis of the data is being conducted at present, with expectation of completion by the end of 1988.

D. Nicol of the University of Tasmania concluded his research into patterns and possible causes of cetacean strandings around Tasmania. The spatial distribution of the strandings was found to be influenced by several factors including the combination and interaction of oceanographic conditions and geographic topography. The sites of active strandings were generally characterised by two features of the geomagnetic field; sites where contours of magnetic intensity tend to cross the coast rather than run parallel with it and where local minima exist in the geomagnetic field.

The temporal distribution of stranding was influenced by a variety of environmental factors. Seasonally, most strandings were reported during the summer months just prior to maximum sea surface temperatures. The summer, however, is also the period of maximum levels of human activity around Tasmania's beaches. Annual variations in several environmental factors, e.g. air pressure, number of westerly winds and the timing of the spring bloom in planktonic biomass, were significantly correlated with peaks in the stranding frequencies of some cetacean species and species groups. There appears to be a relationship between the major disruptions of oceanographic and oceanic circulation (ENSO – El Niño and Southern Osculation) and stranding frequencies. The peaks of sperm whale *Physeter macrocephalus* and false killer whale strandings are significantly correlated with the level of geomagnetic disturbances.

Sightings data

Humpback whales

Queensland

The ANPWS funded survey by M.M. Bryden of northward-migrating humpback whales in 1987 involved 668 hours of observation at Point Lookout, North Stradbroke Island, from 25 May to 16 August. Observations were attempted on 76 of the 84 days in that period. A total of 302 humpback whales in 174 pods were observed. Weather conditions were divided into good, fair and poor. There was no significant difference in sighting rate between good and fair conditions, but these did differ from poor conditions. Sightings data from good and fair conditions were pooled, and comparison of data from 1982 and 1987 was made. The best estimate for annual net increase in whale numbers between 1982 and 1987 was 13.9%. Thus the large increase in the population in recent years, observed in 1986, was confirmed in 1987.

The long term study of the east Australian humpback whale population by R. Paterson from the Cape Moreton/Point Lookout region of northern Queensland is now in its tenth year and a recovery trend has been documented. Reports received from other observers demonstrated the temporal and spatial distribution of humpback whales in east Australian waters. In recent years three eye-witness accounts of humpback whale calving in Great Barrier Reef waters further support earlier opinions (Paterson and Paterson, 1984; Simmons and Marsh, 1986) that the central section of the Reef is an important calving ground for the east Australian humpback whale stock.

Detailed land-based observations were again made in 1987 at Point Lookout, North Stradbroke Island, Queensland by the Pacific Whale Foundation during the humpback whale's northward and southward migration, as outlined in Table 2.

Table 2

Summary of land-based effort and observations in 1987

Migration	Dates	Obs. days	Obs. hours	Pods	Whales
Northward	20 Jun - 31 Aug	48	330.1	106	189
Southward	1 Sep - 25 Oct	37	274.9	121	262
Pod compositions					
Northward	126 adults	29 subadults	0 calves		34 unknown
Southward	173 adults	22 subadults	23 calves		44 unknown

In addition to marine mammal sightings recorded by QNPS officers during a routine aerial surveillance program in the Capricornia Section of the Great Barrier Reef Marine Park, a sightings questionnaire has been circulated among Charter boat operators reef-wide and reports are being collected and analysed in collaboration with the Marine Mammal Sightings Program of James Cook University, Townsville. It is intended to produce an annual report of whale movements for distribution to all interested parties.

Project Jonah Qld conducted two land based whalewatches from Cape Byron (28°38′S, 153°37′E) in 1987. As in previous years, these were scheduled to coincide with the expected northern and southern humpback whale migration peaks. The periods of observation were 27 June to 12 July and 19 to 27 September respectively. Teams of observers watched from 0700 to 1630hrs daily, documenting the numbers, behaviour and transit paths of cetaceans. Project Jonah is presently preparing a detailed report of the results of the past four winter surveys, 1984–87, and publication was scheduled for April 1988. Winter and spring surveys are presently being planned for 1988.

Tasmania

The Tasmanian Department of Lands, Parks and Wildlife again kept records of sightings of humpback whales in Tasmanian waters. In 1987, humpback whales were sighted 11 times (5 sightings of single adults, 2 sightings of a pair of adults, 1 sighting of three adults and 3 sightings of female/calf pairs). Sightings were reported in two periods, presumably representing the northward and southward migrations. Three sightings were reported between 20 and 28 July (2 sightings of single adults, 1 sighting of a pair of adults) off the south and east Tasmanian coasts. The second period of sightings started on 18 September (one adult) followed by six more sightings between 10 October and 8 November all off the north coast (2 sightings of single adults, 1 of a pair of adults, 1 of three adults and 2 of female/calf pairs). Dates and locations suggest the presence of eight individual adults and at least one young calf in the second period.

An unexpected event for this latitude was the report of a newly born humpback whale calf, still with an umbilicus, found floating in a decomposing condition on 9 August in Recherche Bay (43°33′S, 146°54′E) in the far south of Tasmania. There were reports of an adult carrying the dead calf on its head, three days earlier.

Southern right whales

South Australia

J. Ling continued his ANPWS funded survey of South Australian southern right whales (*E. australis*) in 1987. One regular aerial survey (7–9 September) and one opportunistic helicopter flight (6 August) were made in 1987. Efforts were hampered by a prolonged spell of bad weather and an absence of whales. A *Cessna 172* high-wing monoplane was flown at a height of 460m (1,500ft) and an air speed of 185kph (100 knots) along the shoreline. Surveys were conducted between Ceduna, South Australia (32°08′S, 133°41′E) and Twilight Cove, Western Australia (32°16′S, 126°02′E). When southern right whales were sighted, they were circled at heights of 460, 305 and 150m (1,500, 1,000 and 500ft), counted and their relative and absolute sizes, callosity patterns, colour and behaviour were noted. Photographs were taken while the plane circled at 150m head-on to the whales.

At least 26 southern right whales (8 calves) were seen in the area between Twilight Cove, WA, and the Head of the Bight, SA (31°28′S, 131°08′E) in August-September 1987. During one flight it was possible to calculate the average swimming speed of two cow-calf pairs. One pair had moved westwards 6 n.miles in three hours (2kts) and the other swam westwards 7.5 n.miles in 5 hrs 40 mins (1.25kts). Groups of two or three adult whales without calves were seen during each survey. Some adult whales had distinctive body markings such as white flashes on their bodies or flukes. One pure white calf was seen and another with one side of its flukes white. As for humpbacks in Australian waters, it would be useful to develop a collection of photographs showing identifiable body markings in addition to the standard photographs of callosities.

There were 57 reported sightings of right whales in 1987. Correcting for possible repeat sightings and including aerial counts, a total of 32 adults and 16 calves was obtained for the whole State during the 1987 season.

Combining counts made on aerial surveys with confirmed sightings of southern right whales on the same or very nearly the same day at localities far removed from each other, minimum counts have been derived for the whole South Australian coast for the years 1983–87 which are listed in Table 3.

Table 3

South Australian southern right whale sightings from 1983 to 1987

Year	Adults	Calves	Total	Year	Adults	Calves	Total
1983	92	32	124	1986	53	28	81
1984	80	34	114	1987	32	16	48
1985	101	25	126				

J. Ling and D. Needham of the South Australian Museum continued to co-ordinate the South Australian 'Whale-watch' program. There were about half the number of reported sightings of southern right whales in 1987 compared with 1986. These sightings, in addition to whales sighted during the aerial surveys, accounted for between 32 and 48 southern right whales in the whole State, which was about half the number seen in previous years.

Other species were also reported, including a blue whale *Balaenoptera musculus* in Nepean Bay, Kangaroo Island (35°42′S, 137°37′E) (confirmed from photographs) in April.

Western Australia

The survey of southern right whales by the Western Australian Museum continued in 1987. Three survey flights were made along the southern Western Australian coastline between Augusta (34°19′S, 115°09′E) and Caiguna (32°16′S, 125°28′E) in August, September and October with a total of 46.5 hr flying time. A total of 187 right whale sightings were made including 39 calves. This does not allow for repeated sightings of individual animals. Preliminary sighting results are included in Table 4.

Table 4

Western Australian southern right whale sightings of adults (A) and calves (C) on survey flights in 1987

Date	Albany - Augusta - Albany	Albany - Esperance - Caiguna	Caiguna - Esperance - Albany
6 - 8 Aug	4A + 1C	48A + 8C	14A + 4C
7 - 9 Sep	0	33A + 13C	17A + 1C
5 - 7 Oct	1A + 1C	22A + 11C	9A

Victoria

Monitoring of southern right whale activity in Victorian coastal waters during the 1987 winter was achieved through the co-operation of staff of the Department of Conservation, Forests and Lands, engaged in various coastal duties. Very few animals were sighted and no aerial reconnaissance was carried out. A copy of private video-tape footage was obtained of a male and female encountered off Kilcunda (38°30′S, 145°29′E) and again off Woolamai Beach (38°33′S, 145°20′E) on 3 and 4 July respectively.

Three southern right whale sightings were made in the Colac region of Victoria in 1987. On 1 August at Loutit Bay, Lorne (38°33′S, 143°59′E) two whales were seen. On 25 August, 4km east of Port Campbell (38°38′S, 143°01′E) one animal was reported by a fisherman to be about 15m long in seven fathoms of water, surfacing and sounding. Finally on 18 September at Apollo Bay (38°45′S, 143°40′E), two animals, possibly a female and young, were seen about 300m offshore.

New South Wales

A. Karacsonyi, a Fisheries Inspector of Ulladulla, NSW, observed and photographed an 18m southern right whale visiting the local coastline on 26 August 1986 and again on 4 September 1987 at Narawallee Beach (35°18′S, 150°28′E). Photographs of its callosity patterns confirm that the whale seen in each year was the same animal. Two days after the 1986 sighting a southern right whale and calf were seen at Jervis Bay (35°02′S, 150°46′E) only 25km north. Because of the rarity of sightings of this species in this area, it is likely that the animal seen on 26 August had moved north and calved.

Tasmania

The Tasmanian Department of Lands, Parks and Wildlife continued its programme of recording sightings of large whales in Tasmanian waters. In 1987, over 40 sightings of one, two or three southern right whales were recorded between 26 June and 22 October. Most were multiple sightings of groups which stayed in one spot or could be tracked over a period of time.

Although calves had been seen before, this season has provided the first definite evidence of calves born in Tasmanian waters in recent years.

On 26 June, two adults were seen east of Hobart in Frederick Henry Bay (42°54′S, 147°36′E) where these whales have been recorded regularly in the last few years. Of 12 reports, some indicated the presence of two groups of two animals. On 11 July one report involved two adults with a grey coloured calf, 5m, followed by a sighting on 25 July of two adults with a calf and another pair of adults about 1km away. The second and third new calves were recorded on the east coast. Both were reported as very dark to black. The distance between the sightings (260km in a straight line) and sighting dates make it unlikely that either of these was a resight of the first calf.

A female with a 5m calf was seen on 5 August south of Falmouth (41°33′S, 148°17′E). This was followed by simultaneous sightings, 65km apart, on 10 August, one north of Bicheno (41°49′S, 148°16′E), the other at Binnalong Bay (41°15′S, 148°19′E). Between 21 and 27 August the Binnalong group slowly moved north to George Rocks (40°56′S, 148°20′E) covering distances of 7–15km per day between sightings. A further sighting of a female and calf was made at Bridport (41°00′S, 147°25′E) on 31 August about 90km west along the Bass Strait coast. Sightings of female and calf pairs were also made from 21–24 September at Bruny Island (43°21′S, 147°20′E) in the south and on 6 October at Penguin (41°06′S, 146°03′E) on the north coast.

Between 15 and 26 August, three adults were present at Port Arthur (43°08′S, 147°53′E). Two were continuously together, touching and rolling, apparently engaged in sexual behaviour. The third often participated but tended to be more on its own nearby but was also absent for periods of one day. Other adult whales (three groups of one and two pairs) were reported from the south, east and north coasts between 25 July and 22 October.

Minke whales – Tasmania

The Tasmanian Department of Lands, Parks and Wildlife reported their first recorded sighting of minke whales, *Balaenoptera acutorostrata*, in Tasmanian waters. Two minke whales were seen near Swansea (42°07′S, 148°05′E) on 4 August 1987. Local residents reported observing them on and off for nearly a week in other parts of Great Oyster Bay (42°09′S, 148°10′E), feeding on dense schools of small fish. On 6 September a single minke was observed by a fisherman near Visscher Island (42°52′S, 147°59′E), where it circled his boat for 20 minutes at a distance of less than 20m.

Strandings

The ANPWS continued to receive and collate stranding reports from the States and the Northern Territory. Since May 1987 ANPWS received reports of 70 stranding incidents involving 76 animals of 20 species. The number of reported stranding incidents by species was as follows: Humpback whale (3); fin whale *Balaenoptera physalus* (1); minke whale (3); pygmy right whale *Caperea marginata* (2); sperm whale (11); pygmy sperm whale *Kogia breviceps* (1); Cuvier's beaked whale *Ziphius cavirostris* (2); Andrew's beaked whale *Mesoplodon bowdoini* (1); Gray's beaked whale *Mesoplodon grayi* (1); straptoothed beaked whale *Mesoplodon layardi* (1); Unidentified mesoplodont (1); killer whale *Orcinus orca* (2); long-finned pilot whale *Globicephala melas* (2); short-finned pilot whale *G. macrorhynchus* (1); Risso's dolphin *Grampus griseus* (1); bottlenose dolphin (20); striped dolphin *Stenella coeruleoalba* (1); Irrawaddy dolphin *Orcaella brevirostris* (1); common dolphin *D. delphis* (13); unidentified dolphin (2).

The multiple strandings involved groups of 3 and 5 common dolphins. For information on any of the above strandings ANPWS should be contacted in the first instance.

Pollution studies

The Victorian Department of Conservation, Forests and Lands reported that there were no studies of the effects of pollution on cetaceans in that state.

The Tasmanian Department of Lands, Parks and Wildlife reported that strandings are investigated and where possible, autopsies are carried out. Tissue samples are taken for pesticide and heavy metal analysis in conjunction with veterinary offficers of the Department of Agriculture and D. Nicol of the University of Tasmania.

The New South Wales National Parks and Wildlife Service advises that an analysis of heavy metals in the body tissues of false killer whales, which mass stranded at Crowdy Head (31°50′S, 152°45′E) in June 1985, has been conducted and the results of this work are expected to be published in the near future.

Statistics and data for small cetaceans

Incidental captures in fisheries

The Western Australian Department of Conservation and Land Management reports that three bottlenose dolphins were drowned through entanglement in a fishing net at Mandurah (32°32′S, 115°44′E) in January 1988. Tooth samples were obtained by the Western Australian Museum.

Accidental captures in protective shark nets

The Shark Operations and Development program manager of the Queensland Boating and Fisheries Patrol reports that 15 small cetaceans were captured between 1 March 1987 and 29 February 1988 in nets set off Queensland beaches to protect bathers from sharks. Of these 11 were reported to be dead. The status of the remaining four animals was unknown. The species was unreported but is expected to be the bottlenose dolphin. The Boating and Fisheries Patrol has been requested by ANPWS to provide this information in future.

Captive animals

All Cetacea held in Australian dolphinaria are listed in Table 5.

Table 5

Cetacean holdings in Australian dolphinaria Tt = *Tursiops truncatus*, Pc = *Pseudorca crassidens*, Sc = *Sousa chinensis*. M = male, F = female, a = sex of new Sea World calf as yet unknown

Facility	Deaths/ captures	Births	Total holdings at April 1988			
Sea World (Qld)	1/0	la	1?	8M	12F	Tt
					3F	Pc
					1F	Sc
Hamilton Is. (Qld)	1/0	0			2F	Tt
King Neptune's Marine Park (NSW)	0/0	0		1M	1F	Tt
Pet Porpoise Pool (NSW)	0/0	1F		1M	3F	Tt
African Lion Safari (NSW)	0/0	0		3M	1F	Tt
Marineland of S. Australia (SA)	0/0	0		4M	2F	Tt
Atlantis Marine Park (WA)	0/0	0		3M	4F	Tt
Totals		2Tt	46Tt, 3Pc, 1Sc			

Publications

Kaufman, G.D., Smultea, M.A. and Forestell, P.H. 1987. The use of lateral body colouration patterns for photographhic identification of East Australian (Area V) humpback whales. *Cetus* 7:5–13.

Paterson, R. 1987. Recovery in the east Australian humpback whale stock. *Aust. Fish.* 46(8):32–36.

DENMARK. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO MAY 1988
PART 1. GREENLAND AND DENMARK

Greenland Fisheries Research Institute (GFRI), Tagensvej 135, DK-2200 Copenhagen N.

This report refers to work involving: Danbiu ApS (Biological Consultants), Henningsens Alle 58, DK-2900 Hellerup, Denmark; Hubbs Marine Research Center (HMRC), 1700 South Shores Road, San Diego, CA 92109, USA; Institute of Genetics (IG), University of Copenhagen, Øster Farimagsgade 2 A, DK-1353 Copenhagen K, Denmark; Institute of Zoology and Zoophysiology (IZZ), University of Aarhus, Universitetsparken, DK-8000 Arhus C, Denmark; Sea Mammal Research Unit (SMRU), High Cross, Madingley Road, Cambridge CB3 0ET, UK; Zoological Museum (ZM), University of Copenhagen, Universitetsparken 15, DK–2100 Copenhagen Ø, Denmark. The report was compiled by F. Larson, GFRI.

Species and stocks studied

An aerial survey was conducted off West Greenland to determine distribution and abundance of minke whales (*Balaenoptera acutorostrata*), fin whales (*Balaenoptera physalus*) and long finned pilot whales (*Globicephala melaena*) in July-August 1987.

Shore-based observations and recordings of underwater vocalisation of narwhals (*Monodon monoceros*) in Inglefield Fjord (Thule area, NW Greenland) were made in August-September 1987.

Opportunistic data on observations of cetacean species in North and West Greenland were collected in July-September 1987.

Harbour porpoises (*Phocoena phocoena*) and other cetaceans occurring in Danish waters were studied.

Field observations and collections

Greenland

As a part of the North Atlantic Sightings Survey 1987 (NASS-87) approximately 70 hours were used between 28 July and 13 August during aerial surveys conducted by GFRI in cooperation with SMRU to determine the distribution and abundance of minke, fin and pilot whales off West Greenland (from 58°45′N to 71°30′N). A total of 36 minke, 59 fin, 36 humpback (*Megaptera novaeangliae*), 2 blue (*Balaenoptera musculus*), 8 sperm (*Physeter macrocephalus*), 6 beaked, probably northern bottlenose (*Hyperoodon ampullatus*) and approximately 450 pilot whales were observed. Preliminary results are presented in papers SC/40/O 11 and SC/40/O 12.

Between 10 August and 4 September Danbiu ApS, HMRC and IZZ made a total of 70 hours observations on narwhals from a 78m promontory on the island of Qeqertat in the head of Inglefield Bay (Thule area) where similar studies were made by GFRI in 1984 and 1985 (Heide-Jørgensen, Dietz and Leatherwood, in prep.).

In the same period IZZ recorded under–water vocalisations of narwhals using a vertical array of 3 hydrophones at 5, 35 and 65m depths. A total of 8 recordings were made, usually at distances between 500 and 1,000m.

Data on the occurrence of cetaceans in North and West Greenland were collected by Danbiu ApS, HMRC and others from 'platforms of opportunity'. Some of these data are presented in paper SC/40/O 6.

Denmark

Cetacean species occurring in Danish waters were studied through a stranding scheme run by ZM and through a series of sighting cruises conducted by the Sea Bird Group of the Danish Ornithological Society. Special emphasis was put on the harbour porpoise. Under the 'umbrella' of the Danish Harbour Porpoise Project sightings, strandings and by-catch data were collected. A series of field cruises were conducted in the waters north of Funen in order to study abundance and calf occurrences (Kinze *et al.*, 1987).

Marking

No marking was carried out.

Laboratory work

Stomach samples from 35 narwhals collected in Thule in 1984 and 1985 were analysed by Danbiu ApS and HMRC in cooperation with GFRI (Heide-Jørgensen, Dietz and Leatherwood, in prep.).

Studies of variation in mitochondrial and ribosomal DNA in minke whale tissue from the Barents Sea and from West Greenland were initiated by IG in cooperation with GFRI.

Research results

Greenland

Preliminary results of the aerial survey off West Greenland are presented in papers SC/40/O 11 and SC/40/O 12.

Preliminary analyses of the under-water vocalisation of the narwhal suggests that the frequency range of the narwhal sonar is within the 'normal' range of other odontocetes. The narwhal sonar-pulse seems to be more similar to that of relatively unspecialised dolphins like the bottlenose dolphin than to that of e.g. the harbour porpoise.

Preliminary results of analyses of the variation in DNA from 24 minke whales seem to indicate that whales from the Barents Sea and West Greenland differ in genetical composition, but a more complete and thorough study based on a larger number of individuals is necessary to confirm these very preliminary results.

Denmark

Nine field cruises, each lasting a week, were conducted in the waters north of the Danish island of Funen in order to study the relative abundance of the different age classes of harbour porpoise and the behaviour of the animals towards boats, especially in the supposed breeding period. Relative abundance increased markedly from spring to summer, and the occurrence of calves reached a peak in July and August. Subadults showed the greatest curiosity towards the vessels, while females with calves always remained at some distance. No significant difference was found in the reaction of animals towards sailing vessels and motorised vessels, with the possible exception of criscrafts.

The following species occur regularly in Danish waters as documented by recorded stranded specimens and sightings: white-beaked dolphin (*Lagenorhynchus albirostris*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), killer whale (*Orcinus orca*), long-finned pilot whale and minke whale. As a northern straggler an adult male specimen of white whale (*Delphinapterus leucas*) was recorded stranded.

Pollution studies

In GFRI's three-year study 'Heavy Metals in the Greenland Marine Environment' analyses of mercury, cadmium, selenium and zinc has been carried out for white whale, narwhal and minke whale. Results will be published in 1988.

Catch statistics

A total of 86 minke whales and 9 fin whales were taken in West Greenland and 4 minke whales were taken in East Greenland in 1987 as presented in Table 1 (source: Greenland Home Rule Authorities, Department of Fisheries and Industry).

Table 1

Catch of minke and fin whales in Greenland in 1987 (source: Greenland Home Rule Authorities, Department of Fisheries and Industry)

Municipality	Minke	Fin	Municipality	Minke	Fin
West Greenland			**West Greenland**		
Thule	0	0	Godthåb	14	1
Upernavik	3	0	Frederikshåb	6	2
Umanaq	4	1	Narssaq	3	0
Godhavn	4	0	Julianehåb	7	0
Jakobshavn	9	2	Nanortalik	6	0
Christianshåb	4	0			
Egedesminde	8	0			
Kangatsiaq	5	1	**East Greenland**		
Holsteinsborg	6	1	Angmagssalik	4	-
Sukkertoppen	7	1	Scoresbysund	0	-

The reporting system for whale catching recently established by the Greenland Home Rule Authorities has resulted in a large increase in the number of whales for which detailed information is received. In 1987 biological information was received for 46 minke whales and 5 fin whales.

No information on the catch of small cetaceans in Greenland has been received by GFRI from the Greenland Home Rule Authorities.

Publications

Born, E.W. 1987a. Narwhal. *Whalewatcher* 21: 12–16.

orn, E.W. 1987b. Naturfolk og hvaludnyttelse (Indigineous people and exploitation of whales). *Kaskelot* 75: 2–13.

Heide-Jørgensen, M.-P. 1988. Occurrence and hunting of killer whales in Greenland. *Rit Fiskideildar* April 1988 issue.

Heide-Jørgensen, M.-P., Dietz, R. and Leatherwood, S. (in prep.). Studies of narwhals in the Avanersuaq district, North Greenland.

Jensen, B., Kinze, C.C. and Sørensen T.B. 1987. Observation of white whale (*Delphinapterus leucas*) in Danish waters during 1983 and 1984. *Natura Jutlandica* 22(4): 85–8.

Kinze, C.C. 1987a. Hvad ved vi om marsvinet?. *Kaskelot* 75: 14–23.

Kinze, C.C. 1987b. Ny dansk stranding af hvidhval (*Delphinapterus leucas*). *Flora og Fauna* 93(3): 81–2.

Kinze, C.C., Baagøe, H.J. and Jensen, B. 1987. Danish strandings and sightings 1977–1985. *European Cetacean Society Newsletter* 1: 47–53.

Larsen, F., Martin, A.R. and Nielsen, P.B. North Atlantic sightings survey 1987: Report of the West Greenland aerial survey. Paper SC/40/O 11 presented to the IWC Scientific Committee, May 1988.

Leatherwood, S., Heide-Jørgensen, M.-P. and Hobbs, L. 1988. Observations of cetaceans off North and West Greenland, August-September 1987. Paper SC/40/O 6 presented to the IWC Scientific Committee, May 1988.

PART 2. FAROE ISLANDS (DENMARK)

Dorete Bloch
Museum of Natural History, FR-100 Tórshavn

Kjartan Hoydal
Director of Fisheries, Tinganes, FR-100 Tórshavn

Species and stocks studied

Pilot whales

An international research programme on the pilot whale (*Globicephala melas*) exploited off the Faroes continues. A total of 1,422 pilot whales was caught in 19 drives in 1987. Nine different bays were used out of the 18 authorised. All schools were found close to land, either by people on land, or by people going out for fishing for one day in small boats. Details of the catches are given in Table 1, including weight assessments in the traditional unit, the *skinn*. From all 19 schools biological samples were taken.

White-sided dolphin

A total of 76 white-sided dolphins (*Lagenorhynchus acutus*) were caught in 2 drives in 1987, 60 in Hvalvik just before a school of pilot whales on 7 February, and 16 in Skálabotnur on 29 August. From both drives biological samples were taken.

Table 1

Pilot whale drives in the Faroe Islands in 1987

Date	Location	Number	Weight in 'Skinn'
22 January	Hvannasund	150	850
23 January	Vagur	155	739.5
31 January	Leynar	26	226
7 February	Hvalvík	80	505
23 March	Leynar	64	361
10 April	Tórshavn	225	1,273.5
23 April	Fuglafjorður	68	517
16 May	Vagur	36	166.5
22 July	Leynar	90	508
24 July	Miðvagur	103	494.25
28 July	Sandur	158	972
2 August	Miðvagur	47	291
20 August	Vagur	45	206.5
26 August	Hvannasund	5	-
29 August	Klaksvík	14	113
18 September	Vagur	17	84.5
8 October	Tórshavn	45	248.5
20 October	Vagur	51	283
24 October	Hvalvík	72	521
Total		1,422	8,360.25

Bottlenose dolphin
One bottlenose dolphin (*Tursiops truncatus*) was caught of several present in a school of pilot whales on 22 July in Leynar. Biological samples were taken.

Common porpoise
One harbour porpoise (*Phocoena phocoena*) was shot north of Klaksvik on 3 August. Biological samples were taken.

Sperm whale
One sperm whale (*Physeter macrocephalus*) was found beached on 13 March. Because of its advanced state of decay, no samples could be taken except for teeth. Its length and sex were ascertained and the skeleton is being prepared for the museum collection.

Killer whale
Following a request from Hubbs Marine Research Center, San Diego, USA, and in collaboration with Christina Lockyer, Sea Mammal Research Unit, Cambridge, UK, (SMRU), material has been collected concerning the distribution, abundance and behaviour of killer whale (*Orcinus orca*) in Faroese waters. This material will form part of the report on the killer whale in the North Atlantic which will be published in *Rit Fiskideildar* (Journal of the Marine Research Institute), Reykjavík, Iceland.

Table 2

Other whale species caught in the Faroe Islands 1987

Date	Location	Number	Species
7 February	Hvalvík	60	White-sided dolphin
22 July	Leynar	1	Bottlenose dolphin
1 August	Klaksvík	1	Common porpoise
29 August	Skalabotnur	16	White-sided dolphin

The North Atlantic Cetacean Survey
From 15 June to 15 August, the Faroe Islands participated in the North Atlantic Cetacean Survey with Spain, Denmark (working in Greenland), Norway, and Iceland, and with technical help from SMRU. The Faroe Islands used *Hvitaklettur*, a former whaling boat in the survey, and covered an area of 164,000 sq n.miles. An aircraft intended to carry out an aerial survey of 60 flying hours tragically crashed into a mountain in the Faroe Islands on 6 July *en route* from Scotland, costing the lives of Timothy David Waters, SMRU, and Fred Fairfield, Rhode Island, USA. All the data from the survey will be presented in a special report.

Field observations and collections
From 1 January to 31 December 1987, 1,422 specimens of pilot whale were sampled extensively by the scientists and the staff of the Museum of Natural History, joined in the summertime by different members of the international team. In 1987 the team comprised: D. Bloch, Museum of Natural History, Faroes; G. Desportes, Museum of Natural History, Faroes in cooperation with 'Centre d'Etudes Biologiques des Animaux Sauvages', CNRS, France; C. Lockyer, T.D. Waters and A.R. Martin, SMRU; B. Amos, University of Cambridge, England; F. Jean-Caurant, University of Nantes, France; L.W. Anderson, University of Aarhus, Denmark; A. Raga and J.A. Balbuena, University of Valencia, Spain; A. Aguilar, University of Barcelona, Spain.

In addition samples were taken for: P. Reyndjers, University of Amsterdam, Netherlands and J. Geraci and J. St. Aubin, University of Guelph, Ontario Veterinary College, Canada.

FEDERAL REPUBLIC OF GERMANY. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO APRIL 1988

This report was compiled by R. Kröger, Max-Planck-Institut für biologische Kybernetik, Spemannstr. 38, D-7400 Tübingen and J. Plötz, Alfred-Wegener-Institute for Polar and Marine Research, Columbusstr., D-2850 Bremerhaven.

Species and stocks studied
In field studies, the primary species of interest is *Phocoena phocoena*, mainly the stocks in the Baltic and North Sea. Stranded specimens of other species were subject to research on an opportunistic basis.

Field observations and collections
Stranded specimens are collected and investigated at a variety of institutions. No central strandings record is kept. The feasibility of coordinated efforts in field research by several institutions is under investigation.

Laboratory work
Post-mortem studies on stranded animals were carried out, primarily on *Phocoena phocoena*. The functional anatomy of a variety of sensory organs was investigated on a comparative basis. The development of the integument was studied in *Physeter macrocephalus*, *Balaenoptera acutorostrata* and *Phocoena phocoena*.

Methods for age determination in *Phocoena phocoena* were compared and improved.

Results of a comparative study on the osteology and myology of the cetacean shoulder girdle and flipper are being examined in conjunction with investigations of their function from film and video recordings.

Statistics and data for small cetaceans
All accessible data concerning *Phocoena phocoena* in the North and Baltic Seas have been compiled in an international study in co-operation with Sweden.

Publications

Behrmann, G. 1987. Die Funktion von Sinnesorganen caudal der Ohrkapsel (Bulla tympanica) bei Zahnwalen (Odontoceti). *Lutra* 30: 113–22.

Benke, H. 1987. Funktionsmorphologische Untersuchungen an der Vorderextremität bei Walen und Delphinen (Cetacea). *Hauptvers Dt. Ges. Säugtierk.* 61(7–8): 131–78.

Klima, M., Seel, M. and Deimer, P. 1986. The morphogenesis of the high specialised nasal skull in the sperm whale, *Physeter macrocephalus*. Part 1. *Gegenbaurs morph. Jahrb., Leipzig* 132(2): 245–84.

Klima, M., Seel, M. and Deimer, P. 1986. The morphogenesis of the high specialised nasal skull in the sperm whale, *Physeter macrocephalus*, Part 2. *Gegenbaurs morph. Jahrb., Leipzig* 132(3): 349–74.

Kröger, R.H.H. 1986. The decrease of harbour porpoise populations in the Baltic and North Sea. Final report to World Wildlife Fund in Sweden and Germany, and the Swedish National Environment Protection Board. 55pp.

Neuhaus, W. 1986. Die Bedingungen für das Sehen des Weisswals, *Delphinapterus leucas* Pall., in Wasser und in Luft. *Z. Säugetierk.* 51: 66–173.

Oehlschläger, H.A. 1986. Comparative morphology and evolution of the otic region in toothed whales (Cetacea, Mammalia), *Am. J. Anat.* 177: 353–68.

Oehlschläger, H.A. 1986. Tympanohyal bone in toothed whales and the formation of the tympano-periotic complex (Mammalia, Cetacea). *J. Morph.* 188: 157–65.

FRANCE. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO APRIL 1988

This report concerns cetacean research conducted by or in co-operation with the Centre National d'Etude des Mammiferes Marins, La Rochelle and Paris.

Species and stocks studied

All cetacean species, mainly Delphinids, occuring off the coasts of France (the Channel, Atlantic and Mediterranean) and those living around the Kerguelen Islands (South Indian Ocean), mainly *Cephalorhynchus commersonii*.

Field observations and collections

The local populations of *Tursiops* and *Grampus* around Normandy and Brittany are regularly observed and photo-identified (in co-operation with Groupe Mammalogique Normand and the Societe pour l'Etude et la Protection de la Nature en Bretagne).

Sightings of cetaceans from various sources are collected by the CNEMM La Rochelle. The CNEMM Paris collects information from the Indian Ocean: this year, a plane used for assisting the tuna fisheries around the Seychelles Islands has reported several sightings of large whales.

Strandings

Between June 1987 and April 1988, over 300 cetaceans stranded on the French coast. This figure is much larger than in previous years (since 1980, the mean annual number of strandings is about 130) due to many multiple strandings of common dolphins on the Atlantic coast in February and March 1988 (over 150 individuals).

Detailed information on the strandings and collections made can be obtained from the CNEMM, La Rochelle.

Laboratory work

Studies on age determination and reproductive status of the stranded dolphins continue in La Rochelle. Male *Delphinus* reproductive cycles are analysed in co-operation with the Southwest Fisheries Center of La Jolla (USA). Pathological tissue are examined with the co-operation of the Centre Hospitalier Universitaire de Poitiers (France), and parasites are determined with the University of Valencia (Spain).

Pollution studies

Tissue samples are collected from stranded or captured dolphins when ever it is possible.

Statistics and data for small cetaceans

Data from stranded and captured marine mammals are kept on a computer data base. Information on reported captures is presented in Table 1.

Table 1

Reported captures of dolphins off the coast of France in 1987. IC = incidental catch, DC = directed catch

Species	Date	Locality	Depart. no.	Type of capture
Stenella coeruleoalba	15.03.87	Ramatuelle	83	DC Harpooned
Stenella coeruleoalba	27.09.87	Villenueve	34	DC Shot
Delphinus delphis	27.01.87	Le Farou	29	DC Harpooned
Delphinus delphis	09.04.87	La Guérinière	85	DC Shot
Delphinus delphis	19.08.87	Lampaul	29	IC Net
Delphinus delphis	22.11.87	Carantec	29	DC Shot
Grampus griseus	07.05.87	Marseille	13	DC Net
Globicephala melas	02.10.87	Hyères	83	IC Net
Globicephala melas	30.11.87	Eculeville	50	IC Net

Publications

Abril, E., Almor, P., Raga, J.A. and Duguy, R. 1987. Parasitisme par *Anisakis typica* (Diesing, 1860) chez le Dauphin bleu et blanc (*Stenella coeruleoalba*) dans le Nord-Est Atlantique. *Bull. Soc. Zool. France* 111(1-2):131–3.

Bayed, A. and Beaubrun, P. 1988. Les Mammiferes marins du Maroc: inventaire préliminaire. *Mammalia* 51(3):437–46.

Collet, A. and Duguy, R. 1987. *Les Dauphins, Historique et Biologie*. Editions du Rocher, Monaco. 126pp.

Desbrosses, A. and Etcheberry, R. 1987. Statut des Mammiféres marins de Saint Pierre et Miqelon. *Arvicola* 4(1):113–21.

Duguy, R. 1987. Un échouage en masse de *Delphinus delphis* a l'île d'Oléron (Charente-Maritime). *Ann. Soc. Sci. nat. Charente-Maritime* 7(5): 615–6.

Duguy, R. 1987. Rapport annuel sur les Cétacés et Pinnipèdes trouvés sur les côtes de France – XVI – Année 1986. *Ann. Soc. Sci. nat Charente-Maritime* 7(5):617–39.

Duguy, R. 1988. Rapport annuel sur les Cétacés et Pinnipèdes trouvés sur les côtes de France – XVII – Année 1987. *Ann. Soc. Sci. nat. Charente-Maritime* 7(6): 653–69.

Melot, C.G. 1987. Contribution a l'étude de la pathologie cardio-pulmonaire du dauphin. Thèse de Doctorat Veterinaire, Maison-Alfort, Universite de Creteil. 66pp.

Raga, J.A., Petter, A.J. and Duguy, R. 1987. Catalogue des parasites de Cétacés des collections du Musée Océanographique de La Rochelle. *Bull. Mus. His. nat., Paris* 4(9):159–68.

ICELAND. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO MAY 1988

The following reports on studies conducted by or in cooperation with the Marine Research Institute (MRI), Reykjavík, Iceland.

Species and stocks studied

In 1987 systematic studies were carried out on fin and sei whales off west Iceland under special permit issued by the Government of Iceland under the conduct of the MRI, Programme for Whale Research. The implementation of a wide ranging four year programme of research into the whale stocks off Iceland was initiated in 1986 and is reported on in separate papers (SC/40/O 10, 29, 30, 31, 33, 34 and 35; SC/40/Ba4, 5, 6, 7, 8, 9, 10, ll and 12; SC/40/Mi22 and 23). The programme consists of 32 projects, headed under 10 separate research areas which all aim to improve the basis for management of the stocks off Iceland and provide a better understanding of the ecological role played by cetaceans in the area. The research programme was revised both in 1986 and 1987 (see *Rep. int. Whal. Commn* 37:169–71; *Rep. int. Whal. Commn* 38: 190–4) in the light of discussions in the Scientific Committee and after consultation with scientists in the different fields of whale research.

The research programme assumed catches of 80 fin, 40 sei and 80 minke whales in each of the 1986–1989 seasons. The Government of Iceland issued special permits to catch fin and sei whales in both 1986 and 1987, but no permits were issued for the take of minke whales. A total of 76 fin and 40 sei whales was caught under the permit in 1986. In 1987 permits were issued for the take of 80 fin and 20 sei whales – 20 less sei whales than originally planned. The Government of Iceland issued permits for the take of 68 fin whales and 10 sei whales in 1988. No permits have been issued for the take of minke whales.

Studies were made on the distribution and abundance of other whale species off Iceland, particularly blue, humpback, sperm, minke, killer, Northern bottlenose and pilot whales, but also smaller odontocete species.

Most of the investigations that are to be conducted according to the programme are long-term studies, which although not completed will be reported on by the end of the research period. The present report gives a review of the status of the programme and plans for the immediate future, including a few changes of the plan for 1988. It covers all activities by the MRI and cooperating institutions, in particular The Genetical Division of the Reykjavík Blood Bank and Science Institute, University of Iceland. Table 1 gives the status of the different projects with regard to implementation of the plan, particularly, laboratory analysis, computerisation and reported progress.

Table 1

Programme for whale research 1986–1989 status of implementation Status codes: 1. Under laboratory analysis; 2. Laboratory analysis completed; 3. Partly computerized; 4. Computerized; 5. Computerized and validated; 6. Report under preparation; 7. Progress reported; 8. Study completed; 9. Delayed; 10. Under preparation

		Planned	Status
1.	BIOLOGY OF EXPLOITED SPECIES		
1.1.	Fin whales	1986–89	2,5,6,7
1.2.	Sei whale	1986–89	2,4,7
1.3.	Minke whale	1986–89	1,9
1.4.	Growth layers in tympanic bullae: studies on applicabilty for age determination	1987	1,4,7
1.5.	Analysis of catch data	1986–89	1,5
2.	BIOLOGY OF PROTECTED SPECIES IN ICELANDIC WATERS		
2.1.	Analysis of catch data from 1883–1915	1986	2,7
2.2.	Analysis of censuses by whaling vessels: vessels: Blue and humpback whales	1986	1,4,6,7
3.	CATCH/EFFORT RELATIONSHIP		
3.1.	Fin whale	1986–89	2,3,6,7
3.2.	Sei whale	1989	10
3.3.	Minke whale	1986	1,3,7,9
4.	WHALE MARKING		
4.1.	Fin whale	1986–89	1,7
4.2.	Sei whale	1986–89	1,7
4.3.	Recovery rate of whale marks: an experiment	1986–89	10
4.4.	Pathological investigation of whale tissue after mark implantation	1986–89	1
5.	RADIO TAGGING AND TRACKING OF LARGE WHALES		
5.1.	Radio tagging and aerial monitoring	1988	10
5.2.	Radiomonitoring by satellite	1986–89	10
6.	WHALE SIGHTINGS		
6.1.	Sightings of large cetaceans in the northeastern Atlantic: a shipboard survey	1987	1,7
6.2.	Sightings of minke whale in Icelandic coastal waters: a shipboard survey	1987	1,7
6.3.	Aerial survey of large cetaceans off Iceland	1988	9
6.4.	Aerial census of minke whales in coastal waters	1986	8
6.5.	Annual census of cetaceans in Icelandic and adjacent waters in 0–group fish survey	1986–89	1,2,4,7
6.6.	Analysis of accumulated sightings data from different Icelandic vessels	1989	10
6.7.	Analysis of censuses by whaling vessels: all cetacean species	1989	1,3
6.8.	Assessment of abundance by acoustic techniques	1987	9
7.	PHOTOIDENTIFICATION OF WHALES		
7.1.	Humpback and blue whale	1986–89	1,10
7.2.	Killer whale	1986–89	1,7
8.	THE ROLE OF WHALES IN THE MARINE FOOD WEB OFF ICELAND		
8.1.	Food and energetics of whales	1986–89	1,3,7
8.2.	Biology of Euphausids on the whaling grounds	1986–89	1,3,7
8.3.	Whales as intermediate hosts for nematodes	1987	1
8.4.	Food web studies	1989	10
9.	WHALE POPULATION MODELS	1986–89	7
10.	PROTEIN MARKERS IN BLOOD AND TISSUES OF WHALES		
10.1.	Fin whale	1986–89	1,3,7
10.2.	Minke whale	1986–87	1,3,7,9

Table 2

1987 sightings of blue and humpback whales in the Icelandic whaling grounds

Species	Total days worked	Number of sightings	Sightings per day	Number of whales	Whales per day
Blue	82	47	0.57	80	0.98
Humpback	82	91	1.11	159	1.94

Field observations and collections

From the landstation in Hvalfjördur, 80 fin and 20 sei whales were caught during 16 June to 27 September 1987. Sampling and measurements at the whaling station and at sea were greatly intensified compared with previous years.

As previously, detailed time budget data were collected onboard the two operating whaling vessels, *Hvalur 8* and *Hvalur 9*, with several important modifications made in order to obtain density estimates of the different whale species on the grounds. Sightings and effort data were recorded in accordance with line-transect methodology (primary/secondary, group size, angles, distances, etc.) to obtain density estimates of the different species at different

Table 3

Hvalur 8 and 9. Catch and effort data for 1st fin whale caught in a trip during 15 June to 20 July 1987. See further explanation in *Rep. int. Whal. Commn* 35: 110

	Hvalur 8	Hvalur 9		Hvalur 8	Hvalur 9
FI	21	20	SE	0	0
TS	134	218	SEL	0	0
BW	64	121	FO	0	0
UW	0	0	DO	7	6

Table 4

Number of whales recorded onboard Hvalur 8 and Hvalur 9 in the 1987 season. n.s. = number of sightings, n.a. = number of animals

	Hvalur 9		Hvalur 8		Total		
Species	n.s.	n.a.	n.s.	n.a.	n.s.	n.a.	Calves
Blue	31	57	16	23	47	80	
Fin	105	258	89	166	194	424	5
Sei	13	30	13	27	26	57	2
Minke	189	244	87	96	276	340	
Humpback	56	99	35	60	91	159	5
Sperm	8	13	8	10	16	23	
N. bottlenosed	9	30	3	11	12	41	
Killer	3	10	2	10	5	20	
Pilot	17	536	11	305	28	841	
Unsp. dolphin	43	532	7	135	50	667	

times and in different areas. Catch and effort data are presented in Table 3 and the total sightings of all species are given in Table 4. Each of the two whaling vessels operated for 41 days.

The fin whales were caught during 15 June – 19 July, while the sei whale catch was taken during 17–27 September 1987. The operation was closed from late July to early September. The details of caught animals are given in Table 5. Table 6 gives an overview of measurements, field assessments and biological collections made at the field laboratory in Hvalfjördur. Apart from the routine samples and observations indicated in the table, observations and samples of tumours and other abnormalities were made. Weighing of fin and sei whales was continued and information on different organ weights collected. Detailed material was collected on food selection and general conditions of whales caught, with special reference to the energetic status of the animals (SC/40/Ba7). Sampling and measurements of ecological factors such as prey density, primary productivity and temperature distribution on the grounds were also carried out for comparative analyses (SC/40/O 33). Blood and tissue samples were collected for electrophoretic and DNA studies (see below).

As in earlier seasons, MRI offered scientists from other countries free room and board during their stay at the field laboratory at Hvalfjördur, and full access to research facilities and scientific material as required. In 1987 scientists from several universities and research institutions in five countries took advantage of this or requested specific material to be collected for their studies.

During June and July 1987, a systematic aerial sightings survey (SC/40/O 10) was conducted in coastal (within the 600m depth contour) Icelandic waters. Systematic sightings were also conducted onboard three sightings vessels *R/V 'Arnie Fridriksson, M/V Skínir and M/V Kefvíkingur* in Icelandic and adjacent waters during June-July 1987 (SC/40/O 29; SC/40/O 30). Both aerial and shipboard surveys were conducted as a part of the 1987 North Atlantic Sightings Survey (NASS-87).

Table 5

Details of fin and sei whales landed at Hvalfjordur whaling station in the 1987 season. Lengths in feet. M = male. F = female. * = lost at sea

No.	Date	Sex	Length	No.	Date	Sex	Length
Fin whales							
1	17.6	F	62	41	2.7	F	59
2	17.6	M	52	42	3.7	F	62
3	17.6	M	57	43	3.7	F	59
4	17.6	M	61	44	3.7	F	65
5	19.6	F	70	45	3.7	M	63
6	19.6	M	57	46	5.7	F	65
7	19.6	M	63	47	5.7	F	65
8	19.6	M	59	48	5.7	M	59
9	20.6	M	59	49	5.7	M	58
10	20.6	F	62	50	5.7	M	58
11	21.6	F	63	51	6.7	F	65
12	22.6	F	65	52	6.7	M	61
13	22.6	F	63	53	6.7	M	60
14	23.6	M	62	54	6.7	F	58
15	23.6	F	57	55	6.7	F	58
16	23.6	F	70	56	7.7	F	63
17	24.6	F	61	57	7.7	M	69
18	24.6	F	65	58	8.7	F	59
19	25.6	F	64	59	8.7	F	58
20	25.6	F	65	60	8.7	M	61
21	25.6	M	61	61	9.7	M	61
22	26.6	M	59	62	9.7	M	60
23	26.6	M	58	63	9.7	F	62
24	26.6	M	61	64	10.7	F	65
25	26.6	M	59	65	10.7	F	69
26	27.6	M	60	66	11.7	F	70
27	27.6	F	68	67	11.7	F	67
28	28.6	F	69	68	11.7	F	63
29	29.6	F	67	69	13.7	M	59
30	29.6	M	55	70	13.7	M	57
31	30.6	F	57	71	13.7	M	53
32	30.6	F	69	72	15.7	M	61
33	30.6	M	60	73	15.7	M	54
34	1.7	M	61	74	16.7	M	59
35	1.7	M	62	75	17.7	M	62
36	2.7	F	72	76	18.7	M	51
37	2.7	F	57	77	18.7	F	56
38	2.7	M	56	78	18.7	F	58
39	2.7	F	61	79	19.7	F	52
40	2.7	F	64	80	19.7	M	62
Sei whales							
81	17.9	F	45	91	26.9	F	42
82	17.9	F	49	92	26.9	F	47
83	17.9	F	47	93	26.9	F	49
84	17.9	M	41	94	26.9	F	ca 46*
85	17.9	F	46	95	27.9	F	37
86	19.9	F	47	96	27.9	F	47
87	19.9	F	45	97	27.9	F	49
88	19.9	M	40	98	27.9	F	49
89	19.9	F	45	99	27.9	F	43
90	26.9	F	47	100	27.9	F	48

A special project designated to killer whale studies was continued. Its main aim is to estimate the stock size off Iceland and the predation of killer whales on local herring stocks. Up to and including 1986, 143 animals were photoidentified. During the NASS-87 vessel surveys and during October – November in conjunction with the herring fishery, new photographic material was collected. Analysis is in progress, and further field work is scheduled for autumn 1988. Similarly, humpback whale fluke photographs obtained in 1987 and earlier seasons are being compiled and analysed.

Marking

No marking experiments at sea were conducted in the 1987 season, nor were any recoveries of whale marks reported. An analysis of markings and recoveries in earlier years is reported in SC/40/O 35. Satellite tracking experiments of killer whales are scheduled for the fall of 1988. Natural marking data for killer and humpback whales are discussed in the previous section.

Table 6

List of samples taken and measurements, assessments and weighings made at the field laboratory in Hvalfjordur, Iceland in the 1987 season

- (1) Measurements
  - Girths
  - Morphometry
  - Blubber thickness
  - Mammary depth
  - Cornua width
  - Stomach volume
- (2) Assessments
  - Stomach content
  - Scarring
  - Parasites
  - Sperm analysis
  - Corpora count
- (3) Weighings
  - Whole animals
  - In pieces
  - Ovaries
  - Testes
- (4) Samples
  - (a) Biological
    - Ear plugs
    - Bullae
    - Testes
    - Ovaries
    - Parasites
    - Stomach content
  - (b) Chemical analysis
- (4) (b) (cont.)
    - Muscle
    - Blubber
    - Visceral fat
    - Internal organs
    - Stomach content
  - (c) Histological samples
  - (d) Genetical studies
    - Blubber
    - Muscle
    - Kidney
    - Liver
    - Spleen
    - Pancreas
    - Smooth muscle
    - Heart
    - Thyroidea
    - Adrenals
    - Uterus
    - Testes
    - Brain
    - Red cells
    - Serum
    - Plasma
    - Eye liquid
  - (e) Hormonal studies
    - Serum

Laboratory work and research results

Working up of age and reproductive material from fin and sei whales was completed (data validation in its final stage) and is now in preparation for publication (e.g. SC/40/Ba5, 8 and 12). This comprises a review of 20 years sampling of biological information. Similar studies are underway as regards minke whales (SC/40/Mi22). Studies on morphometry in sei whales are in progress (see SC/40/Ba6) and SC/40/Ba7 reports on chemical and calorific analysis of fin and sei whale tissues. Progress on hormonal assay in fin whales is reported in SC/40/Ba8. SC/40/Ba5 reports on study on growth layers in bulla tympanica in fin whales. The analysis of phytoplankton samples is completed, while working up (species composition, density estimates, chemical and bomb calorimetric analysis) of zooplankton samples is in progress (SC/40/O 33). The results are being compared with temperature on the grounds, energetic content and chemical composition of food in whale stomachs (samples were also collected at the catch position), and similar studies on the different parts of the whale with special respect to the reproductive success of animals.

Electrophoretic studies on blood and tissue proteins in fin, sei, sperm, killer and pilot whales were continued by the Genetical Division of the Reykjavík Blood Bank in cooperation with foreign research institutions. Studies on differences in biochemical markers in fin whales off Iceland and Spain are reported in SC/40/Ba9, 10 and 11 and DNA in fin, sei and minkes in SC/40/O 34.

Simulation studies are being made with special reference to alternative management strategies in whaling (SC/40/O 32), and on the development of the fin whale stock off Iceland, in part based on hitherto unpublished catch data for the period 1883–1987 (SC/40/Ba4).

Development of techniques

Experiments conducted by E.O. Øen (Norwegian College of Veterinary Medicine, Oslo) using penthrite as a detonating charge in grenades for 90mm harpoons were continued in 1987 and will most probably be concluded during 1988 (TC/39/HK4). In addition, experiments with new equipment for the killing of bowhead whales in the Alaskan hunt were carried out on seven sei whale carcasses for testing a new projectile under development.

Sightings data

As in recent years, blue and humpback whale sightings have been regularly recorded onboard the whaling vessels operating west off Iceland. Table 2 summarises the results in 1987, while sightings of other whale species are given in Table 4. SC/40/O 10, 29 and 30 give the details of the aerial and shipboard surveys and analyses of species abundance. A total of 11,786 n.miles was cruised by the three vessels participating. A total of 1,203 primary sightings of approximately 5,400 whales were made. The total sightings (including secondary) were distributed by species as follows: 275 fin (446 animals), 33 sei (60), 26 blue (41), 89 humpback (147), 1 right (1), 89 sperm (108), 93 Northern bottlenose (239), 24 killer (177), 183 minke (200), 82 pilot (1,834), in addition to a large number of small odontocete whales.

In June 1988, an additional aerial survey experiment will be conducted in nearshore waters southwest of Iceland. The aim is to compare aerial observations with shipboard results by simultaneously repeating the same strip from aircraft and whaling vessel(s). Independent observer experiments, not part of the original research plan, will also be conducted onboard one of the whaling vessels in 1988. For the conduct of this experiment an extra barrel at the same height as the barrels on the sightings vessels in 1987, has been installed.

Strandings

The MRI staff investigated a number of whales that beached or were washed on land in 1987 and 1988. These include an 9.2m female humpback whale in western Iceland (14.4.87), an 8.9m minke whale in western Iceland (20.4.87), a 14m sperm whale in southwest Iceland (16.6.87), a 9m humpback in eastern Iceland (11.87), a 2.6m white-beaked dolphin in southwest Iceland (17.11.87), a pilot whale in southwest Iceland (12.87), an approx. 17m male sperm whale in northern Iceland (23.3.88) and a 13.3m male sperm whale in southern Iceland (19.5.88).

Statistics and data on small cetaceans

Four killer whales were live-captured in Icelandic waters in 1987.

Publications (excluding those in IWC volumes)

Andrésdóttir, V., Magnadóttir, B., Andrésson, 'O.S. and Pétursson, G. 1987. Subclasses of IgG from whales. *Developmental and Comparative Immunology* 11: 801–6.

Anon. 1987. Nytjastofnar sjávar og umhverfisþaettir 1986 – Aflahorfur 1987 (State of stocks and environmental conditions in Icelandic waters 1986 – Fishing prospects 1987). *Hafrannsóknir* 36: 1–105 [In Icelandic with English summary].

Anon. 1987. Skýrsla um starfsemi Hafrannsóknastofnunarinnar 1986 (Annual report of the Marine Research Institute). *Hafrannsóknir* 37: 1–81 [In Icelandic with English summary].

Jakobsson, J. 1987. Scientific Whaling. *The Siren* 33:11–14.

Lyrholm, T., Leatherwood, S. and Sigurjónsson, J. 1987. Photo-identification of killer whales (*Orcinus orca*) off Iceland, October 1985. *Cetology* 52: 1–14.

Please note: the Japanese progress report begins on p. 201.

REPUBLIC OF KOREA. PROGRESS REPORT ON CETACEAN RESEARCH, SEPTEMBER 1987 TO MARCH 1988

This report summarises the work carried out by the NFRDA (National Fisheries Research and Development Agency) in Korean waters.

Species and stocks studied

Studies concentrated on the minke whale (*Balaenoptera acutorostrata*) and other cetaceans in Korean waters.

Sightings

A project of systematic whale sightings in Korean waters is being carried out, based on the line transect method, for the four years from 1986–1989, in order to obtain a stock assessment of minke whales and other cetaceans found in Korean waters. The observed time, location, distance and angle from the vessel to the whale, and the visibility and sea state possibly affecting the sighting observations are recorded, as are the searching effort and weather conditions.

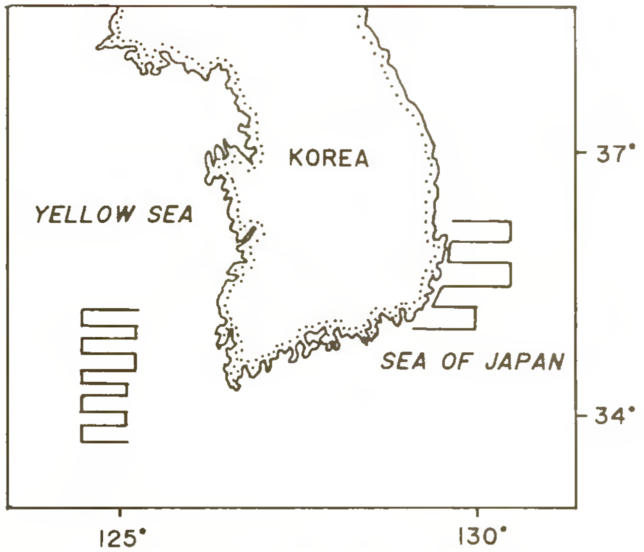


Fig. 1. Sightings cruise tracks and areas of the southern part of the Japan Sea surveyed in 2 – 11 September 1987 and of the southern part of the Yellow Sea in 17 – 30 March 1988.

The southern part of the Japan Sea (35°00′N–36°15′N and 129°12′E–130°40′E) (Fig. 1) was covered by the *R/V Pusan 852* (350 GRT) from 2 – 11 September 1987 on systematic transects 15 miles apart. During this cruise, one minke whale and about 40 common dolphins were sighted with total cruising distance of 456 miles and 29.3 hours of effort.

The southern part of the Yellow Sea of 33°30′N–35°20′N and 124°00′E–125°30′E (Fig. 1) was covered by the *R/V Pusan 852* from 17 – 30 March 1988 on systematic transects 10 miles apart. During this cruise, about 50 common dolphins were seen in 33 hours of effort.

Table 1

Summary of the whale sighting observations and effort in Korean waters

Sighting type	Date	Location		Species	Animals sighted	Estimated length (m)
		Lat.	Long.			
Yellow Sea, 16–27 April 1987, R/V Pusan 852						
1	18/4	36°50'N	124°42'E	Minke	1	6.5
Sighting hours = 52.6; distance = 478 n.miles; area = 6,921 n.mile						
Southern Japan Sea, 7–11 May 1987, R/V Kangwon 867						
1	7/5	35°01'N	129°22'E	Minke	1	6.5
1	8/5	35°21'N	129°53'E	"	1	7.0
Sighting hours = 38.8; distance = 523 n.miles; area = 5,449 n.mile						
Southern part Japan Sea, 2–11 September 1987, R/V Pusan 852						
1	8/9	36°10'N	130°40'E	Minke	1	6.5
2	8/9	36°00'N	129°38'E	Common dolphin	20±10	1.5
2	8/9	36°01'N	129°38'E	"	20±10	1.5
Sighting hours = 29.3; distance = 456 n.miles; area = 3,779 n.mile						
Southern Yellow Sea, 17–30 March 1988, R/V Pusan 852						
1	25/3	34°46'N	124°30'E	Common dolphin	50±10	1.5
Sighting hours = 33.0; distance = 455 n.miles; area = 4,960 n.mile						

The results of these and previous sightings cruises are shown in Fig. 1 and Table 1. Although sightings are considered to be the most effective method to obtain an estimate of stock size the small number of sightings preclude useful analysis of the results. This seems to be due to the poor weather conditions and the behaviour of the animals.

MEXICO. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO MAY 1988

Luis A. Fleischer
Centro Regional de Investigacion Pesquera, Km 1, Carretera a Pichilingue,
La Paz, Baja California Sur, Mexico

This annual report summarises cetacean research conducted by the National Marine Mammal Research and Conservation Program, supported by the Secretaria de Pesca, Mexico, including the projects sponsored by the Mexican Government and those research activities developed in coordination with the National Program of Mexico realised under research permits granted by PESCA.

Species and stocks studied

Continued research with the gray whale (*Eschrichtius robustus*) in Mexican waters focussed upon the objectives of the National Program, and specially to monitoring its abundance and winter distribution along the Mexican Pacific coast. Aerial surveys were carried out in the breeding lagoons, giving continuity to ten years of national research effort. The surveys were expanded to the entire west coast of the Peninsula and the Gulf of California.

Research with baleen whales in the Gulf of California initiated in 1983 was continued, specifically with the Bryde's whale (*Balaenoptera edeni*) which showed a continuous presence through the year and at least three preferential zones of distribution. Calves have been seen repeatedly through the years and feeding behaviour has proved to be constant. These factors indicate a possible resident population in Mexican waters. Other species under study are the fin (*B. physalus*), blue (*B. musculus*) and minke (*B. acutorostrata*) whales.

Research activities with the cetacean populations in the Gulf of California at the present include: aerial and ship surveys along the entire Gulf and ecological and footmarking studies in specific or preferential zones of distribution, well known since the summer of 1986.

Field observations and collections

As in previous years, sightings of all cetacean species were recorded in a systematic way using platforms of opportunity at sea, or specifically designed cruises, including research and navy ships, outboard motor boats and different types of airplanes. Cetacean stranding information was collected regionally. No osteological or histological materials from large cetaceans were collected during this period.

Marking

None was undertaken by the National Program itself, nor were any research permits for marking experiments officially granted.

Laboratory work

The histological and microscopic analysis of materials from stranded marine mammals initiated in 1983 was continued. However, since not a single large cetacean stranding was reported or attended during this period in Mexico, no new results are available.

Sighting data

The sighting information on the different cetacean species obtained from the research projects realised in the Gulf of California and Mexican Pacific, suggests that Bryde's whales may be residents of the Gulf of California and that the reproduction of this population occurs in Mexican waters. Based upon sighting reports, the blue and fin whales are known to be present seasonally in some areas of the Gulf. Their presence might be correlated with certain food resources. However, no calves of this species have been reported in the sighting surveys since 1983.

Further information about these sightings are available through the National Program, however the use of this information for publications is restricted, granting preference to the authors of the data, or the personnel working in the National Program.

Research results

Occurrence, distribution and relative abundance of Bryde's whales (Balaenoptera edeni) *in the Gulf of California*. This is a report on the distribution, abundance and seasonal occurrence of the Bryde's whale in the Gulf of California from 1985 to 1987. It shows that the species is present in this area all year and that it has three preferential zones of distribution in the areas of: Bahia de los Angeles, including the area of Islas de la Cintura, Loreto and the Bay of la Paz. It is one of the most abundant large cetaceans seen in the Gulf. The evidence of calves indicates that breeding occurs in Mexican waters. Its presence and behaviour seem correlated with food availability and water temperatures in the Gulf.

NETHERLANDS. PROGRESS REPORT ON CETACEAN RESEARCH, MAY 1987 TO APRIL 1988

This report summarises research on cetaceans carried out by relevant organisations and was compiled by Kees Lankester, Research Institute for Nature Management, PO Box 46, 3956 ZR Leersum.

Species and stocks studied

The species of primary interest were the harbour porpoise (*Phocoena phocoena*) and *Lagenorhynchus* spp., with particular reference to their distribution in the North Sea.

Field observations and collections

Sightings data were collected from both dedicated and opportunistic surveys (see below). Stranded animals and animals taken incidentally in fisheries operations continued to be reported and collected (see below).

Research results

A preliminary study on harbour porpoises has developed into a larger scale programme, which is to start in 1988. This includes a bycatch programme, ecotoxicological work and the testing of acoustic techniques.

Sightings data

A pilot study on harbour porpoises in the North Sea was carried out with a sailing vessel in a joint venture with UK scientists during 1987. The objectives were to investigate local distributions and opportunities for future field studies. The research area was along the English coast. Both visual and passive acoustic techniques were tried out. No animals were observed south of 54°N. Thirteen primary sightings of *Phocoena* (at least 21 individuals) were made. The project was sponsored by WWF-UK and WWF-Netherlands.

Shipboard sightings of cetaceans were collected during line transect surveys for birds in the North Sea. A programme was initiated to collect sightings in the North Sea, from vessels as well as from non-moving platforms.

Published sightings data can be found in the journal of the Dutch Ornithological Society, *Sula*.

Sightings of harbour porpoises in the Western North Sea will be described in a paper (Northridge and Lankester) currently being prepared.

One group of 17+ harbour porpoises was observed from the Dutch coast in January 1988.

Pollution studies

Material for contamination studies was collected from harbour porpoises taken as bycatches in various areas.

Statistics and data from small cetaceans

Seven incidentally caught harbour porpoises were recorded from the North Sea in Dutch trawl fisheries. The exact positions and dates are unknown. It is estimated that several tens of animals are caught in Dutch set nets annually. Three live stranded harbour porpoises have been held in captivity for treatment and will be released after full recovery.

Publications

Baptist, H.J.M. 1987. Sightings of marine mammals in the Dutch sector of the North Sea. *Lutra* 30: 93–106. [In Dutch].

Beek, J.G. van. 1987. Historical review of the management measures taken by the International Whaling Commission. *Lutra* 30: 199–93.

Haase, B.J.M. 1987. A mixed herd of white-beaked dolphins, *Lagenorhynchus albirostris* and white-sided dolphins, *L. acutus*, in the North Sea. *Lutra* 30: 105–7.

Haase, B.J.M. 1987. A group of goose-beaked whales *Ziphius cavirostris* G. Cuvier, 1823 near the Cape Verde Islands. *Lutra* 30: 107–9.

Hacquebord, L. 1987. Migration, life pattern and habitat of the bowhead whale *Balaena mysticetus* L., 1958 in the North Atlantic in the 17th century. *Lutra* 30: 123–42. [In Dutch].

Lankester, K. 1987. The scientific justification for the management of whale stocks in the International Whaling Commission. *Lutra* 30: 157–66. [In Dutch]

Perrin, W.F., Mitchell, E.D., Mead, J.G., Caldwell, D.K., van Bree, P.J.H. and Dawbin, W.H. 1987. Revision of the spotted dolphins *Stenella* species. *Mar. Mam. Sci.* 3(2): 99–170.

Smeenk, C. 1987. The harbour porpoise *Phocoena phocoena* (L., 1958) in the Netherlands: stranding records and decline. *Lutra* 30: 77–91.

NEW ZEALAND. PROGRESS REPORT ON CETACEAN RESEARCH, JANUARY 1987 TO APRIL 1988

M.W. Cawthorn

Conservation Sciences Centre, Department of Conservation, P.O. Box 10420, Wellington, New Zealand

This report summarises cetacean research conducted in 1987–88 by the Department of Conservation (DOC) and MAF Fisheries Research Division, and notes research by F. Cipriano (Dusky dolphins), and E. Slooten and S. Dawson (Hector's dolphins).

Species and stocks studied

During the past year studies have continued on the following:

(a) sperm whales (*Physeter macrocephalus*) in the Tasman Sea and off New Zealand;
(b) right whales (*Eubalaena australis*) off New Zealand and in the sub-Antarctic;
(c) rorquals in New Zealand waters; and
(d) small cetaceans in New Zealand coastal and sub-Antarctic waters.

Field observations and collections

Sightings records of all species continue to be collected from vessels at sea, aircraft, lighthouses and other shore-based observation points. Strandings of cetaceans were recorded from which data were collected by MAF Fisheries Officers and DOC Conservation Officers, and by provincial museum and university personnel.

Photographic recording and identification programmes have been continued by staff at offshore island meteorological stations and the Royal New Zealand Air Force (RNZAF). P. Ensor participated in the 1987/88 IDCR minke whale assessment cruise in Area III of the Antarctic. Material has been collected from 10 cetaceans that either stranded or were found as beach pick-ups. Field observations of the distribution and behaviour of dusky dolphins (*Lagenorhynchus obscurus*) in the waters off Kaikoura Peninsula were made by F. Cipriano, University of Arizona (USA), and B. Würsig, Moss Landing Marine Laboratory (USA). E. Slooten and S. Dawson, University of Canterbury, continue to collect data on the distribution, behaviour, biology and bioacoustics of Hector's dolphin around Banks Peninsula.

Marking

No whales were marked with artificial tags in the New Zealand region in 1987–88. Photographs of natural markings of 60 right whales were taken near Campbell Island, bringing the total number of identified animals to 163.

Laboratory work

Detailed examination of a juvenile Risso's dolphin with a grossly deformed caudal spine has been carried out in the Department of Anatomy and Physiology at Massey University. Personnel from the Otago Museum and Otago University have collaborated in the post-mortem examination of the following: *Tasmacetus shepherdi, Mesoplodon grayi, Globicephala melas* and *Balaenoptera acutorostrata*. Tooth sections from sperm whales, pigmy sperm whales and Risso's dolphins were prepared and read at MAF Fisheries Research Division in Wellington. Autopsies of incidentally-caught *Cephalorynchus hectori* and analysis of the vocalisations of this species continue at the University of Canterbury.

Development of techniques

A national database for the recording of all stranding events has been created by Mr M. Brabyn (Canterbury University) under contract to DOC. All strandings and details of the events are recorded and will soon be accessible to all DOC regional offices. The database incorporates historical and current information from strandings. Radiotelemetry was used by F. Cipriano and B. Würsig to monitor the movements of *L. obscurus* in waters off the Kaikoura Peninsula.

Research results

A total of 450 right whales was seen around New Zealand and at Campbell Island between January 1986 and December 1987. Right whales were also recorded from fishing vessels working the squid grounds north of the Auckland Islands, confirming the simultaneous presence of two groups of right whales 170 miles apart between July and August. Many of these right whales were observed indulging in mating behaviour.

Blue whales, although uncommon, are more frequently seen than in the past. Observations have again been made off Cape Egmont by crews of oil-rig supply vessels and from merchant ships. The largest pod sighted was of seven whales with total lengths estimated to range from a maximum of 26m to a minimum of 21m.

Until about 1960, humpback whales were one of the most frequently observed species in New Zealand waters. They are now sighted only in very low numbers and have not been reported from either Cook Strait or Foveaux Strait, two of their major migratory routes, for over 10 years. In January 1988, a single humpback was reported travelling south, 300m offshore from Raoul Island (29°16′S, 178°05′W) in the Kermadec Group. The whale was observed through binoculars and had what appeared to be a 'metallic tag' on or near the dorsal fin. The whale was extensively photographed with telephoto 35mm and recorded on video tape by meteorological station staff.

Sightings data

Sightings of 15,762 cetaceans were recorded at sea between January 1986 and March 1988 (Tables 1, 2, 3). Any observations which were insufficiently detailed to make reliable identifications were recorded as 'unidentified'. Of the total sightings, 1,511 (9.6%) are of large whales including minke (>10m), 1,378 (8.7%) are of medium whales (4–10m) and 12,878 (81.7%) are of small whales (<4m). Large whale sightings are showing rising numbers of sperm whales around New Zealand. Sperm whales comprise 34.2% of all large whales recorded at sea during this reporting period. They are now frequently observed feeding on spawning aggregations of orange roughy *Hoplostethus atlanticus*, particularly on the fishing grounds of the Challenger Plateau (39°S 168°30′E) and Chatham Rise (43°30′S 178°E).

Interspecific associations have been noted in 15 sightings. These detail associations of sperm whales with *L. obscurus* and *D. delphis; Lissodelphis* with *D. delphis*; *Eubalaena* with *L. obscurus*; *Orcinus* with *L. obscurus* and *Tursiops* with *Globicephala*.

Table 1

Reported sightings—large whales (>10m)

	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
1986													
Sp	21	16	6	21	–	16	15	6	–	16	14	28	159
Bl	–	–	–	–	–	–	–	–	–	4	–	2	6
Fi	–	–	4	–	–	–	–	–	–	–	50	15	69
Se	–	8	4	–	–	–	–	–	34	12	4	12	74
Br	–	–	–	–	2	2	–	–	–	2	9	1	16
Mi	–	–	–	–	–	–	–	–	2	34	6	–	42
Hu	6	–	3	1	1	21	1	–	50	12	22	3	120
Ri	–	–	–	–	2	20	19	4	2	–	1	–	48
Un	1	–	1	11	–	–	–	3	–	2	–	1	19
Total													553
1987													
Sp	3	13	4	13	9	25	49	41	20	12	3	50	242
Bl	–	–	–	–	–	9	–	1	1	1	–	1	13
Fi	1	2	–	–	–	–	–	2	–	20	–	–	25
Se	–	3	–	–	30	–	–	6	–	1	–	–	40
Br	–	–	–	–	–	–	–	–	–	–	–	1	1
Mi	10	2	–	–	6	–	–	10	–	1	16	–	45
Hu	4	–	–	14	2	6	3	4	12	6	11	2	64
Ri	–	1	13	3	19	57	231	78	–	–	–	–	402
Un	–	3	–	–	–	–	–	1	–	6	–	–	10
Total													842
1988*													
Sp	34	2	80	–	–	–	–	–	–	–	–	–	116
Bl	–	–	–	–	–	–	–	–	–	–	–	–	–
Fi	–	–	2	–	–	–	–	–	–	–	–	–	2
Se	2	2	–	–	–	–	–	–	–	–	–	–	4
Br	14	–	–	–	–	–	–	–	–	–	–	–	14
Mi	–	–	–	–	–	–	–	–	–	–	–	–	–
Hu	25	–	1	–	–	–	–	–	–	–	–	–	26
Ri	–	2	–	–	–	–	–	–	–	–	–	–	2
Un	–	–	–	–	–	–	–	–	–	–	–	–	–
Total													116

Key: Sp = sperm; Bl = blue; Fi = fin; Se = Sei; Br = Bryde's; Mi = minke; Hu = humpback; Ri = right; Un = unidentified. * = incomplete year

The MAF Fishery Observer Scheme has provided quality observations from the trawling grounds off the west coast of the South Island, in southeastern and southern areas generally, and particularly in the New Zealand sub-Antarctic. In November 1986 a total of 30 small cetaceans was recorded on three separate occasions on the fishing grounds north of the Auckland Islands (50°25′S

Table 2

Reported sightings—medium whales (4–10m)

	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
1986													
Ki	12	31	12	23	4	4	15	6	–	–	1	11	119
Pi	30	3	40	48	–	3	–	–	17	52	168	112	473
Be	–	–	–	–	–	–	–	–	–	–	2	–	2
Bo	4	–	–	–	–	–	–	–	–	–	–	–	4
FK	–	–	–	30	–	–	–	–	–	24	–	–	54
Un	–	3	–	–	–	–	–	–	–	–	4	–	7
Total													659
1987													
Ki	10	–	4	2	1	6	10	–	18	7	14	2	74
Pi	59	38	5	114	–	34	–	51	35	60	23	5	424
Be	–	–	–	2	–	–	–	–	–	–	–	–	2
Bo	–	–	–	–	–	–	–	–	–	–	–	–	–
FK	–	–	–	–	25	–	–	–	–	–	–	–	25
Un	–	–	–	–	8	–	–	–	–	–	–	–	8
Total													533
1988*													
Ki	2	8	–	–	–	–	–	–	–	–	–	–	–
Pi	149	3	24	–	–	–	–	–	–	–	–	–	176
Be	–	–	–	–	–	–	–	–	–	–	–	–	–
Bo	–	–	–	–	–	–	–	–	–	–	–	–	–
FK	–	–	–	–	–	–	–	–	–	–	–	–	–
Un	–	–	–	–	–	–	–	–	–	–	–	–	–
Total													186

Key: Ki = killer; Pi = pilot; Be = beaked; Bo = bottlenose; FK = false killer; Un = unidentified. * = incomplete year

Table 3

Reported sightings—small whales (<4m)

	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
1986													
De	270	20	256	700	28	–	50	–	8	2	236	253	1,823
Du	–	–	–	40	60	–	–	–	–	50	80	93	323
He	40	–	–	–	–	–	–	–	–	–	3	11	54
Tu	4	–	180	–	–	200	–	–	23	–	–	103	510
St	–	–	70	70	–	–	–	–	–	–	12	–	152
Spi	–	–	–	–	–	–	40	–	–	–	–	–	40
Rt	–	–	–	–	–	–	–	–	175	–	200	–	375
PD	–	–	–	–	–	–	–	–	–	–	30	–	30
Un	–	–	–	–	–	–	–	–	–	–	–	–	–
Total													3,307
1987													
De	160	198	310	59	2,175	874	124	945	156	–	165	65	5,231
Du	532	445	1,342	198	50	14	424	424	–	301	58	205	3,569
He	3	40	14	–	6	–	1	–	–	3	–	5	72
Tu	25	20	2	–	–	–	–	–	30	8	–	–	85
St	–	–	–	–	200	–	–	–	–	–	–	–	200
Spi	–	–	–	–	–	–	–	–	–	–	–	–	–
Rt	–	–	–	–	1	150	–	–	–	–	–	–	151
Total													9,308
1988*													
De	–	95	15	–	–	–	–	–	–	–	–	–	110
Du	–	–	–	–	–	–	–	–	–	–	–	–	–
He	3	–	–	–	–	–	–	–	–	–	–	–	3
Tu	1	145	–	–	–	–	–	–	–	–	–	–	146
St	–	–	–	4	–	–	–	–	–	–	–	–	4
Total													263

Key: De = Delphinus; Du = dusky; He = Hector's; St = striped; Spi = spinner; Rt = right whale dolphin; PD = *P. dioptrica*. * = incomplete year

166°E). Detailed descriptions of colour, shape of prominent features and behaviour identify these animals as spectacled porpoises *Australophocoena dioptrica*. Raw data are held by the author.

Strandings

Eighty-five strandings involving 1,132 cetaceans of 18 identified species and one unidentified dolphin were recorded from mainland New Zealand, Stewart Island and Chatham Islands between January 1986 and April 1988. All incidents were attended by personnel attached to either MAF, DOC, universities or provincial museums. Samples of gonads, teeth, stomach contents, parasites, skulls and foetuses have been collected and await examination. Eleven massed strandings involving 10 or more individuals accounted for 1,039 cetaceans, of which 998 (96%) were *Globicephala melas*. The fifth recorded massed stranding of *Mesoplodon grayi* took place in February 1988 in the Marlborough Sounds at the north end of the South Island. All animals involved were successfully refloated.

Some localities have become reliable sources of data on certain species. The Mahia Peninsula, north of Hawke Bay, is a regular stranding site for *Kogia breviceps*. Okawa in the Chatham Islands has been the scene of a number of *Globicephala melas* massed strandings – e.g. 223 in 1978, 93 in 1983, 133 in 1985, 63 in 1986 and 310 in 1987. At the five massed stranding incidents where it was possible for MAF and DOC staff to summon assistance to refloat animals, a 71% success rate was achieved.

Details of strandings can be obtained from the Department of Conservation.

Pollution studies

Protocols are being drawn up to standardise the sampling from all stranded and incidentally caught cetaceans. These will include requirements for sampling tissues for heavy metals and persistent pesticides. The results from analyses of these pollutants in Hector's dolphins will be published by E. Slooten and S. Dawson of the University of Canterbury.

Statistics and data for small cetaceans

With the introduction of an Individual Transferrable Quota system for the regulation of fisheries in New Zealand, commercial set-netting effort has declined over the past two years. However, in the Banks Peninsula area, where amateur set netting is popular, incidental catches of Hector's dolphins remain a problem. Catches by commercial and amateur fishermen are reported sporadically to either DOC or MAF officers, or to University of Canterbury personnel. Exact mortality figures have been impossible to obtain. Confirmed deaths of dolphins from gill net fisheries in the Banks Peninsula area reported by E. Slooten and S. Dawson to DOC are as follows: 1985/86 (91), 1986/87 (44), 1987/88 (27).

Table 4

Some reported catches of small cetaceans

Date	Species	Location	Gear	No.	Sex	Length (m)
02 May 86	*C. hectori*	New Brighton	Set net	1	M	1.07
14 May 86	*C. hectori*	New Brighton	Set net	1	F	1.19
17 Nov 86	*C. hectori*	Pegasus Bay	Set net	2	F	1.19
					F	1.06
04 Jan 87	*C. hectori*	43°30'S 172°45'E	Set net	2	M	1.17
12 Jan 87	*C. hectori*	Godley Head	Set net	1	M	1.15
18 Jan 87	*C. hectori*	Taylor's Mistake	Set net	2	F	–
02 Feb 87	*C. hectori*	Sumner Beach	Set net	1	–	1.27
12 Feb 87	*C. hectori*	Glen Bay, Akaroa	Set net	1	–	–
28 Feb 87	*C. hectori*	New Brighton	Set net	1	–	0.90
16 May 87	*D. delphis*	40°15'S 173°13'E	Trawl	1	–	–
02 Aug 87	*C. hectori*	Akaroa	Set net	1	–	0.46
18 Jan 88	*C. hectori*	Timaru	Set net	2	–	–
03 Feb 88	*D. delphis*	Young Nicks Head	Set net	2	–	–
					Calf	–
07 Apr 88	*L. obscurus*	Cloudy Bay	Set net	1	F	1.65

Publications

Hutton, J., Blair, D., Slooten, E. and Dawson, S.M. 1987. Case studies of fluke induced lesions in the mesenteric lymph node of Hector's Dolphins *Cephalorynchus hectori*. *Diseases of Aquatic Organisms* 2: 83–6.

Fordyce, R.E. 1986. [Letter on fossil Cetacea in freshwater sediments.] *Geotimes* 31 (7): 3–4.

Fordyce, R.E. 1987. Review [of C. de Muizon, Les vertebres fossiles de la Formation Pisco (Perou). Deuxieme partie...Institut Francais D'Etude Andines, Memoire 50]. *Nomen nudum* 16: 19–20.

Fordyce, R.E. 1987. Major find on Seymour Island. *Antarctic* 11(5): 210–13.

McKee, J.W.A. and Fordyce, R.E. 1987. Dolphin mandible (Delphinidae) from the Waipipian Stage (Pliocene), Waihi Beach, Taranaki, New Zealand. *NZ J. Geol. Geophys.* 30: 321–3.

NORWAY. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO MAY 1988

Sea Mammal Section, Institute of Marine Research, P.O. Box 1870, N-5024 Bergen, Norway

This report concentrates on research related to Norwegian small-type whaling by the Sea Mammal Section of the Institute of Marine Research, Bergen (IMR). A comprehensive five-year minke whale research programme which will also involve laboratories at the Universities in Bergen, Oslo, Tromsø and Trondheim, has been developed for implementation from 1988 (SC/40/Mi7).

Species and stocks studied

Work concentrated on minke whales from the Northeastern Atlantic stock during the 1987 whaling season. Some work on stranded and incidentally caught harbour porpoises was undertaken. Available data on killer whales in Norwegian waters have been reviewed and analyzed.

The minke whale was the target of Norwegian shipboard transect surveys in 1987. However, sightings of other species, e.g. fin, humpback, sperm and killer whales, were also recorded.

Field observations and collections

Biological material was collected in connection with small-type whaling from 14 male and 42 female minke whales; about 15% of the total catch in 1987. The collected material includes 20 standard morphometric measurements and material for age determination and studies of reproduction and food intake.

Ribs of minke whales were collected for examination of fluorine contents in bones. Samples of meat, liver, heart and kidney were collected for the Greenland Fisheries and Environment Research Institute, Copenhagen, for examination of population criteria in the North Atlantic using the 'DNA fingerprinting' method.

Under a joint international program to survey whales in the North Atlantic in 1987 (NASS-87), line-transect surveys were carried out by three Norwegian ships in July. These shipboard surveys covered allocated areas of the Barents Sea and the northern and eastern Norwegian Sea over a period of three weeks. Supplementary surveys were carried out by one aircraft flying about 40 hours off the west coast of Svalbard and over parts of the coastal waters of northern Norway in July-August.

Two groups of Norwegian and Swedish scientists and students have been engaged in photo-identification and sound recording of killer whales at Møre and at Lofoten on the coast of Norway in 1987.

Four stranded and incidentally caught harbour porpoises were collected and examined (see below).

Marking

Three minke whales were marked by Norwegian expeditions in 1987 (Table 1).

A total of 369 minke whales were marked by Norway from 1954 to 1987; 33 marks have been recovered, two of them eleven years after tagging. Between 1971 and 1985, 44 fin, 24 humpback, 7 sperm and 12 killer whales have also been tagged by Norwegian expeditions in the North Atlantic.

Table 1

Marking in 1987

Mark no.	Date	Position	Estimated length
N 1355	9 July 1987	77°31'N, 10°39'E	18 - 19ft
N 1361	7 July 1987	72°33'N, 22°53'E	-
N 1371	7 July 1987	72°33'N, 22°53'E	-

Laboratory work

Work on age determination of minke whales by examining laminations in the bullae tympanica was continued at the IMR and the biological material collected in 1986 has been processed. Four harbour porpoises, three caught in fishing nets and one stranded, were examined at the IMR. The stranded female had died giving birth to a calf. The calf was bent double in the vagina, with the head and tail inside and the middle part of the calf protruding through the genital opening. The length of the calf was 71cm, and the date of birth 22 June.

Research results

Analysis of five questionnaire surveys of killer whales in Norwegian coastal waters from 1982 to 1987, indicate seasonal movements of transient killer whales related to the migration of spring spawning herring, but the data also suggest local resident populations. Analyses of Norwegian catches of killer whales during the period 1938–81 and incidental sightings during 1967–87, show that killer whales are distributed over wide areas of the North Atlantic. Annual Norwegian catches have varied between 0 and 246, with particularly high catches in coastal waters off Møre in 1968–70 and at Lofoten in 1978–81.

Sightings data

Shipboard sightings in the Barents Sea and the northern and eastern Norwegian Sea comprise a total of 751 whales recorded in 267 sightings over 3441 n.miles of effective sighting effort. The sightings include 111 minke, 67 fin, 33 sperm and 191 killer whales. One blue whale was sighted at Svalbard. Eight dive-time experiments were successfully completed. Photographs were obtained from about 20 killer whales.

Sightings recorded in about 40 hours of aerial surveys include 61 minke, 14 humpback and 6 fin whales at Svalbard and 17 minke, 3 fin and 36 killer whales off northern Norway.

The collected shipboard data have been coded and entered on file at the IMR and aerial survey data are being transcribed. Additional opportunistic sightings have also been recorded on a separate data file which was completed in 1987.

Table 2

Norwegian catches of small whales in each of the seasons 1967–1987

Season	Minke	Bottlenose	Killer	Pilot	Total
1967	2,175	264	36	117	2,592
1968	2,733	384	86	31	3,234
1969	2,391	485	231	27	3,134
1970	2,307	535	246	43	3,131
1971	2,330	213	57	0	2,600
1972	2,650	17	28	0	2,695
1973	2,055	3	1	0	2,059
1974	1,820	0	6	1	1,827
1975	1,788	0	2	0	1,790
1976	2,146	0	0	0	2,146
1977	1,772	0	7	0	1,779
1978	1,592	0	63	0	1,655
1979	1,980	0	221	0	2,201
1980	2,002	0	52	0	2,054
1981	1,877	0	13	0	1,890
1982	1,963	0	0	0	1,963
1983	1,869	0	0	0	1,869
1984	804	0	0	0	804
1985	771	0	0	0	771
1986	379	0	0	0	379
1987	373	0	0	0	373

Table 3

Norwegian catches of minke whales by statistical area and month in 1987. Area coding as shown in Fig. 1, *Rep. int. Whal. Commn* 36: 167

Area	May	June	July	August	September	Total
00 Vestfjorden	1	6	8	0	0	15
03 East-Finnmark	15	46	0	0	0	61
04 West-Finnmark	2	2	0	0	0	4
05 Rostbanken to Malangsgrunnen	5	3	4	0	0	12
07 Møre	0	0	1	0	0	1
08 Egersundbånken	0	13	0	0	0	13
12 Nordkappbånken	33	5	0	0	0	38
20 Bear Island	1	26	0	0	0	27
21 West Spitsbergen	0	95	1	0	0	96
22 South Spitsbergen	0	1	0	0	0	1
25 Northwest Spitsbergen	1	7	14	0	0	22
27 Southwest Spitsbergen	0	9	0	0	0	9
28 Vikingbanken	0	1	12	0	0	13
30 Southern Norwegian Sea	0	1	1	0	0	2
35 South of Jan Mayen	0	23	20	1	0	44
37 Norwegian Sea	1	0	0	0	0	1
38 Northwestern Norwegian Sea	0	1	0	1	0	2
41 Central North Sea	5	3	0	0	0	8
62 Gammeloch	0	1	1	2	0	4
Total	64	243	62	4	0	373

Table 4

Catches, catching effort and sex ratios in the Norwegian minke whale fishery in the North Atlantic in 1987. S = ships, M = males, F = females, C = total catch, %F = females, C/S = catch per ship, SD = ship days, C/SD = catch per ship day. Totals are the numbers of individual vessels participating in each area, not the sums of all months

Area	Month	S	M	F	C	%F	C/S	SD	C/SD
Barents Sea (01,02,10,11,13, 14,15,16,17,18)	May								
	June				NO CATCH				
	July								
Svalbard (12,20, 21,22,23,24,25, 27,29,39)	May	14	19	16	35	45.7	2.5	52	0.67
	June	26	60	83	143	58.0	5.5	295	0.48
	July	5	2	13	15	86.7	3.0	15	1.00
	Total	27	81	112	193	58.0	7.1	362	0.53
Coast of Finnmark (03,04)	May	14	7	10	17	58.8	1.2	25	0.68
	June	20	34	14	48	29.2	2.4	114	0.42
	July	1	0	0	0	0	0	2	0.00
	Total	26	41	24	65	36.9	2.5	141	0.46
Coast of Nordland (00,05,06 34,37)	May	12	3	4	7	57.1	0.6	42	0.17
	June	12	3	6	9	66.7	0.7	19	0.47
	July	10	3	9	12	75.0	1.2	26	0.46
	Total	22	9	19	28	67.9	1.3	87	0.32
Møre (07,30)	June	2	1	0	1	0.0	0.5	3	0.33
	July	2	2	0	2	0.0	1.0	4	0.50
	Total	3	3	0	3	0.0	1.0	7	0.43
North Sea (08,09,28, 40,41,42)	May	1	3	2	5	40.0	5.0	7	0.71
	June	7	7	10	17	58.8	2.4	31	0.55
	July	5	10	2	12	16.7	2.4	30	0.40
	Total	7	20	14	34	41.2	4.9	68	0.50
Iceland - Jan Mayen (26, 35,36,38,50,51 54,56,59,62,63)	June	2	2	23	25	92.0	12.5	19	1.32
	July	2	9	12	21	57.1	10.5	39	0.54
	Aug.	2	1	3	4	75.0	2.0	24	0.17
	Total	4	12	38	50	76.0	12.5	82	0.61
Northeast Atlantic stock	May-July	47	154	169	323	52.3	6.9	665	0.49
Central North Atlantic stock	June-Aug.	4	12	38	50	76.0	12.5	82	0.61
West Greenland stock					NO CATCH				
All areas	May-Aug.	51	166	207	373	55.5	7.6	747	0.50

Management

The Norwegian Government set catch quotas of 325 minke whales from the Northeastern and 50 from the Central North Atlantic stocks for 1987. The total quota of 375 was allocated between 51 licencees. In anticipation of the IWC Comprehensive Assessment by 1990, the Government provisionally stopped the fishery after the 1987 season.

Catch statistics

Statistics for Norwegian small-type whaling in 1987, given in Tables 1–3, are based on the compulsory reports in log books submitted by the whalers. Within the prescribed season the whalers could start operations at their own preference and because quotas had been allocated, they also could afford to spend time searching for large whales. As in the last few years, the average effort used to catch a whale in 1987 therefore cannot be compared directly to the effort in years prior to 1984. Soviet areas of the Barents Sea and the East and West Greenland whaling grounds were closed to Norwegian whalers in 1987.

With the transmission in February 1988, of catch and effort data for killer, bottlenose and pilot whales, all available data on Norwegian small-type whaling in the North Atlantic from 1938 to 1987 have now been submitted to the IWC Secretariat and made available on magnetic tape for use by the Scientific Committee. The submitted tapes contain records of nearly 124,000 whales.

Publications

Christensen, I. 1987. ICES Marine Mammals Committee. Report of activities 1986. *Coun. Meet. int. Coun. Explor. Sea.* 1987:6pp.

Christensen, I. 1988. Distribution, movements and abundance of killer whales (*Orcinus orca*) in Norwegian coastal waters 1982–1987, based on questionnaire surveys. *Rit Fisk.*, 11 (in press).

Griffiths, D.J., Øritsland, N.A. and Øritsland, T. 1987. Marine mammals and petroleum activities in Norwegian waters (Sjøpattedyr og petroleumsvirksomhet i norske farvann). *Fisken Hav., Ser.B* 1987(1):1–179.

Øien, N. 1988. The distribution of killer whales (*Orcinus orca*) in the North Atlantic based on Norwegian catches, 1938–1981, and incidental sightings, 1967–1987. *Rit. Fisk.*, 11 (in press).

SPAIN. PROGRESS REPORT ON CETACEAN RESEARCH, MAY 1987 TO MARCH 1988

This report summarises research conducted by the Instituto Espanol de Oceanografia of the Ministry of Agriculture, Fisheries and Food, and the Department of Animal Biology (Vertebrates) Faculty of Biology, University of Barcelona.

Species and stocks studied

Studies were carried out on the fin whales of the British Isles-Portugal-Spain stock and on some small cetacean species.

Field observations and collections

As part of the North Atlantic Sightings Survey (NASS-87), a Spanish sighting cruise was carried out between 6 July and 3 August covering the area 42°N – 52°N and 9°W – 18°W. A small part of the Cantabrian Sea was also searched.

Anatomical measurements and biological samples have been collected from stranded cetaceans both on the Atlantic and the Mediterranean coasts.

Laboratory work

The information from the sightings cruise is being analysed in relation with both the distribution and the abundance of the species sighted.

A project to transfer the information from Spanish whaling activities since 1954 to data files should be completed by 1989.

Pollution studies

Studies on pollution and stress tracers of the pilot whale (*Globicephala melas*) from the Faroe Islands and Mediterranean small cetaceans are in progress.

Sightings data

The results of the NASS-87 sightings cruise are presented in papers SC/40/O 15 and SC/40/Ba13, both of which are published in this volume.

Strandings data

Information can be obtained from the Department of Animal Biology (Vertebrates), University of Barcelona.

Publications

Aguilar, A. and Lockyer, C.H. 1987. Growth, physical maturity and mortality of fin whales (*Balaenoptera physalus*) inhabiting the temperate waters of the north-east Atlantic. *Can. J. Zool.* 65(2): 253–64.

Aguilar, A. 1987. Las ballenas capturadas por los vascos. pp. 21–25. In: *Itsasoa. El Mar de Euskalerria. La Naturaleza, el Hombre y su Historia*, Vol. 3. Editorial Etor Argitaletxea.

Aguilar, A. 1987. Using organochlorine pollutants to discriminate marine mammal populations: a review and critique of the methods. *Mar. Mamm. Sci.* 3(3): 242–62.

Aguilar, A. and Grau, E. 1987. Cetacis: balenes i dofins. pp. 396–422. In: *Historia Natural dels Paisos Catalans*, Vol. 13: Amfibis, Reptils i Mamifers, *Enciclopedia Catalana, S.A.*.

Quiroga, H. and Lens, S. 1987. Informe sobre la actividad ballenera espanola durante la temporada de 1985. *Inf. Tec. Inst. Es. Oceanogr.* 54: 1–24.

SWEDEN. NATIONAL PROGRESS REPORT ON CETACEAN RESEARCH, MAY 1987 TO APRIL 1988

This report summarises cetacean research conducted by the University of Stockholm, Swedish Museum of Natural History and Fisheries in Lysekil.

Species and stocks studied

The following species and stocks were studied: sperm whales in the eastern tropical Pacific and North Atlantic; killer whales off Iceland and Norway; harbour porpoises along the Swedish coast; and smaller cetaceans off the Azores and northern Norway.

Field observations and collections

Sperm whales and other cetaceans near the Azores were studied for a period of two months in summer 1987. Data collected included distribution and observed behaviour of all cetaceans; acoustic behaviour and photographic length measurements of sperm whales; and photo-identification of sperm whales and Risso's dolphins.

In Lofoten, northern Norway, the ongoing killer whale project was continued with photo-identification and underwater recordings. A new project was initiated to study cetaceans off Vesterålen, northern Norway. Sperm whales and humpback whales were photo-identified and underwater recordings were made of the sperm whales. Observations of other cetacean species were also noted.

Biological samples were collected from harbour porpoises and one striped dolphin for reproduction and contaminant analysis.

Research results

Sperm whales and Risso's dolphins were photo-identified off the Azores.

Large male sperm whales and humpback whales were individually photo-identified in northern Norway.

A preliminary report of the Swedish incidental catch of harbour porpoises from 1973 to 1986 estimates that the number of animals killed each year was between 75 to 140. This is three to seven times higher than has been reported to the Swedish National Museum of Natural History.

Sightings data

A total of ten different odontocete species were observed off Azores in 1987. Beaked whales were observed on seven occasions; bottlenosed whales (2 times), Mesoplodon sp. (1) and unidentified beaked whales (4). More detailed information is available from J. Gordon, Department of Zoology, University of Cambridge, Downing Street, Cambridge, UK.

Pollution studies

Investigation of the contamination of smaller cetaceans which were found dead on beaches or in fishing nets along the Swedish coast was continued (Swedish Museum of Natural History).

Statistics and data for smaller cetaceans

There were no direct or live-capture fisheries for cetaceans. Smaller cetaceans reported caught in Swedish fishing gear or stranded from 1 January to 31 December 1987 are shown in Table 1.

Table 1

Statistics of smaller cetaceans along the Swedish coast, 1987. Biological samples were collected from all except one animal (Swedish Museum of Natural History).

Date	Species	Number	Comments
30/12/86	Striped dolphin	1	Dead on beach
13/04/87	Harbour porpoises	2	Gillnet
13/04/87	Harbour porpoise	1	Gillnet
20/04/87	Harbour porpoise	1	Gillnet (cod)
27/04/87	Harbour porpoise	1	Gillnet
07/05/87	Harbour porpoise	1	Propeller wounds
10/06/87	Harbour porpoise	1	Gillnet
08/07/87	Harbour porpoise	1	Dead on beach
25/07/87	Harbour porpoise	1	-
31/07/87	Harbour porpoise	1	Gillnet (cod)
02/08/87	Harbour porpoise	1	Dead on beach
13/08/87	Harbour porpoise	1	Gillnet (cod)
23/08/87	Harbour porpoise	1	Dead on beach
10/09/87	Harbour porpoise	1	Gillnet
27/09/87	Harbour porpoise	1	Dead on beach
07/10/87	Harbour porpoise	1	Gillnet (herring)
12/11/87	Harbour porpoise	1	Gillnet
20/11/87	Harbour porpoise	1	-
22/11/87	Harbour porpoise	1	Gillnet
02/12/87	Harbour porpoise	1	Gillnet
07/12/87	Harbour porpoise	1	Gillnet (cod)

Publications

Arnbom, T. 1987. Behaviour of female and immature groups and of large males of sperm whales near the Galapagos Islands. *Abstract, Seventh Biennial Conference on the Biology of Marine Mammals*. Miami, December 1987.

Arnbom, T., Gordon, J., Martins, H., Santos, R. and Walsh V. 1988. Individual photographic identification of Risso's dolphins *Grampus griseus* near the Azorean Islands. *Abstract, European Cetacean Society*, Troia, Portugal, February 1988.

Lyrholm, T., Sigurjónsson, J. and Leatherwood, S. 1987. Assessment of killer whales of Iceland through photoidentification. *Abstract, VII Biennial Conference on the Biology of Marine Mammals*, Miami, December 1987.

SWITZERLAND. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO APRIL 1988

Species and stocks studied

Whale research in Switzerland comprises mainly anatomical studies on fossil and living whale species carried out at the Institute for Brain Anatomy of the University of Berne.

Publications

Pilleri, G. 1987. *Investigations on Cetacea.* Vols I-XX, 1969–1987: Index nominum et rerum.

Purves, P.E. and Pilleri, G.E. 1988. *Echolocation in Whales and Dolphins.* Brain Anatomy Institute, University of Berne.

UNITED KINGDOM. PROGRESS REPORT ON CETACEAN RESEARCH, MAY 1987 TO APRIL 1988

This report covers the activities of the Sea Mammal Research Unit (SMRU) of the Natural Environment Research Council, the University of Cambridge, the Ministry of Agriculture, Fisheries and Food (MAFF), and the Renewable Resources Assessment Group (RRAG) of Imperial College of Science and Technology.

Species and stocks studied

Research has been conducted on Southern Hemisphere fin whales (*Balaenoptera physalus*) and minke whales (*B. acutorostrata*), on long-finned pilot whales (*Globicephala melaena*), harbour porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncatus*) in the North Atlantic, and on killer whales (*Orcinus orca*) in the North and South Atlantic and in the North Pacific.

Field observations and collections

Studies by the SMRU of long-finned pilot whales in the Faroe Islands have continued with particular emphasis on the reproduction, energetics and genetics of the population from which the Faroese catch is taken. The programme of comprehensive sampling of all whales taken in the drive fishery, which is undertaken in collaboration with the Torshavn Natural History Museum and the Faroese Ministry of Fisheries, has been completed. Samples have now been taken from complete pods in almost every month of the year, subsequent fieldwork will be designed to increase sample sizes from the periods which have been relatively poorly covered.

A preliminary survey of incidental catches of marine mammals in British fisheries, and damage by marine mammals to fishing gear in Britain has been conducted by the RRAG. The results are published in Northridge (1988).

A pilot survey of the distribution of harbour porpoises along the English North Sea coast was conducted in 1987 using a sailboat. Both visual and passive acoustic techniques were tried out for use in surveys of *Phocoena* in these waters. *Phocoena* density appears to be low and distribution patchy. In 219 hours of observation 13 positively identified sightings of at least 21 *Phocoena* individuals were made. No sightings were made south of 54°N, density appeared to be low from 54°45′N to the Scottish border. This project was carried out by the RRAG and was jointly funded by WWF (UK) and WWF (Netherlands).

The Mammal Society Cetacean Group continues to coordinate the collection of data from an expanding network of voluntary observers working around the UK coast. More detailed studies of selected species (*Phocoena phocoena, Lagenorhynchus acutus, Grampus griseus*) are also being carried out.

The social organisation and feeding associations of killer whales in Argentina and Puget Sound are being investigated by the University of Cambridge.

Laboratory work

The biochemical composition of various tissues collected from the Faroese pilot whale drive-fishery is being investigated by the SMRU.

Information on sightings and strandings of killer whales in the North Sea and the southern Northeast Atlantic has been collated by SMRU.

As part of a contract with the International Whaling Commission, the use of various molecular biology techniques to investigate social organisation and stock identity in whale populations is being investigated by the Department of Genetics at the University of Cambridge.

Information on the behaviour and sound production of captive cetaceans, particularly killer whales, in Europe, is being collected by the University of Cambridge. The aim is to coordinate this with field studies to identify the pods of Icelandic killer whales from which the captive animals were taken.

A dead harbour porpoise was found on the beach near the Sellafield nuclear reprocessing plant in Cumbria on 9 December 1986. Samples of flesh and liver were taken for gamma-spectrometry analysis by MAFF. There were low levels of radio-caesium in both samples and a small amount of Ag^{110}.

The possible effects of a krill fishery on the Antarctic ecosystem, and on baleen whales in particular, are being studied with the aid of mathematical models at the RRAG.

RRAG is also attempting to measure the density-dependent response in populations of the southern fin whale. A length-structured population model is being developed; three difference equations describe temporal changes in the number of whales greater than the legal minimum, their total length, and their total squared length.

Development of techniques

The SMRU has continued to develop and improve techniques for using cue counting and the determination of blow rates to estimate whale density.

SMRU has also designed and built radio transmitters for attachment to pilot whales. These will permit tagged animals to be tracked for a period of 6–12 months using satellite-derived locations.

The use of sonobuoys for monitoring the activities of wild cetaceans is being investigated by the Universities of Cambridge and Loughborough.

Sightings data

The SMRU has assisted in the design and execution of aerial and shipboard surveys of large cetaceans in the northeast Atlantic conducted by laboratories in Denmark, the Faroe Islands, Iceland and Norway during the summer of 1987. It also provided specialist equipment and personnel, and will assist in the analysis of data from the aerial surveys.

Statistics and data for small cetaceans

It has been recognised that the current system for reporting incidental captures in the UK has not worked efficiently. Ways of improving reporting are now being investigated.

Captures reported in England and Wales between 1 January 1987 and 31 March 1988 are nil. For Scotland in the period 1971 to 1988 there were reported captures of 85 harbour porpoises, 2 pilot whales, 2 white-beaked dolphins and 2 unidentified small cetaceans.

Publications

Goodson, A.D., Klinowska, M. and Morris, R. 1987. Interpreting the acoustic pulse emmissions of a wild bottlenose dolphin *Tursiops truncatus*. *Aq. Mamm.* 14: 1–6.

Hammond, P.S. 1987. Techniques for estimating the size of whale populations. *Symp. Zool. Soc. Lond.* 58: 225–45.

Horwood, J. 1987. *The Sei Whale: Population Biology, Ecology and Management*. Croom Helm, London. 325pp.

Horwood, J. 1987. Bias and variance in Allen's recruitment rate method. *Fish. Bull., US* 85: 117–25

Klinowska, M. 1987. The cause of cetacean live strandings. *Lutra* 30: 207.

Klinowska, M. 1988. Cetacean 'navigation' and the geomagnetic field. *J. Navig.* 41: 52–71.

Klinowska, M. and Brown, S. 1987. Cetaceans in captivity. pp.51–61. *In:* T.E. Gobson and D.A. Paterson (eds.) *The Welfare of Animals in Captivity*. BVA Animal Welfare Foundation, London.

Lockyer, C.H. 1987. Observations on the ovary of the southern minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 38: 75–89.

Lockyer, C.H. 1987. Problems and approaches to the study of cetacean bioenergetics. pp. 183–203. *In*: A.C. Huntley, D.P. Costa, G.A.J. Worthy and M.A. Catellini (eds.) *Approaches to Marine Mammal Energetics*. Allen Press, Lawrence, Kansas. 253pp.

Lockyer, C.H. 1987. The relationship of body fat, food resources, and reproductive energy costs in North Atlantic fin whales (*Balaenoptera physalus*). *Symp. Zool. Soc. Lond.* 58: 225–45.

Lockyer, C.H. and Morris, R. 1987. Observed growth rate in a wild juvenile *Tursiops truncatus*. *Aq. Mamm.* 13: 27–30.

Lockyer, C.H. and Morris R. 1987. Observations on diving behaviour and swimming speeds in a wild juvenile *Tursiops truncatus*. *Aq. Mamm.* 13: 31–35.

Martin, A.R., Reynolds, P. and Richardson, M.G. 1987. Aspects of the biology of pilot whales (*Globicephala melaena*) in recent mass strandings on the British coast. *J. Zool., Lond.* 211: 11–23.

Northridge, S. 1988. *Marine Mammals and Fisheries – A Study of Conflicts with Fishing Gear in British Waters.* Wildlife Link, London. 140pp.

UNITED STATES. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO MAY 1988

This report briefly summarizes cetacean research conducted or supported from June 1987 to May 1988 by the US National Marine Fisheries Service (NMFS) at NMFS headquarters in Washington D.C. and at the four NMFS Research Centers: National Marine Mammal Laboratory (NMML), Northwest and Alaska Fisheries Center (NWAFC), Seattle, Washington; Southwest Fisheries Center (SWFC), La Jolla, California; Northeast Fisheries Center (NEFC), Woods Hole, Massachusetts; Southeast Fisheries Center (SEFC), Miami, Florida, and the Marine Mammal Events Program (MMEP), Smithsonian Institution, Washington, D.C.

Species and stocks studied

During the past year studies were conducted on the following species in the following areas:

Gray whale *Eschrichtius robustus* – central California.

Fin whale *Balaenoptera physalus* – western North Atlantic, Iceland and North Norway.

Humpback whale *Megaptera novaeangliae* – Southeast Alaska, western North Atlantic (Nova Scotia to the Caribbean), California and Hawaii.

Minke whale *Balaenoptera acutorostrata* – central North Atlantic and northeastern Atlantic.

Right whale *Balaena glacialis* – western North Atlantic (Florida to Nova Scotia).

Bowhead whale *Balaena mysticetus* – western US Arctic.

Dolphins (Delphinidae) – California, eastern tropical Pacific, *Stenella attenuata, S. longirostris, S. coeruleoalba.*

Common dolphin *Delphinus delphis* – western North Atlantic.

Bottlenose dolphin *Tursiops truncatus* – southeastern US waters.

Killer whale *Orcinus orca* – western Alaska.

Harbor porpoise *Phocoena phocoena* – California, Oregon, Washington and Maine.

Dall's porpoise *Phocoenoides dalli* – North Pacific and Bering Sea.

Pilot whales *Globicephala sp.* – western North Atlantic.

Field observations and collections

(1) NWAFC

Bowhead whale

Field research in 1987 consisted of aerial photogrammetric flights in the area near Point Barrow, Alaska, from 19 April to 7 June. Procedures for collecting photographs of bowhead whales were consistent with those used in 1985 and 1986. No photogrammetric flights are being conducted in 1988.

Dall's porpoise

The cooperative USA-Japan research program assessing the impact of the incidental take of Dall's porpoises by the Japanese salmon fisheries was continued in 1987 aboard Japanese salmon motherships and catcherboats. Data and specimens were collected by US biologists aboard the salmon motherships. Biological samples taken included reproductive tissues, teeth, liver and muscle samples, pancreas, lungs, blubber and thoracic vertebrae. A total of 347 Dall's porpoises were examined, including one *truei* phenotype and 14 porpoises collected whole.

Five US and one Japanese observer monitored the incidental catch of marine mammals and other species in each of the three salmon mothership fleets inside the US EEZ. Two types of nets were used in 1987. Nine catcherboats (21%) in each fleet used nets with three strands of multifilament material along the midline of the net sections. The remaining vessels used three strands of hollow tube material along the midline. One observer in each fleet monitored the multifilament nets while the remaining observers monitored hollow tube nets.

The behavior and movements of Dall's porpoise are being studied in Puget Sound as part of a cooperative study with the University of Washington, with an emphasis on the timing of calving.

Killer whale

Investigations on fishery interactions involving killer whales and longline catches of blackcod (*Anoplopoma fimbria*) in Alaskan waters were continued in 1987 and 1988. Recently scientists from the National Marine Mammal Laboratory assisted the longline industry in developing data gathering methods to assess the magnitude and nature of these interactions in the southeastern Bering Sea. In addition, NMML assisted in developing an educational brochure that was distributed to fishermen suggesting possible ways to reduce these fishery interactions. In February 1988, NMML scientists conducted dockside interviews with vessel captains at Dutch Harbor, Alaska, which will help focus NMML's future research into these fishery interactions in the Bering Sea.

Humpback whale

Independent researchers conducting field work in Alaska, Hawaii, California and Mexico continued their cooperative efforts with the NMML on photo-identification.

(2) SWFC

Harbor porpoise

Harbor porpoise mortality continues to be a problem in California gillnet fisheries; however, the level of mortality is believed to be much reduced due to recent legislation which limits fishing areas. Previous research had shown a population of approximately 1,900 porpoises in the region of intense gillnet fishing. The current level of mortality is not known, but prior to the new regulations estimates of mortality ranged between 200–300 porpoises per year. This high level of mortality is believed to have caused local declines in porpoise abundance. It is hoped that local populations will now recover. To check progress in this area, the Southwest Fisheries Center, Southwest Region, and California Department of Fish and Game have begun a cooperative program to monitor porpoise abundance in central California with aerial surveys.

(3) NEFC

Foreign fishery compliance inspectors have continued to monitor and record all incidental takes of marine mammals in east coast distant-water fleet fishing operations. Pilot whales (*Globicephala* sp.) and common dolphins are the principal species taken in the Atlantic mackerel and squid fisheries, respectively. Additionally, when feasible, all incidentally taken non-endangered animals were frozen for processing by the Smithsonian Institution. These specimens are providing new information on the food habits, morphometrics, reproductive biology, physiology, parasitology, etc., of two offshore odontocetes.

The NMFS, Northeast Regional Office and NEFC coordinated research efforts in response to the stranding deaths of twenty-one large whales (2 fin, 4 minke and 15 humpback whales) in the Cape Cod area and nearby waters between 26 November 1987 and 19 January 1988. Most of these animals appeared to have died suddenly with no evidence of external trauma or severe disease problem, and with significant amounts of partially digested Atlantic mackerel in their stomachs.

Laboratory tests of stomach material taken from stranded animals and of viscera from freshly caught mackerel revealed the presence of shellfish biotoxins. These biotoxins were also found in the stomach contents of sea birds found in a paralytic state on Cape Cod. Researchers working on the event concluded that the whales probably died from the biotoxin. The possibility of such toxins causing respiratory difficulties is supported by observations of violent breaching and open mouth gasping by one humpback seen off Cape Cod. Additionally, necropsies revealed the presence of fluid in the animals' lungs, which has rarely been seen in other cetacean necropsies. However, the levels of toxicity measured in laboratory tests were low relative to that usually associated with shellfish poisoning in humans.

Because many of the stranded humpback whales were known Gulf of Maine individuals, attempts were made to obtain earplugs and baleen for age determination studies; ageing techniques for baleen whales have never been confirmed with known-age individuals. To assist in the recovery of the earplugs, M. Kozicki from the Arctic Biological Station, Ste Anne de Bellevue, Canada, an authority on baleen whale ageing techniques, was invited to assist. Stranding sites, animal condition, weather and tides limited sampling opportunities, so that only three sets of bullae were collected. Researchers at the Provincetown Center for Coastal Studies (PCCS) are summarizing the life history information on the known individuals, including one humpback calf who was a third generation known animal.

Humpback whale

Researchers at the College of the Atlantic are continuing to maintain the North Atlantic humpback fluke photo-catalogue. This catalogue contains over 3,600 photographs and is helping researchers to monitor the population demographics, mortality and habitat use of individual animals. These data will also be used to determine population estimates through mark-recapture analysis.

Researchers at the PCCS are continuing to study the seasonal distribution and abundance of fin and humpback whales in Cape Cod Bay, along the Provincetown Slope and in the Great South Channel. Also oceanographic, behavioral, photographic and population demographics information were collected. Additionally, in high use habitats, researchers documented the oceanographic (biological, physical) and geographic characteristics of those regions to identify the mechanisms which attract and maintain groups of whales. The photo-identification and demographics of known humpbacks were extremely important in determining tissue sampling priorities for the humpback whales that died off Cape Cod in December 1987.

A study was initiated on the stability of humpback fluke patterns over time. This research will involve the analysis of a time series of photographs of known animals archived at the PCCS. The analysis will quantify degree of change in North Atlantic humpback fluke patterns over time.

(4) SEFC

Bottlenose dolphin

The SEFC initiated support, through competitive contracts, for two 'low-level monitoring' studies of bottlenose dolphins. The purpose of these studies is to provide the information necessary to detect a halving or doubling of the dolphin population within a limited geographic area. Dolphin Biology Research Associates, Inc., will be using small boat surveys and photo-identification to monitor the bottlenose population in the Sarasota-Tampa Bays, Florida area. The Mote Marine Laboratory is using aerial surveys to assess the status of the population of bottlenose dolphins in the Indian-Banana Rivers, Florida area. These contracts are scheduled for three years, beginning September, 1987.

SEFC staff participated in numerous field activities involving the massive, unprecedented die-off of bottlenose dolphins along the US Atlantic coast. Many other organizations, including the Marine Mammal Commission, the US Department of Agriculture, the Smithsonian Institution, the University of Guelph, Canada (under Dr J. Geraci) and many other public and private concerns, were and are also heavily involved in the investigation. The die-off began along New Jersey in June-July 1987, continued there and along Virginia and North Carolina, reaching a peak in August. SEFC staff participated in stranding recovery operations and in aerial population assessment surveys during this period. The die-off began moving south in late September, apparently reflecting the winter migration of these animals. A live-capture of 24 bottlenose dolphins occurred off the Virginia coast during October. This operation was organized to collect various samples from apparently healthy animals and to collect obviously diseased animals. SEFC staff participated in the capture and in aerial surveys for bottlenose dolphins. Strandings subsided significantly during October and November, but increased along northeastern Florida in December and continued there through February 1988. SEFC maintained a field team in northeastern Florida during January and February to record, collect samples and thoroughly examine the stranded dolphins. Slightly over 700 bottlenose dolphins were reported stranded during the die-off.

The SEFC has contracted the Virginia Institute of Marine Science (VIMS) to conduct an analysis of the impact of the mortality on the near-shore bottlenose dolphin stock. This analysis is based on a six year time series of aerial survey data collected by VIMS. The final report is expected before June 1988.

Right whale

The SEFC continues to take part with the NEFC and University scientists in research on North Atlantic right whales. SEFC personnel participated in a 19-day aerial survey in early September designed to define the summer right whale density distribution along the Scotian Shelf from Browns Bank to Sable Island.

Marking

No artificial (e.g. Discovery) marks were placed under US government sponsorship during the time period of this report. Natural marking studies, using photo-identification techniques, continued at NWAFC, where catalogs of known humpback and bowhead whales and Dall's porpoises have been developed, and at NEFC, where catalogs of known humpback and right whales have been developed.

Laboratory work

(1) NWAFC

Bowhead whale

The 322 photographs of bowhead whales collected in the spring of 1987 have been processed and analyzed for re-identifiable whales, and preliminary length measurements have been made. Many photographs from 1985 and 1986 have been remeasured, including lower quality images not used before, in order to increase the available sample. Locations of photographed whales were calculated for a study of offshore distribution.

Dall's porpoise

Male reproductive tissues collected from 1981 to 1987 were weighed and measured. From the western North Pacific Ocean, 2,119 males were examined, and from the Bering Sea, 468. Ovaries collected in 1987 were also examined.

Pancreas collected in 1986 were examined for evidence of parasite infestation. Parasite loads in animals collected in the Bering Sea are being compared with those collected in the North Pacific Ocean.

Thoracic vertebrae collected in 1987 were examined for evidence of fusion of vertebral epiphyses. The physically mature portion of the 1987 sample was identified for use in various ongoing studies.

Gray whale

The two sighting data bases from the shorebased census were compared using a scoring system to establish which whale groups were seen by both observers. Matched groups were treated as recaptures in a mark/recapture analysis to provide an estimate of the number of whales in the viewing area relative to the number counted by each observer.

(2) SWFC

Dolphins

In 1988, the SWFC initiated a study to examine trends in age-dependent life history parameters. Teeth collected from northern offshore spotted dolphin in the moderate fishing effort area, will be used to examine (1) age at sexual maturation (ASM); (2) transition layer formation; and (3) calcium resorption. The common element linking these studies is that all have the potential for providing quantitative indices of population condition. Additionally, all require the preparation of a carefully selected sample of teeth from northern offshore spotted dolphins.

Preliminary investigation for the projects relating to ageing and tooth material indicates that detecting trends in ASM may be the most demanding in terms of the number of samples required. Evaluations of the ability to detect a trend in ASM were based on available information about the estimation of ASM and provided information about the number of teeth required to estimate ASM, as well as estimates of variance. The procedures for calculating statistically detectable rates of change are described in a recent *Ecology* [68(5):1,364–72] publication by Dr. Tim Gerrodette entitled 'A power analysis for detecting trends.' Using significance levels of $\alpha=\beta=0.05$, it was determined that 1,000 teeth, that is, 50 teeth per year, would provide both a reasonable sample to estimate ASM and an acceptable chance of detecting a significant trend over the 20-year period: 1969–88. A statistically significant trend of 15.6% or greater would be detectable, which is equivalent to a change in ASM of 1.87 years.

Utilizing the same sample of teeth, the formation of transition layers is also being investigated. Evidence for the formation of a transition layer has been found in baleen whale earplugs. Baleen whales exhibit a sharp decrease in the thickness of layers deposited at approximately the age at which sexual maturity is reached. Additionally, a small sample of teeth collected from bottlenose dolphins have been examined and all exhibit a sharp transition layer comparable to that found in the earplugs. If a transition layer can be identified in spotted dolphins, this study may provide a good indicator of fishery effects on the age at attainment of sexual maturity as animals that matured prior to the start of the fishery may be examined.

The third research topic being investigated concerns calcium resorption. Calcium resorption may serve as an indicator of stress induced by fishing operations: evidence exists linking stress with the degree to which calcium is resorbed from the teeth. Currently, the SWFC is trying to quantify the occurrence of calcium resorption with intensity of fishing pressure.

A more comprehensive assessment of trends would include comparison of high, medium and low areas of fishing effort. With each phase of the study, the goal is to better correlate life history parameters with fishing activity and trends in population abundance.

With the changes implemented with the 1984 re-enactment of the Marine Mammal Protection Act, the SWFC has changed the approach in life history studies of dolphins taken in the fishery. Specifically, rather than estimating absolute reproductive rates, life history parameters are examined for trends that may determine whether the various stocks are decreasing, and, if so, if their decline is related to the activities of the tuna fleet.

A further change in approach is that, rather than considering the broad definition of stocks defined in the past, and, hence, pooling data within those broad ranges, provisional stocks have been defined based on reasonable geographic separation between high densities of animals within the old stock boundaries. These provisional stocks can also be separated by the relative amount of fishing pressure (cumulative number of sets on dolphin schools) received by areas of the fishery; the areas have been designated as high, medium and low effort. The high effort area was first fished in 1959. In 1969, the fishery moved offshore (to our defined medium-effort area). This region is the far-western part of the fishery, outside the Commission Yellowfin Regulatory Area (CYRA). In the low effort area, fishing has occurred only sporadically over the years, but did not begin until the mid-1970s. Our biological sampling began in earnest in 1969, the same year that fishing began in the medium effort area.

Because the fishery and data collection for the medium effort area began simultaneously, this area affords us the best opportunity of detecting temporal trends correlated with fishing effort. The moderate effort area was also selected because the distance separating this area from that of the major fishing grounds, those inside the CYRA, is relatively large. This distance may be large enough to minimize the effects of migratory movements.

Harbor porpoise

One of the most uncertain elements in the assessment of the status of the harbor porpoise is the determination of stock structure. If the animals that live in the region of intensive gillnetting are a separate stock, that stock could be depleted. Work is continuing with the use of pollutant residues as stock markers. Based on samples from 45 stranded porpoises, a strong gradient has been found in the ratio of PCB:DDT from Puget Sound to central California. This indicates that movement of animals is restricted to some degree within that range. Thus far, however, no discontinuities have been found in the gradient which would indicate discrete stocks. Work is continuing as more samples are collected and analyzed.

(3) NEFC

Humpback whale

A final report on humpback whale biopsy studies was submitted to the NEFC by Drs R. Lambertsen and D. Duffield.

(4) SEFC

Bottlenose dolphin

Age structure analysis and stock structure analysis of bottlenose dolphins stranded during the massive die-off has been initiated. Both the age analysis and stock structure analysis will be done under contract by Dr S. Hersh. Ageing will be carried out using tooth samples, and the stock structure analysis will be done using skull and body morphometry.

SEFC staff collected numerous tissue samples from bottlenose dolphins stranded during the die-off described above. Tissues collected for histopathology will be examined by Dr J. Geraci and staff at the University of Guelph. Some of the tissues collected for toxicology have been analyzed by the National Veterinary Services Laboratory in Ames, Iowa, but it has not yet been decided where the rest of the tissues will be examined. Samples collected for virology are being analyzed by Dr K. Somers of the Eastern Virginia Medical School.

Development of techniques

(1) NWAFC

Dall's porpoise

A study to classify Dall's porpoise color patterns based on variations in common features and to examine geographical variation in color patterns was initiated. Eleven common features were identified and criteria were developed to differentiate variant types in each. In addition, measurements useful in characterizing the size, shape and orientation of the flank patch were defined.

Independent observers were placed on research vessels to determine whether porpoises are missed near the transect line during sighting surveys. Mark–recapture methods were used to estimate a correction factor for missed animals. Mark-recapture methods were also used to estimate a correction for the responsive movements of the porpoise. A study of the accuracy of estimates of angles and distances during marine mammal sighting surveys was also conducted.

(2) SWFC

Dolphins

This year a helicopter (*Hughes* model 500D) was added to the NOAA ship *David Starr Jordan* to obtain aerial photographs of schools sighted during the dolphin monitoring cruises. Aerial photographs are being used to calibrate estimates of school size that are made by the usual teams of shipboard observers. Counts made from a series of overlapping photographs give a much more precise estimate of school size than can be made from the deck of a rolling ship. Two camera systems were used. The primary system consisted of a pair of high-resolution aerial reconnaissance cameras loaned by the US Navy. These cameras were mounted vertically underneath the helicopter. The secondary system consisted of a hand-held 70mm camera, the *Agiflite* (also loaned by the Navy), which was specifically designed for use from helicopters. The hand-held camera was used to take oblique photographs when sun glare prevented using the vertically mounted cameras.

Imagery collected from the first year demonstrated the utility of this approach. Despite experiencing worse weather than usual, approximately 160 flight hours were logged and over 6,000 feet of film were exposed. More than 100 schools of dolphins and other small cetaceans were photographed, and approximately one-third of these appear suitable for calibrating ship-board estimates of school size. In addition to school size estimation, some of the better images can be used to obtain length measurements. It is hoped that by knowing the length distribution of a large sample, the recruitment rate of young animals into the population can be measured. Work is proceeding in making both photographic counts and measurements.

In addition to using data collected during the research vessel surveys, NMFS is also developing methods to use information collected by observers on tuna vessels for the purpose of monitoring changes in the relative abundance of ETP dolphins. This approach utilizes dolphin sightings and life history data, along with ship operations data, which are collected on an opportunistic basis by observers. Because it is not possible to control the sampling strategy of the tuna vessels, assumptions and techniques applicable in standard data analyses and suitable for data collected by research vessel observers may not be suitable for data collected by tuna vessel observers.

The goals of the NMFS program to analyze dolphin sightings data from tuna vessels are to define and identify various attributes of the fishery, describe the environmental features that affect the distribution of dolphins, and then develop a model that can be used to evaluate the utility of various methods in detecting trends in abundance of ETP dolphins, based on observer data. During 1987 a model of the tuna fishery – dolphin populations – ETP environment, called the 'TOPS' model (Tuna-vessel Observer Program Simulator) was formally planned and begun. It is expected that in 1988 the model would produce results evaluating the use of line transect methods for estimating trends in dolphin abundance from observer data. Line transect methods are the most widely accepted and used for analysis of wildlife sighting censuses, and have been applied to tuna vessel observer data by scientists from the IATTC (Inter-American Tropical Tuna Commission). The NMFS observer data research program is being coordinated closely with the IATTC research, aiming for a common goal of the fullest possible utilization of tuna vessel observer data that is scientifically valid.

(3) NEFC

Researchers at the Woods Hole Oceanographic Institution designed a comprehensive reference database for marine mammal literature. The system uses a bibliographic software package (INMAGIC) software to format, search, sort and store the data. The database was organized to complement the format used by Dr William E. Schevill for his extensive collection of cetacean literature. The database allows the user to retrieve references based on topic, author, species, geographic region and taxonomic levels.

(4) SEFC

Right whale

The SEFC has continued to provide support to the Cooperative Institute of Marine and Atmospheric Science (CIMAS) at the University of Miami for design and development of a microcomputer based image and analysis system for photo-identification of individual right whales. The system is being developed as an 'expert system', with operator intervention limited. The procurement of all component parts has been completed, and the system is expected to be operational by May 1988.

Research results

(1) NWAFC

Bowhead whale

The aerial photogrammetric study conducted in the Point Barrow, Alaska, area 19 April to 7 June 1987, resulted in 395 bowhead sightings of which 281 were photographed (duplicates removed). From 79 to 153 re-identifications were made, all indicating whales traveling along the expected migratory corridor. Details are reported in SC/A88/ID15. Only 3 calves (1.1% of all whales) were photographed. Problems with the aircraft's altimeter and long periods of dense fog prevented a full-season study of the migration.

The distribution of bowhead whales in the Point Barrow area, from 1984–86, during the spring migration was examined (see SC/40/PS11). Data from transects flown in 1978, 1979, 1981 and 1984 show 6% of the whales passed beyond the viewing range of ice-based observers (5km). Transects in 1985 and 1986 indicate 58% were beyond this range; however analysis of locations made during non-systematic flights for photographing whales during the same periods in 1985 and 1986, showed only 3% in 1985 and 42% in 1986 were beyond 5km. Transect surveys should be less biased, because of their systematic approach; however, since the sample sizes (33 in 1985 and 31 in 1986) were small, these data are imprecise. The estimated distribution from the photogrammetric flights, with larger sample sizes (294 in 1985 and 80 in 1986) may be more representative of the actual distribution of whales in and around the nearshore lead. Although spatially no significant size segregation was found in 1985, immature whales traveled significantly further offshore than mature whales and cow/calf pairs in 1986.

Dall's porpoise

Genetic variation was examined using mitochondrial DNA collected from 100 porpoise from the Bering Sea and western North Pacific Ocean, including two *truei* phenotype porpoises, and two from Puget Sound, Washington. No distinct genetic differences were detected between porpoises from different geographic areas.

Gray whale

A total of 2,988 groups (6,094 whales) were counted at one shorebased observation site and 2,981 groups (6,000 whales) at the other. Preliminary analysis indicates that observers at each site observed (counted) 81% of the whales in the viewing area. Aerial transects indicate that virtually all of the migratory corridor was within the shorebased observers viewing area. A population estimate and further results are given in SC/40/PS12.

Humpback whale

A final report on identification, reproduction and distribution of humpback whales in Hawaiian waters in 1984 and 1985 was submitted by Glockner-Ferrari and Ferrari. During the 1984–1985 period, these researchers identified 127 adult humpback whales and 45 calves. From 1977–1985, they resighted 22 known female humpback whales at intervals from one to eight years.

As of late April, 1988, there were 4,400 humpback whales entered into the NMML Humpback Whale Photo-Identification Encoding System (HUMPIES). A description of the encoding system is provided in SC/A88/ID11.

The NMML coordinated the organization of the 'Conference on the Use of Non-Lethal Techniques, especially Photo-identification Techniques, to Estimate Cetacean Population Parameters', sponsored by the IWC and NMFS as a contribution to the Comprehensive Assessment. The steering group for the Conference included researchers from the IWC Secretariat, the Sea Mammal Research Unit, Cambridge, UK, College of the Atlantic, Long Term Research Institute, SWFC and SEFC. SWFC coordinated all the local arrangements at the Conference site in La Jolla, CA.

(2) SWFC

Dolphins

The Senior Scientist unit completed and published the results of reviews of the worldwide distributions of *Stenella attenuata*, *S. longirostris* and *S. coeruleoalba*. Work continued on a review of morphological differentiation of *Stenella* spp. in the eastern Pacific. An 'Action Plan for Conservation of Dolphins, Porpoises and Whales: 1988–1992' was developed for the SSC Cetacean Specialist Group of the IUCN and will be published in 1988. The proceedings of the workshop on biology and conservation of the platanistoid dolphins held in 1986 in Wuhan, PRC, have been edited and will also be published by IUCN in 1988.

(3) NEFC

Final reports were received from Clapham on fin whales, Katona and Beard on humpback whales, Mayo, Mattila, Pittman and Baraff on whales in the southern Gulf of Maine, and Stone, Mainwaring and Beard on fin whales.

(4) SEFC

Right whale

Final reports on the historical abundance and take of North Atlantic right whales were submitted by R. Reeves and E.D. Mitchell. This work was supported by the SEFC, NEFC and the NWAFC. As previously reported, the reports concluded that the historical catch records provided more evidence of a right whale wintering/calving ground off the southeastern US Atlantic coast, and that the western North Atlantic right whale stock provided a sustained and highest kill from about 1680–1730.

Bottlenose dolphin

Work continues on the analysis of aerial survey data collected during 1980–86 to provide estimates of the abundance of the bottlenose dolphin in southeastern US waters. A preliminary analysis on the seasonal sighting density distribution of bottlenose herds has been completed. This analysis indicates that there are patterns in seasonal density of these dolphins both in the Gulf of Mexico and along the southeast US Atlantic coast. The data provide support for the commonly assumed winter southerly migration of bottlenose dolphins along the US Atlantic coast. The abundance estimation has not been completed, but is expected to be finished during 1988.

Final reports have been prepared on two research projects on bottlenose dolphins in the Mississippi Sound. The first report, concerning abundance, was based on small boat line transect surveys. The surveys were conducted during 1984–85. Abundance was found to fluctuate from 400 to 2,200 animals, with numbers lowest in the winter and greatest in the late summer and fall. Average herd size varied from a low of 3.4 in January and February to a high of 7 in June.

The second report pertains to monitoring the effects of the removal of bottlenose dolphins from the Sound. During 1982 and 1983, 57 bottlenose dolphins were captured, marked and released in the Sound. Resighting surveys, totaling 1,344 hours of survey effort, were initiated in August 1982 and continued through September 1985 (some of these surveys were also used for the line transect data collection). In 1984, 30 bottlenose dolphins were removed under permit from the Sound. Because this take greatly exceeded the quota for the area, funding was secured to complete more surveys and to analyze the data to determine if the effects of the removal could be detected by mark-recapture analysis. The mark-recapture analysis resulted in a pre-removal estimate of 2,594 (95% CI 1,474 to 3,714), post-removal estimate of 7,052 (95% CI 2,086 to 12,018). The report mentions several reasons why the removal could not be detected, and among those, the low number of animals marked could have the greatest effects on the resulting estimates. Based on the population estimates, the report concluded that somewhere in the range of 1,500 dolphins would have to be removed before the removal could be detected.

Two literature reviews on bottlenose dolphins were completed under contract. The first report was a comprehensive review of the evidence for various competing hypotheses about the structuring of bottlenose dolphin stocks in the southeastern USA. This report concluded that there is good evidence (both morphological and genetic) that two general types of bottlenose are found in the area: an inshore type and an offshore type. There is also some evidence for the existence of discrete coastal stocks. The author concluded that until more is known about the degree of genetic exchange between the coastal populations, they be managed as separate stocks. The second report was a review of the literature on bottlenose dolphins and other related species to determine the likely bounds for demographic rates of bottlenose dolphins.

Although nearly all of the information collected on the die-off of bottlenose dolphins has yet to be analyzed, SEFC staff have prepared two reports. The first report was an analysis of the potential impact of the die-off on the offshore stock of dolphins along the US mid-Atlantic, and compares the results of an offshore aerial survey conducted during late August 1987 with aerial survey results from 1979–81. The results of this comparison indicate there was about a 60% chance that there was a decline in abundance, but there was more than a 90% probability that the decline was less than 40%. The other report is a summary on the progress of along-the-beach aerial surveys being conducted to index the stranding rate.

Sightings data

(1) NMFS headquarters

Seven US scientists participated on vessel cruises undertaken by the North Atlantic sightings survey. This was a multi-national research effort which was endorsed by the Scientific Committee as a contribution to the Comprehensive Assessment. The major focus of the aerial and vessel surveys undertaken during June-July 1987 was to determine the distribution and abundance of fin, minke and pilot whales in the central and eastern North Atlantic. US scientists participated on the Icelandic and Norwegian segments of planned vessel surveys. The surveys utilized line transect methodology adapted from the experience gained during IDCR Southern Hemisphere cruises.

Three Norwegian vessels surveyed the Barents Sea and the northern and eastern Norwegian Sea during July 1987. A total of 751 whales were observed in 267 sightings, including 111 minke, 67 fin, 33 sperm and 191 killer whales. The three Icelandic vessels surveyed waters around Iceland and off the east coast of Greenland during June-July 1987. A total of 1,211 sightings were recorded, including 370 fin, over 200 minke, 104 humpback, 90 sperm, 20 sei and 15 blue whales, as well as various smaller odontocetes. It is expected that the primary national groups (Iceland, Norway, Spain, Denmark-Greenland and Faroes) will present provisional reports to the Scientific Committee in May 1988 and produce coordinated comprehensive analyses to be presented in June 1989.

(2) NWAFC

Dall's porpoise

Sighting surveys were conducted aboard commercial salmon vessels and Korean, Taiwanese, Japanese, Canadian and US research vessels. Incidental take and sighting data were collected in the high seas squid driftnet fishing area in 1986 and 1987 during research and commercial cruises.

Gray whale

A shorebased census was conducted 10 December 1987 to 7 February 1988 at the Granite Canyon Research Station, near Carmel, California, in a manner comparable to previous years. Systematic searches were maintained 10 hours per day at two identical sites 5m apart on the edge of a 24.4m high bluff. Through the season, observers were rotated between sites, but no sighting information was exchanged during watches. Therefore the two sighting records provide independent, parallel censuses. From 7–24 January 1988, tracklines were flown at distances up to 15 n.miles offshore to establish the proportion of the gray whales' migratory corridor lying within shorebased observers' viewing area.

(3) SWFC

Research vessel survey

During 1987, the SWFC completed the second of six surveys (during a five-year sampling period) to monitor stocks of dolphins in the ETP. The primary purpose of the series of surveys is to conduct line transect procedures in a 17,000,000km^2 area to determine temporal changes in the numbers of dolphins for each stock taken by US purse seiners fishing for tuna in the ETP. The same two vessels were used to traverse similar tracklines as completed during the 1986 survey. During the 1987 survey, 1,240 marine mammal schools consisting of approximately 54,859 animals were detected from aboard both ships. Of these schools, 926 were dolphin schools.

Preliminary results from the *Jordan* indicate that 628 marine mammal schools, totaling approximately 31,635 animals, were sighted; 75% of all schools sighted contained dolphins. In addition, 107 sea turtles were sighted.

Preliminary results from the *McArthur* indicate that 612 marine mammal schools were sighted, totaling approximately 23,224 animals; 65% of the schools were dolphins. In addition, 63 sea turtles were sighted.

(4) NEFC

Since 1980, Manomet Bird Observatory has used principally NMFS research vessels as survey platforms to gather sea bird, marine mammal, and sea turtle sightings of all species between Nova Scotia and Cape Hatteras, North Carolina. The 1980–1986 data are on the NEFC VAX computer. This data base is compatible with the NEFC trawl survey data, thus it will allow researchers to correlate sightings with fisheries, plankton and oceanographic data.

Right whale

A consortium of research institutions was funded through a cooperative agreement to the University of Rhode Island for the continuation of an integrated research program on the North Atlantic right whale. The overall goal of this research is detecting changes and causes of changes in the North Atlantic right whale population distribution and size. The research comprises the following four tasks.

(1) *Data base development.* This will incorporate right whale data collected since 1956. These data will be computerized in a format compatible to the NEFC's data base, and will be in a format that allows each sighting event to be recreated.
(2) *Aerial surveys.* Surveys using an AT-11 were conducted off the Scotian Shelf in September 1987 to collect distribution, abundance, photo-identification, population demographics and other data.
(3) *Shipboard surveys.* Surveys were conducted principally in the northeast region (Nova Scotia to Great South Channel). Goals were to obtain data on distribution, respiration rates, micro-scale movements, high-use habitats, behavior, social groups, ecological and oceanographic parameters, and take photographs for individual identifications and of cow/calf pairs to determine calf size/age estimations, reproductive and mortality rates.
(4) *Data analyses.* Analyses included abundance estimates using standard line and strip transect methods, and mark-recapture studies, population demographics using field sighting data, including length and size composition, sex, calving rates, nursing duration and mortality rates. Additionally, high-use habitats were documented and described in relation to oceanographic and biological parameters.

Harbor porpoise

In August 1987 the NOAA R/V *Gloria Michelle* was used to conduct a three day harbor porpoise survey off Grand Manan, Nova Scotia. Participants included US and Canadian scientists that had previous experience with harbor porpoise sighting surveys. The objectives of this study were to review and evaluate methods of conducting cetacean sighting surveys that might be used to estimate the size of the population or populations of harbor porpoise in the Gulf of Maine and Bay of Fundy regions.

Strandings

A list of cetacean strandings has been compiled and can be obtained from the Marine Mammal Events Program (MMEP), Smithsonian Institution, Washington, D.C.

Statistics and data for small cetaceans

(1) NWAFC

A total of 206 driftnet operations (1,956km) were observed in 1986 and 1987 on research and commercial vessels in or near the squid driftnet fishing area. Cetacean entanglements included 48 northern right whale dolphins, 16 Pacific white-sided dolphins, 17 Dall's porpoises and 3 common dolphins.

Dall's porpoise

In 1987, a total of 78 Dall's porpoise entanglements were observed in 303 gillnet operations of the Japanese salmon mothership fishery. The mean observed take rate in the US EEZ was 0.24 porpoises per gillnet operation of 330 tans (15km) using three strand hollow tube gillnet (n=242) and 0.34 porpoises per operation using three strand multifilament gillnet (n=61). There was no statistically significant difference between take rates of the two types of nets. Incidental take was estimated using the total number of gillnet operations and the mean observed take rate combined for both gear types (0.26 porpoises per gillnet operation). For the US EEZ the total estimated take of Dall's porpoises was 741 (95% CI: 558–925). In addition, 43 Dall's porpoises were reported taken south of the US EEZ and 82 north of the US EEZ in the Bering Sea for a total reported take of 801 Dall's porpoises.

(2) SWFC

Dolphins in the eastern tropical Pacific (ETP)

In 1987, 123 tuna/porpoise observer cruises were made aboard commercial tuna purse seiners of US registry. Eighty trips were made by National Marine Fisheries Service (NMFS) and 43 by Inter-American Tropical Tuna Commission (IATTC) observers. This is 83 more trips than were observed in 1986.

Dolphins have been killed incidentally in the eastern tropical Pacific (ETP) tuna purse-seine fishery since 1959. In 1968, the NMFS began a program to monitor mortality and estimate reproductive rates for the purpose of assessing the affects of the fishery on the dolphin stocks. The species taken most often in the fishery are spotted (*Stenella attenuata*) and spinner (*S. longirostris*) dolphins.

NMFS-fielded observers recorded 7,871 dolphins killed during 74 of the 80 US purse-seine trips. The offshore spotted dolphin was again taken most often.

Publications

(1) NWAFC

Breiwick, J.M. and Marquette, W.M. 1987. [Review]. Whales, Ice, and Men. The History of Whaling in the Western Arctic. *Marine Mamm. Sci.* 3(3):289-90.

Dahlheim, M.E. 1987. The bio-acoustics of the gray whale (*Eschrichtius robustus*). Ph.D. dissertation. University of British Columbia, Vancouver, Canada. 266pp.

Fowler, C.W. 1987. A review of density dependence in populations of large mammals. pp. 401–41 *In*: H. H. Genoways (ed.), *Current Mammalogy*, vol. 1, Plenum Publ. Corp, New York, New York.

Heyning, J.E. and Dahlheim, M.E. 1988. *Orcinus orca*. Mammalian Species Account No. 304. *Amer. Soc. Mamm.*, 9 pp.

Mizroch, S.A. 1987. [Review] *Marine Mammals of the Eastern North Pacific and Arctic Waters*, edited by Delphine Haley. *Cetus* 7(2):31.

Mizroch, S.A. 1987. Humpback whales as individuals. *Animal Welfare Institute Quarterly* 36(4):18.

Rice, D.W. 1987. *Platanista* Wagler, 1830 (Mammalia, Cetacea): proposed conservation. *Bull. Zool. Nomencl.* 44(4):253–54.

Rice, D.W. 1987. [Review] *Right whales: past and present status*, edited by R. L. Brownell, Jr, P. B. Best and J. H. Prescott. *Mar. Mamm. Sci.* 4(1):79–80.

Winans, G. and Jones, L.L. 1988. Electrophoretic variability in Dall's porpoise (*Phocoenoides dalli*) in the North Pacific Ocean and Bering Sea. *J. Mammal.* 69(1):14–21.

(2) SWFC

Holt, R.S. 1987. Estimating density of dolphin schools in the eastern tropical Pacific Ocean by line transect methods. *Fish. Bull.*, US 85(3):419–34.

Holt, R.S. and Cologne, J.B. 1987. Factors affecting line transect estimates of dolphin school density. *J. Wildl. Manage.* 51(4):836–43.

Holt, R.S., Gerrodette, T. and Cologne, J.B. 1987. Research vessel survey design for monitoring dolphin abundance in the eastern tropical Pacific. *Fish. Bull., US* 85(3):435–46.

Perrin, W.F., Mitchell, E.D., Mead, J.G. Caldwell, D.K., Caldwell, M.C., van Bree, P.J.H. and Dawbin, W.H. 1987. Revision of the spotted dolphins, *Stenella* spp. *Mar. Mamm. Sci.* 3(2):99–170.

Williams, G., Crawford, M.A. and Perrin, W.F. 1987. Comparison of the fatty acid component in structural lipids from dolphins, zebra and giraffe: possible evolutionary implications. *J. Zool. Soc., Lond.* 213:637–84.

USSR. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO MARCH 1988

M.V. Ivashin
VNIRO, 17 V. Krasnoselskaya, Moscow 107140, USSR

This report summarises investigations on marine mammals at laboratories of the Ministry of Fisheries of the USSR (VNIRO, TINRO, AzCherNIRO, SevPINRO) and research carried out by specialists from institutes of the Academy of Sciences of the USSR and other organisations.

Species and stocks studied

During the period under consideration, most attention was given to the study of the gray whales of the Chukotka-Californian stock.

In 1987, 158 gray whales (including two animals lost in the course of whaling and two animals which broke away from anchors and were carried out to sea) were taken to meet the needs of the native people of Chukotka. The Soviet share of the total catch limit (169 whales) was not fully taken because of the late commencement of whaling by the catcher boat and unfavourable weather conditions (frequent storms) and ice conditions.

Field observations and collections

During the whaling season (5 September–30 November 1987) 154 gray whales (46 males and 108 females) were brought to the coastal processing stations of Chukotka. The testes of 19 males and ovaries of 30 females were measured and weighed. Earplugs were collected from 36 animals, but it was possible to determine the age of only 16. Reproductive condition was determined for 87 whales (of the examined females, 37 were sexually mature of which 7 were pregnant).

Stomach contents from 43 whales were examined, and food samples were taken. Collection of phenological data continued.

Laboratory studies

Age determination of minke whales taken in the Southern Hemisphere during the Antarctic seasons 1985/86 and 1986/87 was completed. Processing of previously collected biological samples and earlier observations of various species of whales and dolphins continued.

Development of techniques

The study of strata in the dentine of toothed whales was continued in order to determine 'breeding marks' more clearly (Klevezal, Sukhovskaya and Vilenko, 1987).

Sightings data

From 5 September – 30 November 1987, sightings of all whales and dolphins encountered during whaling were recorded. The results are summarised in Table 1. For the first time, bowhead whales were seen almost every day from November 23 (school size 1–2 to 10 animals).

Table 1

Sightings data obtained by the whale catcher 'Zvezdny' during 1987. G = gray, R = greenland right, H = humpback, F = fin, M = minke, K = killer whale

		Whale species								No. gray whales	
Month	Sq.	G	R	H	F	M	K	Miles covered	Vessel days	Per one vessel day	Per 100 miles
Sept.	Q25	155	–	–	–	–	–	230	6	2.5	6.52
	Q26	507	–	1	–	16	5	1,253	19	26.7	40.7
Oct.	Q25	42	–	–	–	–	–	77	2	21.0	54.5
	Q26	310	–	50	4	15	10	1,440	21	14.8	21.5
Nov.	Q26	126	39	8	–	18	9	965	14	9.0	13.1
Total	1987	1,140	39	59	4	49	24	3,965	62	18.4	28.8
Season	1986	1,563	–	83	–	21	14	7,961	63	24.8	19.6
Season	1985	1,296	25	3	3	17	16	3,433	64	20.3	37.8

Research results

Agarkov *et al.* (1987) summarised the results of investigations into the functional morphology of endocrine glands in a number of cetacean and pinniped species.

A publication (edited by Belkovitch) provides original information on the behaviour and bioacoustics of bottlenosed dolphins and white whales under natural living conditions, as well as analysis of data on acoustic signalling of cetaceans, techniques of ethological acoustic research and development of equipment for bioacoustic studies.

Klevezal (1988) investigated the structure and causes of yearly and intra-year (down to daily) strata in dentine, cement and periostal bony tissue. She has demonstrated the possibility of using these strata to determine the age of all marine and terrestrial mammals living in the USSR as well as to provide information on the season in which the animal was born or died, the age of reaching sexual maturity, growth rate, frequency of reproduction and feeding. Techniques using tetracyclines and other markers in the study of recording structures, for group marking of animals in nature and for studies of food storing and consumption, are discussed.

Pavlinov and Rossolimo (1987) include the gray whale in a list of animals found in Soviet waters, but agree with Sokolov's (1979 – see *Rep. int. Whal. Commn* 31: 224) view that the species name should be *Eschrichtius gibbosus* (Erxleben, 1777).

Krupnik (1987) reported on the harvesting of bowhead and gray whales by native peoples of Chukotka since the beginning of the present era and identified four periods based on hunting techniques and species taken. Before the 1930s, bowhead whales were the primary species with gray whale hunting important in only limited areas. He identified whaling areas, and provided information on whaling from the mid-19th century up to the beginning of the 20th century, data on whaling between 1910 and 1938, and information on local whalers.

Ivashin and Borodin (1987) described the principles and methods of whaling control in Antarctic waters and estimated the initial and present stock status. Various criteria of whaling control based on mathematical simulation studies were discussed. The prospects for whaling and the recovery of major whale species were outlined.

Klevezal *et al.* (1987) studied the tooth structure in sperm whale females and noted high-contrast bands (HCB) in the dentine. These turned out to be 'breeding marks' containing more calcium salts than the adjacent dentine. After staining with haematoxylin, alcyan blue and toluidine blue, they become two transparent hyperchromatic bands between which there is a less transparent hypochromatic band. The latter can be divided into 3–5 narrow bands. It is assumed that the formation of a complex HCB in the sperm whale is related to the dentine's response to hormone changes during the breeding cycle. In male sperm whales, the HCB is not divided and does not reveal a similar calcium-traumatic reaction of the dentine.

Yukhov *et al.* (1986) used a new technique to determine the abundance of dolphins in the Black Sea. The average density and speed of dolphins' motion were determined from results of sightings made *en route* or during stops based on information on the speed of the observer, the time of observation (during stops) and recorded areas.

According to Vladimirov and Melnikov (1987), the results of an aerial survey carried out in Sakhalin Bay and the Amur estuary in 1980/81 and 1982 confirm that the abundance of white whales reaches 15,000 – 20,000 during the period of salmon spawning. In summer the major concentration was found between Zotov Bank (northwestern Sakhalin) and Baidukov Island (north of the city of Nikolaevsk-on-Amur) from where white whales migrate to the northeast as well as to the Amur estuary. In Shelikhov Bay (the western Okhotsk Sea) the abundance of white whales in the Okhotsk Sea was corroborated: even at the coldest time of the year the white whales do not leave for ice-free waters.

Nazarenko *et al.* (1987) noted that fin, sei and minke whales, as well as sperm whales and harbour porpoises are sometimes sighted in the White Sea. So far it is impossible to estimate their influence upon biocenotic relations. White whales arrive between May and October (from 200 – 2,000 animals, occasionally 3,000) sometimes wintering in unfrozen water areas in the ice. Their major food species are the herring, flounder, navaga; *Melanorgammus aeglefinus, Boreogadus saida* and *Malotus*.

Proceeding from the results of aerial surveys, Ognetov (1987) examined white whale distribution and believes that 97% of those found in the White Sea are within 10km of the coast. In summer they are found along the whole coast but there is a tendency for more to be seen towards the southern part of the sea.

Zinchenko and Ivashin (1987a) analysed pregnancy data for minke whales taken in the 1979/80 and 1980/81 seasons:

34 cases of multiple foetuses were recorded of which 7 were monozygotic; extra-uterine pregnancies (up to 6 foetuses), growth anomalies and embryonic mortaility were also found. Most cases of multiple foetuses and growth anomalies were from the Indian Ocean sector (especially in Prydz Bay) suggesting a powerful mutagenic source in the breeding waters of the Indian Ocean.

Zinchenko and Ivashin (1987b) described Siamese twins found in a 9m minke whale taken in January 1981 in the western part of Area IV.

Krushinskaya (1986) reviewed cetacean behaviour with respect to: (1) population structure of toothed whales; (2) social behaviour of toothed whales; (3) population structure of baleen whales; (4) forms of social behaviour in baleen whales and (5) perculiarities of brain structure and development of cognitive abilities in cetaceans.

Studies of reasoning abilities and hearing in some dolphins were continued.

Statistical data on the take of small cetaceans

During 1987, 34 white whales were taken: 27 in the White Sea, 4 in the Chukotsk Sea and 3 in the Bering Sea.

Publications

(i) Books and collected articles

Agarkov, G.B., Nechayeva, O.V. and Homenko, B.G. 1987. *Functional Morphology of Endocrine Glands in Marine Mammals.* Naukova dumka Kiev, 119pp. [In Russian].

Belkovitch, V.M. (Ed.), 1987. *Behaviour and Bioacoustics of Cetaceans.* Publishing house of the Institute of Oceanology of the USSR Academy of Science, Moscow, 219pp. [In Russian].

Klevezal, G.A. 1988. *Recording Structures of Mammals in Zoological Research.* Nauka, Moscow. 250pp. [In Russian].

Pavlinov, I. Ya. and Rossolimo, O.L. 1987a. *Systematisation of Mammals of the USSR* [Cetaceans, pp. 91–106] Collected works of the Zoological Museum of Moscow State University, Moscow University Publishing House. 250pp. [In Russian].

(ii) Problems of Study, Rational use and Protection of Natural Resources of the White Sea (Abstracts of reports to 3rd Regional conference). Kandalaksha, Vol. 1. 1–201pp., Vol. 2. 202–393pp. [In Russian].

Nazarenko Yu. I., Ognetov, G.N. and Yablokov, A.V. Role of marine mammals in biocenosis of the White Sea, *Ibid.* pp.54–6. [In Russian].

Ognetov, G.N. Dynamics of white whale abundance and distribution in the White Sea, *Ibid.* pp. 343–44. [In Russian].

(iii) Other publications

Fless, D.A., Starodubtsev Yu. D. and Krushinskii, L.V. 1988. Study of the reasoning ability (extrapolarity reaction) in dolphins *Tursiops truncatus* ponticus Borabosh. *Dokl. AN SSSR* 293 (5): 1,269–73. [In Russian].

Ivashin, M.V. and Borodin, R.G., 1987. Whales of the Antarctic: regulation measures, harvesting and present stock conditions. pp. 414–28. *In: Biological Resources of the Arctic and the Antarctic* Nauka 447pp. [In Russian].

Klevezal, G.A., Sukhovskaya, L.I. and Vilenko, A.Yu., 1987. Structure of 'breeding marks' in Odontoceti dentine. *Zool. Zh.* 64(12): 1,886–91. [In Russian].

Krupnik, I.I. 1987. The bowhead and gray whale in Chukotkan aboriginal whaling. *Arctic* 40 (1): 16–32.

Krushinskaya, N.L. 1986. The behaviour of cetaceans. *Invest. Cetacea* 19: 115–273.

Popov, V. V. and Supin, A.Ya. 1987. White whale (*Delphinapterus leucas*) hearing characteristics. *Dokl. AN SSSR* 294 (5): 1,255–8. [In Russian].

Vladimirov, V.L. and Melnikov, V.V. 1987. Distribution and abundance of white whales in the Okhotsk Sea. *Mar. Biol.* (5): 65–9. [In Russian].

Zinchenko, V.L. and Ivashin, M.V. 1987a. Polyembryony and developmental abnormalities in minke whales (*Balaenoptera acutorostrata*) of the Southern Hemisphere. *Zool, Zh.* 64(7): 1,075–85. [In Russian].

Zinchenko, V.L. and Ivashin, M.V. 1987b. Siamese twins of minke whales of the Southern Hemisphere. *Sci. Rep. Whales Res. Inst., Tokyo* 38: 165–9.

Yukhov, V.L., Petukhov, A.G. and Korkhov, A.I. 1986. Estimation of the abundance of Black Sea Dolphins. *Mar. Biol.* (6): 64–8. [In Russian].

JAPAN. PROGRESS REPORT ON CETACEAN RESEARCH, JUNE 1987 TO APRIL 1988

This report summarises cetacean research conducted from June 1987 to April 1988 by the Far Seas Fisheries Research Laboratory (FSL), Fisheries Agency with the co-operation of other related organisations including the Institute of Cetacean Research (ICR) and the Japan Fisheries Agency (JFA).

It should be noted that in April 1988, the Cetacean Resources Research Station of the Far Seas Fisheries Research Laboratory was divided into two sections: large cetaceans and small cetaceans. We hope that we are able to obtain additional researchers in the near future.

Species and stocks studied

The following species and stocks were studied:

(1) minke whale – Antarctic and Okhotsk Sea-West Pacific stocks;
(2) Bryde's whale – western North Pacific stock;
(3) sperm whale – western North Pacific stock;
(4) Baird's beaked whale – those migrating off the Pacific coast of Japan;
(5) short-finned pilot whale – two stocks off the Pacific coast of Japan exploited by small-type whaling, crossbow and drive fisheries;
(6) Dall's porpoise – stocks in the Bering Sea, northern North Pacific and Sea of Japan;
(7) bottlenose dolphin – those taken by the drive fishery at Taiji off the Pacific coast of Japan;
(8) dolphins taken by Japanese squid driftnet fishery in the northern North Pacific;
(9) additional species sighted during sighting cruises.

The Japanese government issued the Institute of Cetacean Research (ICR) a permit to take 300 minke whales in the Antarctic. The results will be reported separately.

Field observations and collections

Biological materials and data were collected from whales processed by Japanese coastal whaling and from the research take of Antarctic minke whales (Table 1). Time budget data were collected from the whaling operations and drive fisheries for dolphins.

Table 1

Approximate number of biological materials collected in 1987/88

Species	Isozyme materials	Ear plugs	Teeth	Gonads (pairs)
Bryde's whale	–	180	–	40
Minke whale (N)	250	200	–	130
Minke whale (S)	275	275	–	275
Sperm whale	70	–	140	150
Baird's beaked whale	40	–	40	40

Antarctic minke whales were studied by H. Kato (ICR). He collected biological data and samples from the catch under special permit.

Bryde's whales were studied at the Bonin Islands station by M. Yoshioka (ICR) from May to July.

Sperm whales were studied by S. Wada (FSL) and H. Kato in November and December at the Yamada whaling station.

Baird's beaked whales were studied by T. Kasuya (FSL), R. L. Brownell Jr (US Fish and Wildlife Service) and W. F. Walker (Santa Barbara Museum of Natural History, USA) at Wadaura in July and August.

Short-finned pilot whales (northern form) were photographed for individual identification during the cruise of the *Toshimaru No. 15* (T. Miyashita, FSL). Hunting of this stock by small-type whaling was suspended in the 1987 season. T. Miyashita investigated the operation of the crossbow fishery for the southern form in Okinawa (March).

Sixty-four Dall's porpoises, a portion of the incidental take in the Japanese land-based salmon gillnet fishery, were returned to Japanese ports and studied by N. Miyazaki (National Science Museum). He also collected biological materials from Dall's porpoises taken incidentally by the salmon research vessels.

M. Yoshioka collected 64 Dall's porpoises, 10 common dolphins and seven Pacific white-sided dolphins during the cruise of *Hoyomaru No. 12* in the northern North Pacific for the sighting of Dall's porpoises.

Incidental takes of marine mammals in the squid driftnet operation were observed by M. Amano (JFA) for six commercial operations (*Koeimaru No. 68*), S. Wada (FSL) for 15 commercial operations (*Kineimaru No. 81* and *Kineimaru No. 88*), Y. Kuboshima (JFA) for 25 experimental operations (*Shoyomaru*), and M. Yoshida for 20 experimental operations (*Hokuhomaru*). Cetacean specimens collected from these catches are being analysed by N. Miyazaki. He also obtained 21 delphinid specimens returned by nine squid driftnet fishing vessels.

Marking

No whale marking was conducted and no whale marks were recovered. Natural marks of the northern form of the short-finned pilot whale were investigated by T. Miyashita. About 500 photographs of northern form short-finned pilot whales were analysed for individual identification.

Laboratory work

Earplugs of minke whales taken during the 1986/87 Antarctic season and Bryde's whales taken during the 1987 North Pacific season were read by H. Kato and M. Yoshioka.

Ovaries collected during the 1986/87 Antarctic and 1987 North Pacific whaling seasons were examined by the staff of FSL, H. Kato and M. Yoshioka.

Isoenzymes of 148 Dall's porpoises taken during the cruises of the *Hoyomaru No. 12* in 1984, 1986 and 1987 were analysed by S. Wada.

Teeth and gonads of 135 Baird's beaked whales taken in the 1975 and 1985–1987 seasons off the Pacific coast of Japan were examined by T. Kasuya for age and reproductive status,

Biological data and sightings data of Bryde's whales in the western North Pacific were analysed by M. Yoshioka and T. Miyashita, respectively.

T. Kasuya and T. Miyashita analysed the whaling statistics and movement of marked whales, and examined the current stock boundary and historical change in the growth of sperm whales.

The distribution of cow-calf Dall's porpoise pairs was examined by M. Yoshioka and T. Kasuya. M. Kato (FSL) estimated the abundance of Dall's porpoises in the North Pacific and Bering Sea using sightings data obtained during the cruises of salmon research vessels from 1980 to 1987. T. Miyashita and T. Kasuya analysed the distribution and abundance of Dall's porpoises off Japan using data from whale sighting cruises.

Development of techniques

Y. Hatakeyama (National Research Institute of Fisheries Engineering) and his team tested the effect of attaching a sound generator to gillnets in an attempt to reduce the take of Dall's porpoises in the salmon gillnet fishery. They also studied the response of aquarium-reared harbour porpoises to salmon gillnets and made an acoustic study of Commerson's dolphins.

Research results

North Pacific sperm whales were considered to include at least three stocks each breeding in the Alaskan Gyre, Western North Pacific Gyre and the Kuroshio and its counter current area, and males were found in recent years to have grown 5–10 ft larger than in earlier years in all the three North Pacific stocks. This probably resulted from the density dependent improvement of growth in immature stages.

Six schools (about 300 individuals) of the northern form short-finned pilot whales were sighted during a 60 days cruise of the *Toshimaru No. 15* in the expected range of the stock. Photo-identification suggested that three of them were duplicate sightings of the same school on different days. Morphology of saddle mark differed between schools, suggesting that many of the members in a school were genetically related.

Additional records of possibly undocumented ziphiids (c.f. *Hyperoodon* sp.) were collected in the tropical western North Pacific. Analysis of the distribution of these records is in progress.

An examination of the distribution of cow-calf Dall's porpoise pairs indicated four isolated calving grounds of the *dalli*-type individuals in the northern North Pacific and Bering Sea, which possibly represent individual stocks. H. Kato estimated the offshore population of Dall's porpoises in the North Pacific and Bering Sea (mainly *dalli*-type) as about 2,200,000 and those in the coastal Pacific (mainly *truei*-type) at about 135,000 using sightings data from salmon research vessels. T. Miyashita and T. Kasuya estimated the population in the latter area as 73,000, and that in the Sea of Japan and Okhotsk Sea well above 32,000 using data from whale sighting cruises. Isoenzyme analysis confirmed no geographical difference in the gene frequency of Dall's porpoises in the North Pacific and Bering Sea.

Sightings data

An IWC/IDCR minke whale assessment cruise was conducted in Antarctic Area IV. Japan provided two vessels and two scientists from the Japan Whaling Association were on board: H. Shigemune on *Shonanmaru* and F. Kasamatsu on *Shonanmaru No. 2*. Sightings were also conducted on the way to and from the Antarctic (Tables 2, 3 and 4).

Table 2

Whales sighted by Japanese research vessels and scouting boats in the Southern Hemisphere in 1987/88 (IDCR/minke whale assessment cruise of Japanese vessels included, based on the noon position of vessels). B = blue, F = fin, H = humpback, Se = sei, Br = Bryde's, Mi = minke, Sp = sperm, Ba = Arnoux's or Baird's beaked whale, K = killer, Pi = pilot, Zi = ziphiids other than Ba

10° sq.	Distance surveyed (n.miles)	No. of whales sighted											
		B	F	H	Se	Br	R	Mi	Sp	Ba	K	Zi	Pi
A 9	302	–	1	2	–	–	–	–	–	–	–	3	–
10	246	–	2	3	–	–	–	2	–	–	–	7	–
14	102	–	–	–	–	–	–	–	1	–	–	7	–
15	109	–	–	–	–	–	–	–	–	–	–	–	–
16	208	–	–	2	–	–	–	–	–	–	–	–	40
B 7	298	6	–	–	–	–	–	303	–	–	8	6	–
8	1,089	–	–	10	–	–	–	222	30	–	10	41	–
9	692	–	–	2	–	–	–	219	8	–	5	56	–
10	826	–	30	4	–	–	–	82	9	–	–	119	–
11	523	–	5	–	–	–	–	6	2	–	33	27	–
12	753	2	–	12	–	–	–	66	12	–	–	72	–
13	631	–	–	4	–	–	–	12	10	–	4	9	–
14	77	–	–	–	–	–	–	1	–	–	–	–	–
D 10	63	–	27	–	–	–	–	–	–	–	1	–	100
11	307	1	–	–	–	–	1	–	1	–	–	10	–
16	164	–	–	–	–	–	–	–	–	–	–	1	50
E 11	469	–	–	–	–	–	–	–	8	–	–	45	–
14	213	–	–	–	–	–	–	–	–	5	–	13	–
15	444	–	1	–	–	–	–	–	1	–	–	35	270
16	226	–	–	–	–	–	–	–	–	–	–	3	–
17	2,998	–	–	–	1	–	–	4	66	–	16	45	140
18	309	–	–	–	1	–	–	–	–	–	4	3	50
F 12	383	–	–	–	–	–	–	1	2	–	–	–	–
13	567	–	–	–	–	–	–	–	–	–	–	1	–
14	272	–	–	–	–	–	–	–	–	–	–	–	–
17	3,063	–	–	–	–	2	–	3	101	–	–	18	–
G 17	1,527	–	–	–	–	7	–	2	40	–	–	–	5
18	630	–	–	–	–	4	–	–	28	–	–	–	–
Total	17,491	9	66	39	2	13	1	923	319	5	81	521	655

Table 3

Whales sighted by Japanese research vessels in 1987/88 Antarctic season while they were not conducting ordinary sightings under poor visibility, rough weather or fishery conservation zones of other countries (IDCR/minke whale assessment cruise of Japanese vessels included, based on the noon position of vessels). Both hemispheres included. For species key see Table 2

10° square	No. of days	No. of whales sighted											
		B	F	H	Se	Br	R	Mi	Sp	Ba	K	Zi	Pi
A 15	2	–	–	1	–	–	–	–	–	–	–	2	–
B 7	1	–	–	–	–	–	–	13	–	–	–	–	–
12	1	–	–	–	–	–	–	4	–	–	–	–	–
13	1	–	–	–	–	–	–	–	–	–	–	2	–
14	1	–	–	–	–	–	–	–	–	–	–	2	–
D 16	1	–	–	–	–	–	–	–	–	–	–	–	2
E 18	2	–	–	1	–	–	–	–	18	–	–	–	–
H 18	4	–	–	–	–	–	–	–	11	–	5	–	–
N 22	3	–	–	–	–	–	–	–	1	2	10	2	–
26	1	–	–	–	–	–	–	–	–	–	–	3	–
Total	17	–	–	2	–	–	–	17	30	2	15	11	2

Table 4

Whales sighted by Japanese research vessels in the North Pacific, on the way to and from the Antarctic, November 1987 to March 1988 (based on the noon position of vessels). Ps = southern form short-finned pilot whale. For other species see key Table 2

10° square	Distance surveyed (n.miles)	No. of whales sighted								
		F	Br	R	Mi	Sp	Ba	K	Zi	Ps
J 18	0	–	–	–	–	–	–	–	–	45
19	0	–	–	–	–	2	–	–	–	–
K 19	464	–	–	–	–	1	–	–	–	–
L 20	823	–	–	–	–	18	–	–	–	–
M 20	336	–	–	–	–	4	–	–	–	–
Total	1,623	–	–	–	–	25	–	–	–	45

A sighting survey was conducted in the western North Pacific using four whale catcher boatts: *Toshimaru No. 25* (24 July–20 September); *Toshimaru No. 18* (5 June–2 August), *Toshimaru No. 15* (1 September–30 October); and *Shinhoyomaru* (6 August–22 September) (Table 5). Scientists on board were T. Miyashita on *Toshimaru No. 15*, and M. Masuda and T. Okumura (JFA) on *Shinhoyomaru*.

Table 5

Whales sighted by Japanese research vessels operated in the North Pacific, June to October 1987 (based on the noon position of vessels). Ps = southern form short-finned pilot whale, Pn = northern form short-finned pilot whale. For other species see key Table 2

10° square	Distance surveyed (n.miles)	No. of whales sighted										
		B	F	Se	Br	Mi	Sp	Ba	K	Zi	Ps	Pn
L 19	579	–	–	–	–	–	47	–	3	10	–	–
20	3,203	–	–	–	–	–	202	–	–	19	210	–
21	2,538	–	–	–	17	–	176	–	14	20	57	–
22	737	–	–	–	10	–	38	–	–	–	–	–
M 19	142	–	–	–	–	–	–	–	–	–	–	–
20	1,944	–	–	–	–	–	34	19	–	18	40	–
21	3,791	–	–	–	–	–	159	94	9	21	40	40
22	384	–	–	–	3	–	57	–	–	4	–	–
N 21	1,619	–	–	–	–	2	–	57	21	11	–	273
23	204	–	–	–	–	–	–	–	–	2	–	–
24	691	1	1	3	–	–	5	3	9	5	–	–
25	525	1	–	2	–	–	–	–	14	2	–	–
26	333	–	–	3	–	–	48	–	–	11	–	–
27	561	–	9	8	–	–	1	–	–	6	–	–
28	493	–	3	2	–	–	–	–	–	–	–	–
Total	17,744	2	13	18	30	2	767	173	70	129	347	313

Protected species sighted by catcher boats operating in the North Pacific are listed in Table 6.

Marine mammals were also sighted by M. Yoshioka during the trans-Pacific Dall's porpoise cruise of *Hoyomaru No. 12* (3 August–26 September) and on the commercial and experimental cruises of the squid driftnet fishery by M. Amano, S. Wada, M. Yoshida and Y. Kuboshima. M. Kato collected sightings records of Dall's porpoises using nine salmon research vessels operating in the northern North Pacific from 1 June–23 August. Some additional cetacean sightings were recorded on *Wakashiomaru* by K. Yoshida (13 April–7 May) and N. Baba (8 May–10 June, 16 January–14 February) during the cruises for fur seal research off the Pacific coast of northern Japan.

Table 6

Protected whales sighted by operating catcher boats in the coastal waters of Japan 1987/88 (based on the noon position of vessels)

10° square	No. of whales sighted						Effort (CDW)
	Blue	Fin	Humpback	Sei	Right	Gray	
L 20	–	–	–	–	–	–	10
21	–	–	1	–	–	–	406
M 20	–	–	–	–	–	–	58
21	–	–	2	–	–	–	244
N 21	–	–	–	–	–	–	40
Total	–	–	3	–	–	–	758

Table 7

Whales taken by Japanese whaling in 1987/88

Type of whaling	Minke	Bryde's	Sperm	Baird's	Total
Coastal, large-type	–	317	188	–	505
small-type	304	–	–	40	344
Total	304	317	188	40	849

Table 8

Catch of cetaceans by local fisheries other than whaling in 1987, by species and type of fisheries. Numbers in parentheses are number of individuals dead or alive that were released or discarded after take

Species	Gillnet[4]	Driving	Hand harpoon	Trap net	Total
Common dolphin	27 (3)	–	6	4	37 (3)
Striped dolphin	76	2,173	–	–	2,249
Spotted dolphin	–	–	–	–	–
Bottlenose dolphin	1	1,670	142	(3)	1,813 (3)
Pacific white-sided d.	3 (185)	11	5	1	20 (185)
Right whale dolphin	7 (254)	–	–	–	7 (254)
Rough toothed dolphin	–	–	1	–	1
Common porpoise	–	–	8	21	29
Dall's porpoise	9 (807)	–	13,406	–	13,415 (807)
Risso's dolphin	–	2	1	–	3
Short-finned pilot whale	2	294	92	7	395
False killer whale	–	–	2	–	2
Killer whale	–	3	–	–	3
Pygmy sperm whale	–	–	–	1	1
Unknown delphinid	277[1] (17)	–	667[2]	–	944 (17)
Minke whale	–	–	–	5	5
Sei whale[3]	–	–	–	4	4
Total	402 (1,266)	4,153	14,330	43 (3)	18,928 (1,269)

[1] Includes 275 individuals calculated assuming 40 kg meat (with blubber) production per individual.

[2] Calculated assuming 81 kg for a carcase without viscera.

[3] Reported as sei whale but probability of being minke whale is high.

[4] Partial representation of incidental takes by tuna, salmon, squid or other gillnet fisheries.

Strandings

Information on stranded cetaceans has been collected by the Institute of Cetacean Research, 3-32-11, Ojima, Kotoku, Tokyo, 136 Japan.

Statistics and data for small cetaceans

The catch of small cetaceans by Japanese fisheries is listed in Tables 8 and 9. The position of the catch is recorded at the place of registration of the operating bodies. Thus the operation area and the place of registration will differ for many of the gillnet takes and some of the harpoon fishery for Dall's porpoises. The coverage of statistics of gillnet fisheries is less complete than that for the hand-harpooning and drive fisheries.

Table 9

Catch of cetaceans by local fisheries other than whaling in 1987, by prefecture of registration of operating bodies and type of fisheries. In parentheses are number of individuals dead or alive that have been released or discarded after take

Type of fishery/ Prefecture	Fishing boats	Season (month)	Catch (species:number)
Hand harpoon			
Hokkaido, Pacific	1	7–8	Common d.:8
Iwate	207	1–12	Common d.:6; Dall's p.:13,198; Bottlenose d.:124; Pacific white-sided d.:5
Miyagi	–	1–12	Dall's p.:208; Unknown delphinid:667[2]
Okinawa	4	1–12	Short-finned pilot w.:92; Bottlenose d.:18; False killer w.:2; Risso's d.:1; Rough toothed d.:1
Driving			
Shizuoka	1	9–12	Striped d.:1,815
Wakayama	14	10–4	Striped d.:358; Pacific white-sided d.:11; Bottlenose d.:1,670 Short-finned pilot w.:294; Killer w.:3; Risso's d.:2
Trap (set) net			
Hokkaido, Pacific	4	4–12	Common p.:17
S. of Japan	–	7	Sei w.:1[1]
Iwate	7	1–12	Common d.:4; Short-finned pilot w.:4
Toyama	9	1–12	Minke w.:1
Niigata	25	8	Sei w.:1[1]
Ishikawa	22	1–12	Short-finned pilot w.:3; Pygmy sperm w.:1; Minke w.:1
Chiba	8	1–12	Minke w.:1
Kyoto	7	1–12	Pacific white-sided d.:1; Minke w.:1
Simane	4	2–4	Sei w.:2[1]
Nagasaki	3	1–12	Common p.:4; Minke w.:1
Gillnet			
Hokkaido, Pacific	48	5–12	Dall's p.:(363); Pacific white-sided d.:(65); Right whale d.:(115); Common d.:(3); Unknown delphinid:(16)
Aomori	58	2–12	Pacific white-sided d.:(119); Dall's p.:(316); Right whale d.:(102)
Miyagi	–	1–12	Common d.:27; Striped d.:3; Unknown delphinid:275[3]
Ibaraki	1	1–4	Dall's p.:6
Chiba	5	1–12	Striped d.:73; Short-finned pilot w.:2
Toyama	22	6–12	Pacific white-sided d.:(1); Right whale d.:(30); Dall's p.:(103); Unknown delphinid:(1)
Yamagata	1	6–12	Pacific white-sided d.:1; Right whale d.:1; Unknown delphinid:1
Tottori	2	6–11	Pacific white-sided d.:2; Right whale d.:6; Dall's p.:3
Akita	2	4	Bottlenose d.:1; Unknown delphinid:1

[1] Reported as sei whale but probability of being a minke whale is high.

[2] Calculated assuming 81 kg for a carcass without viscera.

[3] Calculated meat (with blubber) production of 40 kg per individual.

Publications

Honda, K., Yamanoto, Y., Kato, H. and Tatsukawa, R. 1987. Heavy metal accumulations and their recent change in sourthern minke whales *Balaenoptera acutorostrata*. *Arch. Environ. toxicol.* 16: 209–16.

Kasuya, T. 1988. Recent change in the distribution and growth of North Pacific sperm whales. Abst. of papers presented to the spring meeting of the Jap. Soc. Sci. Fish., Apr. 1988, p. 220 [in Japanese].

Kasuya, T. and Miyashita, T. 1988. Distribution of sperm whale stocks in the North Pacific. *Sci. Rep. Whales Res. Inst., Tokyo* 39: 31–75.

Kasuya, T., Miyashita, T. and Kasamatsu, F. 1988. Segregation of two forms of short-finned pilot whales off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 39: 77–90.

Kasuya, T., Sergeant, D. E. and Tanaka, K. 1988. Re-examination of life history parameters of long-finned pilot whales in the Newfoundland waters. *Sci. Rep. Whales Res. Inst., Tokyo* 39: 103–19.

Miyashita, T. and Kasuya, T. 1988. Distribution and abundance of Dall's porpoises off Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 39: 121–50.

Miyashita, T. and Kasuya, T. 1988. Abundance and segregation of Dall's porpoise stocks off Japan. Abst. of papers presented in the spring meeting of the Jap. Soc. Sci. Fish., Apr. 1988, p. 221. [in Japanese].

Miyashita, T., Kasuya, T., Wada, S., Mori, K. and Shimazu, C. 1988. Biological study of pilot whales by photo-identification, II. Abst. of papers presented to the spring meeting of the Jap. Soc. Sci. Fish., Apr. 1988, p. 221. [in Japanese].

Perrin, W. F., Miyazaki, N. and Kasuya, T. 1987. A new spinner dolphin from Thailand. Abstract 7th Biennial Conf. Bio. Mari. Mamm., Dec. 1987, p. 53.

Subramanian, An., Tanabe, S. and Tatsukawa, R. 1987. Age and size and male-female differences of PCBs and DDE in *dalli*-type Dall's porpoises, *Phocoenoides dalli* of northwestern North Pacific. *Proc. NIRR Symp. Polar Bio.* 1: 205–16.

Takagi, K. (ed.) 1987. Comprehensive report on researches of marine mammals in the North Pacific Ocean relating to Japanese salmon driftnet fisheries, 1984–1986. Fish Agency Japan. 129pp. [in Japanese].

Wada, S. 1988. Genetic differentiation between two forms of short-finned pilot whales off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 39: 91–101.

Wada, S. and Ohsima, Y. 1988. Difference of number of vertebrae and ribs observed between North Pacific and Antarctic minke whales. Abst. of papers presented to the spring meeting of the Jap. Soc. Sci. Fish., Apr. 1988, p. 222. [in Japanese].

Sperm Whales

Sperm whale off the coast of Spain, August 1983.
Photographs courtesy of Anne Collet.

SC/40/Sp2

Seasonality of Sperm Whales off the Galápagos Islands, Ecuador

Hal Whitehead, Linda Weilgart and Susan Waters
Biology Department, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1

ABSTRACT

Sperm whales were observed off the Galápagos Islands from February – April 1985 and January – June 1987. Large mature males reached a peak abundance of 2–3% of the population in April-May, and were very scarce in January, February and June. Measurements and observations of calves suggest that these sperm whales may generally give birth in June and July. This seasonal breeding cycle is consistent with results from Northern Hemisphere sperm whale populations, and suggests a gestation period of approximately 14 months. The distribution of sperm whales around the Galápagos varied with season but was similar in the two studies. There was no statistically significant variation in the rate at which we encountered sperm whales in different seasons.

INTRODUCTION

The Galápagos Islands lie on the Equator and therefore the stock identity and seasonality of the sperm whales (*Physeter macrocephalus*) in the region is not obvious (Rice, 1977). They could be from a North Pacific stock, or a South Pacific stock; members of each stock could move into and out of the region at different seasons; or there could be a reasonably discrete local population. We would expect different temporal patterns of breeding in each of these circumstances.

Determining the breeding season is important if we are to draw firm conclusions about the breeding system from observations made at a particular time of year. For instance, a possible reason for the low proportion of mature males observed off the Galápagos during a study between February and April 1985 is that this did not include the peak breeding season (Whitehead, 1987; Whitehead and Arnbom, 1987).

In this paper we present evidence bearing on the seasonality of the sperm whales around the Galápagos from a longer study between January and June 1987, as well as from the 1985 study. We first give data on variations in the relative density and behaviour of large male sperm whales in the study area. Observations and measurements of calves are then discussed. Finally we describe the seasonal distribution and abundance of the sperm whales around the Galápagos.

METHODS

Research was carried out from a 10m ocean-going sloop in the waters around the Galápagos Islands, Ecuador (0°N, 91°W), from 23 February – 20 April 1985 (a total of 30 days spent tracking sperm whales) and 3 January – 28 June 1987 (57 days). Virtually all the tracking was of 'mixed groups' consisting of female sperm whales and their offspring (Best, 1979), although large mature males sometimes accompanied the groups. Details of the field techniques are given by Whitehead and Gordon (1986), Whitehead and Arnbom (1987) and Whitehead and Waters (in press). The techniques most relevant to this paper are summarised below.

(a) We searched for sperm whales by sailing over deep water at about 4.5 knots, listening every 30 or 60min through an omni-directional hydrophone for the characteristic clicks of sperm whales (Backus and Schevill, 1966), as well as watching visually in daylight. The great majority of sperm whales were found acoustically. Once sperm whales were located they were followed for as long as possible both visually and using a directional hydrophone to obtain a bearing on their clicks. Navigation was by satellite navigator supplemented by occasional celestial fixes and compass bearings on landmarks.

(b) When following the whales in daylight, we recorded the ranges, bearings and behaviour of all the whales that we could see, as well as the presence of large (>12m) males and calves 0–1 years old, every 5min. For the analysis in this paper we only used sightings less than 500m from the boat in order to minimise the effects of varying sighting conditions and observers, and the difficulties of recognising large males and calves at such a long range.

(c) Photographs taken from a fixed point up the mast were used to estimate the lengths of individuals (Gordon, 1985; Whitehead and Arnbom, 1987).

(d) Recordings of the whales' sounds were made for 5min every hour, and a distinctive 'slow click' used as an indicator of the presence of large males (Weilgart and Whitehead, 1988). The occurrence of slow clicks in sequential recordings (no gaps longer than 4hr) was used to estimate the duration of contacts between mature males and the groups of females and immatures that we were following. In calculating this measure, only occasions on which the same group of whales was photographically identified before, during and after the encounter with the male(s) were used (Whitehead and Arnbom, 1987; Whitehead and Waters, in press).

RESULTS

Large males

In Fig. 1 the changing relative abundance of large males in our study area is indicated by the two measures given below.

(a) The proportion of hourly recordings in which slow clicks were heard

There were significant differences among months in the rates at which slow clicks were heard during both 1985 (χ_2^2=35.1, P<0.01) and 1987 (χ_5^2=90.82, P<0.01). Slow clicks were most frequently heard in April and May, and were rare, but occasionally present, in January, February and June.

(b) The ratio of sightings of large males to sightings of females and immatures (excluding first-year calves) during 5min periods

The data from the two years are consistent and show male densities rising from low (but not zero) levels in January and February, to constitute about 2–3% of the population in April-May, before falling again in June. There were significant differences in the proportion of days that large males were sighted among months in 1987 (χ^2_5=15.69, P<0.01), but not in 1985 (χ^2_2=3.71, P>0.1).

Another measure of male abundance, sightings per hour (not given in Fig. 1), showed a very similar temporal pattern to the ratio of male sightings to those of other sperm whales. Both sighting rates showed temporal patterns similar to that from the slow clicks (Fig. 1).

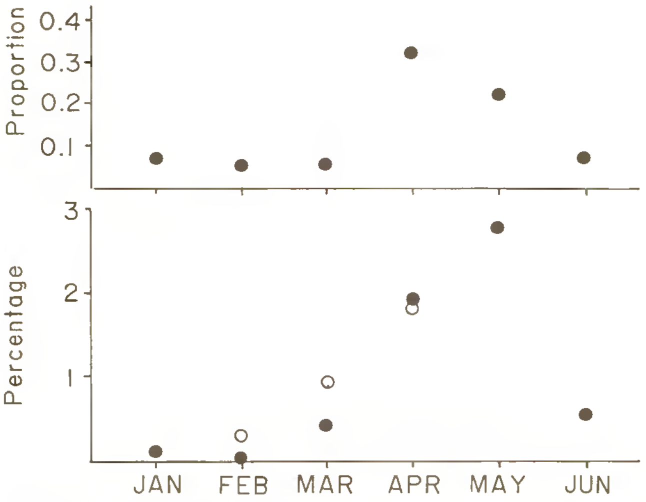


Fig. 1. Seasonal changes in the abundance of large male sperm whales off the Galápagos Islands as indicated by the proportion of hourly recordings at which the distinctive slow clicks of the large males were heard (above), and the rate of sighting large males as a percentage of other whales less than 500m from the research vessel excluding first year calves (below). The data for 1985 are represented by open circles and those for 1987 by closed circles.

Duration of encounters with mixed schools

The mean estimated duration of encounters between males and groups of females as indicated by the presence of slow clicks is given in Fig. 2. The durations of these encounters were longer in April of both years, but this tendency is not statistically significant (Kruskal-Wallis non-parametric test statistic for differences with month for both years combined = 7.36, P=0.195).

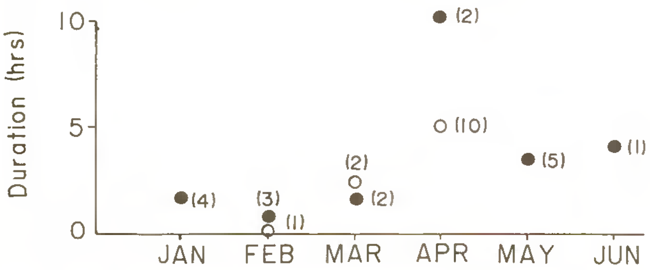


Fig. 2. Mean duration of associations between large males and groups of females in hours as indicated by recordings of slow clicks. Sample sizes (number of associations) are given in parentheses beside each point. The data for 1985 are represented by open circles and those for 1987 by closed circles.

Calves

There was no statistically significant variation in the rates of sighting calves less than one year old with season in either 1985 or 1987 using both the number of days on which calves were sighted and the maximum number of calves sighted with each group (as in Whitehead and Waters, in press—all tests Chi-squared, P>0.10). No 'very small' (< ca. 5.0m) calves were sighted in 1985 or before April in 1987. Sightings of very small calves, and measurements of calves, between April and June 1987 are given in Table 1. These data suggest that the majority of calves present at this time were about 6m long, or very roughly approaching 1 year old according to the data presented by Best, Canham and Macleod (1984). However one newly born calf was sighted and had its umbilical cord photographed on 28 April, and at least three different very small calves were sighted in June.

Table 1

Sightings of very small or 'tiny' (< ca. 5.0 m) calves in 1987 and measurements of calves between April and June 1987, with the group of females and immatures (as in Whitehead and Waters, in press) present during the sighting

Date	Group	Comments
16 April	H13	Measured at 6.2m
17 April	H12/H13	Measured at 6.2m
19 April	H12/H13	Measured at 5.1m
26 April	H23	'Very small' calf
28 April	H7	'Tiny' calf, ca. 4m, unhealed umbilicus photographed, bent dorsal fin.
12 May	H4	'Small calf'
2 June	H6	2 calves, one 'tiny', one larger
3 June	H6	3 calves, one 'tiny', one measured at 6.9m
4 June	H36	2 calves, one 'tiny'
19 June	H11	'Tiny calf'

Seasonal changes in distribution and abundance

The rate at which we encountered sperm whales off the Galápagos is indicated for each 1° square in Fig. 3 for the 1985 study and three two-month periods of the 1987 study. The rate is in encounters (visual or acoustic) with sperm whales per hour searching over water deeper than 500m. We never encountered sperm whales in water less than 500m deep. Only 1° squares where greater than 10hr were spent searching for whales are included for each period. Fig. 4 shows the tracks taken by the research vessel while following sperm whales in each of these periods.

In 1985 (23 February – 20 April), and in March-April 1987, the whales were generally found and followed to the west of the islands. Earlier, and later in 1987, they occupied the more northern part of the archipelago.

There was no significant difference in the rates at which sperm whales were encountered for the four research periods (February-April 1985, January-February 1987, March-April 1987, May-June 1987 – χ^2_3=4.52, P>0.1).

DISCUSSION

Our observations strongly suggest that, within the period of our study (January-June), most interactions between mature male and female sperm whales took place in April and May. It is very likely that this is the peak mating season

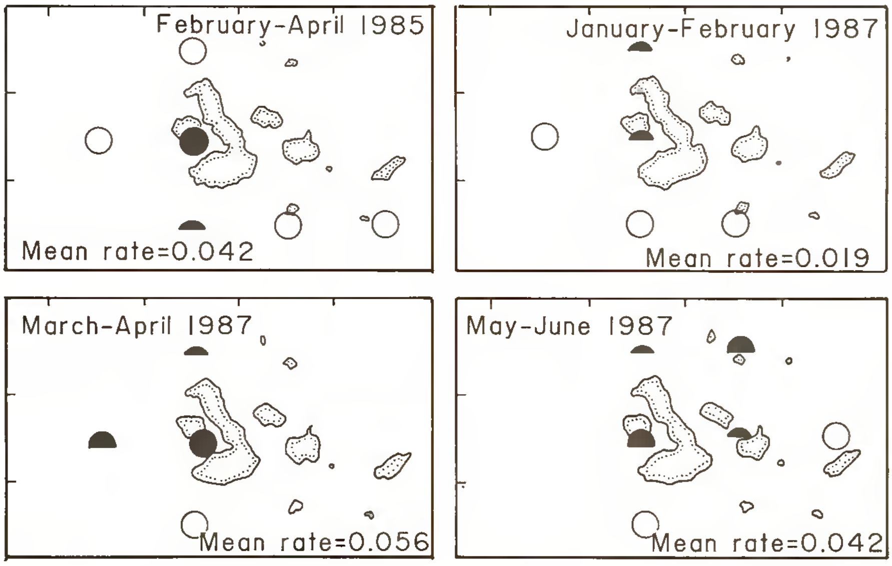


Fig. 3. Rates at which sperm whales were encountered per hour of searching off the Galápagos in 1985 and 1987. The mean rate is given for each time period. Squares where less than 10hr were spent searching for sperm whales are not represented for that time period. Rates (per hour): ○ = 0–0.01; ⌓ = 0.01–0.06; ◓ = 0.06–0.09; ● = 0.09–0.12.

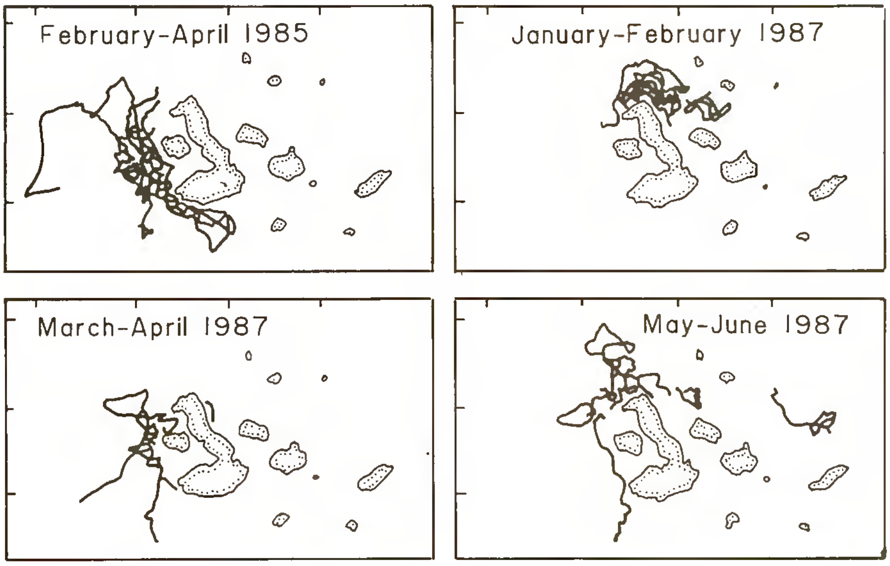


Fig. 4. Track of research vessel while following sperm whales.

for the females that we were studying off the Galápagos. However males were sometimes present, and successful matings may occur, at other times of year.

Our evidence suggests that the main calving season for these animals probably begins in June: the lack of sightings of very small calves between January and the end of April in either year; the preponderance of calves about 6m long, and so roughly approaching one year old (Best *et al.*, 1984), between April and June; and the appearance of a number of very small calves in June. The recently born calf sighted on 28 April appears to be an outlier (by about 6 weeks) to the general distribution of births, perhaps because of a premature birth and/or an earlier conception. Similar outliers seem to be present in the data compiled by Best *et al.* (1984). Best *et al.*'s (1984) data suggest that, at least for 'Southern Hemisphere' populations, the peak calving season has a duration of about 2 months. If this is also true off the Galápagos, the calving season for the whales we studied may be June and July. A mating season in April-May and calving season in June-July suggests a gestation period of 14 months. This is in general agreement with Best *et al.*'s (1984) conclusion that 'most modern interpretations' of sperm whale gestation are between 14–15 months.

This seasonal cycle is consistent with results from studies made in the Northern Hemisphere, as well as those made in the Southern Hemisphere lagged by six months (studies summarised by Best *et al.*, 1984). Thus the whales that we observed off the Galápagos between January and June appeared to be on a 'Northern Hemisphere' reproductive schedule. In contrast, sperm whales caught at Paita, Peru, about 1,000km to the southeast of the Galápagos, were on a 'Southern Hemisphere' reproductive schedule (Clarke, Aguayo and Paliza, 1980). A 9.8m female sperm whale marked with a 'Discovery' tag 400km northwest of the Galápagos was killed off the Peruvian coast (Ivashin, 1978). It is possible that sperm whales off the Galápagos between July and December are on a different reproductive schedule from those that we observed, and that they may be part of the stock whaled off Peru, or that the tagged whale was a 'transient' (Whitehead and Waters, in press). However, in the first half of the year, the Galápagos sperm whales showed strong indications of a 'Northern Hemisphere' cycle.

The presence of sperm whales around the Galápagos for at least six months of the year is in agreement with the records of the 18th and 19th century sperm whalers who took sperm whales off the islands throughout the year (Townsend, 1935). The western part of the archipelago, where the sperm whales were most often found between March and April, is generally thought to be the most productive region around the Galápagos, but there are considerable seasonal and annual variations (Feldman, Clark and Halpern, 1984; Houvenaghel, 1978).

It would be most interesting to have information on the identity, reproductive status, distribution and abundances of the sperm whales off the Galápagos during the second half of the year. Results of current field studies by T. Lyrholm (pers. comm.) and examination of 19th century whalers' logbooks by P. Hope (pers. comm.) will help to fill this gap. However, we believe that the data presented in this paper give a reasonably clear picture of the situation during the period January-June.

ACKNOWLEDGEMENTS

Those who took part in, funded, and assisted the 1985 study are acknowledged in Whitehead and Arnbom (1987). The 1987 study and analysis was funded principally by an operating grant and University Research Fellowship (to H.W.) from the Natural Sciences and Engineering Research Council of Canada, and grants from the International Whaling Commission and the Dalhousie University Research Development Fund, with a generous contribution from Wild Country Productions. World Wildlife Fund kindly loaned equipment. We are very grateful to the crew of *Elendil*: David Day, Leesa Fawcett, Matt Friedl, Cheryl Hendrickson, Garry Kealy, Gary Kendrick, Bill Lambert, Dan Loehr, Katherine Lynch, George Prehmus, Margo Rice, Xavier Romero, Sean Smith, Caroline Smythe, Jennifer Staniforth, Susan Staniforth, Tui de Roy, and Benjamin Weilgart-Whitehead, and Miguel Zatapin. We thank the Estación Científica Charles Darwin, and especially Sylvia Harcourt and Henk Kasteleijn, for support and assistance. Juan Black helped us greatly in Quito and Godfrey Merlen and Gail Davis rescued us several times. The hospitality of Frau Erna Sievers and the practical assistance of Rolf Sievers were also greatly appreciated. Dr Ian McLaren, Annick Faucher (Biology Department, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1), Dr Robert Clarke (San Andrés, Pisco, Peru), and an anonymous reviewer kindly reviewed the manuscript.

REFERENCES

Backus, R.H. and Schevill, W.E. 1966. *Physeter* clicks. pp. 510–27. *In*: K.S. Norris (ed.) *Whales, Dolphins, and Porpoises*. Univ. of Calif. Press, Berkeley.

Best, P.B. 1979. Social organization in sperm whales. pp. 227–89. *In:* H.E. Winn and B.L. Olla (eds) *Behavior of Marine Animals, Vol.3* Plenum Press.

Best, P.B., Canham, P.A.S. and Macleod, N. 1984. Patterns of reproduction in sperm whales, *Physeter macrocephalus*. *Rep. int. Whal. Commn* (special issue 6): 51–79.

Clarke, R., Aguayo, A. and Paliza, O. 1980. Pregnancy rates of sperm whales in the southeast Pacific between 1959 and 1962 and a comparison of those from Paita, Peru between 1975 and 1977. *Rep. int. Whal. Commn* (special issue 6): 151–8.

Feldman, G., Clark, D. and Halpern, D. 1984. Satellite color observations of the phytoplankton distribution in the eastern equatorial Pacific during the 1982–1983 El Niño. *Science* 226: 1,069–71.

Gordon, J.C.D. 1985. A method for measuring the length of whales at sea. Paper SC/37/O 15 presented to the IWC Scientific Committee, June 1985 (unpublished).

Houvenaghel, G.T. 1978. Oceanographic conditions in the Galápagos Archipelago and their relationships with life on the islands. pp. 181–200. *In*: R. Boje and M. Tomczak (eds) *Upwelling Ecosystems*. Springer Verlag, New York.

Ivashin, M.V. 1978. Soviet investigations of Cetacea, June 1976 to May 1977. *Rep. int. Whal. Commn* 28: 119–22.

Rice, D.W. 1977. Sperm whales in the equatorial eastern Pacific: population size and social organization. *Rep. int. Whal. Commn* 27: 333–6.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica* 19: 1–50.

Weilgart, L.S. and Whitehead, H. 1988. Distinctive vocalizations from mature male sperm whales (*Physeter macrocephalus*). *Can. J. Zool.* 66: 1,931–7.

Whitehead, H. 1987. Social organization of sperm whales off the Galápagos: implications for management and conservation. *Rep. int. Whal. Commn* 37: 195–9.

Whitehead, H. and Arnbom, T. 1987. Social organization of sperm whales off the Galápagos Islands, February-April 1985. *Can. J. Zool.* 65: 913–9.

Whitehead, H. and Gordon, J. 1986. Methods of obtaining data for assessing and modelling sperm whale populations which do not depend on catches. *Rep. int. Whal. Commn* (special issue 8): 149–66.

Whitehead, H. and Waters, S. In press. Social organization and population structure of sperm whales off the Galápagos Islands, Ecuador (1985 and 1987). *Rep. int. Whal. Commn* (special issue 12).

Minke Whales

Minke whale taken during the 1981/82 IWC/IDCR Assessment Cruise in Area II
Photograph courtesy of Tim Waters (SMRU, UK).

SC/40/Mi1

'The State of the Northeast Atlantic Minke Whale Stock' – A Critique

Sidney J. Holt

Podere 'Il Falco', 06062 Città della Pieve (PG), Italy

ABSTRACT

This paper provides a critical review of the scientific aspects of a report entitled 'The State of the Northeast Atlantic Minke Whale Stock' produced by a group of scientists set up to provide advice to the Norwegian Government. It reveals fundamental flaws in the methodology and conclusions drawn in the report concerning the calculation of replacement yield. The model developed in the report requires unattainable precision in estimates of five independent variables and its estimate of a 'safe' catch is not supported by the analysis presented. This paper also critically reviews the research needs suggested in the report to improve understanding of the stock and finds both the identified needs and the methodology proposed unconvincing.

INTRODUCTION

During the 1987 IWC Scientific Committee meeting, a report with the above title was distributed (Walløe, Anderson, Beverton and Semb-Johansson, 1987) but arrived too late for comment (IWC, 1988a). This paper is a response to that report*. The authors of the report had been chosen by the Norwegian Government to review the basis for Norway's harvest of minke whales and were free to determine their own terms of reference. Those relevant to the IWC Scientific Committee's area of competence were:

(1) to assess the evidence and arguments for the size and depletion of the Northeast Atlantic minke whale stock;
(2) to evaluate possible methods for assessment of this stock;
(3) to determine whether a sustainable yield could, in principle, be harvested from this stock;
(4) to specify the management requirements appropriate for obtaining such a yield;
(5) to consider how future research may best be conducted to promote sound management of the species; and
(6) to comment on the management procedures of the IWC and its plans for a Comprehensive Assessment by 1990.

This was an ambitious set of tasks to be achieved in the ten months between the establishment of the group (on 8 August 1986) and the publication of its report; this paper shows that it was too ambitious.

GENERAL POINTS

Before examining Walløe *et al.* (1987) in detail, I would make the following general points. Firstly, it is surprising that much of the recent IWC material available before the report was finalised is either not referred to or only briefly so, e.g. the report of the 1986 Scientific Committee meeting (IWC, 1987), the relevant associated papers (see IWC, 1987, Annex C) and the reports of the IWC Comprehensive Assessment Workshops on Catch-per-Unit-Effort (CPUE) and Management (IWC, 1988 b and c). Consideration of these would surely have led the authors to modify several sections of their report and increased its relevance to the work of the IWC Scientific Committee.

Secondly, and perhaps as a result of insufficiently considering recent literature, several areas of their report betray a lack of understanding of the work carried out by the Scientific Committee. While it is not profitable here to itemise all of these, the summary below of the two major areas where these occurred will be helpful in considering their report.

(a) Management Procedures

In their criticism of the Scientific Committee's operations in the context of the 'New Management Procedure' (NMP), Walløe *et al.* (1987) fail to recognise:

(1) that the Committee of necessity is bound by management objectives determined by the Commission within the context of the International Convention for the Regulation of Whaling;
(2) that the NMP was developed by the Committee itself and not the Commission;
(3) that the Committee has already documented the problems associated with the NMP, is actively engaged in developing new procedures and had already progressed considerably further in this work than the general expression of the need for a feedback system made by Walløe *et al.* (e.g. see IWC, 1988c);
(4) that the NMP does not necessarily assume that the carrying capacity is constant, as they assert – in fact it can be applied if the carrying capacity changes or has changed, provided there is information on the changes and their effect on stock dynamics. However in the absence of clear evidence of change the Scientific Committee has agreed to act as if there has been no change.

(b) Modelling

In their criticism of the Scientific Committee's use of models, Walløe *et al.*, made a number of incorrect assertions:

(1) that too much weight is placed on model predictions, despite uncertainties — in fact recent discussions in the Committee have concentrated on such uncertainties;

---

*This revised paper comments only on the scientific aspects of the report. The original paper, which is available from the author or the IWC Secretariat, also comments on other aspects of the report.

(2) that estimates of a series of population parameters are made from a single time series of data reflecting changes in population abundance – in fact recent work has concentrated on estimating only one parameter (e.g. the resilience 'A' or the initial stock size) from such series;

(3) that the worth of a model appears to be assessed by the ease with which it can be fitted to observed 'abundance' trends – in fact if a model does not fit the data, the data are re-examined and either they or the model are corrected/rejected.

More detailed comments on models are given where appropriate in the sections below.

REPLACEMENT YIELD CALCULATIONS AND THEIR IMPLICATIONS

The model

Walløe *et al.* (1987), having stated that debate on the relative merits of different models of unknown biological processes was fruitless, constructed a simple static model without density dependence to estimate replacement yields (RYs), of the following form:

$$I_{t+1} = I_t e^{-m1} + psN_t\, e^{-m2} - psN_{t-d} e^{-m2-m1(d-1)}$$

for immatures of both sexes (I)

$$N_{t+1} = N_t e^{-m1} + psN_{t-d} e^{-m2-m1(d-1)}$$

for matures of both sexes (N)

where d=age at maturity, m1=natural mortality rate of adults and immatures aged 1 and over, m2=calf mortality over first year of life, p=proportion of mature females giving birth in any one year and s=proportion of mature females in the population (although ambiguous, the context reveals this to mean in the female population). If catches, Q, are taken, they are assumed to be of mature animals with no selectivity by sex. This ignores, of course, the fact that the northeast Atlantic fishery has a long history of sexual selection in the catch in favour of females; the model will thus overestimate RY for any given parameter set.

Sensitivity 'tests'

Walløe et al. (1987)

Walløe *et al.* then attempted an unusual and, as will be seen, unsuccessful form of sensitivity analysis. For each of the four variables, d, m1, m2 and p, they chose a range of 'possible' values and took three values, one at the end of the range which would lead to a low estimate of RY ('bad'), one at the opposite end which would lead to a high estimate ('good') and one at around the mid-point ('moderate'). They assumed that a combination of the extreme values for each variable was unlikely to occur in nature and thus that the resultant range in RY values would overestimate the 'true' possible range of RY.

The ranges for the different variables had different bases in fact. Thus there are data to provide some information on a likely range for d and m1. For p, which reported pregnancy rates in certain areas (e.g. Christensen, 1975) suggest might be close to 1.0 (one calf per year), they took the median value, 0.75, between females calving once per year and once per two years (0.5), and chose an asymmetrical range of 0.65 and 0.95, offering no rationale for it. They noted that there was no information on juvenile mortality rates for minke whales and chose values of fraction surviving from birth to recruitment of 0.4, 0.5 and 0.6, based on survivorship curves (not specified) for large terrestrial mammals.

Interpretation of the effects of m1 and m2 in Walløe *et al.* is made difficult because the range of m1 is given as exponential rates ± about 10%, whereas that for m2 is given as fractions ± about 20%. Converting the latter to exponential rates gives m2 values of 0.916, 0.693 and 0.511. The 'moderate' value is thus some 7 times the m1 value, with the extremes 32% higher and 26% lower than that.

Given their choice of parameter values and the taking of a catch which balances replacement, Walløe *et al.* used a value of 0.5 for s, the approximate value at which the proportion of matures stabilises. In fact, if calculated precisely, these values are 0.58, 0.53 and 0.53 for the 'bad', 'moderate' and 'good' parameter sets. Table 1 (based on table 4 of Walløe *et al.*) shows their results and the modified results arising out of comments made here. It shows that using the calculated s values does not cause a major difference in the RY values for the parameter sets chosen. However for the overall domain of the variable ranges, the calculated s values can range from 0.43 to 0.64; over that range the errors from assuming 0.5 are substantial.

Although they noted the different factual bases for their chosen values of the variables, Walløe *et al.* did not take them adequately into account in their interpretation of the results of Table 1. They concluded that the range in RY was extremely sensitive to the estimates of the parameters, particularly for m2 and p which are also the least known. However, this conclusion cannot be validly drawn from calculations in which all but one of the parameter values are altered simultaneously. Interpretation is further confounded by the fact that the changes are by different amounts and in two cases are asymmetrical.

The lack of rigour in their analysis is surprising in view of their comment that the IWC Scientific Committee should test the sensitivity of model predictions to parameter values, apparently ignoring the systematic work that has been done recently in this regard (e.g. Holt, 1985; Lankester and Cooke, 1987). The above discussion makes it clear that orthodox sensitivity tests are required and I provide these in the following section.

Table 1

Parameters and replacement yield calculations for 6 alternatives. Replacement yields are based on 50% matures in the total population (from Walløe *et al.*, 1987). Values in parenthesis are the modifications referred to in the text; m2 has been expressed as an exponential rate

Case	Bad	Moderate	Good
Parameters			
m1	0.11	0.10	0.09
m2	0.916	0.693	0.511
p	0.65	0.75	0.95
s	0.5 (0.58)	0.5 (0.53)	0.5 (0.53)
d	8	7	6
r	-0.044	-0.00774	0.09566

Present total population 50% mature	Present replacement yields		
	Bad	Moderate	Good
15,000	-300	58	717
50,000	-1,100 (-1,274)	194 (207)	2,391 (2,539)

Revised sensitivity tests

Walløe *et al.* used two values for current stock size: 50,000, approximately the value of the mark-recapture estimate of Cooke and Rørvik (1985) and 15,000, approximately the lower confidence bound. In this section I use the 50,000 value. I have also used, for consistency of comparison, the calculated s values (see above).

Walløe *et al.* had noted that in one sense the 'moderate' parameter set might be thought to give the most reasonable RYs, later stating that they believed it doubtful that quotas of over about 200 could be considered 'safe'.

For this reason I have first concentrated on the sensitivity of the calculations in the vicinity of the 'moderate' set, for each parameter individually (except s, for which they used a constant value of 0.5). The results are summarised in Table 2. I have calculated the effects on the RY of a 10% change in each variable and also the effects of the full range assumed by Walløe *et al.*; the effects are large in each case but RY is found to be most sensitive to m1, not to m2 or p.

A more standard approach is to determine the *specific sensitivities* as the ratio of the relative change in RY to the relative change in each variable for very small changes in the latter. These are given in Table 3 for the region of parameter space giving an RY of approximately 200.

A 'negative' specific sensitivity means that the change in the RY will be in the direction opposite from that of the variable. The sensitivities, for any combination, are strictly additive. Thus for the 'good' or 'bad' parameter sets, a 1% change would result in a 67% change in RY.

The sensitivity of the model to the variables can be further illustrated by examining what range of a single variable is needed to encompass a fourfold range in RY (100–400), if the assumption is made that the other variables are precisely known and are equal to the 'moderate' values given by Walløe *et al.* The results are given in Table 4. Positive values for RY are obtained only if m1 <0.105; m2<0.77 ($>46\%$ first year survival); p>0.69; s>0.46; d<7.8 years.

Table 2

Sensitivity of RY to individual variables

		Variable value			Replacement yield		Percent change in RY	
Variable	Lower	Mid	Higher	Lower	Mid	Higher	Lower	Higher
m1 -10% +10%	0.09	0.1	0.11	624	207	-192	291	-193
m2 -10% +10%	0.624	0.693	0.762	393	207	24	90	-88
m2 -26% +33%	0.511	0.693	0.916	708	207	-370	242	-296
p -10% +10%	0.625	0.75	0.825	-268	207	465	-230	125
p -13% +13%	0.650	0.75	0.950	-168	207	863	-181	198
p -33% +33%	0.500	0.75	1.000	-816	207	1,014	-494	390
d -10% +10%	6.3	7	7.7	427	207	20	106	-90
d -14% +14%	6	7	8	534	207	-51	158	-125

Table 3

Specific sensitivities (see text)

Variable	Specific sensitivity	Variable	Specific sensitivity
m1	-20	p	+14
m2	-9	s	+14
		d	-10

Table 4

Ranges of variables required to produce a range of RY of 100–400 (see text)

m1	0.095 - 0.103	s	0.48 - 0.54
m2	0.62 - 0.73 (48 - 54% survival)	d	6.3 - 7.4 years
p	0.72 - 0.81		

Discussion

Walløe *et al.* refer in several places to the futility of debating the relative merits of different models of unknown biological processes, with the implication that such debates have occurred within the Scientific Committee. In fact the Committee has not indulged in such debates, recognising the impossibility of distinguishing between such models given current and even potentially available data (e.g. see Holt, 1985). The main criterion of choice in the Committee has in fact been simplicity, especially in number of parameters.

Walløe *et al.* also expressed concern that the Committee has used models which assume that the carrying capacity remains constant. It is sufficient to note here that this is also true of any predictions made by their model.

As a basis for their interpretation of results, Walløe *et al.* assumed that a combination of the extreme values for each variable was unlikely to occur in nature. In that sense they stated that the 'moderate' set of values might also give the most reasonable result. The logic of this view, however, only holds if the range of values chosen by them includes the 'possible' range of each variable. This was not the case; they did not in fact use the 'possible range' of most of the variables. For example the range selected for m1 was arbitrary: no evidence was cited that it could not have a value of, say, 0.115 or 0.85. Conversely, the range for p did not extend to what they noted might be biologically feasible values close to 1.0 or 0.5. Whether their view of the most reasonable result is true or false depends entirely on whether or not the most probable values of all the variables actually lie near the middle of the ranges assumed by the group.

A simple example serves to illustrate this. Suppose the true value of p is close to 0.5, which might be the case if there was considerable segregation of females by reproductive class to confound the interpretation of observed pregnancy rates in the catches (Walløe *et al.*, 1987, pp. 7–8); the value is not *a priori* less likely than 0.75. The available information about m1 does not justify a statement that it is less likely to be 0.11 than 0.10. There is no evidence to suggest that a first year survival of 40% is less probable than one of 50% (or even 30%). The published point estimate of mean age at maturity of females is 7.1 years (Christensen, 1980; 1981). This less-than-extreme variable set [m1$=$0.11, m2$=$0.92, p$=$0.5, d$=$7.1, s$=$0.5] gives an RY of —1,744, i.e. a much higher negative number than Walløe *et al.*'s worst case value of 1,100. Using the same reasoning higher 'plausible' RY values can be obtained than Walløe *et al.*'s 'best' case value of +2,391.

If we tend to reject such results it is not because the set of variable values is unlikely to occur in nature but because we have a sense from other information that they may not be reasonable.

The sensitivities illustrated in Tables 3 and 4 and the discussion above clearly shows the approach of Walløe *et al.* to be simplistic and not able to support the conclusions drawn. In particular their view that the RY from the moderate parameter set (of about 200) is the most reasonable, even though they state it to be a 'very crude' estimate, is clearly without substance: RYs of zero or 400 are no less 'reasonable', nor even are negative values or values greater than 400.

Furthermore, even the above analysis does not consider all the problems associated with their approach. Additional confounding factors include:

(i) the age at maturity of males and females is assumed equal – in fact as they note, Christensen (1980; 1981) also gives a point estimate of 6 years for males – using this leads to substantial changes in calculated RY values;
(ii) the model assumes constant natural mortality for both sexes after the first year of life – this is not *a priori* likely and an examination of the sensitivity to this (Table 5) shows that to obtain managerially useful estimates of RY, impossibly precise (and independent) estimates of adult and juvenile mortality rates are required.

Table 5

Sensitivity to assumptions of constant natural mortality

m1	m2	Specific sensitivity
1% increase	constant	- 12%
constant	1% increase	- 8%

In fact the simple model used by Walløe *et al.* is less robust than the conceptually simple procedure used by the Scientific Committee to calculate the RY of the stock by relating recent catches to an apparent slow decline in the stock (IWC, 1984; 1985). Following this, my 1985 paper (Holt, 1985) had two objectives. The first was to examine the implications of the previous conclusions about current replacement yield with respect to the likely state of the stock. This involved using the catch data both prior to and following the time period used originally to estimate the replacement yield. Formally, it also involved making an assumption about the general form of a stock-recruitment function, but not about its parameters. Lastly, it involved use of values for adult natural mortality and age at sexual maturity; it has been shown that the results with respect to depletion are insensitive to the values of those variables (e.g. IWC, 1987, p.38).

The second objective was to examine more closely the RY estimate. The RYs calculated from a simple model of this kind necessarily fall within the general domain of those calculated directly from the trend in an abundance index, the average catch and a point estimate of stock size, and lead to a type of 'average' RY. If there is a medium-term trend, and particularly if there have been substantial changes in the catch rate, then the RY might change rapidly, even during the period to which the 'average' refers. Application of the simplest possible population model demonstrated that this phenomenon is to be expected in the present case and permitted estimation of a more precisely defined 'current' RY – which, in the circumstances, must be lower than the preceding average. This confirmed that the RY estimates depended critically on the estimate of the rate of population change.

In this regard, an important omission in Walløe *et al.* is reference to the method of de la Mare (1987) which was adopted by the Committee. His method fits a population model simultaneously to both a time series of indices of relative abundance and point estimates of absolute abundance. It therefore makes possible the combining of different data with appropriate weights and thus facilitates the search for greater coherence of an entire data set and full use of whatever data may be available.

Finally, it is of interest to examine the conclusions of Walløe *et al.*, to their implicit assumption that the stock has not changed over a period of time t to t−d; essentially their model is a constant recruitment rate model. Such models are known to be unstable: there is no sustainable yield at any stock level when, as is usual, the recruitment rate is estimated from a balance equation pertaining to an initial unexploited stock in which net recruitment is presumed to be zero. If the fixed recruitment rate is set in another way, as in Walløe *et al.*, and is positive, then an unstable equilibrium will be found at some intermediate stock level.

Any chosen part of the trajectory of this population can be modelled using the 'moderate' set of values and the recorded catches. As the catches have greatly exceeded the estimated RY, the stock must have been declining for many years. Using the mark-recapture estimates for the late 1970s of 50,000 would require a mid-1960s stock of about 63,000 and a late 1980s stock of around 38,500. The model predicts a rapidly changing RY with the changing stock composition e.g. 140 in 1986 and 330 in 1988. A projection assuming a long term catch of the estimated RY of 207 shows the stock to increase slightly until 1991 and then to decline continuously, since the unstable equilibrium for these variable values is around 170.

If the annual catch is set following the method of Walløe *et al.* but using the catch history to recalculate an RY each year, then the catch would increase until 1991 and thereafter be reduced until the unstable equilibrium was approached in around 2010–20. Any errors leading to an overestimate of RY would cause the decline to start earlier and accelerate more rapidly. Whether this is a matter of concern depends upon one's expectations that precise estimates of all the variable values could be obtained in, say, a decade, or that monitoring methods of such precision could be developed as would permit rapid detection of the necessarily slow trend.

In conclusion the methodology and results presented by Walløe *et al.* concerning RY calculations are fundamentally flawed and cannot be used either to indicate whether the stock in its present state can sustain any yield or to give a useful estimate of RY.

ADDITIONAL CONSIDERATION

Interpretation of catch per unit effort series

Much of the difficulty in interpreting the CPUE data for the northeastern stock of minke whales has centred around the different trends shown by the series from the Barents Sea and Vestfjorden areas during certain time periods. Those CPUE series have been extensively discussed e.g. see IWC (1985; 1987), Holt (1985; 1986), Øien, Jørgensen and Øritsland (1987), Rørvik (1987).

Walløe *et al.* found no evidence that a trend in under-reporting of catches by whalers could account for the crucial 1973–1983 trends in CPUE in either the Barents Sea or the Vestfjorden area. So the debate can be narrowed to the question of why the middle parts of the two CPUE series are not compatible with each other and in particular why the Barents Sea series shows essentially no trend over the period of roughly 1951 to 1971.

Discussions at recent IWC Scientific Committee meetings (IWC, 1985; 1986; 1987) have led to a series of possible explanations for the differences between the series. Two hypotheses I suggested (Holt, 1985; 1986) were:

(i) that multispecies operations in the Barents Sea had distorted CPUE values for several seasons in the 1950s and 1960s;

(ii) that the discrepancy might be partially explained by the age at recruitment being younger in the Vestfjorden area, especially in the earlier years.

The data to test (i) only became available to the Walløe group late in its work and it is not surprising it did not use them. Subsequently Øien (1987) presented an analysis which found that multispecies catching had no important effect on the series but the data were not presented in such a way that the Scientific Committee was able to judge the validity of the conclusion (IWC, 1988, p.44).

Although the raw data were not available, 'rough' analyses (Holt, 1986; Cooke and Lankester, 1987) revealed that the effect of (ii) could be substantial. The necessary data (length composition of catches by area) were available to the Walløe group but were not analysed in their report. It is disappointing that Walløe *et al.* did not attempt to examine the CPUE data, the major data set available for this stock, and try to resolve some of the problems it poses.

Further hypotheses (e.g. changes in the distribution of whaling effort within the Barents Sea – IWC, 1988, p.89) will probably all require analysis of detailed catch and effort data which have only recently been made available (IWC, 1989a).

RESEARCH PROPOSALS

Walløe *et al.* identify a large number of research items they consider are necessary to improve knowledge of the stock. Unfortunately they appear to ignore the impracticality, for the management of whaling, of the use of analytical models that incorporate many independent variables, all of which must be estimated with precision. This fact has been recognised by the IWC Scientific Committee in all its recent discussions on management.

Based on this false premise, Walløe *et al.* proceed to list in their table 5, 37 'parameters', 17 of which are given 'high' priority in terms of their importance to stock assessment and for which present knowledge is poor or none existent. For 12 of these they state that catches are required for new information (of the 37 parameters, 26 are identified as requiring catches).

Even accepting their false premise, the sensitivity analysis given in this paper has shown that no amount of sampling could either provide estimates of variables such as m1 of sufficient accuracy for use in the way Walløe *et al.* have attempted or give any estimates of, for example, m2. I have shown above that even if all other parameters were known precisely, without a precise estimate of m2 their approach is of no particular use for management.

Furthermore, as was brought out clearly in the discussion at the 1987 meeting of the Committee, regarding the Japanese proposals for estimating m1 and recruitment from representative samples, there are serious unresolved methodological problems in achieving this (IWC, 1989b). In particular, in the present context, the use of a series of age-compositions to estimate mortality depends critically and directly on the precision of independent annual or other periodic estimates of the number of whales; even the best such estimates are subject to statistical error far exceeding the requirements for precise estimation of m1.

Walløe *et al.*, although making the general statement that the sampling strategy and sample size must be able to give statistical validity to the extrapolation of data to the whole population, unfortunately offer no suggestions as to how this as yet unattained aim might be achieved.

Similarly, while noting the need for a broad study of the interactive role of minke whales in the North Atlantic ecosystem, they offer no suggestions as to how this monumental, if worthy, task might be achieved.

CONCLUSIONS

A critical review of Walløe *et al.* (1987) reveals a number of problems stemming from an apparent misunderstanding of the recent work of the Committee, particularly due to an inadequate examination of the reports and papers of the Committee at its 1986 meeting and 1987 special meetings.

The model developed in Walløe *et al.* is shown to be inadequate and the conclusions drawn from it unsupported. The view that any such analytical model, requiring impossibly precise knowledge of a range of population parameters, can form the basis of management is one which the Scientific Committee has rightly abandoned. Their recommendations on research needed to improve the management of the stock by attempting to estimate these parameters, many of which require the killing of whales, are consequently unhelpful.

Walløe *et al.* did conclude that in the context of the New Management Procedure, the present IWC classification of this stock as a Protection Stock was not unreasonable, although they believed 'unclassified' would be more scientifically reasonable. However even if the feature of the NMP which leads to protection of depleted stocks is rejected, there remains the problem of determining a catch limit which would at worst be reasonably sure to keep the stock unchanged or, better, to permit it to increase even while whaling continues. Walløe *et al.* do not justify such a number, and indeed neither has the IWC Scientific Committee yet been able to do so.

In conclusion I believe that there is nothing in Walløe *et al.* (1987) which advances either whale population biology in general or the work of the IWC Scientific Committee in particular.

ACKNOWLEDGEMENTS

The work on which this critique is based was supported by the International Fund for Animal Welfare. I am grateful to Greg Donovan for his assistance in revising this paper for publication, and to reviewers who offered suggestions in that regard.

REFERENCES

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 on the biology of small whales. *J. Fish. Res. Bd Can.* 32: 1,083–94.

Christensen, I. 1980. Catch and effort in 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.

Cooke, J.G. and Lankester, K. 1987. Population assessment of Northern Hemisphere minke whale stocks. Paper SC/39/Mi23 presented to the IWC Scientific Committee, June 1987. (Unpublished).

Cooke, J.G. and Rørvik, C.J. 1985. Estimate of mark shedding in the Northeast Atlantic stock. *Rep. int. Whal. Commn* 35: 98.

de la Mare, W.K., 1987. Fitting population models to combinations of CPUE series and absolute abundance estimates. *Rep. int. Whal. Commn* 37: 379–81.

Holt, S.J. 1985. Classification of North Atlantic minke stocks. Paper SC/37/Mi4 presented to the IWC Scientific Committee, June 1985. 34pp. (Unpublished).

Holt, S.J. 1986. Northeast Atlantic minke stock: Reassessment. Paper SC/38/Mi3 presented to the IWC Scientific Committee, June 1986. 34pp. (Unpublished).

International Whaling Commission. 1984. Report of the Scientific Committee. *Rep. int. Whal. Commn* 34: 35–181.

International Whaling Commission. 1985. Report of the Scientific Committee. *Rep. int. Whal. Commn* 35: 31–152.

International Whaling Commission. 1986. Report of the Scientific Committee. *Rep. int. Whal. Commn* 36: 30–140.

International Whaling Commission. 1987. Report of the Scientific Committee. *Rep. int. Whal. Commn* 37: 28–145.

International Whaling Commission. 1988a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38: 32–155.

International Whaling Commission. 1988b. Comprehensive Assessment Workshop on Catch Per Unit Effort (CPUE). *Rep. int. Whal. Commn* 38: 157–62.

International Whaling Commission. 1988c. Comprehensive Assessment Workshop on Management. *Rep. int. Whal. Commn* 38: 163–70.

International Whaling Commission. 1989a. Report of the Scientific Committee (published in this volume).

International Whaling Commission. 1989b. Report of the Special Meeting of the Scientific Committee to consider the Japanese Research Permit (Feasibility Study), December 1987 (published in this volume).

Lankester, K. and Cooke, J.G. 1987. On the adequacy of simplified population models for the assessment of exploited whale stocks. *Rep. int. Whal. Commn* 37: 383–6.

Øien, N. 1987. Multispecies catches by Norwegian small-type whalers with special reference to the significance of bottlenose catches for the Barents Sea minke whale CPUE indices. Paper SC/39/Mi12 presented to the IWC Scientific Committee, June 1987. (Unpublished).

Øien, N., Jørgensen, T. and Øritsland, T. 1987. A stock assessment for northeast Atlantic minke whales. *Rep. int. Whal. Commn* 37: 225–36.

Rørvik, C.J. 1987. Northeast Atlantic minke whales re-assessed. *Rep. int. Whal. Commn* 37: 241–52.

Walløe, L., Anderson, R.M., Beverton, R.J.H. and Semb-Johansson, A. 1987. *The State of the Northeast Atlantic Minke Whale Stock: Report of the group of scientists appointed by the Norwegian Government to review the basis for Norway's harvesting of minke whales.* Økoforsk, As, Norway. 100pp.

SC/40/Mi3

Minke Whales in the Pack Ice Zone, East Antarctica, During the Period of Maximum Annual Ice Extent

Paul H. Ensor

*Australian Antarctic Division, Kingston, 7050 Tasmania, Australia**

ABSTRACT

Minke whales (*Balaenoptera acutorostrata*) were observed to be widely distributed in the pack ice zone off the East Antarctic coast during two complete traverses from the outer-edge of the pack ice to the coast of Antarctica when the pack ice was at its predicted maximum annual extent. Shipboard and aerial observations were conducted off Enderby Land (October to December 1985) and off Prydz Bay (October to November 1987). Killer whales (*Orcinus orca*) were observed in the pack ice in October 1985 and southern bottlenose whales (*Hyperoodon planifrons*) were recorded near the pack ice edge in both 1985 and 1987.

The pack ice conditions recorded in October off Enderby Land and Prydz Bay would not exclude whales from travelling throughout the pack ice zone and since these conditions presumably represent winter conditions in the pack ice it is suggested some minke whales could possibly spend the winter in the pack ice.

INTRODUCTION

Two extensive surveys of seals were undertaken in the pack ice zone of Eastern Antarctica during October-December 1985 and 1987. All whales sighted during these cruises were recorded also. This note presents observations of minke whales in the pack ice zone off East Antarctica, conducted on two complete traverses (October to December 1985), off Enderby Land and (October to November 1987), off Prydz Bay. The traverses began in October when the pack ice was at its predicted maximum annual extent (Jacka, 1983). Observations were conducted from the MV *Nella Dan* and helicopters operating from the vessel.

In addition, sightings of other whales in the pack ice and on the transit voyages from Hobart to the pack ice edge are presented.

Minke whales were recorded by Taylor (1957) in the pack ice zone in October after spending the winter apparently trapped in the pack ice off Graham Land. This was thought to be an isolated event caused by an unusual freezing pattern of the sea ice. Recently, minke whales have been observed within the pack ice of the Weddell sea during winter and spring conditions: in July – August 1986, 29 minke whales were recorded from the RV *Polarstern* during a traverse of the pack ice zone in the eastern Weddell Sea (Schnack-Schiel, 1987); and they were again recorded in spring 1986 (Stonehouse and Hempel, 1987) on a subsequent voyage of the RV *Polarstern*, in polynyas and a shore lead in the eastern Weddell sea (southern bottlenose whales were the most common species recorded and killer whales were also seen).

The paucity of information on the distribution of whales within the pack ice zone in the spring is probably because few vessels penetrate the pack ice this early in the season. It is commonly believed that minke whales in the Southern Hemisphere at this time of the year are mostly migrating south towards the Antarctic from breeding grounds in more temperate waters.

The International Whaling Commission (IWC) has conducted research cruises, during the past ten austral summers (1979–88), aimed at assessing the distribution and abundance of minke whales in the Southern Ocean (e.g. see Joyce, Kasamatsu, Rowlett and Tsunoda, In Press). These cruises have surveyed the open ocean north of the pack ice; research has been scheduled to coincide with the peak in the seasonal abundance of minke whales in the Antarctic, which occurs in January (Kasamatsu and Ohsumi, 1981). Minke whales are frequently observed throughout the pack ice zone during the summer months (Naito, 1982), however, their distribution and abundance in this habitat at other times of the year remain an enigma.

METHODS

While in the pack ice, shipboard observations for whales were conducted in concert with studies on pack ice seals, during all daylight hours. Pack ice concentration; size, development and topography of floes were systematically recorded as part of the seal study. Observations from helicopters were also conducted, during both cruises, on line transects ranging up to 30 n.miles from the vessel. Two *Hughes* 500 helicopters, flying in company, were used for the surveys with one observer in each aircraft. Flights were made radially out from the vessel on pre-determined tracks. No attempt was made to follow open water or leads. Speed and altitude were maintained as close as possible to 90 knots and 750 feet, respectively. A transect width of 1km was surveyed.

Cruise narratives and pack ice conditions encountered

Characteristics of the pack ice are presented only in general terms in this note. A more comprehensive description will be presented elsewhere in relation to the besetment of the *Nella Dan* and the distribution and abundance of crabeater seals. Jacka *et al.* (1987) describe the pack ice conditions in 1985.

The 1985 cruise

The 1985 cruise (Fig. 1), in transit from Hobart to Heard Island, encountered the pack ice edge on 27 September at 57°05′S, 85°35′E. From this position the pack ice was penetrated for a distance of 55km, after which the *Nella Dan* left the ice and visited Heard Island. She re-entered the pack ice on 8 October at 59°30′S, 60°00′E, off Enderby

---

* Present address: Governors Bay, R. M. D., Lyttleton, New Zealand.

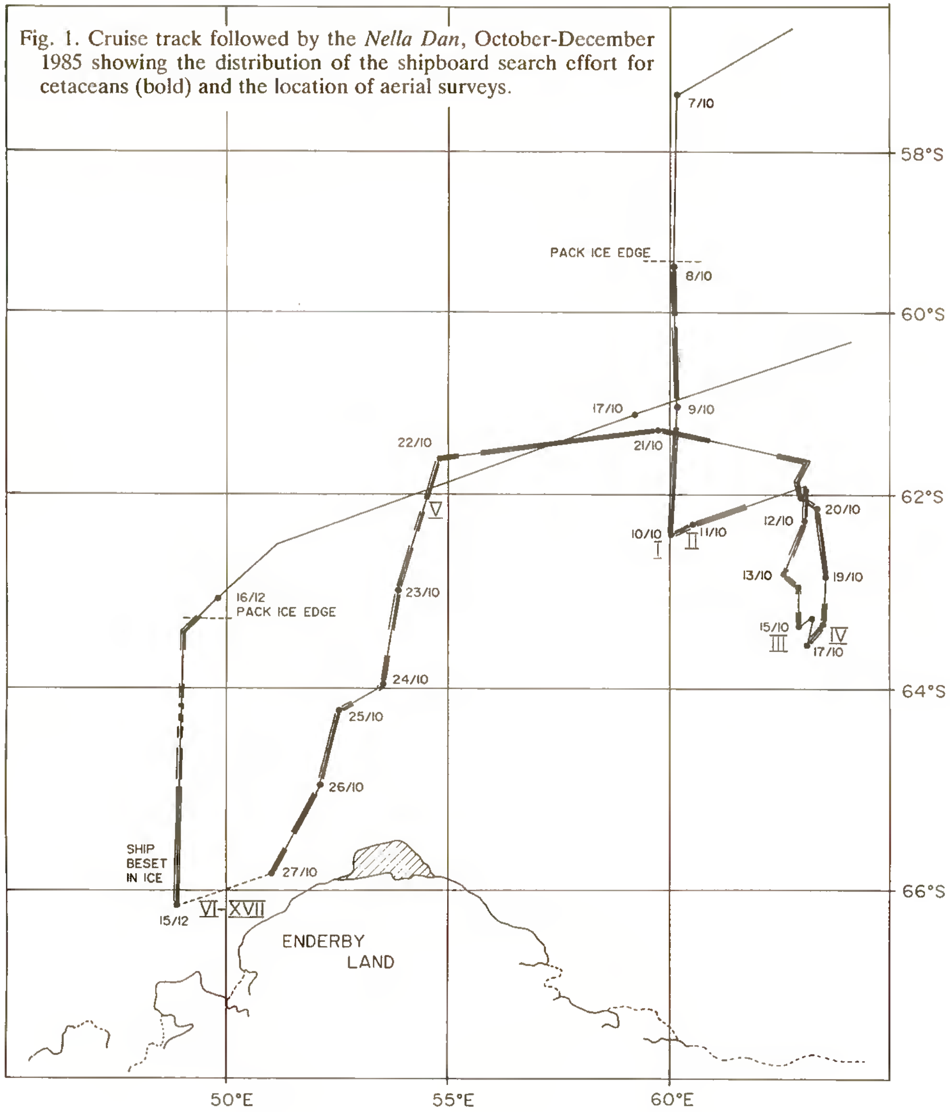


Fig. 1. Cruise track followed by the *Nella Dan*, October-December 1985 showing the distribution of the shipboard search effort for cetaceans (bold) and the location of aerial surveys.

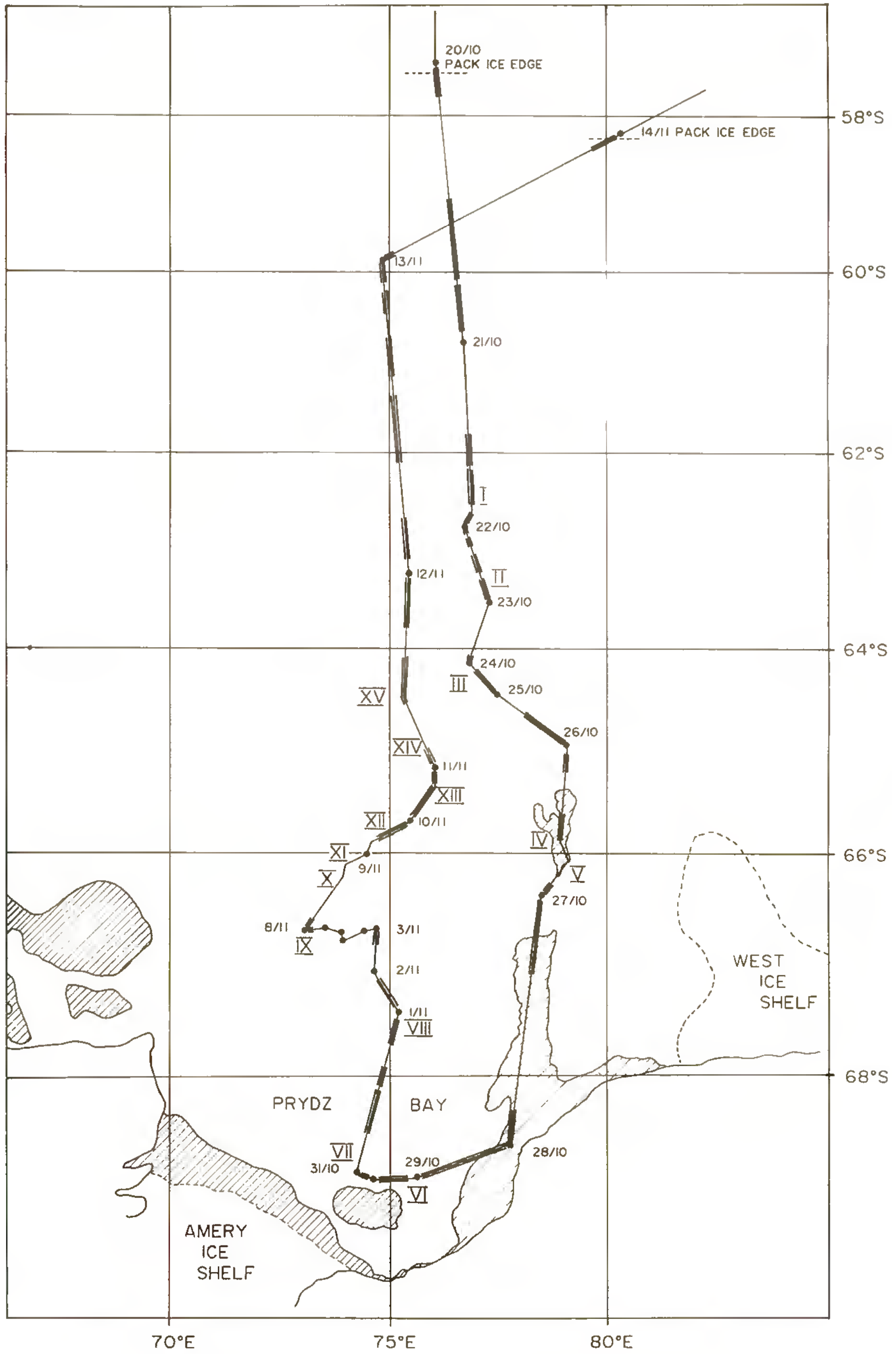


Fig. 2. Cruise track followed by the *Nella Dan*, October-November 1987 showing the distribution of the shipboard search effort for cetaceans (bold) and the location of aerial surveys.

Land and traversed the pack ice zone to near Cape Ann (66°10′S, 51°22′E) where the vessel became beset on 28 October. While beset, the vessel drifted with the pack ice until broken out by the Japanese icebreaker *Shirase* on 14 December. The vessel left the pack ice on 16 December at 63°07′S, 49°25′E.

On 8 October the pack ice margin consisted of streaks of shuga and grease ice. Within 50km of the ice edge, the concentration of the pack ice increased to 9/10; floes were small (less than 20m diameter). There was a gradual increase in size of floes as the vessel progressed south to 62°20′S and small polynyas, up to 0.5km by 2km were a feature. Between 62°20′S and 62°45′S, the pack ice concentration was 9/10 to 10/10 and floes were large (up to 2km by 5km, with occasional floes to 10km) and open water was rare (although some scattered polynyas up to 2km by 2km were recorded). South of this band of high concentration, the pack ice was more varied in composition (although concentrations to 10/10 were occasionally encountered, floes were generally smaller in size) and belts of lower concentration were encountered. Small polynyas were commonly encountered and also several branching polynyas more than 20km long, oriented North-South. Some of these polynyas interconnected, or were separated by narrow belts of looser pack ice and formed continuous open water areas up to 35km in length. Almost all open water areas throughout the pack ice were partially covered with grease ice and new ice. Near the fast ice edge at the Antarctic coast (near 66°00′S, 51°00′E), which was reached on 27 October, the pack ice was 9/10 to 10/10 in concentration, floes were small and extensively pressure ridged. Along the fast ice edge, extensive shore leads were observed. Satellite imagery showed the existence of a large polynya system joining to the shore lead to the east near Cape Close (65°55′S, 52°50′E).

The *Nella Dan* was broken free from her beset position on 14 December. The pack ice concentration at this position was 10/10 (although a narrow shore lead was present in places along the coast). Pack ice concentration gradually decreased towards the north and polynyas and leads became increasingly common. Occasional belts of higher concentration of pack ice were present. These belts were aligned east-west.

Mainly open water existed north of 64°30′S with bands of floes and scattered brash ice forming the northern limit at 63°07′S, 49°25′E.

The pack ice edge had retreated over 400km since early October. In October all leads and polynyas within the pack ice were partially covered with grease ice and new ice while in December, new ice was not encountered.

The 1987 cruise

On the 1987 cruise (Fig. 2), the *Nella Dan*, in transit between Macquarie Island and Heard Island, encountered the pack ice edge several times between 59°56′S, 114°07′E and 59°43′S, 102°57′E. After a visit to Heard Island the vessel entered the pack ice on 20 October at 57°35′S, 75°55′E and traversed the pack ice zone to the fast ice edge in Prydz Bay at 68°33′S, 77°40′E by 28 October. She then proceeded north through the pack ice and on 14 November departed the ice edge at 58°15′S, 80°18′E.

The pack ice edge on 20 October consisted of scattered belts of pack ice up to 4/10 in concentration. Open water was present between the belts. South to 64°10′S, the pack ice gradually increased in concentration (at times to 10/10) and floes increased in size up to 10km. Scattered, relatively large polynyas, separated by areas of lower concentration of pack ice, however were still present. South of this area of higher pack ice, the concentration was generally lower and extensive north-south polynyas were encountered. Some of these polynyas interconnected but bands of heavier pack ice up to 10/10 concentration were also present. An extensive polynya joined the shore lead on the east of Prydz Bay (from 66°30′S to the fast ice edge at 68°38′S). The fast ice edge was reached on 28 October. Satellite imagery showed an extensive shore lead along the entire coast of Prydz Bay.

On the northward track, through the pack ice in central Prydz Bay, the pack ice was higher in concentration and polynyas were less frequently encountered. Floes were generally larger and pressure in the pack ice was greater than that encountered on the southward track. North of 66°S the pack ice was variable in concentration but up to 8/10 – 9/10 in some areas. Polynyas and areas of low concentration of pack ice were frequently encountered. North from 64°S to the pack ice edge at 58°32′S, 80°23′E floes were small and belts of loose pack ice were encountered with open water areas becoming more frequent.

RESULTS

The total distance travelled by the vessel in pack ice zone on the 1985 cruise was 2,562km and survey was conducted along 1,618km of this distance. The 1987 cruise covered 2,935km in the pack ice and 1,510km of the trackline was surveyed.

On the 1985 cruise six flights surveying 641km^2 were conducted over the pack ice. Eleven flights were made while the vessel was beset and 1,471km^2 was surveyed. Fifteen flights during the 1987 cruise surveyed 2,152km^2.

The cruise tracks followed by the vessel, distribution of search effort along the tracks and locations of the aerial surveys during the cruises are shown in Fig. 1 (1985) and Fig. 2 (1987). Cetacean sightings made are presented in Tables 1–3. The identification of whales to species was not always possible, since some whales were only seen at long distances from the vessel, or seen only briefly. Those whales not positively identified to species but probably belonging to that species are presented in the tables as ‘like’ the given species.

The distribution of whale sightings within the pack ice zone are shown in Fig. 3 (1985) and Fig. 4 (1987).

Minke whales were observed at the pack ice edge in late September 1985 and early October 1987 and they were widely distributed throughout the pack ice zone to near the edge of the fast ice during October in both 1985 and 1987.

Killer whales were observed also in the pack ice zone in October 1985 and southern bottlenose whales were recorded near the pack ice edge in both 1985 and 1987.

During aerial surveys in 1985 no whales were seen; 25 minke whales and 5 unidentified whales were seen during the 1987 aerial surveys (Table 2).

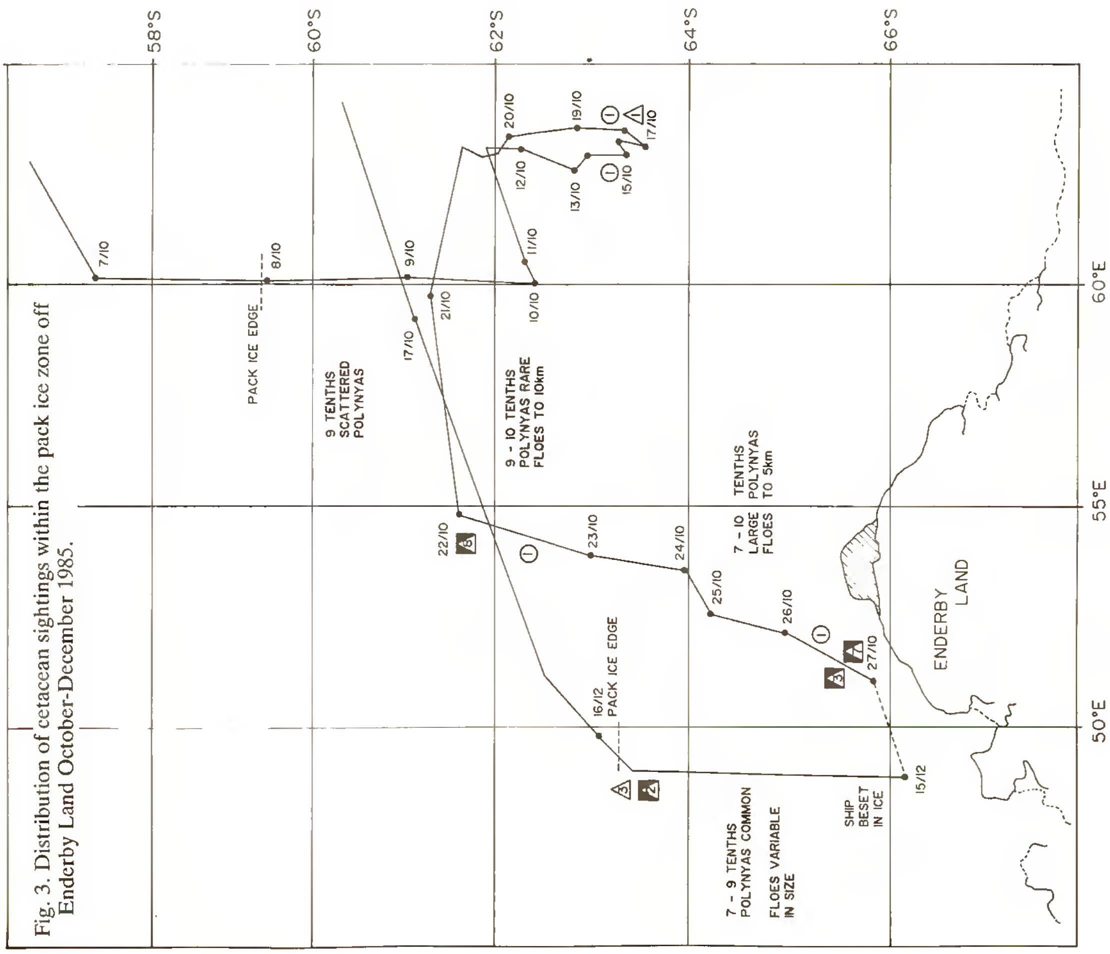


Fig. 3. Distribution of cetacean sightings within the pack ice zone off Enderby Land October-December 1985.

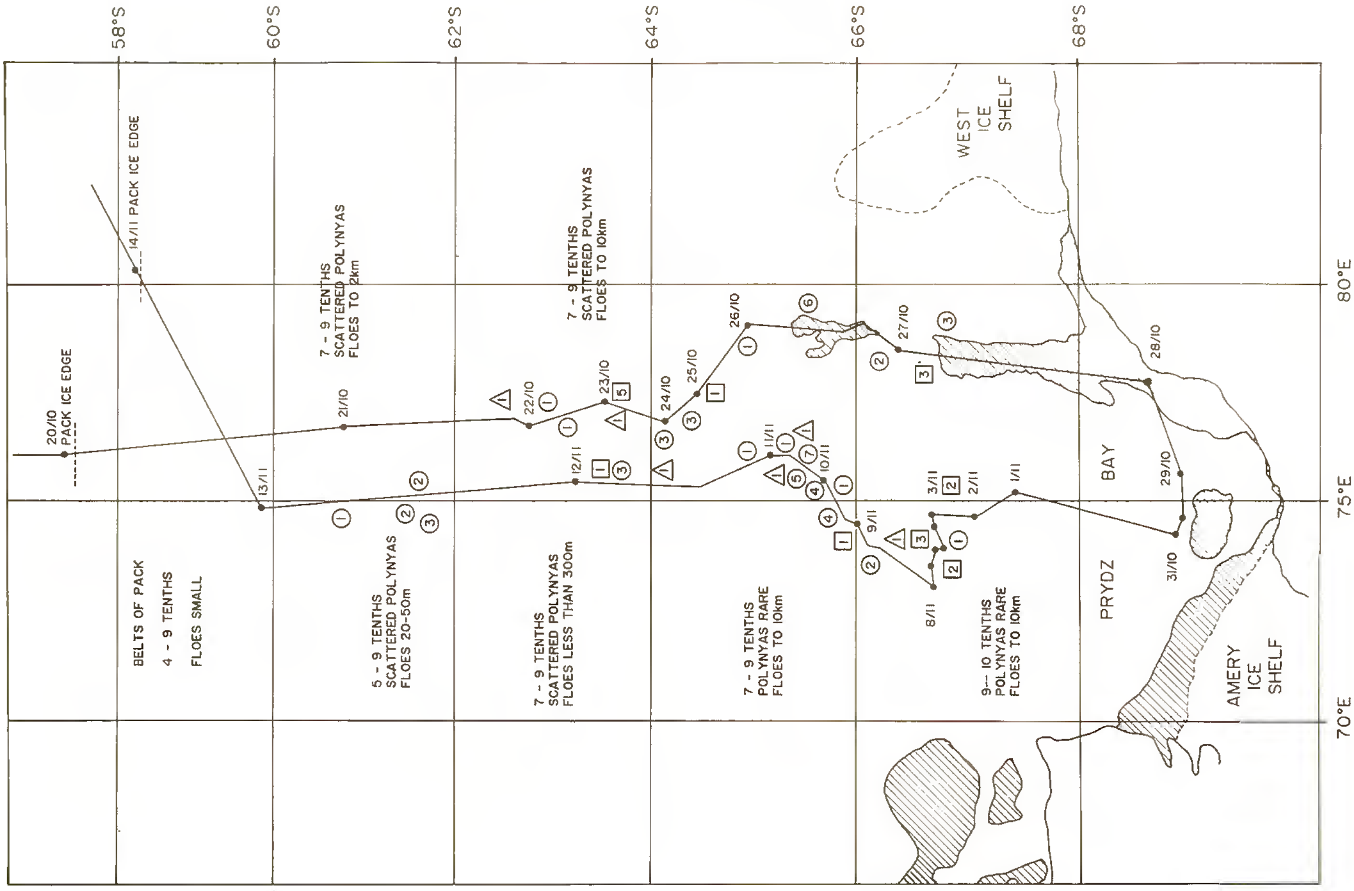


Fig. 4. Distribution of cetacean sightings within the pack ice zone off Prydz Bay October-November 1987.

Table 1

Shipboard observations of Cetacea in the pack ice, 1985 and 987. M = minke whale, K = killer whale, B = southern bottlenose whale, ?M = like minke, ?B = like bottlenose, ? = unidentified whale

								Ice	
Date	Position	M	K	B	?M	?B	?	Cover (tenths)	Conditions at sighting position
1985, September									
27	57°00'S 85°40'E	–	–	2	–	–	–	0	Near pack ice edge
27	57°03'S 85°20'E	–	–	–	1	–	–	0	Near pack ice edge
27	52°28'S 88°45'E	2	–	–	–	–	–	0	Between belts of pack ice
1985, October									
15	63°15'S 63°04'E	1	–	–	–	–	–	7–9	Narrow lead
17	63°37'S 63°07'E	–	–	–	–	–	1	9	Polynya
18	63°22'S 63°22'E	1	–	–	–	–	–	9	Polynya
22	61°24'S 54°52'E	–	8	–	–	–	–	9	Polynya
22	62°25'S 53°50'E	1	–	–	–	–	–	9	Lead
26	65°17'S 52°05'E	1	–	–	–	–	–	9	Lead
26	65°18'S 51°51'E	–	3	–	–	–	–	5–8	Polynya
26	65°25'S 51°52'E	–	7	–	–	–	–	5–8	Same polynya
1985, December									
16	63°35'S 48°58'E	–	2	–	–	–	–	4	Between belts of ice near pack edge
16	63°23'S 48°57'E	–	–	–	–	–	2	1	At pack ice edge
1987, October									
12	59°56'S 112°43'E	–	–	2	–	–	–	0	Near pack ice edge
12	59°55'S 105°11'E	–	–	–	–	–	3	0	Near pack ice edge
13	59°43'S 102°57'E	1	–	–	–	–	–	0	Near pack ice edge
13	58°31'S 97°00'E	–	–	–	–	1	–	0	Near pack ice edge
22	62°42'S 76°26'E	–	–	–	–	–	1	6–8	Polynya
23	62°56'S 76°44'E	1	–	–	–	–	–	5–8	Lead
23	63°10'S 76°53'E	1	–	–	–	–	–	9	In pack ice near polynya
23	63°40'S 77°12'E	–	–	–	5	–	–	5–7	Polynya
23	63°40'S 77°12'E	–	–	–	–	–	1	5–7	Polynya
24	64°11'S 77°35'E	3	–	–	–	–	–	9	Polynya
25	64°23'S 77°59'E	3	–	–	–	–	–	9	Lead 100m wide
25	64°30'S 78°22'E	–	–	–	1	–	–	9–10	Lead near polynya
26	64°52'S 79°09'E	1	–	–	–	–	–	6–9	Lead
26	65°36'S 79°02'E	6	–	–	–	–	–	5–8	Between belts of pack ice
27	66°10'S 78°09'E	2	–	–	–	–	–		
27	66°42'S 78°08'E	–	–	–	3	–	–	2–5	Polynya joining to shore lead
27	66°56'S 77°48'E	3	–	–	–	–	–	2–3	Shore lead
1987, November									
2	66°48'S 75°05'E	–	–	–	2	–	–	8–9	Lead near polynya
5	66°49'S 74°09'E	–	–	–	3	–	–	9–10	Narrow lead
5	66°49'S 74°04'E	1	–	–	–	–	–	9–10	Breathing at narrow lead
6	66°49'S 74°00'E	–	–	–	2	–	–	9–10	Breathing at narrow lead (in distance)
8	66°20'S 74°53'E	–	–	–	–	–	1	9	In narrow lead
9	66°01'S 74°22'E	2	–	–	–	–	–	7–9	Polynya
9	65°59'S 74°40'E	–	–	–	1	–	–		Lead
9	65°56'S 74°55'E	4	–	–	–	–	–	7–9	Polynya
9	65°51'S 73°36'E	1	–	–	–	–	–		Narrow lead
9	65°49'S 75°52'E	4	–	–	–	–	–	7–9	Narrow lead
10	65°47'S 75°54'E	7	–	–	–	–	–	9	Lead
10	65°43'S 75°36'E	–	–	–	–	–	1	9	Lead
10	65°36'S 75°21'E	5	–	–	–	–	–	9	Lead
11	65°30'S 75°46'E	–	–	–	–	–	1	5–9	Small polynya
11	65°30'S 75°47'E	1	–	–	–	–	–	5–7	Narrow lead
11	65°04'S 75°46'E	1	–	–	–	–	–	4–9	Small polynya
12	64°07'S 75°02'E	–	–	–	–	–	1	0	Small polynya
12	63°48'S 75°06'E	3	–	–	–	–	–	0–2	Between belts of pack ice
12	63°36'S 75°10'E	–	–	–	1	–	–	0–2	Between belts of pack ice
13	61°43'S 74°57'E	3	–	–	–	–	–	4	Between belts of pack ice
13	61°37'S 74°59'E	2	–	–	–	–	–	8	Polynya
13	61°35'S 75°00'E	2	–	–	–	–	–	0–2	Same polynya
13	60°51'S 75°19'E	1	–	–	–	–	–	7–8	Between belts of ice

Table 2

Aerial observations of Cetacea in the pack ice, 1985 and 1987. + = scattered small polynyas and leads; ++ = polynyas and leads present; +++ = extensive polynyas present. Flights VII to XVII (1985) were conducted from near the same position while the vessel was beset, and drifting with the pack ice. Area = Area surveyed (km²), M = minke whale, ? = unidentified whale. Numbers are presented as groups/animals

						Pack ice cover (tenths)	
Date	Flight no.	Start position	Area	M	?	Mean (range)	Polynyas and leads
1985, October							
10	I	62°27'S 59°54'E	177	–	–	9–10 (5–10)	+
11	II	62°22'S 60°24'E	162	–	–	8–9 (5–10)	+
15	III	63°27'S 62°49'E	93	–	–	8–9 (7–10)	+
17	IV	63°27'S 63°08'E	96	–	–	9–10 (5–10)	+
22	V	62°06'S 54°16'E	113	–	–	8–9 (6–10)	+
27	VI	65°55'S 51°15'E	141	–	–	9–10 (1–10)	++
29	VII	65°55'S 50°30'E	101	–	–	9–10 (3–10)	+
30	VIII	–	182	–	–	9–10 (2–10)	+
31	IX	–	102	–	–	9–10 (9–10)	+
1985, November							
1	X	–	90	–	–	9–10 (2–10)	+
3	XI	–	269	–	–	9–10 (5–10)	++
7	XII	–	49	–	–	9–10 (7–10)	+
9	XIII	–	124	–	–	9–10 (6–10)	++
19	XIV	–	143	–	–	9–10 (9–10)	+
1985, December							
3	XV	–	25	–	–	9–10 (9–10)	++
8	XVI	–	58	–	–	9–10 (9–10)	+
14	XVII	–	191	–	–	9–10 (9–10)	+
1987, October							
22	I	62°38'S 76°27'E	242	–	–	9–10 (7–10)	+
23	II	63°32'S 77°03'E	234	–	–	7–9 (7–9)	++
24	III	64°11'S 77°31'E	253	–	–	8–9 (5–9)	+
27	IV	65°54'S 78°42'E	80	–	–	5–9 (5–9)	+
27	V	66°06'S 78°08'E	216	–	–	7–9 (0–9)	+++
29	VI	68°41'S 75°42'E	152	–	–	9–10 (9–10)	++
31	VII	68°43'S 74°37'E	243	–	–	10 (7–10)	+
1987, November							
1	VIII	67°29'S 75°10'E	242	–	–	9 (6–9)	+
5	IX	66°49'S 74°07'E	296	3/15	–	7–10 (7–10)	++
9	X	66°18'S 73°56'E	279	–	–	9 (7–10)	+
9	XI	66°10'S 74°10'E	136	–	–	8–9 (5–9)	+
9	XII	65°59'S 74°40'E	281	2/7	3/4	7–9 (5–9)	+
11	XIII	65°25'S 75°48'E	130	–	–	6–7 (4–9)	+
11	XIV	65°07'S 75°49'E	142	–	–	5–8 (5–8)	+
12	XV	64°32'S 75°17'E	527	1/3	1/1	9 (4–9)	+

Whales were observed from the vessel, in pack ice conditions ranging from narrow leads in ice of 9/10 – 10/10 concentration to large polynyas and shore leads. All the whales seen from the vessel were swimming slowly; swimming direction was usually oriented along with the largest dimension of the open water area if this was narrow – in open water areas there was no obvious north-south swimming direction. Minke whales were seen rising vertically, rostrum first, to breath through narrow cracks in very close pack ice in the manner described by Taylor (1957) and Naito (1982).

The whales observed during the aerial surveys were all in relatively large areas of open water, in compact groups and all were swimming slowly near the water surface. All but five minke whales were outside the 1km transect width and were first observed by the helicopter pilots. The aircraft did not divert from the seal survey transects and the whales were not approached. No reaction of the whales to the aircraft was noted. On one occasion several whales in one group were observed swimming on their sides just below the water surface; this was probably feeding behaviour.

All the minke whales observed in the pack ice appeared to be of adult size.

Table 3

Cetacean sightings in transit between Hobart and the pack ice, 1985 and 1987. M = minke whale, B = southern bottlenose whale, P = pilot whale, K = killer whale, S = sperm whale, R = southern rightwhale dolphin, C = Cruciger dolphin, ?M = like minke, ?H = like humpback, ?S = like sperm, ?K = like killer, ?Z = like ziphiid, ? = unidentified whale, ?C = like Cruciger dolphin, ?D = unidentified dolphin. Numbers are presented as groups/animals

Date	Position	M	B	P	K	S	R	C	?M	?H	?S	?K	?Z	?	?C	?D
1985, September																
18	49°23'S 135°18'E	-	1/3	-	-	-	-	-	-	-	-	-	-	-	-	-
19	50°12'S 133°01'E	-	-	-	-	-	-	-	-	-	-	-	-	1/3	-	-
21	53°03'S 122°48'E	-	-	1/25	-	-	1/8	-	-	-	-	-	-	-	-	-
23	56°19'S 109°40'E	-	-	-	-	-	-	-	-	-	-	-	-	1/3	-	-
29	53°42'S 74°45'E	-	-	-	-	-	-	-	-	-	-	-	1/1	-	-	-
29	53°38'S 74°33'E	-	-	-	-	-	-	-	-	-	-	-	1/1	-	-	-
29	53°21'S 73°21'E	-	-	-	-	-	-	-	-	-	1/1	-	-	-	-	-
1985, December																
18	58°24'S 74°34'E	-	-	-	-	-	-	-	-	-	-	-	-	1/1	-	-
19	58°03'S 76°37'E	1/1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	57°55'S 84°22'E	-	-	-	-	-	-	-	-	-	-	-	-	1/1	-	-
21	57°11'S 96°15'E	-	-	-	-	-	-	-	-	1/1	-	-	-	-	-	-
22	56°28'S 108°09'E	-	-	-	1/7	-	-	-	-	-	-	-	-	-	-	-
23	56°17'S 109°38'E	-	1/1	-	-	-	-	-	-	-	-	-	-	-	-	-
24	54°49'S 118°26'E	-	-	1/3	-	-	-	-	-	-	-	-	-	-	-	-
25	52°12'S 128°27'E	-	-	-	-	-	-	-	-	-	-	-	1/1	-	-	-
26	49°09'S 141°04'E	-	-	-	1/7	-	-	-	-	-	-	-	-	-	-	-
26	49°06'S 141°08'E	-	-	-	-	1/1	-	-	-	-	-	-	-	-	-	-
27	43°13'S 144°35'E	-	-	1/20	-	-	-	-	-	-	-	-	-	-	-	-
28	43°45'S 147°03'E	-	-	-	1/1	-	-	-	-	-	-	-	-	-	-	-
1987, October																
6	55°05'S 158°00'E	-	-	-	1/5	-	-	-	-	-	-	-	-	-	-	-
7	58°23'S 146°59'E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1/3
7	58°42'S 145°46'E	-	-	-	-	-	-	-	-	-	-	1/1	-	-	-	-
8	58°57'S 144°50'E	-	-	-	-	-	-	-	1/5	-	-	-	-	-	-	-
8	59°22'S 142°47'E	-	-	-	-	-	-	-	-	-	-	-	-	-	1/3	-
10	59°59'S 126°31'E	-	1/3	-	-	-	-	-	-	-	-	-	-	-	-	-
1987, November																
14	58°04'S 95°07'E	-	-	-	-	-	1/1	-	-	-	-	-	-	-	-	-
14	57°48'S 93°52'E	-	-	-	-	-	-	1/20	-	-	-	-	-	-	-	-
15	56°48'S 89°06'E	-	-	-	-	-	-	1/4	-	-	-	-	-	-	-	-
15	56°32'S 88°04'E	-	-	-	-	-	-	-	-	-	-	-	-	-	1/3	-

DISCUSSION

More whales were seen during the 1987 cruise than on the 1985 cruise. It is unknown whether this difference reflects a difference in abundance between the two areas during the two years in question. The IWC assessment cruises in the Prydz Bay area have shown that the density of whales was higher there than off Enderby Land. It is likely therefore that the abundance of whales in the pack ice zone off Prydz Bay was higher than that in the pack ice off Enderby Land.

There were no major differences between the pack ice conditions encountered off Enderby Land during October 1985 and off Prydz Bay during October-November 1987, apart from the presence of a band of more concentrated pack ice between 62°00′S and 63°30′S off Enderby Land. Minke whales were, however, observed within this band of pack ice and also south of it. Off Enderby Land breeding crabeater seals were not observed in the pack ice apart from near the Antarctic continent, while off Prydz Bay they were far more abundant and widely distributed through the pack ice zone. It is unlikely that the pack ice conditions resulted in the lower numbers of whales seen on the 1985 cruise.

Off Enderby Land in 1985 where fewer whales were encountered, the abundance of Euphausiids was apparently low, since few were caught in trawls conducted during the cruise and few were seen by divers under the ice. On the 1987 cruise, trawls and diving operations were not conducted but Euphausiids were observed on several occasions stranded on ice floes which were broken and overturned as the vessel proceeded through the ice; particularly on 25 October (64°19′S, 77°43′E), 9 November (66°06′S, 74°03′E), 11 November (65°34′S, 75°23′E), and 12 November (64°07′S, 75°02′E). These positions coincided with the area where minke whales were most commonly encountered (Fig. 4).

From both the vessel and the aircraft, effort was directed at searching for seals on the pack ice, and for this reason many whales were probably missed.

Minke whales were widespread in the pack ice in both regions studied and relatively abundant in the pack ice off Prydz Bay in October and November. Numbers within the pack ice zone would be expected to be even higher in mid–summer when the whale population off the pack ice edge reaches a peak due to the southward migration (this would of course be offset by the recession of the ice edge and consequent decrease in the extent of the pack ice zone).

A feature of the pack ice encountered during the present cruises was that open water areas were widely distributed throughout the pack ice zone. Wind-driven pressure caused localised areas of higher ice concentration. Complete ice cover occurred but this was usually only in areas where floe sizes were small and there was much broken, brashy ice present. When floes were large there were usually small open water areas where parts of broken larger floes were displaced along irregular fractures. These open water areas on occasions were only several meters in size but of sufficient dimension to allow whales to breathe.

The present observations show that as early as October, minke whales are present within the pack ice zone and that they can travel with relative ease throughout the zone (with the possible exception of localised areas of high ice pressure). This raises the possibility that some minke whales may be able to over-winter within the pack ice zone given that ice conditions encountered during October are typical of winter conditions. In a description of the abundance and sex ratio of minke whales near the pack ice edge, based on catch records, Kasamatsu and Ohsumi (1981) showed that in general terms, males preceed females in the migration south towards the pack ice in the early summer. Along the pack ice edge, later in the season, when the abundance of whales is highest, females are more numerous than males. Although the whales observed in the pack ice zone in early spring during the present study all appeared to be of adult size, their age and sex are unknown. Also unknown is the extent of the food resource that would be available to the whales in the pack ice during the winter and early spring, since little information exists on the distribution and abundance of krill under the pack ice zone at this time of the year.

ACKNOWLEDGEMENTS

Thanks are due to Australian National Antarctic Research Expeditions for the priviledge of participating in their crabeater seal research program. I am indebted to Captain A. Sorensen, officers and crew of the MV *Nella Dan* and pilots G. Findlay, C. Pain, L. Hornsby and C. Hardiman from Helicopter Resources Pty Ltd Australia. Jennifer A. Bassett and D. Eslake assisted with aerial observations. Thanks to G. Joyce, 826 NE 80th Street, Seattle, Washington, USA., M. Cawthorn, Department of Conservation, Wellington, New Zealand, and K. Kerry Antarctic Division, Kingston 7050 Tasmania, Australia for their valuable comments on the manuscript.

REFERENCES

Jacka, T.H. 1983. A computer data base for Antarctic sea ice extent. *ANARE Research Notes* 13. 54pp.

Jacka, T.H., Allison, I., Thwaites, R. and Wilson, J.C. 1987. Characteristics of the seasonal sea ice off East Antarctica and comparisons with satellite observations. *Annuals of Glaciology* 9: 85–91.

Joyce, G.G., Kasamatsu, F., Rowlett, R. and Tsunoda, L. In Press. The IWC/IDCR Southern Hemisphere minke whale assessment cruises. *Rep. int. Whal. Commn* (special issue series).

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: 345–355.

Naito, Y. 1982. Sightings records of minke whales in the pack ice and adjacent waters off the coast of Enderby Land. *Rep. int. Whal. Commn* 32: 929–33.

Schnack-Schiel, S. 1987. Die Winter Expedition mit FS 'Polarstern' in die Antarktis (Ant V/1–3). Mammal and seabird observations. *Berichte zur Polarforschung* 39: 116–7.

Stonehouse, B. and Hempel, G. 1987. Aerial counts of emperor penguins, weddell seals and whales. *Bericht zur Polarforschung* 39: 227–30.

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.

SC/40/Mi12

A Note on the North Atlantic Minke Whales and IWC Policy, in Response to SC/40/Mi1

R. M. Anderson[1], R. J. H. Beverton[2] and L. Walløe[3]

INTRODUCTION

Holt (1989) presents a critique of Walløe, Anderson, Beverton and Semb-Johansson (1987). We believe that the critique is largely misplaced and is based on a misunderstanding of Walløe *et al.* (1987). The purpose of this note is not to deal with the minutiae of Holt's (1989) criticisms but rather to summarise concisely the main points of Walløe *et al.* (1987), which we believe to be unaffected by those criticisms.

ASSESSMENT AND MANAGEMENT

The validity of any assessment is dependent on the quality of available data. Walløe *et al.* (1987) discussed the three types of quantitative data available for this stock of minke whales (catch-per-unit effort series, mark-recapture and sightings survey data) and, like Holt (1989), concluded that they were not of sufficient quality to permit an accurate assessment of the current stock size, an appropriate level of exploitation or the maximum sustainable yield level. However, despite the problems identified with the data, Walløe *et al.* (1987) also concluded that the data could not support a view that the stock was in imminent danger. This was further supported by an examination of other factors including the distribution and behaviour of the whales and the nature of Norwegian whaling operations.

From the above examination, Walløe *et al.* (1987) concluded that it could not be argued that this stock was unable to stand any level of harvesting, however small – unless that stock was already in serious decline through adverse natural conditions (see below). There is no scientific reason why, in principle, a strategy for harvesting and monitoring which would enable the yield to be kept within the natural replenishment capacity of the stock, could not be developed. Whether the level of such a harvest would be economic was outside the remit of Walløe *et al.* (1987). Such a strategy would not be compatible with the current management procedure of the IWC. That procedure was strongly criticised in Walløe *et al.* (1987) and, as noted by Holt (1989), has been criticised by the IWC Scientific Committee which is in the process of developing a new procedure.

Walløe *et al.* (1987) therefore advised that if minke whaling was to continue, a cautious stepwise management regime should be adopted, with a low initial annual catch limit. They suggested a value of 200 animals which is (1) between 0.1 and 0.2 of the mean take in the forty or so years prior to the introduction of catch limits and (2) about 1.5% of the lowest mark-recapture estimate for the stock which places it at the lower end of, or below, the range of natural population growth rates reported for other species of whales.

Holt (1989) strongly criticises the calculation of replacement yield in Walløe *et al.* (1987). In fact Walløe *et al.* emphasised that the calculation was *not* used as the basis of a prediction for action, but simply to demonstrate: (a) that with the sparse data on population parameters, the possible range of answers was wide and included negative as well as positive values; and (b) the relative sensitivity of the answer to the numerical values of the main parameters, notably juvenile mortality rate, maturity rate, and pregnancy rate.

In addition, they did not claim that 200 whales corresponded to a particular level of harvesting or was 'safe' if continued indefinitely. It was put forward with the strict proviso that it should be accompanied by appropriate research and monitoring so that the consequences could, in due course, be better assessed and the quota adjusted accordingly. Obtaining detailed and reliable CPUE data is one way forward in this respect. As a precaution against the possibility of a serious depletion being undetected by CPUE data, periodic independent checks on abundance are essential and should be included in the monitoring programme. Provided the whaling effort can, if necessary, be quickly reduced, this form of carefully monitored harvesting involves no tangible risk to the stock.

This pragmatic approach, first enunciated for fisheries by Beverton and Holt (1957), is widely adopted, explicitly or implicitly, in the management of natural living resources. The approach has since been refined and developed by various workers (e.g. see Holling, 1978).

A further reason for continuous monitoring noted by Walløe *et al.* (1987) is one to which little attention seems to have been paid, i.e. the possibility, although speculative, that the northeast Atlantic minke whales might be in difficulties through adverse environmental conditions, unusually low temperatures in the Barents Sea in recent years and a substantial decline in their main fish food species (herring and capelin).

In conclusion, we would like to make the point that we believe that current discussions of the harvesting of whales are no longer purely a scientific/managerial matter. An important factor also appears to be the question of culture and the subjective judgement about the rights and wrongs of killing whales in any circumstances. We believe that it would be in the interests of all concerned, and the credibility of the IWC in particular, if this situation was acknowledged and the implications faced up to.

---

[1] *Department of Pure and Applied Biology, Imperial College, London SW7 2AZ, UK.*

[2] *University of Wales, Institute of Science and Technology, Cardiff, UK.*

[3] *University of Oslo, Department of Physiology, Karl Johans Gt 47, N-162 Oslo 1, Norway.*

REFERENCES

Beverton, R. J. H. and Holt, S. J. 1957. On the dynamics of exploited fish populations. *Fish. Invest. Ser. II Vol. 19.* HMSO, London.

Holling, C. S. (ed.) 1978. *Adaptive Environmental Assessment and Management.* John Wiley, London.

Holt, S. J. 1989. 'The State of the northeast Atlantic minke whale stock' – a critique. Paper SC/40/Mi1 (published in this volume).

Walløe, L., Anderson, R. M., Beverton, R. J. H. and Semb-Johansson, A. 1987. *The State of the Northeast Atlantic Minke Whale Stock: Report of the group of Scientists appointed by the Norwegian Government to review the basis for Norway's harvesting of minke whales.* Økoforsk, As. Norway. 100pp.

SC/40/Mi17

Latitudinal Segregation of the Okhotsk Sea – West Pacific Stock of Minke Whales

Shiro Wada

Far Seas Fisheries Research Laboratory, 5–7–1 Orido, Shimizu 424, Japan

ABSTRACT

The length distribution, sexual maturity rate, apparent pregnancy rate and sex ratio of minke whales from the Okhotsk Sea – West Pacific stock are analysed to clarify the nature of latitudinal segregation in summer by sex, size and reproductive status using data from 2,826 whales taken between 1969 and 1986 by Japanese coastal and pelagic whaling. The analyses reconfirmed the latitudinal segregation in coastal areas reported by previous workers, and also demonstrated a coastal/offshore segregation. The sexual maturity rate and apparent pregnancy rate in the offshore areas were higher than in the coastal areas. The percentage of females was high in the southern part of the Okhotsk Sea. Latitudinal segregation appears to be a common feature of all minke whale stocks.

INTRODUCTION

Latitudinal segregation of minke whales by sex and by size in the coastal waters of Japan has been examined by Matsuura (1936), Omura and Sakiura (1956) and Ohsumi (1983). They found that females were more abundant in northern areas and that mature animals tended to migrate further north than immature animals in both sexes. However, the data source for these studies was limited to the basic catch statistics.

Systematic sampling of testes, ovaries and foetuses has been carried out by Japanese small-type whaling since 1977. In addition, through the experimental operations by the factory-catcher, *Miwamaru* (1973–75) and operations of the Japanese fleets in 1969 and 1970, some biological information on minke whales in the offshore waters of the Okhotsk Sea, the western North Pacific and the Bering Sea is available. These coastal and offshore data have been used to examine aspects of segregation by sex, size and reproductive status in the Okhotsk Sea – West Pacific stock of minke whales.

MATERIALS

This paper examines the 'Record on biological investigations and samplings' for a total of 2,826 minke whales (1,634 males, 1,192 females) taken by Japanese small-type (1973–75 and 1977–86) and pelagic (1969–70) whaling. The 'Record' includes date and position of capture, sex, body length (m), weight of testes (kg), number of corpora and foetal sex and length (cm).

About 98.5% of the biological samples were collected by the whalers. Testes were weighed for 1,606 males. Both ovaries were collected from 1,119 females, and were sent to the Far Seas Fisheries Research Laboratory. Drs S. Ohsumi, T. Kasuya and H. Kato counted the corpora. The whalers collected 199 foetuses. Of the 2,826 whales, 28 males and 73 females were without gonadal data.

RESULTS

Catch and whaling ground

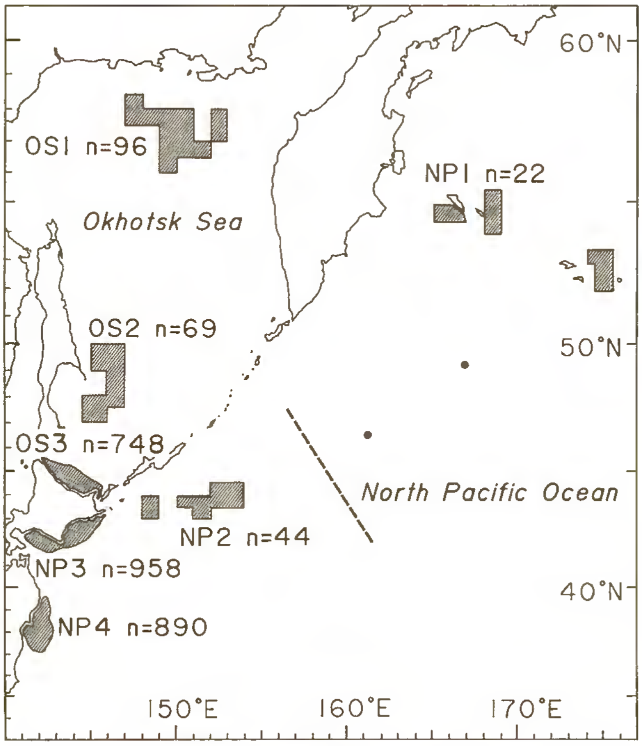


Fig. 1. Approximate range of the sampling areas, showing sample sizes.

For this study, the Okhotsk Sea whaling ground has been divided into three areas: OS1 (56°N-59°N), OS2 (47°N-50°N) and OS3 (44°N-46°N), and the western North Pacific and the Bering Sea into four areas: NP1 (52°N-56°N), NP2 (43°N-45°N), NP3 (41°N-43°N) and NP4 (37°N-40°N) as shown in Fig. 1. The coastal areas OS3, NP3 and NP4 correspond to the Regions A, B and C, respectively, in Ohsumi (1983) and Wada (1988), and the offshore areas OS1, OS2 and NP2 correspond to the Regions A3, A2 and B2, respectively, in Kasamatsu and Hata (1985).

During 1973–75, *Miwamaru* took 215 minke whales (96 in OS1, 69 in OS2, 6 in OS3 and 44 in NP2) outside the normal range of the small-type whaling fleet. In 1969 and 1970, Japanese pelagic fleets took 21 minke whales in NP1. Excluding the six whales in OS3 taken by *Miwamaru*, all catches in OS3, NP3 and NP4 were taken by normal small-type catcher boats between 1977 and 1986. Table 1 gives the sample size by area, sex and month. Catches in the offshore areas OS1, OS2, NP1 and NP2 comprised 3.4%, 2.4%, 0.7% and 1.6% of the total sample, respectively.

Table 1

Sample sizes of minke whales used in this study

Area	Sex	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
OS1	Male	–	–	–	33	8	10	–	51
	Female	–	–	–	27	12	6	–	45
	Total	–	–	–	60	20	16	–	96
OS2	Male	–	–	1	9	8	–	–	18
	Female	–	–	5	16	25	5	–	51
	Total	–	–	6	25	33	5	–	69
OS3	Male	4	80	62	23	12	39	–	220
	Female	123	219	132	27	11	16	–	528
	Total	127	299	194	50	23	55	–	748
NP1	Male	–	–	1	1	9	–	–	11
	Female	–	–	–	–	10	–	–	10
	Total	–	–	1	1	19	–	–	21
NP2	Male	–	–	–	–	–	21	7	28
	Female	–	–	1	–	–	10	5	16
	Total	–	–	1	–	–	31	12	44
NP3	Male	1	8	83	205	203	260	–	760
	Female	–	7	42	70	30	49	–	198
	Total	1	15	125	275	233	309	–	958
NP4	Male	235	172	93	39	7	–	–	546
	Female	198	118	18	10	–	–	–	344
	Total	433	290	111	49	7	–	–	890
Total	Male	240	260	240	310	247	330	7	1,634
	Female	321	344	198	150	88	86	5	1,192
	Total	561	604	438	460	335	416	12	2,826

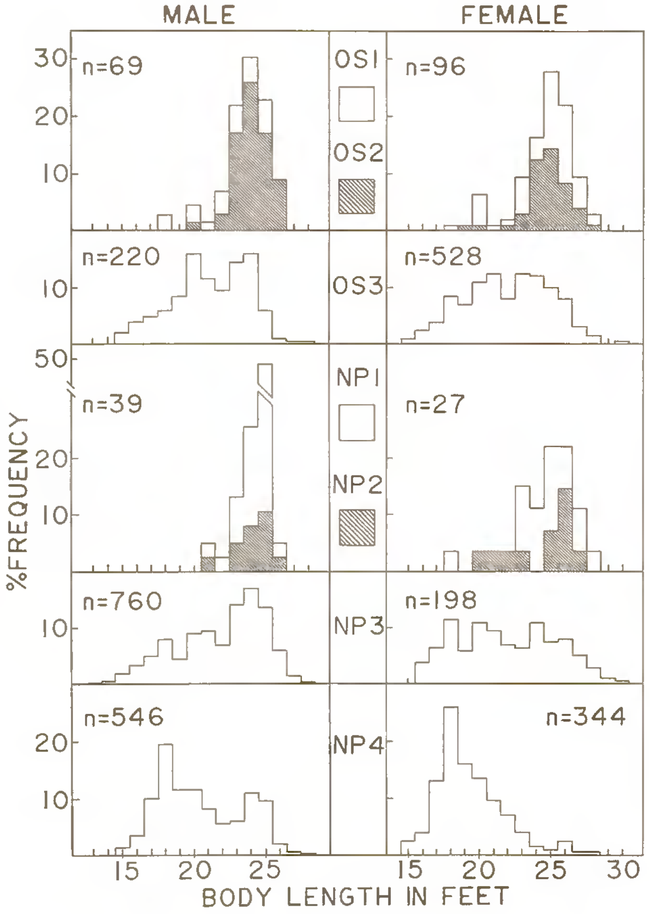


Fig. 2. Length composition of minke whales by sex in each area.

Size distribution

Fig. 2 shows the length compositions by area and sex. The length frequency as a whole showed three peaks: 5.5m; 6.1m; and 7.3–7.6m in males and 7.6–7.9m in females. In areas OS1+OS2 and NP1+NP2, larger animals were dominant in both sexes. In NP3, larger males but not females were dominant. In NP4, smaller animals, especially females, were dominant. The mean body length was largest in NP1+NP2, 7.4m for males and 7.5m for females, and smallest in NP4, 6.2m for males and 5.9m for females.

It should be noted that the length selectivity may vary among operation types. However, according to the 'Report on sightings by *Miwamaru*', she took 77 whales in 1974 out of 131 whales sighted in areas OS1, OS2, OS3 and NP2. The range and mean body length of the whales taken were 5.1–8.3m and 7.38m, respectively; this included 11 (13.8%) whales of 6.9m or less. The range and mean of the estimated body length of 54 whales not taken was 6.0–8.0m and 7.20m, respectively; 8 (14.8%) whales were of 6.9m or less. These small differences suggest that *Miwamaru* did not devote much effort to selecting for larger whales. With respect to the pelagic whaling, the number of whales taken and sighted in NP1 were 11 and 50 in 1969, and 10 and 12 in 1970. The 11 catches in 1969 were taken on 16 August, but the 50 sightings represented all whales seen throughout August. It is unlikely that all were seen on 16 August; according to 'Report on sightings by scouting boats' (from 1972 to the present) the maximum number of minke whales seen in a day in the North Pacific was 19, and that was exceptionally large. It seems that there was similarly little selection for larger whales by the pelagic fleets. Therefore, the differences in length distribution between areas can be considered to be real.

Sexual maturity rate

Males

Kato (1986) reported a mean weight of one testis at sexual maturity for the Antarctic minke whales as 0.4kg after histological analysis. There is no value for this parameter for the western North Pacific, and so here I have tentatively treated males with a testis of 0.4kg or more as sexually mature. Of the 108 males taken in OS1, OS2, NP1 and NP2, 28 were without testes weights. As the sample size was small in these areas, I classified them into 25 mature and 3 immature males using a body length at sexual maturity of 6.9m (22.5ft) after Omura and Sakiura (1956), taken from the male length distribution.

The percentage of males sexually mature varied considerably by area. For the data summed over month, it ranged from 38.9% in NP4 to 92.9% in NP2 (Table 2). The differences in values between adjacent areas were all statistically significant except between OS2 and OS3 and NP1 and NP2; in particular the NP2 value was significantly larger than that in NP3 which is only slightly further south ($\chi^2=6.72$, df=1, $P<0.01$). Of the three coastal areas, NP3 showed the largest value, as had been found previously (Omura and Sakiura, 1956; Ohsumi, 1983).

When looking at the data from July and August only, the areal differences become smaller, ranging from 52.9% in OS2 to 72.8% in NP3. This is due to large monthly changes within areas. Fig. 3 shows the monthly change in percent sexually mature by area and sex (excluding values from four or less samples). This shows a decrease (although not significant) in OS3 and NP3 from May-September and a significant increase in NP4 from April-August ($t=6.17$, df=3, $P<0.01$).

Table 2

Information on male sexual maturity in the catches from the Okhotsk Sea–West Pacific stock of minke whales. Figures in parentheses are not plotted in Fig. 3. N = sample size. M = no. mature. %M = % mature

Area	Males	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
OS1	N	-	-	-	33	8	10	-	51
	M	-	-	-	26	5	10	-	41
	%M	-	-	-	78.8	62.5	100.0	-	80.4
OS2	N	-	-	1	9	8	-	-	18
	M	-	-	0	4	5	-	-	9
	%M	-	-	(0.0)	44.4	62.5	-	-	50.0
OS3	N	4	80	62	23	12	39	-	220
	M	2	51	30	16	5	19	-	123
	%M	(50.0)	63.8	48.4	69.6	41.7	48.7	-	55.9
NP1	N	-	-	1	1	9	-	-	11
	M	-	-	1	1	5	-	-	7
	%M	-	-	(100.0)	(100.0)	55.6	-	-	63.6
NP2	N	-	-	-	-	-	21	7	28
	M	-	-	-	-	-	19	7	26
	%M	-	-	-	-	-	90.5	100.0	92.9
NP3	N	1	8	83	205	203	260	-	760
	M	1	8	57	146	151	153	-	516
	%M	(100.0)	100.0	68.7	71.2	74.4	58.8	-	67.9
NP4	N	235	172	93	39	7	-	-	546
	M	61	57	62	26	7	-	-	213
	%M	26.0	33.1	66.7	66.7	100.0	-	-	38.9

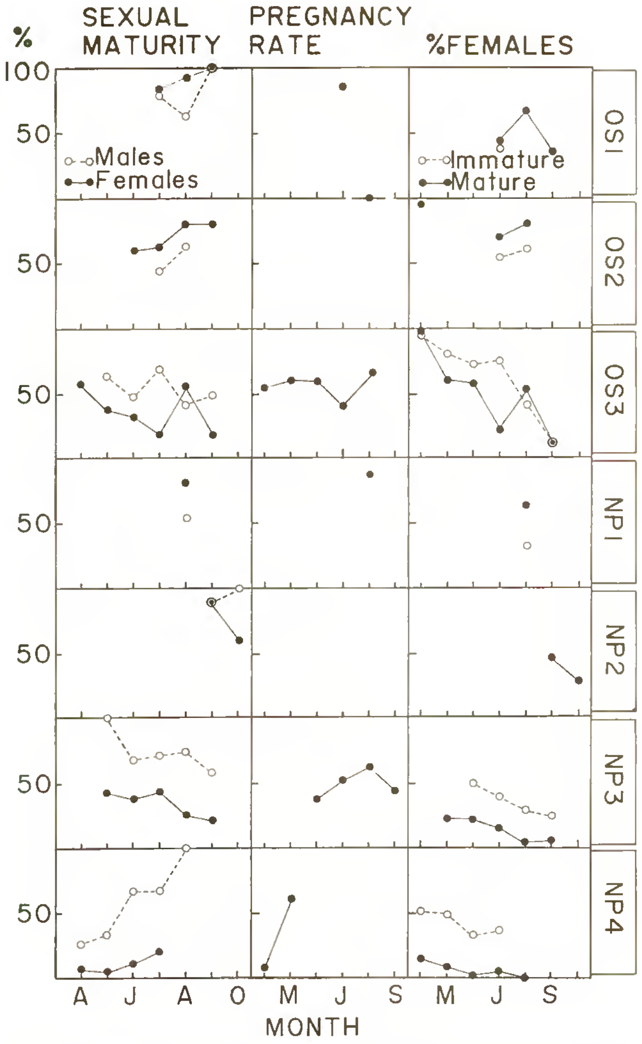


Fig. 3. Sexual maturity rate, apparent pregnancy rate and sex ratio for minke whales from the Okhotsk Sea-West Pacific stock.

Table 3

Information on female sexual maturity in the catches from the Okhotsk Sea–West Pacific stock of minke whales. Figures in parentheses are not plotted in Fig. 3. N = samples size, M = no. mature, %M = % mature

Area	Males	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
OS1	N	-	-	-	27	12	6	-	45
	M	-	-	-	22	11	6	-	39
	%M	-	-	-	81.5	91.7	100.0	-	86.7
OS2	N	-	-	5	16	25	5	-	51
	M	-	-	3	10	20	4	-	37
	%M	-	-	60.0	62.5	80.0	80.0	-	72.5
OS3	N	123	219	132	27	11	16	-	528
	M	71	82	42	5	6	3	-	209
	%M	57.7	37.4	31.8	18.5	54.5	18.8	-	39.6
NP1	N	-	-	-	-	10	-	-	10
	M	-	-	-	-	8	-	-	8
	%M	-	-	-	-	80.0	-	-	80.0
NP2	N	-	-	1	-	-	10	5	16
	M	-	-	0	-	-	9	3	12
	%M	-	-	(0.0)	-	-	90.0	60.0	75.0
NP3	N	-	7	42	70	30	49	-	198
	M	-	3	16	31	8	11	-	69
	%M	-	42.9	38.1	44.3	26.7	22.4	-	34.8
NP4	N	198	118	18	10	-	-	-	344
	M	11	5	2	2	-	-	-	20
	%M	5.6	4.2	11.1	20.0	-	-	-	5.8

Females

Females with one or more corpus lutea or albicantia are sexually mature. The length at attainment of sexual maturity can be obtained from the mean body length of females which have ovulated only once (n=58) i.e. have only one corpus luteum in their ovaries. The mean body length of these females was 7.2m, close to the 7.3m (24ft) estimated by Omura and Sakiura (1956) from the female length distribution in the catch. Using 7.2m as the length at sexual maturity, the 73 females without ovarian data taken in OS1, OS2, NP1 and NP2 were classified into 57 mature and 16 immature females.

The percentages of mature females were high in the offshore areas (72.5%-86.7%) and low in the coastal areas (5.8%-39.6%) Among the coastal areas, it was highest in OS3 but was extremely low in NP4. As in males, the difference between NP2 (75.0%) and NP3 (34.8%) was significant (χ^2=8.55, df=1, P<0.01). This suggests that not only latitudinal but also coastal/offshore segregation occurs by length.

Monthly changes in percentages of mature females are similar to those in males: a non-significant decrease in OS3 and NP3, a non-significant increase in OS2 and NP4, and a significant increase from July-September in OS1 (t=16.86, df=1, P<0.05). In almost all months, the percentages of mature females were higher than males in the areas north of 46°N, and lower south of 46°N. This means that the latitudinal segregation by size is more pronounced in females than in males.

Apparent pregnancy rate

Since very small foetuses are difficult for the whalers to find, the apparent pregnancy rates calculated here are probably underestimates. The relative distribution of pregnant females was very similar to that for mature females (Table 4): high in the offshore areas (85.7–100%) and low in the coastal areas (40.0–58.4%). The differences

Table 4

Apparent pregnancy rate in the Okhotsk Sea–West Pacific stock of minke whales. Figures in parentheses are not plotted in Fig. 3

Area	Females	April	May	June	July	Aug.	Sept.	Total
OS1	No. mature	–	–	–	14	–	–	14
	No. pregnant	–	–	–	12	–	–	12
	Pregnancy rate	–	–	–	85.7	–	–	85.7
OS2	No. mature	–	–	3	2	11	–	16
	No. pregnant	–	–	3	2	11	–	16
	Pregnancy rate	–	–	(100.0)	(100.0)	100.0	–	100.0
OS3	No. mature	71	82	42	5	6	3	209
	No. pregnant	39	50	25	2	4	2	122
	Pregnancy rate	54.9	61.0	59.5	40.0	66.7	(66.7)	58.4
NP1	No. mature	–	–	–	–	7	–	7
	No. pregnant	–	–	–	–	6	–	6
	Pregnancy rate	–	–	–	–	85.7	–	85.7
NP2	No. mature	–	–	–	–	–	2	2
	No. pregnant	–	–	–	–	–	2	2
	Pregnancy rate	–	–	–	–	–	(100.0)	100.0
NP3	No. mature	–	3	16	31	8	11	69
	No. pregnant	–	1	6	16	5	5	33
	Pregnancy rate	–	(33.3)	37.5	51.6	62.5	45.5	47.8
NP4	No. mature	11	5	2	2	–	–	20
	No. pregnant	1	3	2	2	–	–	8
	Pregnancy rate	9.1	60.0	(100.0)	(100.0)	–	–	40.0

Table 5

Number of sexually mature whales and the percentage of females in the catch of the Okhotsk Sea–West Pacific stock of minke whales. Figures in parentheses are not plotted in Fig. 3

Area	Sex	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
OS1	Male	–	–	–	26	5	10	–	41
	Female	–	–	–	22	11	6	–	39
	% females	–	–	–	45.8	68.8	37.5	–	48.8
OS2	Male	–	–	0	4	5	0	–	9
	Female	–	–	3	10	20	4	–	37
	% females	–	–	(100.0)	71.4	80.0	(100.0)	–	80.4
OS3	Male	2	51	30	16	5	19	–	123
	Female	71	82	42	5	6	3	–	209
	% females	97.3	61.7	58.3	23.8	54.5	13.6	–	63.0
NP1	Male	–	–	1	1	5	–	–	7
	Female	–	–	0	0	8	–	–	8
	% females	–	–	(0.0)	(0.0)	61.5	–	–	53.3
NP2	Male	–	–	–	–	–	19	7	26
	Female	–	–	–	–	–	9	3	12
	% females	–	–	–	–	–	47.4	30.0	31.6
NP3	Male	1	8	57	146	151	153	–	516
	Female	0	3	16	31	8	11	–	69
	% females	(0.0)	27.3	21.9	17.5	5.0	6.7	–	11.8
NP4	Male	61	57	62	26	7	–	–	213
	Female	11	5	2	2	0	–	–	20
	% females	15.3	8.1	3.1	7.1	0.0	–	–	8.6

Table 6

Number of sexually immature whales and the percentage of females in the catch of the Okhotsk Sea–West Pacific stock of minke whales. Figures in parentheses are not plotted in Fig. 3

Area	Sex	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
OS1	Male	–	–	–	7	3	–	–	10
	Female	–	–	–	5	1	–	–	6
	% female	–	–	–	41.7	(25.0)	–	–	37.5
OS2	Male	–	–	1	5	3	0	–	9
	Female	–	–	2	6	5	1	–	14
	% female	–	–	(66.7)	54.5	62.5	(100.0)	–	60.9
OS3	Male	2	29	32	7	7	20	–	97
	Female	52	137	90	22	5	3	–	319
	% female	96.2	82.5	73.8	75.9	41.7	13.0	–	76.7
NP1	Male	–	–	–	–	4	–	–	4
	Female	–	–	–	–	2	–	–	2
	% female	–	–	–	–	33.3	–	–	33.3
NP2	Male	–	–	0	–	–	2	0	2
	Female	–	–	1	–	–	1	2	4
	% female	–	–	(100.0)	–	–	(33.3)	(100.0)	66.7
NP3	Male	–	0	26	59	52	107	–	244
	Female	–	4	26	39	22	38	–	129
	% female	–	(100.0)	50.0	39.8	29.7	26.2	–	34.6
NP4	Male	174	115	31	13	–	–	–	333
	Female	187	113	16	8	–	–	–	324
	% female	51.8	49.6	34.0	38.1	–	–	–	49.3

in the values between OS2 and OS3 ($\chi^2=9.17$, df=1, $P<0.01$) and between NP1+NP2 and NP3 ($\chi^2=3.86$, df=1, $P<0.05$) were statistically significant.

In the only areas for which there were sufficient monthly samples to investigate a trend (OS3 and NP3), a non-significant increase was observed.

Sex ratio

Tables 5 and 6 give the percentage mature and immature females in the total catch, respectively, by area and month. The percentage of mature females in the total catch summed over month ranged from 8.6% in NP4 to 80.4% in OS2. It was high in the southern part of the Okhotsk Sea (63.0%-80.4%) and low in the Pacific coastal areas (8.6%-11.8%), with medium values in the northernmost area, (48.8% in OS1 and 53.3% in NP1). The differences between adjacent areas were all significant except between NP3 and NP4 and between NP1 and NP2. It should be noted that the difference between OS3 (63.0%) and NP3 (11.8%) was highly significant ($\chi^2=259.96$, df=1, $P<0.01$) although the latitudinal distance between these coastal areas is not very large.

The range for immature females (33.3%-76.7%) was narrower, suggesting that segregation by sex is more pronounced in mature animals. The larger values were for the southern Okhotsk Sea, as in mature animals. The differences between OS3 (76.7%) and NP3 (34.6%, $\chi^2=140.32$, df=1) and between NP3 and NP4 (49.3%, $\chi^2=20.36$, df=1) were significant at the 1% level, but the difference between NP1+NP2 and NP3 was not significant.

In OS3 in April only four males were taken while 123 females were caught; by May the peak catches of both sexes were taken (Table 1). In addition, catches of mature females were similar between April (71 whales) and May (82 whales), whereas catches of immature females differed greatly between April (52 whales) and May (137 whales). Thus in OS3 females arrive earlier than males and mature females arrive earlier than immature females. A similar pattern is seen in minke whales from East and West Greenland (Larsen and Øien, 1988).

Monthly changes in sex ratio are shown in Fig. 3. In the coastal areas (OS3, NP3 and NP4) the percentages decrease either gradually or sharply for both mature and immature females. These decreasing trends were significant in OS3 (for mature females, t=-3.22, df=4, $P<0.05$; for immature females, t=-5.21, df=4, $P<0.01$) and in NP3 (for mature females, t=-5.44, df=3, $P<0.05$; for immature females, t=-7.06, df=2, $P<0.05$), but not in NP4 for either mature or immature females. No trend could be seen in the offshore areas due to the small sample sizes.

DISCUSSION

Omura and Sakiura (1956) and Ohsumi (1983) reported on area differences in length composition and the sex ratio of minke whales among the coastal areas, OS3, NP3 and NP4. They found that the smaller (immature) females tended to migrate to NP4 and the larger (mature) females to OS3 whereas the larger males tended to be found in NP3, and that the female sex ratio is highest in OS3 and lowest in NP3. The present analyses reconfirmed this and further showed that:

(1) both female sexual maturity rate and apparent pregnancy rate are higher in the offshore areas than in the coastal areas;
(2) the female sex ratio is high in the southern part of the Okhotsk Sea (OS2 and OS3) for both mature and immature animals. In the coastal areas (OS3 and NP3) it decreases with as the season progresses in mature and immature animals;
(3) the male sexual maturity rate is high in the northernmost area of the Okhotsk Sea and the offshore areas of the western North Pacific;
(4) in the coastal area of the southern Okhotsk Sea (OS3) females arrive in April, earlier than males, and mature females arrive before immature females.

It is clear that latitudinal position is not the only factor involved in the segregation of minke whales. The observed values in NP2 differed considerably from those in OS3 and NP3. The sexual maturity rate in NP2 was significantly higher than in OS3 and NP3 in both sexes, and the mature female sex ratio in NP2 was significantly lower than that in OS3 and significantly higher than in NP3. Since the latitudinal distances are small, this suggests a coastal/offshore segregation. However, the small sample size for the offshore areas means that such a conclusion cannot be reached at present.

In the Antarctic, pregnant females are known to migrate further south than males and non-pregnant mature females. Reported apparent pregnancy rates in the main whaling ground (near the pack ice edge) range from 78.9% (Ohsumi, Masaki and Kawamura, 1970), 89.5% (Ohsumi and Masaki, 1975), 89.1% (Masaki, 1979), 88.8% (Kato, 1982) and 89.5% (Kato, 1986). A marked inbalance in the percentage of females (60–85%) is also found (Kasamatsu and Ohsumi, 1981; Shimadzu, 1982). The values of the apparent pregnancy rate (85.7%-100%) in the offshore areas and the female sex ratio (70.6%-75.0%, mature and immature pooled) in the southern part of the Okhotsk Sea were close to those for the Antarctic.

Latitudinal segregation of minke whales by sex and reproductive status is also found in the North Atlantic (Jonsgård, 1951; Sergeant, 1963; Larsen and Øien, 1988) and a similar pattern was suggested for minke whales in the Sea of Japan and the Yellow Sea (Matsuura, 1936; Omura and Sakiura, 1956; Gong, 1981; 1982). This suggests that the nature of latitudinal segregation by sex, size and reproductive status can be considered a common feature of all minke whale schools.

ACKNOWLEDGEMENTS

I wish to thank T. Kasuya and H. Kato of the Far Seas Fisheries Research Laboratory for their valuable comments and critical reading of this paper. Thanks are also due to G.P. Donovan of the International Whaling Commission, Cambridge, UK and two anonymous reviewers for critically reviewing the manuscript.

REFERENCES

Gong, Y. 1981. Minke whales in the waters off Korea. *Rep. int. Whal. Commn* 31: 241–4.

Gong, Y. 1982. A note on the distribution of minke whales in Korean waters. *Rep. int. Whal. Commn* 32: 279–82.

Jonsgård, Å. 1951. Studies on the little piked whale or minke whale (*Balaenoptera acuto-rostrata* Lacépède). *Norsk Hvalfangsttid.* 40: 209–32.

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: 345–48.

Kasamatsu, F. and Hata, T. 1985. Notes on minke whales in the Okhotsk Sea–West Pacific area. *Rep. int. Whal. Commn* 35: 299–304.

Kato, H. 1982. Some biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 32: 935–45.

Kato, H. 1986. Studies on the yearly changes in biological parameters and population dynamics of the Antarctic minke whales. Doctoral thesis submitted to the Faculty of Fisheries, University of Hokkaido, 145pp. [In Japanese.]

Larsen, F. and Øien, N. 1988. On the discreteness of stocks of minke whales at East and West Greenland. *Rep. int. Whal. Commn* 38: 251–5.

Masaki, Y. 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29: 929–33.

Matsuura, Y. 1936. On the lesser rorqual found in the adjacent waters of Japan. *Bull. Jap. Soc. Fish.* 4: 325–30.

Ohsumi, S. 1983. Minke whales in the coastal waters of Japan in 1981, with special reference to their stock boundary. *Rep. int. Whal. Commn* 33: 365–71.

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.

Ohsumi, S., Masaki, Y. and Kawamura, A. 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 22: 75–125.

Omura, H. and Sakiura, H. 1956. Studies on the little piked whale from the coast of Japan. *Sci. Rep. Whales Res. Inst., Tokyo* 11:1–37.

Sergeant, D.E. 1963. Minke whales, *Balaenoptera acutorostrata* Lacépède, of the western North Atlantic. *J. Fish. Res. Bd Can.* 20(6): 1,489–504.

Shimadzu, Y. 1982. The unbalanced sex ratio in the minke whale catch and its effect on management. *Rep. int. Whal. Commn* 32: 905–9.

Wada, S. 1988. Catch and CPUE trend for the Okhotsk Sea-West Pacific stock of minke whales, 1977–86. *Rep. int. Whal. Commn* 38: 281–3.

SC/40/Mi18

Preliminary Report of the 1987/88 Japanese Feasibility Study of the Special Permit Proposal for Southern Hemisphere Minke Whales

Hidehiro Kato[1], *Hisashi Hiroyama*[2], *Yoshihiro Fujise*[3] *and Kiyoshi Ono*[4]

ABSTRACT

The research cruise undertaken as the feasibility study for the Japanese proposal for a special permit to take Southern Hemisphere minke whales took place from 17 January – 26 March 1988. It covered a latitudinally wider range (from 55°S to the ice edge) than commercial whaling, between 105°E and 115°E. The cruise included a systematic sighting survey and a research take of minke whales based on a random sampling scheme. A total of 421 minke whale schools (1,350 individuals) comprising 227 primary and 194 secondary sightings was sighted during 8,482.4n.miles searching. Searching was evenly allocated between the northern and southern strata. Only primary sighted schools were sampled. Employing this strategy, 273 whales (154 males, 119 females) were collected. The body length distribution of these differed considerably from that for commercial whaling, with a higher proportion of smaller animals. Preliminary analyses suggest: (1) minke whale density and school size increases sharply in the waters close to pack ice; (2) sexually mature females tend to concentrate in the pack ice area, immature animals in offshore waters, while sexually mature males are found in both areas; (3) the small or immature animals tend to be solitary, while the larger or mature males usually form larger schools with similar sized females. More detailed analyses of all the data collected during the cruise will be presented in future studies.

1. INTRODUCTION

In October 1987, the Government of Japan (Government of Japan, 1987a) put forward a research plan for a feasibility study of an earlier proposal (Government of Japan, 1987b) for a programme of research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic. These were discussed at the 1987 Scientific Committee and Commission Meetings (IWC, 1988a and b) and a Special Meeting of the IWC Scientific Committee (IWC, 1989). The Government of Japan subsequently gave permission for the feasibility study to proceed under the direction of the newly established Institute of Cetacean Research. The study also included the taking of up to 300 minke whales. Three major factors can be identified in the plan:

(1) it incorporates a random sampling strategy for schools sighted during a systematic sighting survey based on the IWC/IDCR southern minke whale assessment cruises (e.g. Joyce, Kasamatsu, Rowlett and Tsunoda, In Press);
(2) it covers a greater latitudinal range (from 55°S to the ice edge) than commercial whaling, which had concentrated operations near the ice edge (Shimadzu and Kasamatsu, 1981; 1983; 1984);
(3) it scheduled as much scientific information as possible to be collected from each sampled whale.

The four major purposes of the cruise (Government of Japan, 1987a) were: (1) a feasibility study of the stochastic sampling scheme as modified since the original programme (e.g. whether the required number of samples could be collected by the designated method within the given period); (2) a feasibility study on whether concurrent collection of sightings data and sampling could be technically achieved; (3) investigation of the extent of segregation by age, sex and reproductive condition; (4) an investigation on the uniformity or non–uniformity of biological characters with respect to school size.

This report describes the cruise conducted from 23 December 1987 to 20 April 1988 under the above plan and presents some preliminary analyses of the data obtained.

The total research plan also included a sightings survey for minke whales in lower latitudes (about 10°-40°S) between 100°-110°E. The cruise report of that sightings survey is given in Kasamatsu (1988).

2. OUTLINE OF THE CRUISE

Details of the research fleet and personnel

Two catcher boats, *Kyomaru No.1* (K01; 812.08GT.) and *Toshimaru No.25* (T25; 739.92GT.), carried out the sightings and sampling work. The factory ship *Nisshinmaru No.3* (NO3; 23,107.85GT.) provided the research base from which general matters, including consideration of research strategy, weather forecasting and receiving of ice information, were dealt with. The processing of whale carcasses, the taking of biological samples and the collection of data took place on the deck of N03.

The research personnel involved and their assignments are summarised in Table 1.

Research area and cruise track design

Within the area of 105°-115°E, the research area was divided into two strata: a southern stratum (from the pack ice edge to 60°S) and a northern stratum (from 55°-60°S). The cruise track comprised a main trackline and two sub-tracklines, six miles vertically from either side of the main trackline, along which the sampling vessels cruised (occasionally switching tracks). The main track was determined differently for the two strata: in the northern stratum the fleet followed eight pre-determined systematic north/south legs; whereas in the southern stratum the track was randomly established following the 'reflection' method (Anon., 1987). The cruise tracks are shown in Fig. 1.

---

[1] Institute of Cetacean Research (Present address: Far Seas Fisheries Research Laboratory, Japan Fisheries Agency, 5–7–1, Orido, Shimizu, Shizuoka 424, Japan).
[2] Japan Fisheries Agency, 1–2–1, Kasumigaseki, Chiyoda-ku, Tokyo 100, Japan.
[3] Institute of Cetacean Research, Tokyo Sisan Buld., 4–18, Toyomi, Chuo-ku, Tokyo 104, Japan.
[4] Faculty of Fisheries, Nagasaki University, 1–2, Bukyo-cho, Nagasaki 852, Japan.

Table 1

Details of research personnel and their assignments

Personnel	Situation	Ship	Assignment
Hidehiro Kato	Cruise leader	N03	General management of overall research; biological data and sample collection.
Yoshihiro Fujise	Researcher	N03	Biological data and sample collection.
Hisashi Hiroyama	Researcher	K01	Determination of target whale; collection of sighting and sampling data.
Kiyoshi Ono	Researcher	T25	Determination of target whale; collection of sighting and sampling data; oceanographical research.
Masamitsu Yamada	Research assistant	K01	Recording effort and weather data.
Tameo Ryono	Research assistant	T25	Recording effort and weather data.
Shigeo Tabata	Research assistant	N03	Biological data and sample collection.
Yutaka Eguchi	Research assistant	N03	Biological data and sample collection.

The following four points should be noted.

(1) The starting point of the cruise (55°00′S, 108°18′E) in the research area was randomly chosen from one of the northern ends of the eight north/south legs.

(2) The compass direction of 230° was randomly chosen prior to the start of the cruise as the initial penetration direction of the cruise in the southern stratum from the southern end of the selected north/south leg.

(3) The angle of reflection at the boundaries of the research area in the southern stratum e.g. the pack ice edge, 60°S, 105°E and 115°E was chosen as 70° prior to the start of the cruise. When two 70° reflection courses could be taken at a boundary point, the choice of direction was randomly selected.

(4) The timing of the change from the southern to the northern stratum was determined by weather conditions in the latter, regardless of the location of the fleet in the southern stratum. The fleet suspended research and moved to the southern end of the nearest unsurveyed northern leg and cruised north on this leg. After reaching the northern end of the leg (set at 55°09′S to avoid sampling whales found north of 55°S), the fleet cruised to the northern end of the nearest unsurveyed leg, and moved south. It then returned to the 'suspended' position in the southern stratum after completing that leg.

Searching was carried out at 12 knots during daytime, i.e. either between 0600 and 2000hrs or from 30 mins after sunrise to 30 mins before sunset. The fleet stopped at night and resumed searching at the same position the next morning. Sampling was only carried out on primary sightings made within 3n.miles (vertical distance) from the sub-track line. In principle, under unsuitable weather/sea conditions for searching, the fleet was drifting, waiting for an improvement. After confirming, sampling and towing etc., the sampling vessels returned to the positions on the sub-track lines they had left to confirm the sightings and resumed searching from there. All activities were classified and recorded on effort data sheets similar to those used during the IWC/IDCR Southern Hemisphere minke whale assessment cruises (Joyce *et al.*, In press).

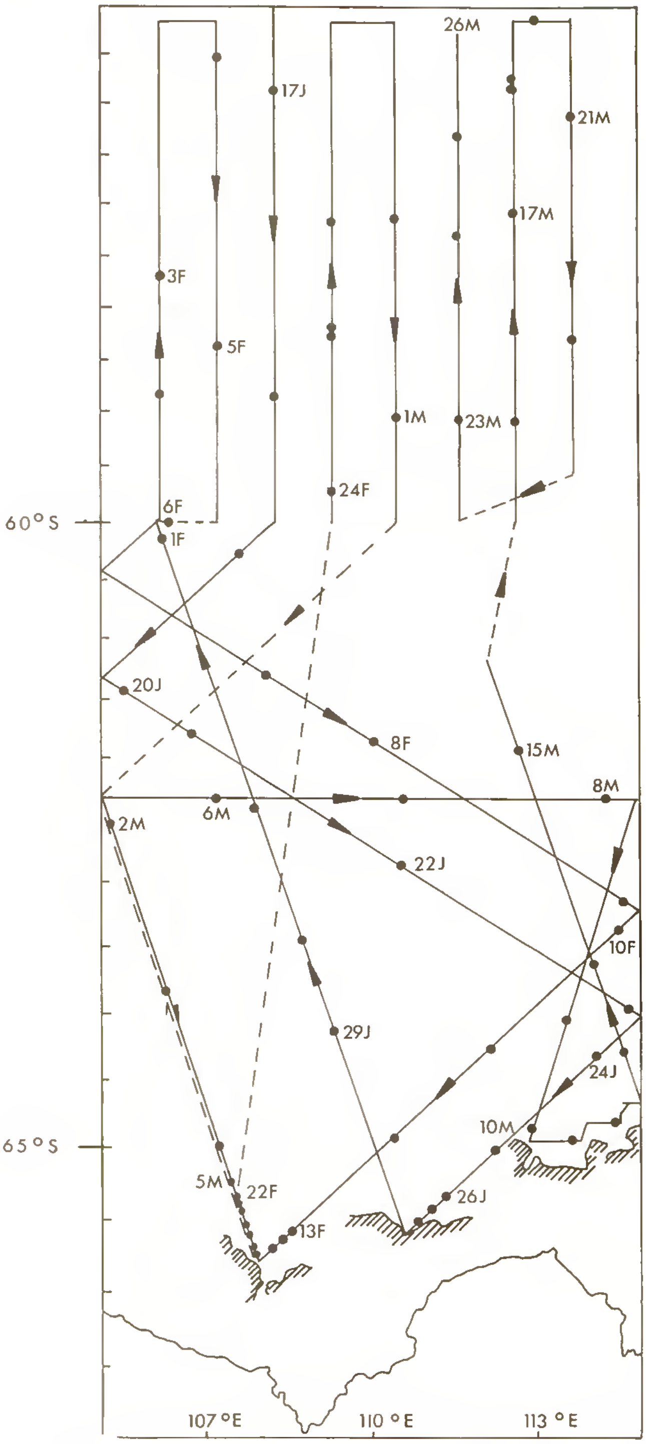


Fig. 1. Cruise track of the present cruise showing noon positions by day.

Narrative of the cruise

The fleet left Japan between 23 and 25 December 1987. After a pre-cruise meeting at 13°52′S, 114°32′E on 5 January 1988, the vessels cruised south towards the starting point in the research area (55°S, 108°18′E). During this time the sampling vessels cruised in searching mode at 12 knots during the day and steamed at night. A similar procedure was adopted on the return journey from the end point of the research area to 200 n.miles south of the Lombok Strait.

The vessels operated in the research area for the 70 days from 17 January to 26 March 1988. The cruise can be divided into three periods based on the nature of the research (Fig. 1 and Table 2).

Table 2

Itinerary of the fleet

Event	Date	Position	
		Lat.	Long.
N03 left Yokohama	23 Dec 1987	35°26'N	139°40'E
K01 + T25 left Shimonoseki	25 Dec 1987	33°58'S	130°57'E
Pre-cruise meeting + refuel	5 Jan 1988	13°52'S	114°32'E
Start of first period	17 Jan 1988	55°00'S	108°18'E
Suspended survey (southern stratum)	1 Feb 1988	60°00'S	106°03'E
Start of survey (northern stratum)	1 Feb 1988	60°00'S	106°06'E
Mid-cruise meeting + refuel	5 Feb 1988	59°21'S	107°12'E
End of first period	6 Feb 1988	60°00'S	107°12'E
Start of second period	6 Feb 1988	60°00'S	106°03'E
Suspended survey (southern stratum)	22 Feb 1988	65°23'S	107°32'E
Start of survey (northern stratum)	24 Feb 1988	60°00'S	109°24'E
End of second period	1 Mar 1988	60°00'S	110°30'E
Start of third period	2 Mar 1988	62°19'S	105°00'E
Mid-cruise meeting + refuel	3 Mar 1988	64°49'S	107°01'E
End of survey (southern stratum)	15 Mar 1988	61°11'S	112°13'E
Start of survey (northern stratum)	16 Mar 1988	60°00'S	112°44'E
End of third period	26 Mar 1988	55°00'S	111°38'E
Post-cruise meeting + refuel	26 Mar 1988	54°58'S	111°49'E
K01 + T25 arrived at Shiogama	18 Apr 1988	38°19'N	141°04'E
N03 arrived at Tokyo	20 Apr 1988	35°38'N	139°45'E

First period (17 January – 6 February)

The fleet began research following the leg at 55°S-108°18′E southwards from 0600 on 17 January. The fleet reached 60°S in the afternoon of 18 January. From here it followed a course of 230°, reaching the western boundary (105°E) at 61°22′S on 20 January and changing course by 70° (i.e. a new course of 120°). The eastern boundary (64°02′S, 115°E) was reached on 23 January (some night and 'topman down' steaming and drifting had occurred due to rough conditions).

After waiting for the weather to recover on 23 January, searching began again following course 230°. The ice edge was reached at 65°37′S, 110°32′E before noon on 28 January and the cruise direction changed to 340°. The fleet followed this course, with occasional drifting due to poor visibility, reaching the northern boundary of the southern stratum at 106°03′E before noon on 1 February. Research in the southern stratum was suspended and the fleet moved to 60°S, 106°06′E, the southern end of the nearest unsurveyed northern leg, and began searching to the north. However, the following day the fleet hove to due to a sudden storm. Searching was resumed at 58°S on the main track on the morning of 3 February. The northern leg was completed and the ship followed the southern leg and reached the end of this on the morning of 6 February. A mid-cruise meeting was held aboard N03 during the refuelling of the sampling vessels at the end of the research on 5 February.

Second period (6 February – 1 March)

The fleet returned to the suspended position (60°S, 106°03′E) of the previous research in the southern stratum and resumed searching from there on the afternoon of 6 February, reaching the western boundary (60°26′S, 105°E) and then changing course to 120°. With alternating searching and drifting due to poor visibility, the eastern boundary (63°10′S, 115°E) was reached on 9 February.

The course was changed to 230° and weather conditions gradually improved. Numbers of sightings (and school sizes) including secondary sightings increased from the evening of 12 February and a high density area was reached on the morning of 13 February (65°15′S, 109°18′E). The ice edge was reached on 16 February and a course of 340° followed. During this high density period (12–22 February), 'stop-catch' had to be invoked on certain occasions when the maximum processing capacity of N03 was approached (around 14 whales).

Due to expected good weather in the northern stratum, research was suspended at 65°23′S,107°32′E on 22 February and the fleet moved to the southern end of the nearest unsurveyed leg (60°S, 09°24′E) in the northern stratum. During this period the sampling vessels operated in passing mode during the day and steamed at night.

Searching along this leg began on 24 February, but operations ceased for two days just before 58°S due to a sudden storm. Searching resumed from the interrupted position on 27 February. This leg was completed and the vessels turned west towards the northern end of the next unsurveyed leg, turning south at 55°09′S,110°30′E. The southern end of this leg (60°S,110°30′E) was reached on 1 March, after occasional drifting or topdown steaming due to strong winds.

Third period (March 1 –26)

By the end of the second period, 245 whales had been sampled, almost 70% in waters south of 65°S. Resuming sampling at the suspended position in the southern stratum (65°20′S,107°30′S) would have concentrated the sampling even further, particularly given the maximum allowed sample size of 300 whales. In order to avoid this, the vessels steamed to 62°19′S,105°E, the position at the western boundary which would have been reached if sampling had been resumed at the suspended position. On arrival there on 2 March, the fleet steamed towards the suspended position (in effect completing the trackline in the reverse direction). This was reached before noon on 5 March. *En route*, however, few sightings were made in this previously high density area (this is discussed later).

The fleet therefore steamed directly back to 62°19′S, 105°E and resumed searching from there following a course of 90° on the morning of 6 March. With occasional drifting due to poor visibility, the fleet reached the eastern boundary (62°19′S,115°E) on 8 March. The course after reaching the boundary had been randomly chosen the day before to be 200°.

Following this course, the ice edge was met on the morning of 10 March (64°58′S, 112°49′E). Because the ice edge followed a line from WNW to ESE, either a course of 310° or 90° was appropriate. The latter was randomly chosen.

Following this easterly course, most sightings were made by T25, which was following the southern sub-track. K01, consequently, was advancing faster (15n.miles ahead and potentially more) than T25. In addition, during the taking of the first whale in a school by T25, accompanying whales often escaped into the pack ice area. To solve these problems, it was decided to employ cooperative sampling between the two vessels from 11 March, with searching only being carried out by T25.

On 12 March, the vessels had to move slightly to the north on two occasions due to T25 unexpectedly encountering the ice edge. The fleet reached the eastern boundary at 64°41′S, 115°E on the same day and then followed a course of 340°.

After waiting for the weather to improve throughout 13 March, searching was resumed with occasional drifting due to poor visibility. Research in the southern stratum was completed on 15 March at 61°11′S, 112°13′E, and the fleet steamed during the night to the southern end of the nearest unsurveyed northern leg, (60°S, 112°44′E).

Searching began along this leg on the morning of 16 March. With repeated heaving to, drifting and topdown steaming due to unsuitable weather conditions, the fleet continued to cruise, via 55°09′S, 112°44′E and 55°09′S, 113°50′E (the north end of the nearest northern leg; randomly chosen from the two possible legs) and reached 59°34′S on the evening of 22 March. In order to save daylight time, the searching along this leg ceased at this position and the vessels steamed that night to the southern end of the final leg (60°S, 111°38′E).

Searching began along this leg on 23 March and research was completed upon reaching 55°S at noon on 26 March.

3. SIGHTING

The strategy and methodology of the sightings work followed that of the recent IWC/IDCR Southern Hemisphere minke whale assessment cruises (Joyce *et al.*, In press) and the data were collected in the same format (sightings, effort and weather). Only preliminary results are presented here. A detailed analysis of the data, including the results of experiments on the accuracy of distance and angle estimation, will be presented in a future paper.

Species found

Table 3 and Fig. 2 summarise the sightings results. Five mysticete and at least six odontocete species were seen during the cruise.

The minke whale was clearly the most common species, with sightings of 421 schools (1,350 individuals). Most schools were seen in the southern stratum; only seven schools were confirmed in the northern stratum. It was noteworthy that a school comprising two minke whales of the dwarf form was seen in the northern stratum (58°23′S, 111°26′E) on 23 March.

The humpback whale (*Megaptera novaeangliae*) was the next most common species with a total of 56 schools (123 individuals) being seen. Its distribution overlapped that of the minke whale in both strata, but its main ground was slightly to the north. Few fin (*Balaenoptera physalus*) and sei whales (*Balaenoptera borealis*) were sighted. It is of particular interest that two sightings of the right whale (*Balaena glacialis*) were made in the southern stratum.

Of the odontocetes, the *Ziphiidae* were the most frequently sighted; 100 schools (234 individuals) throughout the both strata. Species identification was difficult but the southern bottlenose whale (*Hyperoodon planifrons*) was positively identified.

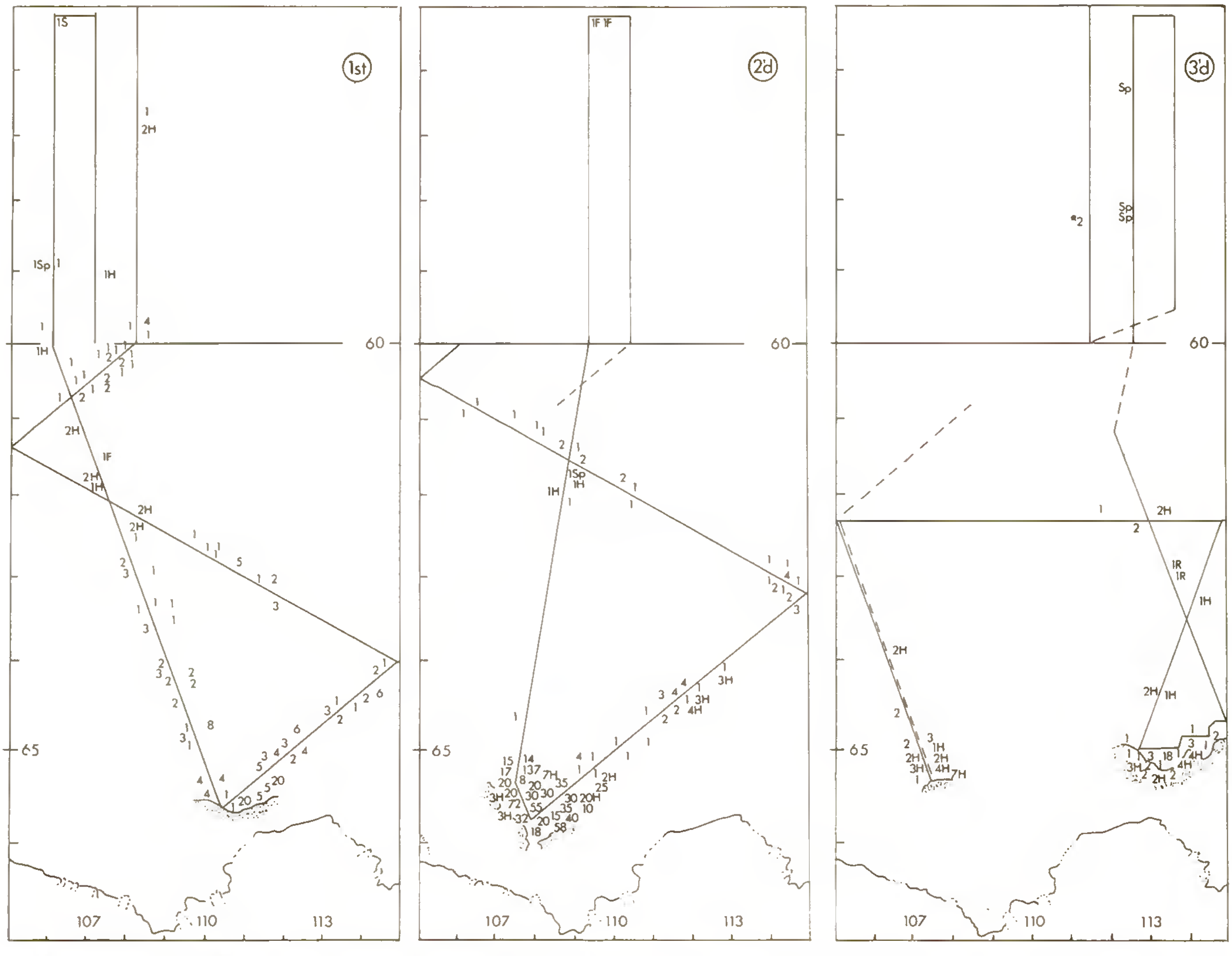


Fig. 2. Distribution of sighting of large whales (including primary and secondary sightings) by the three periods referred to in the text. The numbers principally indicate school size although several neighboring sightings have been combined in high density areas. F = fin whale, S = sei whale, R = right whale, H = humpback whale, no letter = minke whale, Sp = sperm whale.

Table 3

Summary of sightings (no. individuals/no, schools) by species, vessel and type of sighting. S = southern stratum, N = northern stratum

	Primary sightings						Secondary sightings						Grand total		
	K01		T25		Total		K01		T25		Total				
Species	S	N	S	N	S	N	S	N	S.	N	S	N	S	N	Total
Minke whale (ordinal form)	259/92	7/4	395/129	2/2	645/220	9/6	416/97	0	269/97	0	685/194	0	1,339/414	9/6	1,348/420
Minke whale (dwarf form)	0	0	0	2/1	0	2/1	0	0	0	0	0	0	0	2/1	2/1
Humpback whale	47/19	2/2	28/15	0	75/38	2/2	31/14	0	15/6	0	46/20	0	121/54	2/2	123/56
Fin whale	1/1	0	0	2/2	1/1	2/2	0	0	0	2/2	0	2/2	1/1	4/4	5/5
Right whale	2/2	0	0	0	2/2	0	0	0	0	0	0	0	2/2	0	2/2
Sei whale	0	0	0	1/1	0	1/1	0	0	0	0	0	0	0	1/1	1/1
Sperm whale	4/4	0	0	2/2	4/4	2/2	0	0	1/1	0	1/1	0	5/5	2/2	7/7
Ziphiidae*	77/32	30/15	82/30	29/14	159/62	59/29	8/5	0	8/4	0	16/9	0	175/71	59/29	234/100
Killer whale	110/10	5/1	72/7	0	182/17	5/1	45/7	0	32/4	0	77/11	0	259/28	5/1	264/29
Pilot whale	0	85/3	0	0	0	85/3	0	0	0	0	0	0	0	85/3	85/3
Hourglass dolphin	3/1	0	5/1	3/1	8/2	3/1	8/1	0	0	4/1	8/1	4/1	16/3	7/2	23/5
S. right whale dolphin	0	15/1	0	0	0	15/1	0	0	0	0	0	0	0	15/1	15/1
Other dolphin	0	0	49/7	11/4	49/7	11/4	8/1	0	3/1	0	11/2	0	60/9	11/4	71/13

* At least including southern bottlenose whale.

The next most commonly seen species was the killer whale (*Orcinus orca*) of which all but one school was seen in the southern stratum. Sperm whales (*Physeter macrocephalus*) were not frequently seen; all seven sightings were of solitary bulls. Several other odontocetes including the long-finned pilot whale (*Globicephala melas*), the hour-glass dolphin (*Lagenorhynchus cruciger*) and the southern right whale dolphin (*Lissodelphis peronii*) were occasionally seen.

Searching effort (distance)

As noted above, the recording of activities related to both sighting and sampling followed the effort data format of the IWC/IDCR cruises. Although for this cruise a partial indirect closure strategy was used (closing commenced when the sighting angle was 60° or more from the sub-track), for the purposes of this report, searching effort is defined as the distance between the positions at beginning of searching and at the sighting of a school on each sub-track line.

The total searching distance of the fleet (K01 + T25) was 8,482.4 n.miles comprising 4,327.3 and 4,155.1 n.miles in the northern and the southern strata, respectively. The ratio of searching distance (n.miles) to the size of research area (n.miles^2) was 3–4 times that in recent IWC/IDCR Antarctic minke whale assessment cruises (Table 4). Although 11 out of the 110 one degree squares of the research area were not surveyed (especially western squares around 60°S), the cruise covered 90% of the total planned squares. More effort was spent in squares between 63°-64°S and 113°-114°E where the main tracks crossed within a square. Effort had been expected to be evenly allocated throughout latitudes, but in fact was relatively concentrated at 55°S and 62°S where the vessels moved eastwards while there was relatively less effort along 60°S, 61°S and 65°S.

Table 4

A comparison of searching distances (n.miles), size of research area (n.miles^2) between the present cruise and recent IWC/IDCR Southern hemisphere minke whale assessment cruises[1]

Cruise	Area	Searching distance (n. miles) - a	Size of research area (n.m^2) - b	Ratio (a/b)
Present	55°S–ice edge, 105–115°E	8,482.4	190,300	0.045
IDCR, 82/83	I	4,855.8	451,000	0.011
IDCR, 81/82[2]	II	2,999.1	213.007	0.014
IDCR, 79/80	III	7,205.2	569,000	0.013
IDCR, 78/79	IV	7,945.0	507,100	0.016
IDCR, 80/81	V	7,170.0	575,072	0.013

[1] data from Butterworth, Hammond and Mizroch (1984).

[2] east half (0–30°W) of Area II.

Distribution, school size and density of minke whales

For the purposes of this paper the density index, DI, is expressed as the number of whales seen per 100 n.miles steamed:

$$DI = (\text{no. individuals/miles searched}) \times 100$$

Minke whales were found over a wider range of longitudes from 56°S to the ice edge (65°30′S), in the first period. Not all concentrations were seen near to the ice edge (e.g. 65°S, 110°, 111°, 112°E with DI values from 30.8–70.5) but some were seen offshore (e.g. 64°S, 114°E – DI=31.8, 60°S, 107°E – DI=16.5). Mean school sizes were generally larger (3.25–3.50) in the high density areas near the ice edge than in the offshore concentrations (1.38–2.00).

During the second period however no minke whales were seen north of 60°S, whereas high densities were seen further south. Particularly high densities (DI= 301.5–490.4) were recorded in the ice bay between 65°S and 107°-108°E. Mean school sizes were as large as 3.97–4.86.

In the third period, concentrations of whales were also found in the more southerly latitudes. Sightings were not so frequent however, probably because the vessels did not meet the pack ice edge where high densities can be expected. The major decrease in density between the second and third periods around 65°S, 107°E (DI 490.4 to DI 2.3) noted in section 2 was probably due to the fact that the ice edge had moved significantly further south over the two week period.

The reported school of two 'dwarf' form minke whales was seen when 'ordinary' minke whales were thought to be concentrated near the pack ice. Although the dwarf form has been reported from tropical and temperate latitudes (Best, 1985; Arnold, Marsh and Heinson, 1987), this is the first record in the Antarctic region.

Throughout the three periods, the density of minke whales declined as latitude decreased (Fig. 3). An approximate calculation using DI values suggests that over 70% of the total whales were concentrated around 65°S.

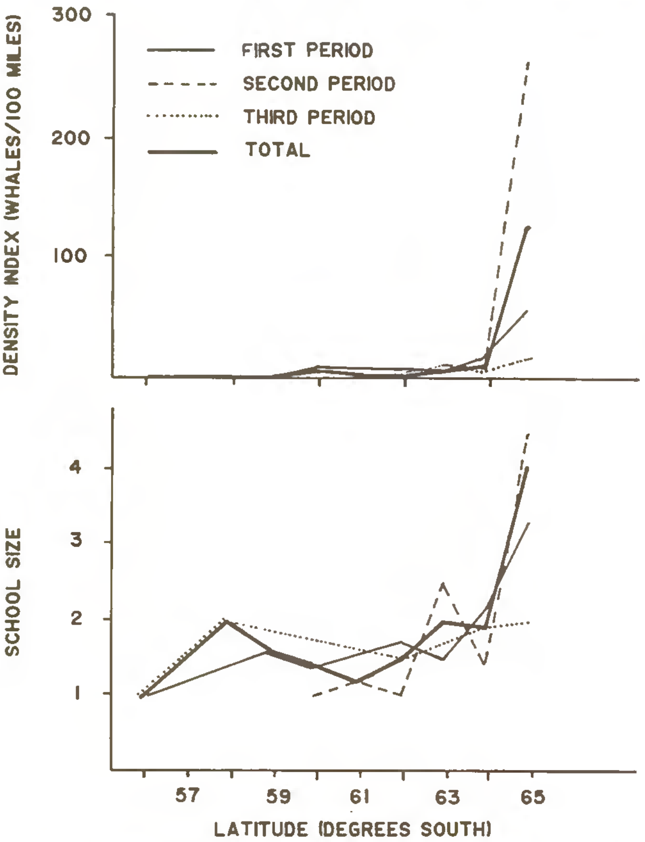


Fig. 3. Latitudinal changes in density index (upper) and mean school size (lower) of the minke whale based on primary sightings.

Fig. 4 also shows latitudinal changes in mean school size. Although no clear trend was revealed in the third period due to the small sample size, in general school size increased with latitude in the first and second periods.

In conclusion both the density and size of schools increases near to the pack ice edge.

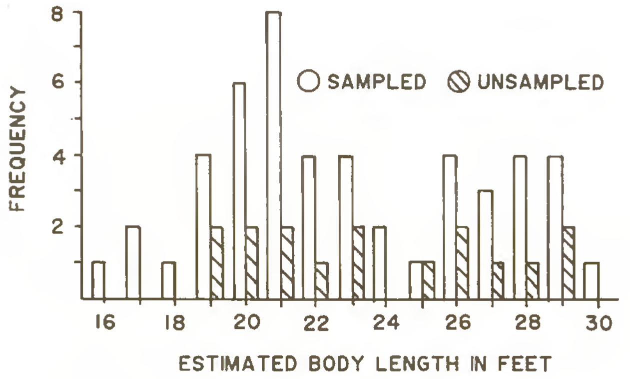


Fig. 4. Comparison of body lengths (estimated by the sampling vessels before catching) of sampled and unsampled single animals.

4. SAMPLING

In the present cruise, samples from all primary minke whale sightings were scheduled, with a maximum of two whales from each school. This section outlines the random sampling scheme adopted.

Sampling scheme

In order to determine which whales in a school were to be sampled, a series of tables of random sampling numbers (TRS), according to school sizes, were prepared.

Numbering of individual whales within a school

When close enough to count the individuals in a school, their relative positions were sketched and a serial number assigned to each individual, ranging from left to right.

Choice of individuals to be sampled

The sampling scheme varied with school size and whale behaviour. If a solitary whale was encountered it was sampled. If a school of two whales was encountered the whale to be sampled first was determined using the TRS. After it had been taken, attention was directed to the other whale.

For schools of three or more, the first target whale was chosen using the TRS specific to the school size. After it was taken, the remaining individuals were renumbered according to their relative positions (see above) and the second target whale chosen using the TRS appropriate for the new school size (i.e. original school size less 1).

If a school separated into sub-groups, a procedure based on sub-group size was adopted. For example, if a school of seven whales separated into sub-groups of five (sub-group A) and two animals (sub-group B), the target sub-group would be determined in the following manner. Serial numbers would be assigned, as above, to the whales, beginning with the larger group. If the value from the TRS for a school of seven whales was 1–5, then the larger sub-group (A) would be the target sub-group (if the number was 6 or 7, sub-group B would be the target sub-group). The first target whale would be chosen from sub-group A by following the procedures for a school of five animals. The second target whale would be determined by repeating the above procedure for school sizes of sub-group A=4 (5–1) and B=2.

Chasing of any target whale ceased after a maximum of one hour, regardless of school size.

Features of sampling

A total of 273 whales were taken following the above procedures, all of which, as planned, were from 'primary' schools. Table 5 shows the proportion of the successfully sampled schools by school size. The causes of failures in sampling are summarised in Table 6.

Sampling rates, as measured by the proportion of whales actually sampled to the 'expected' number varied from 0.57

Table 5

Expected and actual sampling of primary sighted schools by school size

School size (A)	No. primary sightings (B)	Whales to be sampled (C)	Whales sampled (D)			Sampling rate	
			0	1	2	(D/C)	(D/A·B)
1	83	83	30	53	-	0.64	0.64
2	41	82	7	21	13*	0.57	0.57
3	30	60	0	19	11	0.68	0.46
4	30	60	2	5	23*	0.85	0.43
5	21	42	0	2	19*	0.95	0.38
6	8	16	1	0	7	0.88	0.29
7	5	10	0	0	5	1.00	0.29
8	4	8	0	1	3	0.88	0.22
9	1	2	0	0	1	1.00	0.22
10	4	8	0	0	4	1.00	0.13

* including one school by cooperative sampling in each school size.

Table 6

Causes of failure in applying the two whale sampling programme. A = could not identify target; B = lost sight of target due to behaviour (quick, mobile, or long dive time); C = lost sight of target due to weather (strong winds, poor visibility, sunset); D = target escaped into pack ice; E = technical problems; F = unknown.

School size	A	B	C	D	E	F	Total
No sample obtained							
1	–	19	7	1	2	1	30
2	–	4	–	3	–	–	7
3	–	–	–	–	–	–	0
4	–	–	–	2	–	–	2
5	–	–	–	–	–	–	0
6	–	1	–	–	–	–	1
Total	0	24	7	6	2	1	40
Only one sample obtained							
2	–	16	1	3	1	–	21
3	–	8	2	4	5	–	19
4	1	2	–	1	–	1	5
5	–	–	–	2	–	–	2
6	–	–	–	–	–	–	0
7	–	–	–	–	–	–	0
8	–	–	–	1	–	–	1
Total	1	26	3	11	6	1	48

(school size 2) to 1.00 (school sizes, 7, 9 and >10). The dominant cause of sampling failures was the losing of whales due to their behaviour. Of the 30 solitary animals lost, this was the cause for 19 of them. The other major cause for solitary animals was poor weather (7).

Of the 144 primary sightings of schools with two or more whales, the required two animals were taken from 86 schools (60%). The success rate was much greater for schools of five or more (90%) than two or three individuals (34%).

Of the 58 schools for which the required two whales were not taken, in 10 schools no whales at all were taken, due either to the behaviour of the animals (5 schools) or because they escaped into the pack ice (5 schools). In the remaining 48 cases only the first whale of the two was taken. Again the major (54%) cause of this was the behaviour of the whales (26 schools), followed by escape into the pack ice (25%, 11 schools). Cases where only one whale was taken was most common (94%) in smaller schools of 2–4 animals.

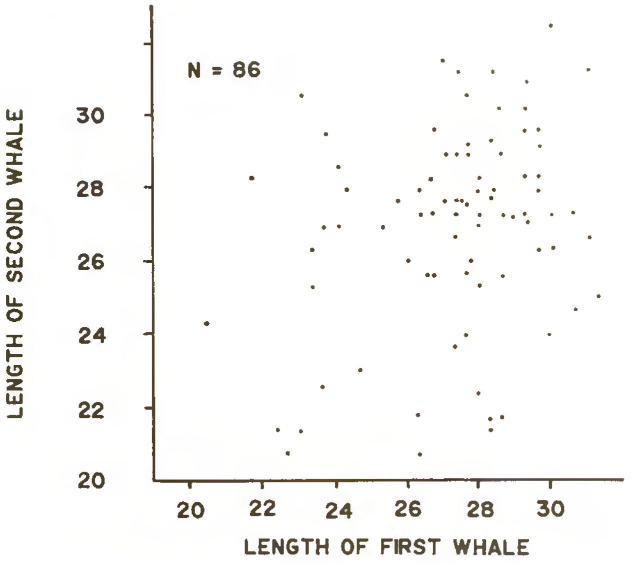


Fig. 5. Relationship between body lengths of the first and the second whales taken from the same school.

Fig. 4 compares the length compositions of sampled and unsampled whales from estimates made before capture from the vessels. Mean values were 22.9ft (SD=3.59, n=48) and 23.9ft (SD=3.77, n=17) respectively. The difference between them was statistically insignificant (t-test, 0.3<P<0.4).

Fig. 5 plots the body lengths of the first and second animals taken from the same schools. The mean difference in body lengths of the pairs (1st – 2nd) was 0.51 ft (SD. 3.35), not statistically significant (t-test, 0.3<P<0.4).

The above discussion reveals that sampling for schools where two animals were required to be taken was easier for larger schools; indeed more animals could have been taken under the present scheme without any serious practical problems. However complete sampling was more difficult for smaller schools. Cooperative sampling by two vessels, whilst still following the correct procedure (see section 2), was found to be an effective way of reducing this problem.

Spatial distribution of samples

Fig. 6 shows the positions of the whales taken during the cruise. Only eight of the 273 whales were obtained from the northern stratum. The sampling distribution reflects the sighting distribution to some extent, as one would expect. For example, 63% of the whales were taken south of 65°S, of which 77% were from the high density area encountered during the second period (65°S-107°, 108°E).

Table 7 shows the number of whales taken by latitude (based on the first sighted position) and the sampling rate (no. whales sampled/no. whales from primary sightings). Throughout the cruise, the sampling rate was higher further north, reaching over 0.7 north of 62°S. In the more southern latitudes (64°-65°S), the rates were as low as 0.36 – 0.50. This clearly reflects the fact that the maximum number of whales taken from a school of any size was two (see Table 5) and the increase in school size with latitude noted earlier.

Table 7

Sampling rate (no. whales sampled/no. whales sighted in primary sightings) by latitude and period. S = sighted; C = sampled; C/S = ratio. First period = 17 Jan.–6 Feb.; second period = 6 Feb.–1 March; third period = 1–26 March.

Latitude (°S)	First period			Second period			Third period			Total		
	S	C	C/S	S	C	C/S	S	C	C/S	S	C	C/S
55	–	–	–	–	–	–	–	–	–	–	–	–
56	1	1	1.00	–	–	–	–	–	–	1	1	1.00
57	–	–	–	–	–	–	–	–	–	–	–	–
58	–	–	–	–	–	–	2	1	0.50	2	1	0.50
59	8	6	0.75	–	–	–	–	–	–	8	6	0.75
60	18	14	0.78	1	0	0.00	–	–	–	19	14	0.74
61	–	–	–	7	5	0.71	–	–	–	7	5	0.71
62	17	8	0.47	4	4	1.00	3	0	0.00	24	12	0.50
63	12	5	0.42	20	9	0.45	–	–	–	32	14	0.44
64	43	17	0.40	20	9	0.45	31	21	0.68	94	47	0.50
65	96	34	0.35	370	133	0.36	12	6	0.50	478	173	0.36
Total	195	85	0.44	422	160	0.38	48	28	0.58	665	273	0.41

5. BIOLOGICAL DATA AND SAMPLE COLLECTION

5.1 Biological data and sample collection

Biological data and samples were collected from all 273 whales taken (154 males including one dwarf form and 119 females). This section is only intended to summarise the information collected (see Table 8). Detailed analyses will be presented in future papers.

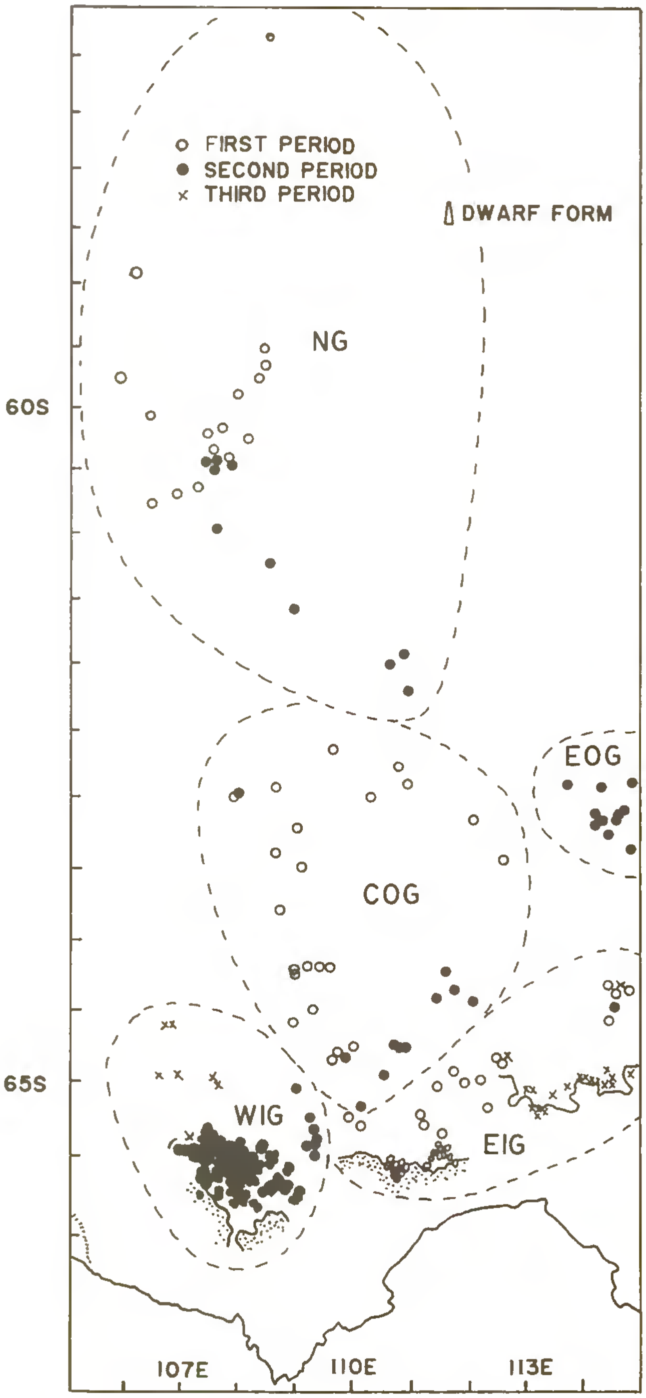


Fig. 6 Positions of whales taken during the cruise. The time/area groups discussed in section 7 are also shown.

Table 8

Check list of biological data and samples collected

Samples and data	No. of whales Male	Female	Total
Body length and sex	154	119	273
External proportion	154	119	273
Photographic records of carcases	154	119	273
Diatom film record and sampling	154	119	273
Standard measurements of blubber thickness	154	119	273
Body weight and detailed measurements of blubber thickness	27	18	45
Mammary gland, lactation status measurements and histology sample	–	119	119
Milk sample for chemical analysis	–	0	0
Ovary collection	–	119	119
Corpora number, counting	–	119	119
Uterine horn measurement and endometrium sample	–	119	119
Uterine fluid for sperm detection	–	70	70
Foetal number	–	57	57
Foetal length	–	55	55
Foetal sex	–	54	54
Foetal weight	–	55	55
Foetus body proportion	–	1	1
Collection of foetus	–	19	19
Testis and epididymis weight and tissue collection	154	–	154
Smear sample from testis tissue	129	–	129
Blood sample for gonadal hormone assay	134	104	238
Muscle, liver and heart samples for electrophoretic study	154	119	273
Skin and muscle samples for DNA study	154	119	273
Tissue samples for pollution study	3	3	6
Blood samples for pollution study	0	43	43
Foetus samples for pollution study	0	10	10
Stomach content, conventional record	154	119	273
Stomach content, weight	51	34	85
Collection of stomach contents for food study	80	54	134*
Earplug for age determination	153	118	271
Earplug for chemical analysis	5	7	12
Tympanic bulla for age determination	31	42	73
Largest baleen plate for age determination	20	25	45
Vertebral epiphyses sample	150	119	269
Skull measurement (length and breadth)	154	119	273
Tissue sampling of various parts of the body for lipid analyses	23	14	37
Collection of whole skeleton	4	0	4

* including 30 individuals whose foods were collected separately from 1st to 4th stomach.

Morphometrics and body weight

After photographing the lateral side of each whale, a series of standard measurements was taken, including body length to the nearest 10cm and body proportions at 17 different points (to the nearest 1cm). The sex of the animal and the level of diatom infection were also recorded at this stage. Total body weight measurements (by parts) were taken once a day (normally the first whale of the day; 39 individuals). The total weight before flensing was occasionally taken for whales less than 6.1m long (11 individuals). Information on body weight before and after flensing is available for six whales.

Standard blubber thickness measurements (to the nearest 0.1cm) were taken at three points on the lateral side of the body at the levels of the ear, umbilicus and dorsal fin. Skull measurements (length and greatest breadth to the nearest 1cm) were taken for all whales using a large pair of vernier calipers.

Reproductive material

After removing the blubber from females, measurements were taken of the greatest breadth and thickness of mammary gland (to the nearest 0.1cm) and tissue samples from it collected and preserved in 10% formalin. Ovaries were also collected. The width of the uterine horn was measured and endometrium tissue collected. Uterine fluid for sperm detection was collected from the vagina or uterus of all sexually mature females and those thought to be pubertal (n=70). The weighing of the ovaries, the counting of the corpora and the measurement of the three dimensional diameter of corpora lutea, corpora albicantia and the three largest graafian follicles present was completed during the cruise.

If a foetus was present in the uterus, the number, sex, length (to the nearest 1cm) and weight were recorded. The identification of the sex of the foetus was based not only on the shape of the sexual organ (which can be misleading for very small foetuses) but also the distance between the anus and the centre of the sexual organ. A total of 57 foetuses from 57 females were found, of which 55 were measured and 54 were sexed. Body proportions were measured in foetuses over 200cm in length (n=1 on this cruise).

In males, both testes and epididymides were separately weighed to the nearest 10g. Tissue samples (1cm^3 and 1cm respectively) were collected from the centre of the right side and preserved in 10% formalin. Smear samples obtained from the centre of both were taken from 129 males.

Age

We attempted to collect both earplugs from each whale and this was possible for 256 (94%) of the animals (one earplug was missing for 15 and both missing for two whales). The earplugs were partially prepared during the return journey. As a supplement for age determination studies, tympanic bullae (73 animals) were collected, mainly from smaller animals (males less than 7.1m and females less than 7.4m) for which aging from earplugs is more difficult or from whales which both earplugs were missing. Similarly the largest baleen plates (45 animals) were collected from whales of either sex smaller than 6.1m long.

Sections (about 4.5 × 7.0 × 0.7cm) of vertebra between the epiphyses and centrum were taken from the 6th dorsal and 3rd lumber vertebra of all whales sampled and preserved in 10% formalin solution.

Tissue and blood samples

We attempted to collect blood (serum) samples for gonadal hormone assay from all whales and it was found to be possible for 238 (87%) whales (134 male and 104 females). Samples were frozen after centrifuging for serum separation. Tissues samples (50g) were collected from all whales for DNA studies (including skin and muscle) and electrophoretic studies (muscle, liver and heart) and stored frozen at about –20°C soon after collection.

Samples from several tissues, including muscle, liver, kidney and pancreas, were collected for pollution studies from six sexually mature animals (3 males; 3 females) and frozen. Serum samples for pollution studies were obtained from 43 pregnant females and their foetuses.

The following tissue samples (500g-5kg) from weighed whales were taken for lipid analysis: muscle (just below dorsal fin); blubber (from two portions); ventral groove; vertebrae (7th lumber); liver; forestomach; heart; kidney; and small intestine.

Stomach contents

'Conventional' stomach content records (species with rough classification and relative abundance) were completed for all whales. If euphausiids were present, their state of digestion was also recorded (three classifications).

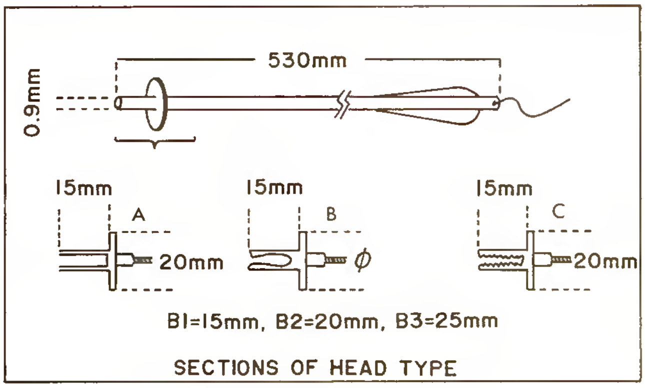


Fig. 7. Biopsy dart experiment – equipment and head type.

In addition, we attempted to weigh the stomach contents for all whales with stomachs more than 25% full; this was done for 85 individuals.

Stomach contents (including euphausiids and fish) were collected from 134 whales with relatively fresh food in their stomachs.

Skeletal material

Four whole skeletons were collected for taxonomic study and museum and educational purposes. These were all males (8.9m, 8.5m, 8.1m and 7.0m – dwarf form).

5.2 Biopsy experiment

As part of a project to develop an efficient biopsy dart, some experiments were carried out on 1 February on deck of N03 on a 6.6m male carcass, using a *Barnett Thunderbolt* crossbow (71cm long and 81cm wide) and a *Barnett* fibre arrow dart. The dart was attached to the bow using a line (No. 200 and No. 8). Several different types of dart head were tried (Fig. 7).

Table 9

Results of the biopsy dart experiment

			Result		
Trial no.	Head type[1]	Shooting distance (m)	Dart release	Dart recovery	Tissue sampling
1	A	35	Yes	–	No
2	C	35	Yes	–	No
3	A	25	No	–	–
4	B1	25	Yes	No[2]	Yes
5	B2	25	Yes	Yes	Yes
6	B3	25	Yes	–	No
7	B2	25	Yes	No[3]	Yes
8	B2	25	No	–	–
9[4]	B2	ca.50	–	–	–
10[4]	B2	ca.40	–	–	–

[1] see Fig. 9.

[2] due to deep penetration of the head (8cm from surface).

[3] a line was snapped on recovering the sample.

[4] only for observing the trajectory of a dart.

Ten trials were conducted at distances of 25m and 35m to the whale lying with its belly on the deck (Table 9). Head type B was found to be the most effective for sampling tissue, but this type, with its smaller stopper, occasionally penetrated into the carcass. Recovery of sampled material may be difficult however. Regardless of head type, some problems in dart release were encountered; this may be due to the use of unsuitable fishing reel. The system was not tested on live whales.

6. OCEANOGRAPHICAL RESEARCH

In addition to routine recording of weather and sea conditions, oceanographic information, including surface temperature and vertical thermal distribution (using XBTs) was collected from T25. The data were normally collected at the end of sampling and sighting work each day (17 January – 25 March, 17:00 – 21:00; 26 March, 10:50). Detailed analyses of the data, including the relationship with whale distribution, will be presented in a future paper.

A survey of marine debris was made from the wheel house of NO3 (height 21m from sea level). The total searching time was 422.75 hrs (176.0 hrs from 17 January – 6 February, 95.0 hrs from 6 February – 1 March and 151.75 hrs from 2 – 26 March). One plastic bottle and one expanded polystryrene box were seen in the first period, but nothing was found in the second and the third periods. A plastic bag (55cm × 38cm) was found from the stomach of a whale sampled in the southern stratum.

Similar surveys were also made during the cruise between the research area and the waters close to Japan. Those data will be analysed in a future paper.

7. PRELIMINARY ANALYSES

This section provides a preliminary analysis of data examined soon after the cruise had finished. As noted earlier, detailed analyses will be presented in future papers.

Although body lengths were measured to the nearest 10cm, for the present analyses they have been grouped to the nearest foot.

Sex, length and reproductive structure of samples

Grouping of samples

From an examination of the sightings data, the spatial distribution of the catch, possible seasonal movement of the whales and the distance from the ice edge, five time/area groups were used to aid examination of the data (Table 10). They are also shown in Fig. 6.

Table 10

Time/area groupings: sample sizes and percentage males in the catch

Group	Catch periods	Catch M	Catch F	Catch (%M)	Catch T	Total catch
Northern (NG)	17–19 Jan, 1–8 Feb, 23 March	23	5	82.1	28	10.3
Offshore central (COG)	22 Jan, 28–31 Jan, 11–12 Feb	17	16	51.5	33	12.1
Eastern offshore (EOG)	8–9 Feb	10	2	83.3	12	4.4
Western pack ice (WIG)	12 Feb–5 March	67	72	48.2	139	50.9
Eastern pack ice (EIG)	24–28 Jan, 10–12 Mar	37	24	60.7	61	22.3

Table 11

Mean body length (ft) and standard deviation (SD) of samples by sex and time/area group

Time/area group	Male			Female		
	Mean (S.D.)	Range	n	Mean (S.D.)	Range	n
NG (56–62°S)	24.5 (4.1)	17.1–29.8	23	21.0 (1.8)	19.0–23.9	5
COG (62–65°S)	24.5 (3.9)	17.4–30.5	17	21.2 (2.6)	17.7–27.6	16
EOG (62–63°S)	25.1 (3.3)	19.7–30.5	10	20.2 (0.5)	19.7–20.7	2
WIG (64–65°S)	26.9 (1.9)	20.3–29.8	67	27.7 (2.6)	21.3–31.5	72
EIG (64–65°S)	27.0 (2.6)	19.0–30.2	37	25.8 (4.0)	18.4–32.5	24
Total	26.2 (3.0)	17.1–30.5	154	26.0 (3.8)	17.7–32.5	119

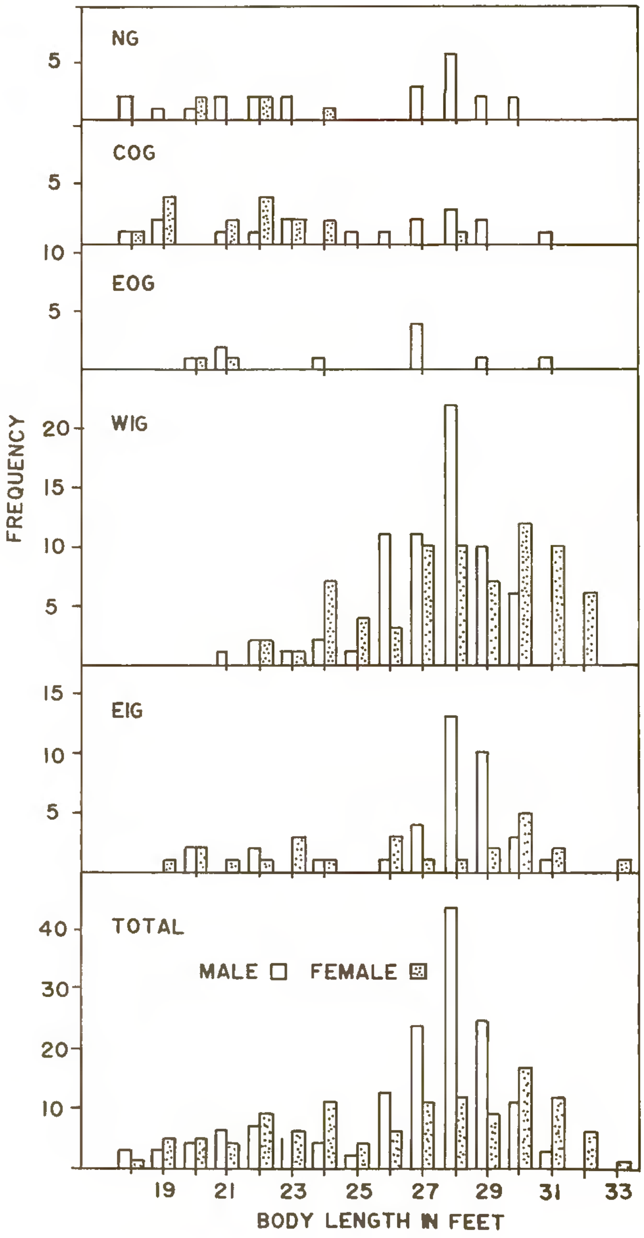


Fig. 8. Length composition (ft) by sex and the time/area/group.

Sex and length composition

Table 10 shows the sex composition of the catch by time/area group. It reveals that males predominated in the northern (82%) and offshore (60%) groups, whereas nearer the ice the sex ratio was almost even.

Fig. 8 and Table 11 show length distributions by sex and time/area group. In both the northern and offshore groups, males (17–30ft) were generally larger overall than females (18–24ft) apart from one large (28ft) female. Although there was little difference in the length range of males among the five time/area groups, there was a statistically significant difference in mean lengths between the northern/offshore groups and the pack ice groups (t-test, $p<0.05$). In the case of females, the range in size (large animals were absent in the northern/offshore groups) was different between the northern/offshore groups and the pack ice groups and statistically significant differences in mean lengths were found between the same groups ($p<0.001$).

Within the pack ice groups, the mean length of females in WIG was statistically greater than that in EIG (t-test, $0.005<p<0.01$); the mean lengths of males were not significantly different.

Reproductive status (Table 12)

Females were considered mature if at least one corpus luteum or albicans was present in the ovary or if a foetus was present in the uterus. It is noteworthy that, throughout sampling, no lactating female was found. As preparation of testes and epididymides tissues for histological analysis has not been completed, the testis weight value (over 0.3 kg on the heavier side – originally provided by Ohsumi, Masaki and Kawamura (1970) and reconfirmed by Kato (1986)) was taken as a tentative criterion of sexual maturity.

Table 12

Reproductive status of samples by sex and time/area group

Time/area group	Male		Female				
				Mature			
	Imm.	Mat.	Imm.	Preg.	Rest.	Lact.	Unknown
NG (56–62°S)	9 (39.1)	14 (60.9)	5 (100)	0	0	0	0
OOG (62–65°S)	8 (47.1)	9 (52.9)	15 (93.8)	1 (6.2)	0	0	0
EOG (62–63°S)	3 (30.0)	7 (70.0)	2 (100)	0	0	0	0
WIG (64–65°S)	8 (11.9)	59 (88.1)	26 (36.1)	44 (61.1)	1 (1.4)	0	1* (1.4)
EIG (64–65°S)	5 (13.5)	32 (86.5)	12 (50.0)	12 (50.0)	0	0	0
Total	33 (21.4)	121 (78.6)	60 (50.4)	57 (47.9)	1 (0.8)	0 (0.0)	1 (0.8)

* Uterine horn was damaged by the harpoon but both ovaries with one corpus luteum remained.

In the offshore groups, all but one female (pregnant) was immature. In the northern and offshore groups the proportions of sexually immature males were also relatively high (30–47.1%). In the pack ice groups however, the proportion of sexually immature animals decreased to 36.1 – 50.0% in females and 11.9 – 13.5% in males. Within the pack ice groups, the proportion of pregnant females was higher in WIG, although the difference was not statistically significant.

Table 13

Mean body length and standard deviation (SD) of samples by sex and school size

School size	Male			Female		
	Mean (S.D.)	Range	n	Mean (S.D.)	Range	n
1	23.1 (3.8)	17.4–28.5	31	21.8 (2.7)	18.0–29.8	22
2	25.9 (3.3)	17.1–30.5	27	25.5 (4.6)	17.7–31.2	20
3	27.2 (1.5)	21.6–29.2	29	27.0 (3.8)	18.4–32.5	12
4	27.6 (1.1)	25.9–29.8	28	27.1 (2.8)	20.7–31.2	23
5	26.9 (2.0)	20.3–29.2	16	27.4 (2.4)	22.3–30.8	24
⩾6	27.0 (1.9)	23.0–30.5	23	27.9 (2.9)	21.3–31.5	18

Biological characteristics by school size

Mean length (Table 13)

The mean body lengths of both males (22.9ft) and females (21.8ft) found alone were statistically smaller than for the other school sizes (t-test, $p<0.001$). No significant differences were found among the larger school size (26.9–27.3ft in males and around 27ft in females), although for schools of six or more, females were slightly larger.

Reproductive status (Table 14)

Sexually immature animals of both sexes predominated in the solitary class. In summary smaller immature animals tended to be solitary in offshore waters whereas larger, sexually mature animals tended to be found in larger schools in the high latitudes.

Combination of animals

As noted earlier, the maximum number of whales to be taken from any school was two. Table 15 gives information on the 86 pairs taken with respect to sex and reproductive status by school size. In general there was no case of both whales being immature males and few cases of an immature male with a mature male. The most frequent combinations were a mature male and mature female (n=23 pairs), two mature males (16 pairs), and a mature male and immature female (15 pairs).

Table 14

Sexual maturity by sex and school size

School size	Male		Female	
	Immature	Mature	Immature	Mature
1	17 (54.8)	14 (45.2)	21 (95.5)	1 (4.5)
2	8 (29.6)	19 (70.4)	10 (50.0)	10 (50.0)
3	1 (3.4)	28 (96.6)	4 (33.3)	8 (66.7)
4	0 (–)	28 (100)	9 (39.1)	14 (60.9)
5	2 (12.5)	14 (87.5)	11 (45.8)	13 (54.2)
⩾6	5 (21.7)	18 (78.3)	5 (27.8)	13 (72.2)
Total	33 (21.4)	121 (78.5)	60 (50.4)	59 (49.6)

Table 15

Combinations of two individuals collected from the same school with respect to sex and maturity (I = immature, M = mature), by school size

School size:		2				3				4			
		Male		Female		Male		Female		Male		Female	
		I	M	I	M	I	M	I	M	I	M	I	M
Male	I	0	0	3	2	0	1	0	0	0	0	0	0
	M	–	2	2	3	–	3	2	3	–	6	5	6
Female	I	–	–	1	0	–	–	0	1	–	–	1	2
	M	–	–	–	0	–	–	–	1	–	–	–	3

School size:		5				6(+)				Total			
		Male		Female		Male		Female		Male		Female	
		I	M	I	M	I	M	I	M	I	M	I	M
Male	I	0	1	1	0	0	3	1	1	0	5	5	3
	M	–	1	4	6	–	4	2	5	–	16	15	23
Female	I	–	–	2	2	–	–	0	1	–	–	4	6
	M	–	–	–	2	–	–	–	3	–	–	–	9

A preliminary examination of the length data for these pairs (Table 16) suggests that combinations of animals of similar (larger) lengths were more common with increasing school size.

Foetus frequency

Of the 59 sexually mature females taken, 57 (96.6%) were pregnant (all single foetuses). The lengths of the foetus varied considerably (<5cm – 207cm). Despite this range (suggesting a similar range in the timing of the conception) the trend in foetal length (L) by date (t) was one of gradual increase (Fig. 9). The fitted linear regression was:

$$L=47.61+0.76t \ (r=0.208; n=55).$$

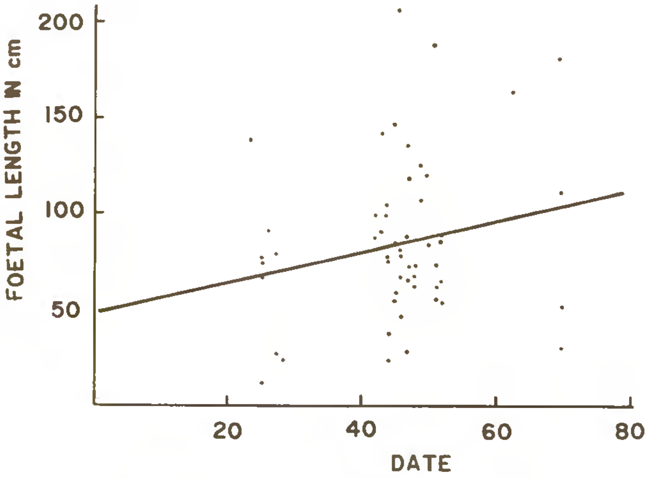


Fig. 9. Length distribution of foetuses collected. Dates: 1 = 1 January 1988.

Table 16

Combinations of two individuals collected from the same school with respect to body length (ft) by school size

Larger whale (ft)

Smaller whale (ft)	School size 2										School size 3							
	22	23	24	25	26	27	28	29	30	31	25	26	27	28	29	30	31	32
17	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
20	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	1	-	-	-	-	-	2	1	-	-	-	-	-	1	-	-	-	-
22	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23		-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-
24			-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
25				-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
26					-	-	1	-	-	-		-	1	1	-	-	-	-
27						-	2	-	1	-			2	1	-	-	-	-
28							-	-	-	-				-	-	-	-	-
29								-	-	-					-	-	-	1

Smaller whale (ft)	School size 4							School size 5						
	25	26	27	28	29	30	31	24	25	26	27	28	29	30
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	1	-	-	-	-	-	1	-	-	-	-	-	-
21	-	-	-	1	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	1	-	-	-
23	-	2	1	-	-	-	-	-	-	-	1	-	-	-
24	-	-	-	-	-	-	-	-	-	-	1	-	-	1
25	1	-	1	-	-	-	-		1	1	2	1	-	-
26		-	2	1	2	1	-			-	2	-	-	-
27			1	2	2	-	-				-	1	1	1
28				1	1	-	1					-	-	1
29					1	1	-						2	1
30						-	-							-

Smaller whale (ft)	School size ≥ 6									Total										
	23	24	25	26	27	28	29	30	31	22	23	24	25	26	27	28	29	30	31	32
17	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
20	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-
21	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	4	1	-	-	-
22	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
23	-	-	-	1	1	1	2	-	-		-	-	1	3	3	1	2	1	-	-
24		-	-	-	-	-	-	-	-			-	-	-	1	-	-	1	1	-
25			-	-	2	-	-	-	-				2	3	5	1	-	-	-	-
26				-	1	-	2	1	1					-	6	3	4	2	1	-
27					1	1	1	-	1						4	7	4	2	1	-
28						-	1	-	-							1	2	1	1	-
29							1	-	-								4	2	-	1
30								-	1									-	1	-

Blubber thickness

Although blubber thickness was measured at three points, this section only examines the data from below the dorsal fin (Table 17).

The mean blubber thickness was greater in females. The relatively wide range in blubber thicknesses might be due to variation in timing of migration, but more information is required to confirm this. Fig. 10 plots blubber thickness (T) by individual against date (t). Despite considerable variation, the minimum and maximum values clearly increased by day. The fitted liner regression was:

$$T=3.07+0.023t\ (r=0.393;\ n=273).$$

The slope is significantly different from 0 (t-test; $p<0.001$).

Table 17

Blubber thickness of samples by sex and time/area group

Time/area group	Incidence (%) by time/area group					
	Male			Female		
	Mean (S.D.)	Range	n	Mean (S.D.)	Range	n
NG (56–62°S)	3.4 (0.8)	2.1–4.6	23	4.4 (0.8)	2.9–5.3	5
COG (56–62°S)	3.9 (0.6)	3.0–5.1	17	4.0 (0.5)	3.2–5.2	16
EOG (56–62°S)	4.2 (0.7)	2.7–5.0	10	5.0 (0.3)	4.7–5.3	2
WIG (56–62°S)	4.1 (0.7)	2.7–5.5	67	4.4 (0.8)	2.9–7.0	72
EIG (56–62°S)	3.6 (0.8)	2.2–5.5	37	4.3 (0.9)	2.7–6.1	24
Total	3.9 (0.8)	2.1–5.5	154	4.3 (0.8)	2.7–7.0	119

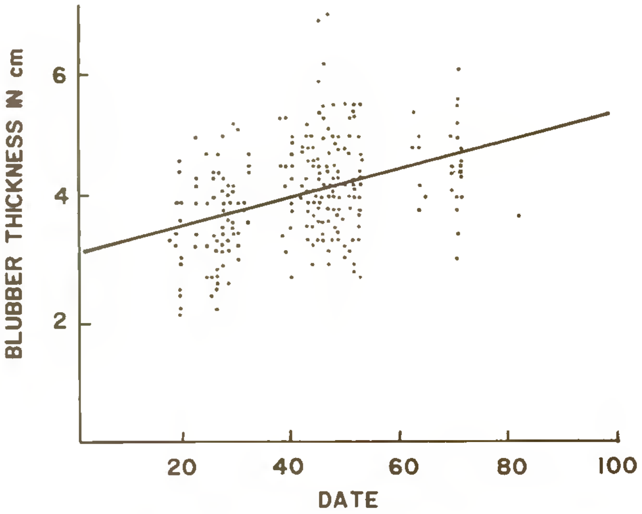


Fig. 10. Blubber thickness (below of dorsal fin). Dates: 1 = 1 January 1988.

Stomach contents

Food species

Stomach contents of all whales were examined visually. Excluding the 13 whales whose stomachs were damaged by the harpoon, 49 stomachs (23%) were apparently empty.

Table 18

A summary of information on food species and their frequency of occurrence. * = dwarf form

Stomach contents	Occurrence (%)	Stomach contents	Occurrence (%)
Euphausiids only	207 (75.8)	Empty	49 (17.9)
Euphausiids and fishes	3 (1.1)	Lost	13 (4.8)
Fishes only	1* (0.4)	Total	273 (100.0)

Table 18 summarises the information on food species so far compiled. Euphausiids predominated, being found in 210 individuals (99.5% of the total). Various fish including *Notothenia* sp. were found with Euphausiids in three stomachs. The stomach of the dwarf form whale comprised only the fish, *Myctophid* sp. More detailed information on stomach contents will be presented in a future paper.

Relative fullness (Table 19)

In the northern and offshore groups, no almost full (75 – 100%) stomachs were found and 57% were in the 3 classes less than half full. In the two pack ice groups, by contrast, a relatively high percentage (17%) of stomachs were over half full.

Table 19

Composition of relative richness of stomach contents based on conventional classification by time/area group

Relative richness (%)	Incidence (%) by time-areal group*				
	NG	COG	EOG	WIG	EIG
75 - 100	0 (0.0)	0 (0.0)	0 (0.0)	5 (3.8)	1 (1.7)
50 - 74	4 (16.0)	4 (13.3)	1 (8.3)	18 (13.7)	8 (13.8)
25 - 49	6 (24.0)	9 (30.0)	6 (50.0)	30 (22.9)	14 (24.1)
< 25	8 (32.0)	13 (43.3)	2 (16.7)	61 (46.6)	17 (29.3)
Empty	7 (28.0)	4 (13.3)	3 (25.0)	17 (13.0)	18 (31.0)
Unknown	3	3	0	8	3
Total	28	33	12	139	61

* percentage to the total excluding stomach status unknown.

Table 20

Daily changes in the relative richness of stomach contents by time/area group (NG, COG and EOG were combined as offshore)

Relative richness (%)	Incidence (%)			
	6:00-9:00	9:00-12:00	12:00-15:00	15:00-Sunset
WIG				
75 - 100	4 (8.3)	0 (0.0)	0 (0.0)	1 (5.0)
50 - 74	8 (16.7)	6 (15.4)	3 (12.5)	1 (5.0)
25 - 49	19 (39.6)	7 (17.9)	0 (0.0)	4 (20.0)
< 25	15 (31.3)	20 (51.3)	17 (70.8)	9 (45.0)
Empty	2 (4.2)	6 (15.4)	4 (16.7)	5 (25.0)
Unknown*	3	4	0	1
Total	51 (100)	43 (100)	24 (100)	21 (100)
EIG				
75 - 100	1 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)
50 - 74	3 (18.8)	2 (18.2)	2 (14.3)	1 (5.9)
25 - 49	5 (31.3)	3 (27.3)	5 (35.7)	1 (5.9)
< 25	5 (31.3)	2 (18.2)	3 (21.4)	7 (41.2)
Empty	2 (12.5)	4 (36.4)	4 (28.6)	8 (47.1)
Unknown*	1	1	1	0
Total	17 (100)	12 (100)	15 (100)	17 (100)
Offshore				
75 - 100	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
50 - 74	3 (21.4)	1 (5.9)	2 (18.2)	3 (12.0)
25 - 49	5 (35.7)	7 (41.2)	3 (27.3)	6 (24.0)
< 25	3 (21.4)	8 (47.1)	4 (36.4)	8 (32.0)
Empty	3 (21.4)	1 (5.9)	2 (18.2)	8 (32.0)
Unknown*	0	1	4	1
Total	14 (100)	18 (100)	15 (100)	26 (100)

* including samples stomach lost.

An examination of stomach fullness and time of day (Table 20) showed that in the pack ice groups, the proportion of empty stomachs increased with time of day, suggesting that the peak feeding time is in the morning or earlier. No clear pattern emerged from the data for the offshore and northern groups.

Comparison with commercial whaling

Fig. 11 compares the length distribution of the present study and commercial whaling from Area IV (Japanese fleet, 1986/87). The range in lengths of males and females was wider in the present study, particularly at the lower end (males 17ft vs 24ft; females 18ft vs 24ft). Statistically significant differences in mean lengths between the research(R) and the commercial(C) catches were found: 26.2ft(R) versus 28.0ft(C) in males and 26.0ft(R) versus 29.5ft(C) in females (t-test, $p<0.001$).

As one might expect from the length data, the percentages of sexually mature animals found (78.6% for males and 49.6% for females) were considerably lower than values given by Masaki (1979) and Kato (1982) for the commercial era using the same maturity criteria (between 92–98% for males and between 68–85% for females).

A preliminary examination of the length at maturity data (Table 21) for males (excluding the dwarf form animal) showed that the smallest mature male was 23ft and largest immature whale was 26ft. The length at which 50% of animals were sexually mature will be between these lengths, and may be higher than previous estimates of Masaki (1979) and Kato (1982) using the same maturity criterion (23ft – 23.5ft). For females, the length at which 50% were sexually mature was between 26 – 27ft, a similar value to the estimate of 26.5ft given by Kato (1987). Mean body length at first ovulation (another measure of length at maturity) was 27.2ft (SD=0.34, n=8), the same value as the proposed mean length at sexual maturity for the total population given by Kato (1987).

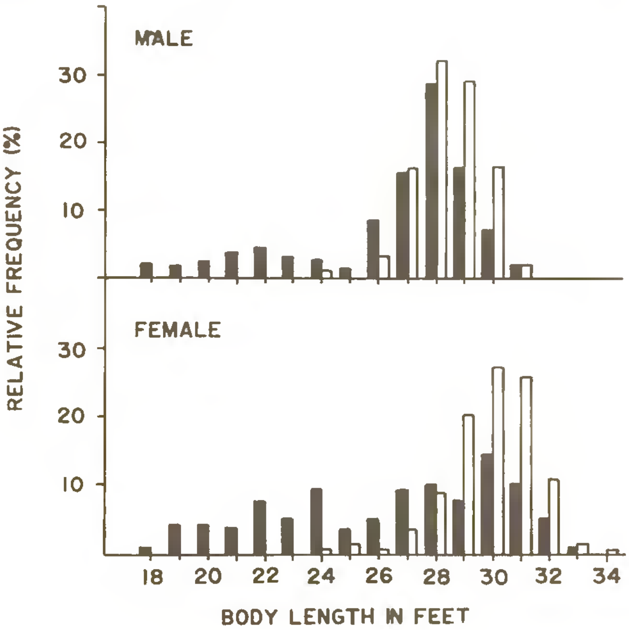


Fig. 11. Comparison of length compositions from the present cruise (solid line) and Japanese commercial whaling in Area IV in 1986/1987 (hatched line).

Table 21

Sexual maturity by sex and body length (ft)

Body length (ft)	Male			Female		
	Immature	Mature	Total	Immature	Mature	Total
17.0-17.9	3 (100)	0	3	1 (100)	0	1
18.0-18.9	3 (100)	0	3	5 (100)	0	5
19.0-19.9	4 (100)	0	4	5 (100)	0	5
20.0-20.9	4 (100)	0	4	3 (100)	0	3
21.0-21.9	5 (100)	0	5	10 (100)	0	10
22.0-22.9	6 (100)	0	6	5 (100)	0	5
23.0-23.9	5 (71.4)	2 (28.6)*	7	12 (100)	0	12
24.0-24.9	1 (50.0)	1 (50.0)	2	4 (100)	0	4
25.0-25.9	1 (7.3)	12 (92.3)	13	6 (100)	0	6
26.0-26.9	1 (4.2)	23 (95.8)	24	4 (36.4)	7 (63.6)	11
27.0-27.9	0	44 (100)	44	5 (41.7)	7 (58.3)	12
28.0-28.9	0	25 (100)	25	0	9 (100)	9
29.0-29.9	0	11 (100)	11	0	17 (100)	17
30.0-30.9	0	3 (100)	3	0	12 (100)	12
31.0-31.9	–	–	–	0	6 (100)	6
32.0-32.9	–	–	–	0	1 (100)	1

* including one dwarf form animal.

8. DISCUSSION

This research programme was the first to incorporate a systematic sighting survey with a concurrent random sampling procedure. In general it can be concluded that the present study proved to be successful.

As noted earlier, the sampling scheme was reasonably successful with no major logistical problems. The actual searching distance achieved (8,482n.miles) was about 12% less than expected (9,600n.miles) mainly due to lengthy periods of unsuitable weather and sea conditions. This partially explains the 10% shortfall in number of whales sampled (273) than expected (300). Weather conditions, therefore are a major factor to be considered in the planning of future cruises.

Three other problems encountered which will need to be considered in future planning with relation to sampling are (1) the need for stop-catch regulations in high density areas; (2) the problem of completing sampling (i.e. reaching the total sample size) before covering the whole research area due to encountering high density areas (see section 2); (3) the need for co-operative sampling by vessels in certain areas to ensure two whales are taken from schools of two or more (see section 2 and below).

Apart from the case where varying densities close to the ice-edge resulted in one (the northern) vessel advancing considerably faster than the other which was carrying out all the sampling, the study generally showed that systematic sighting and sampling work can be conducted concurrently. One of the major factors in this was the fact that most of sampling vessel personnel had experience from the IDCR Southern minke whale assessment cruises and the excellent cooperation between researchers and crew for sighting, sampling and collecting information (especially with regard to school formation). However the number of researchers and assistants on the sampling vessel was slightly too low for the amount of allocated work.

No problems in the biological data and sample collection on the deck of N03 were encountered thanks to the cooperation of the experienced flensing staff and to the contributions of experienced researchers and technicians, although several improvements in equipment are needed.

Certain aspects of segregation, previously suggested by commercial whaling data (e.g. Ohsumi and Masaki, 1975; IWC, 1979; Best, 1982; Kato, 1987) and confirmed in the present study need further detailed study in terms of ensuring that a representative sample is obtained from the wide latitudinal area which needs to be covered.

9. ACKNOWLEDGEMENTS

We are greatly indebted to Dr Ikuo Ikeda, project leader of the present research plan (Director of the Institute of Cetacean Research), for his instructions and valuable suggestions for the cruise. Drs Seiji Ohsumi and Toshio Kasuya (Far Seas Fisheries Research Laboratory) kindly reviewed the present manuscript. Suggestions of Mr Hirohisa Kishino (The Institute of Statistical Mathematics) for the preliminary analyses were of great help.

We also thank to the following persons: *Nisshinmaru* 3, Captain Masafumi Furukawa and his crew and general manager Shigeru Tanifuji and his staff; *Kyomaru* 1, Captain Fumio Yokota and his crew; *Toshimaru 25*, Captain Rintaroo Fukui and his crew. Messrs. Masamitsu Yamada (K01), Tameo Ryono (T25), Shigeo Tabata (N03) and Yutaka Eguchi (N03) successfully completed their assignment as research assistants and we would not have been able to carry out the research works without their cooperation.

Dr Hirosato Kikuchi (on board as a ship's doctor, Associate Professor of Toho University School of Medicine) kindly reviewed an earlier version of this report. The suggestions and modifications suggested by Greg Donovan of the International Whaling Commission and an anonymous reviewer were greatly appreciated.

REFERENCES

Anonymous, 1987. Instruction note for researchers and crew on the implementation of research in 1987/88 preliminary research plan. Paper SC/D87/35 present to the special meeting of the IWC Scientific Committee, December 1987. 25pp.

Arnold, P., Marsh, H. and Heinsohn, G. 1987. The occurrence of two forms of minke whales in east Australian waters with a description of external characters and skeleton of the diminutive or dwarf form. *Sci. Rep. Whales Res. Inst., Tokyo* 38:1–46.

Best, P.B. 1982. Seasonal abundance, feeding, reproduction, age and growth in minke whales off Durban (with incidental observations from the Antarctic). *Rep. int. Whal. Commn* 32:759–86.

Best, P.B. 1985. External characters of southern minke whales and the existence of diminutive form. *Sci. Rep. Whales Res. Inst., Tokyo* 36:1–33.

Butterworth, D.S., Hammond, P. and Mizroch, S. 1984. Summary of Southern Hemisphere minke whale sighting assessment using the stratification method. *Rep. int. Whal. Commn* 34:92.

Government of Japan, 1987a. The research plan for the feasibility study on 'the program for research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic'. Paper SC/D87/1 presented to the Special Meeting of the IWC Scientific Committee, December 1987. 36pp.

Government of Japan, 1987b. The program for research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic. Paper SC/39/O 4 presented to the IWC Scientific Committee, June 1987. 28pp.

International Whaling Commission, 1988a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38: 32–155.

International Whaling Commission, 1988b. Chairman's Report of the 39th Meeting. *Rep. int. Whal. Commn* 38: 10–31.

International Whaling Commission, 1989. Report of the Special Meeting of the Scientific Committee to consider the Japanese research permit (feasibility study). Published in this volume.

Joyce, G.G., Kasamatsu, F., Rowlett, R. and Tsunoda, L. In press. The IWC/IDCR Southern Hemisphere minke whale assessment cruises: the first ten years. *Rep. int. Whal. Commn* (special issue).

Kasamatsu, F. 1988. Report of minke whale sighting survey of low latitudinal waters in 1987/88. Paper SC/40/O 22 presented to the IWC Scientific Committee, June 1988. (Unpublished).

Kato, H., 1982. Some biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 32:393–99.

Kato, H. 1987. Density dependent changes in growth parameters of the southern minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 38: 47–73.

Masaki, Y. 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29:375–96.

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): 995-1004.

Ohsumi, S., Masaki, Y. and Kawamura, A. 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst., Tokyo* 22:75–125.

Shimadzu, Y. and Kasamatsu, F. 1981. Operation pattern of Japanese whaling expedition engaged in minke whaling in the Antarctic. *Rep. int. Whal. Commn* 31: 349–55.

Shimadzu, Y. and Kasamatsu, F. 1983. Operation pattern of Antarctic minke whaling by the Japanese expedition in 1981/82. *Rep. int. Whal. Commn* 33: 389–92.

Shimadzu, Y. and Kasamatsu, F. 1983. Operation pattern of Antarctic minke whaling by the Japanese expedition in 1982/83 season. *Rep. int. Whal. Commn* 34:357–9.

SC/40/Mi21

Norwegian Minke Whaling at West Greenland: Operational Strategies

Finn Larsen

Greenland Fisheries Research Institute, Tagensvej 135, 1. sal DK-2200 Copenhagen N, Denmark

ABSTRACT

The paper gives a description of the operational strategies employed by the Norwegian whaling vessel *Kato* working off West Greenland and attempts to answer some of the questions raised by the IWC Scientific Committee in relation to the interpretation of CPUE data. A summary of the catch and effort data collected on board *Kato* in the period 1979–85 is presented.

INTRODUCTION

The IWC Comprehensive Assessment Workshop on Catch Per Unit Effort (CPUE), held in Reykjavik, March 1987, agreed that CPUE data could not be interpreted without a detailed understanding, both in qualitative and quantitative terms, of the methods used to search for and catch whales (IWC, 1988a). The workshop identified a number of factors that are important in determining the relationship between CPUE and density:

(1) deciding which area to search;
(2) nature of searching within a locality;
(3) relationship between numbers of whales seen and those actually caught;
(4) factors relating to the distribution (patchiness) and behaviour of whales;
(5) exogenous factors (e.g. environmental conditions).

At its June 1987 meeting, the Scientific Committee recommended that the nations who have exploited minke whales in the North Atlantic should provide a detailed description of the methods and strategy of these operations (IWC, 1988b)

This paper describes strategies employed by the Norwegian small-type whaling vessel *Kato* while catching minke whales off West Greenland as they were perceived by the author during long periods of waiting, interrupted by short bursts of activity, on board the vessel in 1979, 1980 and 1981. The description will focus on some of the factors listed above, and will in addition present the types of effort data collected by Greenland Fisheries Research Institute (GFRI) on board the vessel from 1979 to 1985, but will not attempt any new analyses. Results of earlier analyses of some of the data are found in Larsen and Kapel (1982), Kapel and Larsen (1983), Kapel (1984; 1985), Holt (1985) and Larsen (1986).

It is important to keep in mind that the following description is the author's impression of which objective factors were important for the strategies employed by *Kato* in reaching her goal: to catch her share of the quota for the lowest investment. It is also important to realise that the search and catch process is not merely the result of a long chain of rationally based decisions by the crew, but is also shaped by irrational or subjective considerations. The importance of these compared to that of the objective factors is difficult to assess.

NORWEGIAN MINKE WHALING AT WEST GREENLAND

Norwegian minke whaling at West Greenland began in 1968, when four vessels took 27 animals. From 1968–1976, up to seven vessels took between 103 and 260 whales per year. From 1977 to 1983, *Kato* was the only Norwegian vessel allowed to catch minke whales at West Greenland, and was allocated 75 animals per year. In 1984 and 1985 the Norwegian share of the West Greenland quota was reduced to 70 and 52, respectively, and *Kato* had to share these with another vessel.

The vessel

Kato is a Norwegian small-type whaling vessel, but at 115ft and 219 GRT, one of the largest in the Norwegian fleet. It was built in 1969 as a combined fishing/whaling vessel, equipped with two 60mm Hendriksen cannons, a heated crows nest about 12m above sea level and a flying bridge on top of the wheelhouse, from where the ship can be maneuvered. It has a main engine of 750 HP giving a maximum speed of 11 knots, but normal searching speed is usually 7–9 knots. Between the 1980 and 1981 seasons, the vessel was extended to about 125ft and the tonnage to 225 GRT.

Whales are hauled in and flensed on the flensing deck at sea level, from where the meat is hoisted onto the upper deck for cooling for at least 18 hours before processing. During whaling, *Kato* is equipped with a processing/freezing/packaging plant, where the meat is made into products ready for the consumer.

The navigational equipment includes a satellite navigation system, auto-pilot, automatic direction finder (ADF), weather-fax receiver and, from 1981, an automatic track plotter connected to the navigation system.

The normal crew comprises 10 people: 1 captain/gunner; 1 first mate/gunner; 1 engineer; 1 cook and 6 crewmen working in three shifts with 4 hours of searching, 4 hours of processing and 4 hours off duty.

SEARCHING

General strategy

Kato usually arrived in West Greenland in the first week of June and went to either Faeringehavn (at 63°45′N) or Nuuk (Godthåb, at 64°10′N) to resupply after the journey across the North Atlantic.

From there she would head out towards the steep outward slopes of the fishing banks, and follow the slopes northwards searching for the whales that were believed to be migrating north along these slopes (see Fig. 1). Information on catches in previous years, recorded on the navigational charts (and in later years, on the track plotter as well) together with up to date information on weather and ice conditions, formed the basis for the decision of where to start searching. During the search special interest would be paid to areas where whales had previously been caught in large numbers.

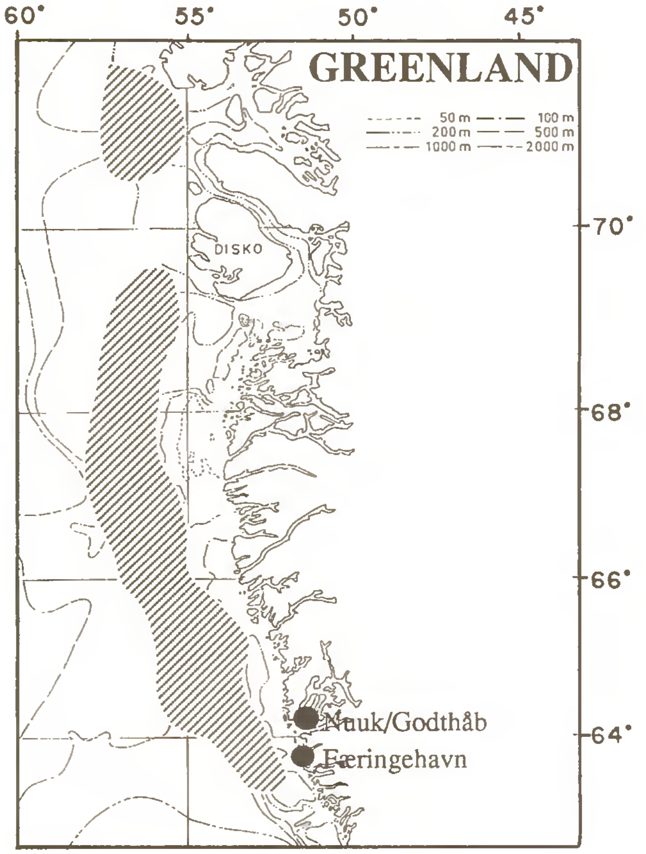


Fig. 1. Map of West Greenland showing crude depth contours and catching areas (hatched).

During the season, each of the main concentration areas for minke whales, as judged from catches in previous years, would be searched at least once.

It is interesting to note that *Kato* never went south of about 64°N to search for whales. This was not because the crew believed that there were no minke whales south of 64°N, but because they considered the weather conditions in South Greenland, with the frequent low pressures passing Kap Farvel, to be unsuitable for minke whaling.

Searching within a locality

Kato would go into 'searching mode' whenever she was outside the 12 n.mile fisheries zone, if weather and light permitted. Searching would normally not be attempted in winds of more than 5–6 Beaufort, because hitting a whale with the harpoon was almost impossible under these conditions. Normal searching speed was 7–9 knots.

In searching mode, at least one man would be in the crow's nest and at least one would be on the flying bridge. They would search for whales using hand held binoculars (usually 7x50) as well as with the naked eye. All sightings would be communicated through the intercom to the wheelhouse, where the gunner would be waiting.

The searching pattern within a locality would be decided by the captain/gunner, but would usually follow a depth contour where whales had been encountered earlier in the season or in previous seasons.

This pattern could be altered by:

(1) lack of animals in the area;
(2) information from other vessels (usually shrimp trawlers) on sightings of minke whales in other areas;
(3) ice conditions forcing a change in track;
(4) weather conditions becoming unfavourable for catching.

A decision to change the searching pattern would be based on an evaluation by the captain of whether the probability of successful catching was sufficiently higher in another area to allow the extra cost of transiting (although he wouldn't put it that way!).

Searching during chasing and handling

When a minke whale was sighted, the steering would be switched from auto pilot to manual, and maneuvering would be taken over by the man on the flying bridge. He would try to bring the vessel within 30–50m of the whale, thereby allowing the gunner a shot at the animal.

During chasing, both spotters would communicate information on other sightings in the vicinity to people in the wheelhouse, who would record it on maps or on the track plotter. When chasing and handling had ended, this information would form the basis for the decision of where to search for the next whale.

From the time a whale had been hit until it was brought to the flensing deck (or secured alongside if the flensing deck was already occupied), the man in the crow's nest would assist on deck and not be searching for whales.

Immediately after a whale had been brought onto the deck or secured alongside, searching for the next whale would commence, unless the captain decided to stop catching in favour of processing. According to Norwegian regulations the meat had to lie in the open air on the upper deck for at least 18 hours before being processed to allow oxygenation of the waste products formed in the muscles during the chase. The size of *Kato*'s upper deck before the lengthening in 1981 allowed the storage of meat from 10–12 whales. After the lengthening, meat from an additional two whales could be stored. Normally it was possible for the processing to keep up with the catching, but a few times during a season, excellent catching conditions would coincide with *Kato* being in an area of high whale density resulting in more whales being caught than could be processed. In these circumstances the captain would normally decide to stop catching for a period, and every crewman except the captain, the cook and the two crewmen off duty would take part in the processing.

CATCHING

A small number of whales were caught while *Kato* was not in 'search mode', some as they approached the vessel when drifting, and some as they were encountered in weather conditions considered too bad for searching and catching but nevertheless caught. The majority of the whales were, however, caught after having been sighted in 'searching mode'.

In the offshore areas at West Greenland, minke whales usually occur as single animals, occasionally as two together. During the 1987 aerial surveys in these areas 40 observations of minke whales were made, of which 34 were of single animals and six were of groups of two animals (Larsen, Martin and Nielsen, 1989).

This would normally mean that no selection by the gunner took place. However, if two whales were sighted together or if, during the chasing of one whale, a second whale was encountered, the gunner would go for the largest one. Very occasionally the chasing of a whale would be abandoned if the animal was considered to be too small to be worth the effort, but this decision would depend on factors such as the time since the last catch and the remaining time available to reach the allowance.

EFFORT DATA

Detailed data on catch and effort was collected by GFRI on board *Kato* in the seasons 1979–83, using the daily record sheet recommended by the IWC Scientific Committee (IWC, 1980). In 1984 and 1985, GFRI did not participate in the Norwegian whaling operations at West Greenland and thus no time budget data was collected. However, the two Norwegian vessels were asked to record the periods spent searching together with information on position, the number of sightings since the last entry and environmental conditions. The data collected are shown in Table 1.

Table 1

The number of minke whales caught for which data on catch and effort was collected together with number of days for which detailed time budget data or data on searching effort were recorded on board *Kato*, 1979–85

Year	Catch data (no. of whales)	Time budget (days)	Search effort (days)
1979	25	46	–
1980	71	59	–
1981	43	73	–
1982	48	56	–
1983	41	56	–
1984	35	–	60
1985	31	–	53

In addition to this, the captain kept a catcher logbook, recording daily the noon position along with information on environmental conditions and the number of sightings made, and for every whale caught, the time, position, environmental conditions and biological information on the animal.

Interpreting the data

At its meeting in 1984, the IWC Scientific Committee decided to use only the CPUE data for the period 1977–83 when *Kato* was operating alone at West Greenland (IWC, 1985), primarily because it was uncertain to what extent cooperation between the vessels had affected the CPUE data in other years. The description above suggests that 'scouting' by other vessels took place between 1979 and 1983 as well, to an unknown extent.

Basing the assessment of the West Greenland minke whale stock on a short time series of CPUE data from a single vessel operating in a limited part of the total stock area and taking only around 30% of the total catch in the period makes it extremely important that we understand not only the factors affecting the catching operation itself, but also the factors relating to the distribution and behaviour of the whales, as expressed by the IWC Scientific Committee (IWC, 1988a).

Unfortunately we know very little about what determines the distribution of minke whales at West Greenland. We can demonstrate that the distribution of minke whales, as judged from the catches and in later years from sightings surveys, has been changing during the last 10–12 years (Larsen and Kapel, 1982; Larsen *et al.*, 1988), but we do not know whether whaling is the most important factor in the disappearance of minke whales from some of the offshore areas, and, if it is not, where they have gone.

ACKNOWLEDGEMENTS

I am indebted to the owners and the crew of *Kato* for their cooperation and kind hospitality during my stay on board the vessel off West Greenland. I am grateful to Mads-Peter Heide-Jørgensen, Greenland Fisheries Research Institute, and to two anonymous reviewers for helpful comments on the draft manuscript.

REFERENCES

Holt, S.J. 1985. Classification of North Atlantic minke stocks. Paper SC/37/Mi4 presented to the IWC Scientific Committee, June 1985, (unpublished). 60pp.

International Whaling Commission, 1980. Report of the Scientific Committee. *Rep. int. Whal. Commn* 30: 88–9.

International Whaling Commission, 1985. Report of the Scientific Committee. *Rep. int. Whal. Commn* 35: 93–4.

International Whaling Commission, 1988a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38: 157–62.

International Whaling Commission, 1988b. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38: 32–155.

Kapel, F.O. 1984. Catch and effort in Norwegian minke whaling off West Greenland, 1982. *Rep. int. Whal. Commn* 34: 293–300.

Kapel, F.O. 1985. The 1983 season of Norwegian small-type whaling in the Davis Strait. *Rep. int. Whal. Commn* 35: 235–8.

Kapel, F.O. and Larsen, F. 1983. Norwegian minke whaling off West Greenland, 1981. *Rep. int. Whal. Commn* 33: 323–8.

Larsen, F. 1986. Norwegian minke whaling off West Greenland, 1984. *Rep. int. Whal. Commn* 36: 239–40.

Larsen, F. and Kapel, F.O. 1982. Norwegian minke whaling off West Greenland, 1976–80 and biological studies of West Greenland minke whales. *Rep. int. Whal. Commn* 32: 263–74.

Larsen, F., Martin, A.R. and Nielsen, P.B. 1989. North Atlantic Sightings Survey 1987: Report of the West Greenland aerial survey. Paper SC/40/O 11 (published in this volume).

Other Baleen Whales

Fin whale off the coast of Spain, October 1983.
Photograph courtesy of G. Donovan

SC/40/Ba1

Pregnancy Rate Versus Length in Southern Fin Whales

David B. Sampson [1]

Renewable Resources Assessment Group, Imperial College of Science and Technology, 8 Prince's Gardens, London, SW7 1NA, United Kingdom

ABSTRACT

For the southern populations of fin whales (*Balaenoptera physalus*) the pregnancy rate, the fraction of females that are pregnant, is a function of the length distribution of the animals. There is a sigmoid-like relationship between pregnancy rate and length; larger females are more likely to be pregnant than smaller ones. Previous statistical analyses of the Southern Hemisphere pelagic whaling data from 1931 through 1975 did not take full account of this.

The relationship between pregnancy rate and length can be modelled by a symmetric logistic equation with a variable upper asymptote. The three parameters which define such a relationship are examined for significant effects with respect to six factors: Season (year), Month, Latitude, Area, Nation and Expedition (factory ship). Only the factors Season and Expedition are required to account for the observed variability in the data. Variability associated with factor Nation is an artefact of the correspondence between Nations and Expeditions. Variability associated with Month, Latitude and Area is indistinguishable from sampling error.

For a statistically significant majority of the expeditions there are increases with season in the parameter for the maximum pregnancy rate and decreases with season in the parameter for the length at which animals obtain half the maximum pregnancy rate; female fin whales of any given length are more likely to be pregnant in more recent years. These results are consistent with the notion that the reproductive rates in southern fin whales increased in a density dependent manner as the size of the baleen whale populations decreased. It is plausible that increased food per capita in more recent years permitted animals to recover more quickly from a pregnancy.

INTRODUCTION

Various researchers have noted increases in the pregnancy rates of the southern populations of baleen whales; pregnant females were occurring more frequently in catches in more recent years. Some scientists speculated that the apparent change in reproductive rates was a density dependent response to exploitation. Mackintosh (1942) observed that the percentage of pregnant females in the catches of blue and fin whales had increased markedly each season. He also mentioned an increase in the frequency of whales that were simultaneously pregnant and lactating. Laws (1961) proposed that the food supply might be an important determinant of maturity; the age at sexual maturity could diminish as 'the result of a higher level of nutrition stimulating bodily growth so that the size threshold for reproduction is reached at an earlier age'. Gambell (1976) presented evidence of an apparent increase in the rate of ovulation in fin whales beginning in the 1930s. These pieces of evidence suggested that the rate of reproduction in whales had increased as a result of reductions in the age at puberty and an increased frequency of reproduction.

These conclusions were based on qualitative judgements, not rigorous statistical analyses. The samples, which contained relatively few animals, were aggregated across potentially important factors such as month and location of capture. In any analysis of proportions, pregnancy rates for example, data pooling can mask or accentuate other effects (Simpson's paradox, Fienberg, 1977). The apparent changes in pregnancy rates may be spurious.

The major published statistical analyses of pregnancy rates in baleen whales are Mizroch (1980, 1981) and Mizroch and York (1985). These studies, which examined catch data from pelagic factory ships operating in the Southern Hemisphere, found no evidence of significant temporal trends in the pregnancy rates of sei whales (*Balaenoptera borealis*), blue whales (*B. musculus*) or fin whales (*B. physalus*). In the 1985 paper, an analysis of the southern whaling industry data for fin whales caught by pelagic factory ships from 1931 until the cessation of fin whaling in 1975, the authors stated that there was

> '... very high variability in pregnancy rates across all factors examined. Thus, it is impossible to show that the population responded to heavy harvesting with increasing pregnancy rates or a shortened breeding cycle. We see significant differences and much variability by season, but no apparent trend.'

I re-analyse these same data below and come to different conclusions. In part, the 'high variability in pregnancy rates' was a result of an inappropriate statistical model; pregnancy rates after logistic transformation (described below) are not linearly related to average whale length. I find significant temporal changes in the relationship between fin whale pregnancy rate and length; females of a given length are more frequently pregnant in the more recent catches.

POSSIBLE DETERMINANTS OF OBSERVED PREGNANCY RATES

One important feature of fin whale pregnancy rates is their dependence on length; smaller females are less often pregnant than larger females (Fig. 1). This is almost certainly due to the whales' growth and maturation. Because of this dependence, the overall fraction of females that are pregnant, the population pregnancy rate, is a function of the female length distribution and also of the underlying relationship between pregnancy and length.

Coarse aggregations of the fin whale data (Fig. 1) suggest that there were substantial increases in the pregnancy rate for a given length; for the larger females the

---

[1] Current address: Portsmouth Polytechnic, Marine Resources Research Unit, Locksway Road, Milton, Southsea, Hampshire PO4 8JF, UK.

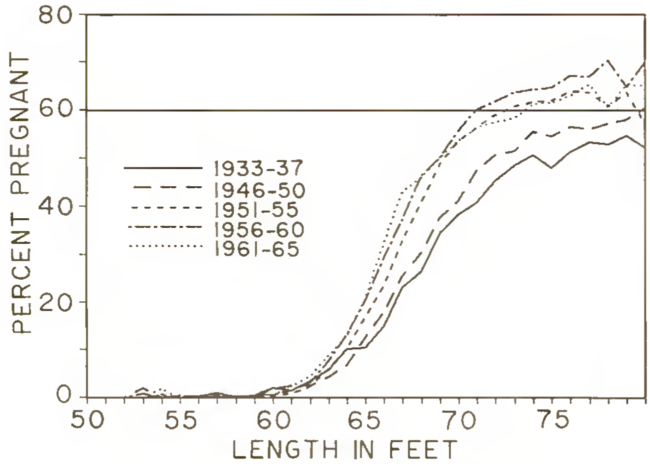


Fig. 1. Fin whale pregnancy rate versus length. The fraction of pregnant animals in the catches of female fin whales by one foot length intervals. The data are aggregated over several five-year time intervals. They include all fin whale catches by all pelagic factory ships that operated in the Southern Hemisphere. The analyses in the text test whether the apparent shift in the relationship between pregnancy rate and length is real or just an artefact of sampling noise or inappropriate data pooling.

Table 1A

Fin whale catches by expedition and season

Fin whale catches, in hundreds of animals of both sexes, by pelagic factory ships in the Southern Hemisphere, by vessels operating only before World War 2. For one analysis the catches in adjacent seasons were aggregated into three Season Groups. The catches which are underlined are the middle group. Season '31' refers to the 1931/2 whaling season.

		Season								
Expedition	Nation	31	32	33	34	35	36	37	38	Total
Major expeditions operating only before World War 2										
1 Salvestria	Britain	3	7	3	11	4	7	14	8	55
2 Sourabaya	Britain	2	3	3	3	4	3	15	4	38
3 Southern Empress	Britain	2	2	6	4	1	3	7	7	30
4 Southern Princess	Britain	3	3		4	4	4	6	3	26
5 Kosmos	Norway		2	5	6	9	6		6	34
6 Kosmos 2	Norway		2	3	7	5	9	11	4	40
7 Lancing	Norway		3		4	4	3	9	3	27
8 Ole Wegger	Norway		2	1	4	1	2	9	8	26
10 Skytteren	Norway			2	4	2	3	5	5	21
11 Solglimt	Norway		2	2	3	6	5	5	8	21
13 Hektoria	Britain		5	3	7	5	5	4	2	30
14 New Sevilla	Britain		5	4	5	7	7	12	5	45
15 Svend Foyn	Britain		4	7[1]	8	6	4	13	8	50
16 Tafelberg	Br/S Af		1	1	8	5	4	11	6	36
17 Vestfold	Br/Pana		3	2	8	3	7	10	5	39
Miscellaneous minor expeditions operating only before World War 2*										
18 N.T. Nielsen-Alonso	Norway			2		3	5	12	3	26
21 Sydis	Norway				3	2	2			7
22 Antarctic Maru	Japan				1					1
23 Strombus	Norway				1		4			5
24 Pioner	Norway				1					1
26 Tonan Maru A	Japan					2	2	4	2	9
28 Vikingen	Panama					3	6			9
29 Fraternitas	Denmark						6			6
30 Jan Wellem	Germany						6	7	7	20
32 Polar Chief	Britain						2			2
33 Terje Viken	Britain						6	9	11	26
34 C.A. Larsen	Norway						2	5	4	12
35 Nisshin Maru 2A	Japan							5	5	10
37 Sudmeer	Germany							6	4	10
38 Tonan Maru 2A	Japan							11[2]	6	17
40 Ulysses	USA							9	5	15
41 Unitas	Germany							8	6	14
42 Walter Rau	Germany							12	8	20
43 Uniwaleco	Britain							4		4
44 Tonan Maru 3	Japan								7	7
45 Kyokuyo Maru	Japan								4	4
46 Wikinger	Germany								5	5

* One Expedition not included: Expedition 25, the *Maudie* from Norway, which took less than 100 animals in an unspecified season.

[1] Excluded from analyses; 344 of 386 females were pregnant.

[2] Excluded from analyses; 519 females and none were pregnant.

pregnancy rate shifted from about 50% during the 1930s to about 65% during the 1950s. But, during this time there were also reductions in the relative frequency of larger females. An analysis of changes in the population pregnancy rate, of changes in the birth rate, would require examinations of changes in the relationship between pregnancy rate and length and also of changes in the female length distribution. This paper examines only the possible changes in the relationship between pregnancy rate and length.

In their analysis of pregnancy rates, Mizroch and York (1985) attempted to mimic the dependence of pregnancy rate on length by using average length as a covariate. However, the higher moments of length can have a major impact on the overall pregnancy rate. Two samples, both with the same relationship between pregnancy rate and length, can have identical mean lengths but, if they differ in variance and skewness, can have very different proportions of pregnant animals overall. Using the average lengths rather than the length distributions decreases the precision of the estimated overall pregnancy rate; changes in the overall pregnancy rate are less easily distinguished from sampling noise. Adjustment for the curved relationship between pregnancy rate and length greatly complicates the analysis of temporal or other changes in pregnancy rates. But, failure to account for this relationship can lead to incorrect conclusions.

Various factors other than length may affect the proportions of pregnant animals in the catches of female baleen whales. Whether there have been real and statistically significant changes in pregnancy rates between whaling seasons is central to the question of density dependent reproduction in whales. I refer to this temporal component as the factor *Season*. The whaling seasons do not correspond to the calendar years; they often started in December and ended in March or April. This term, Season, should not be confused with seasonality.

Baleen whales undergo annual migrations from winter breeding grounds in low latitudes to summer feeding grounds in high latitudes. The populations in the Southern Hemisphere are harvested during the austral summer, December through March, primarily from areas south of 50°S. Pregnant fin whales occur more frequently in catches at the beginning of the austral summer (Mackintosh, 1942; 1965). Also, since the mid 1930s, there has been a prohibition against the harvest of lactating females. Fin whale calves are weaned near the beginning of the summer. If females that were recently lactating are also less likely to be pregnant, then as the calves are weaned during each whaling season there will be an increase in the number of non-pregnant females available for capture and a corresponding decrease in the fraction of pregnant females. Therefore, *Month of capture* may be a significant factor affecting pregnancy rate. Because the timings in the north-south migrations of pregnant and non-pregnant females are different, *Latitude* may also be an important factor.

The Antarctic waters are divided into six sectors (Areas) by the International Whaling Commission. The whales occurring within each Area are treated as separate reproductive stocks and each stock has suffered a different history of exploitation. Whaling operations in the Antarctic from land-based stations began just after the turn of this century in Area II, the western Atlantic sector.

Table 1B

Fin whale catches by expedition and season

Fin whale catches, in hundreds of animals of both sexes, by pelagic factory ships in the Southern Hemisphere from 1931/32 through 1975/6 (excluding those operating only before World War 2). For one analysis the catches in adjacent seasons were aggregated into three Season Groups. Season '32' refers to the 1932/3 whaling season. The catches which are underlined are the middle group.

		Season																																						
Expedition	Nation	32	33	34	35	36	37	38	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	Total
Expeditions operating before and after World War 2																																								
9 Sir J.C. Ross	Norway	1	4	7	6	6	13	8	9	11	14	10	10	8	12	8	12	8	9	13	12	12	11	13	12	3	5	1												239
12 Thorshammer	Norway		2	7	5	4	8	10	4	12	11	11	8	9	2	11	9	7	12	12	9	9	9	9	11															190
19 Pelagos	Norway		2	10	3	5	9	5	5	8	10	9	14	10	9	12	14	14	12	11	10	10	9	9	5															207
20 Suderoy	Norway		2	2	2	3	5	4	8	3	6	5	4	4	5	6	8	6	5	5	3	5																		88
31 Nisshin Maru	Japan					3	8	9		3	4	6	6	12	14	14	18	15	20	16	11	15	14	11	20	16	14	7	2	1	3		9							273
Major expeditions operating only during 1945-67																																								
48 Norhval	Norway								5	11	19	11	9	7	11	16	18	10	11	17	10	12	7	14	11															197
50 Southern Venturer	Britain								17	15	18	12	16	12	6	10	14	7	17	14	7	10	8	13	7															202
52 Kosmos 4	Norway									15	14	11	14	16	19	22	16	15	11	17	14	12	9	12	11	7	5	2	1	5	4									252
53 Balaena	Britain									13	11	12	6	2	10	13	19	25	12	13	20	14	12																	183
54 Southern Harvester	Britain									12	14	12	10	9	14	11	13	18	19	13	12	9	13	10	10	9														209
55 William Barendsz	Holland									3	8	8	9	8	7	9	10	6	8	11	14	19	19	19	11	8	6													186
56 Slava	USSR									2	6	7	12	9	19	24	25	28	21	22	26	22	18	15	9	8	5	2												281
58 Kosmos 3	Norway										10	12	10	11	10		10	14	12	14	11	14	12	10																149
59 Thorshavet	Norway										15	12	8	2	5	12	18	14	10	13	17	15	15	14	9	7	8	2	3	3										204
60 Thorshovdi	Norway											8	18	15	13		10	10	11	8	15	15	14	16	12	5	2	2												174
Major expeditions operating only after 1955																																								
39 Tonan Maru 2B	Japan																				13	13	16	14	17	20	14	5		2	2	7	4	4	4	3	2	2		144
67 Sovietskaya Ukraina	USSR																						17	16	17	13	9	6	4	6	3	5	4	6	5	3	2	2	1	119
68 Kyokuyo Maru 3	Japan																							12	18	12	13	6	1	1			6	4	4	3	3	2	1	85
69 Juri Dolgorukij	USSR																							12	13	10	8	6	3	6	5	3	3	3	4	2	2	1		79
70 Nisshin Maru 3	Japan																								17	12	1	4	2			9		8	5	4	2	2		68
71 Sovietskaya Rossia	USSR																								10	12	7	5	3	4	3	4	5	4	5	1	2	1		66
Miscellaneous major expeditions operating after World War 2																																								
27 Tonan Maru B	Japan														12	6	14	15	15	13	12	13	17	11	19	13	14	9	5											187
36 Nisshin Maru 2B	Japan																				13	12	15	16	15	17	14	8												111
47 Antarctic	Norway								5	8	11	9	9	6	9																									57
49 Empire Victory	Br/S Af								14	10	17	14	12																											66
57 Hashidate Maru	Japan									2	2	4	5	8																										21
61 Abraham Larsen	S Africa													15	15	20	17	12	13	14																				105
62 Olympic Challenger	Panama													8	9	17		20	21																					75
64 Kinjyo Maru	Japan																	12	10	10	10	10	9	9																70
66 Kyokuyo Maru 2	Japan																			10	13	15	16	14	12	14	15	9				2								122
Miscellaneous minor expeditions operating after World War 2*																																								
51 Empire Venturer	Britain								11																															11
65 Matsushima Maru	Japan																			9																				9

* One Expedition not included: Expedition 72, the *Peder Huse* from Norway, which took less than 100 animals in an unspecified season.

Freely ranging factory ships began operating in the 1925/6 season and pelagic operations spread to Area III, the western Atlantic/eastern Indian Ocean sector, on into Area IV, the western Indian Ocean sector, and finally into Areas V, VI and I, the Pacific sectors. If pregnancy rates changed in response to whaling, then the timing of the response should be different in each area; *Area* may be a significant factor.

More than 70 different factory ships from 10 nations have harvested southern fin whales since the collection of detailed whaling statistics began in the 1931/2 season. They did not all operate every season (Table 1). The data are unbalanced as a result of the flux in the fleet composition and the changing geographic distribution of whaling operations.

Mizroch and York (1985) found significant differences between the pregnancy rates reported by different nations. They thought this might 'be due to operational differences or merely differences in experience among those collecting the biological data'. Clark (1983) identified inconsistencies between length measurements of fin whales taken by British workers and those taken by Japanese workers. He conjectured that the otherwise inexplicable differences were due to differing measurement procedures: how rigor mortis was handled; the material of the measuring tape, steel versus cloth. For whatever the cause, *Nation* may also be an important factor affecting fin whale pregnancy rates.

In addition to these six factors, I included factory ship as a potential explanatory variable. No previous studies of baleen whales have examined the possibility that the factory ships might be significant determinants of observed pregnancy rates. Hereafter I refer to each factory ship as an *Expedition*. Except for three expeditions, each operated for a single nation; the factor Expedition is nested within the factor Nation.

THE STATISTICAL MODEL

There are any number of functions which can be used to model the sigmoid-like relationship between length and the fraction of animals that are pregnant, the pregnancy rate. The symmetric logistic equation with a variable upper asymptote is relatively simple and it can accommodate most of the features seen in Fig. 1. Let us denote pregnancy rate by P and length by L, then

$$P(L)=P_{max}/\{1+exp[-B(L-L_{50})]\}$$

where P_{max} is the maximum pregnancy rate, L_{50} is the length at which the pregnancy rate is half of P_{max} and B controls the slope of the curve at the inflection point (L_{50},$P_{max}/2$). The effects of these parameters upon the pregnancy rate versus length curve are illustrated in Fig. 2.

If female fin whales of a given length are captured independently with respect to their pregnancy condition, then R(L), the number of pregnant animals caught of a given length, is a binomially distributed random variable with parameters N(L) and P(L), the total catch of females of length L and the proportion of those animals that are pregnant. If animals of a given length are not caught independently of their pregnancy condition, then the variability in the R(L) could be either under-dispersed or over-dispersed with respect to binomial variation (McCullagh and Nelder, 1983). In this case the significance levels of the tests below would only be approximate.

It is possible that pregnant and non-pregnant females of any given length are not equally susceptible to capture. In that case the relationship between pregnancy rate and length, as observed in the catches, would be a biased measure of the true relationship between pregnancy rate and length.

If the maximum pregnancy rate P_{max} is exactly one, then the pregnancy rate versus length relationship reduces to the well studied linear logistic model (Cox, 1970). This model can be converted to linear form by means of the logistic transformation

$$\ln\{P(L)/[1-P(L)]\}=B(L-L_{50})$$

where ln(X) denotes the natural logarithm of X. Maximum likelihood estimates for parameters B and L_{50} can be obtained by iterative weighted least squares with weights equal to

$$w(L)=Var[R(L)]^{-1}=N(L)/\{\hat{R}(L)[N(L)-\hat{R}(L)]\}$$

where $\hat{R}(L)$ is the predicted number of pregnant animals of length L.

A similar strategy can be employed for the logistic model with a variable upper asymptote

$$\ln\{P(L)/[P_{max}-P(L)]\}=B(L-L_{50}).$$

This equation is in the form of a generalized linear model with a single unknown parameter P_{max} in the link function (McCullagh and Nelder, 1983). Pregibon (1980) suggested that such models could be fitted by means of a first order Taylor series approximation for the link function. However, the Taylor series expansion for ln(X) does not have a sufficiently wide radius of convergence.

In their analysis of fin whale pregnancy rates, Mizroch and York (1985) used the logistic transformation with average female length as a covariate. They implicitly assumed that P_{max} is equal to one for the relationship between pregnancy rate and average length. Also, they incorporated the L_{50} parameter into the regression intercept

$$\ln[P/(1-P)]=u+BL.$$

Note that in their formulation the pregnancy rate P is the overall pregnancy rate; it is not P(L), the pregnancy rate for females that are length L.

In this analysis I use the Gauss-Newton method for fitting the logistic model (Draper and Smith, 1981). The pregnancy rate versus length relationship is expanded in a first order Taylor series about the current estimates for P_{max}, B and L_{50}. At each iteration I evaluate the first partial derivatives of [N(L)P(L)] with respect to these parameters and fit a weighted least squares regression with the partial derivatives as independent variables, with $[R(L)-\hat{R}(L)]$ as the dependent variable and with weights equal to

$$w(L)=Var[R(L)]^{-1}=N(L)/\{\hat{R}(L)[N(L)-\hat{R}(L)]\}.$$

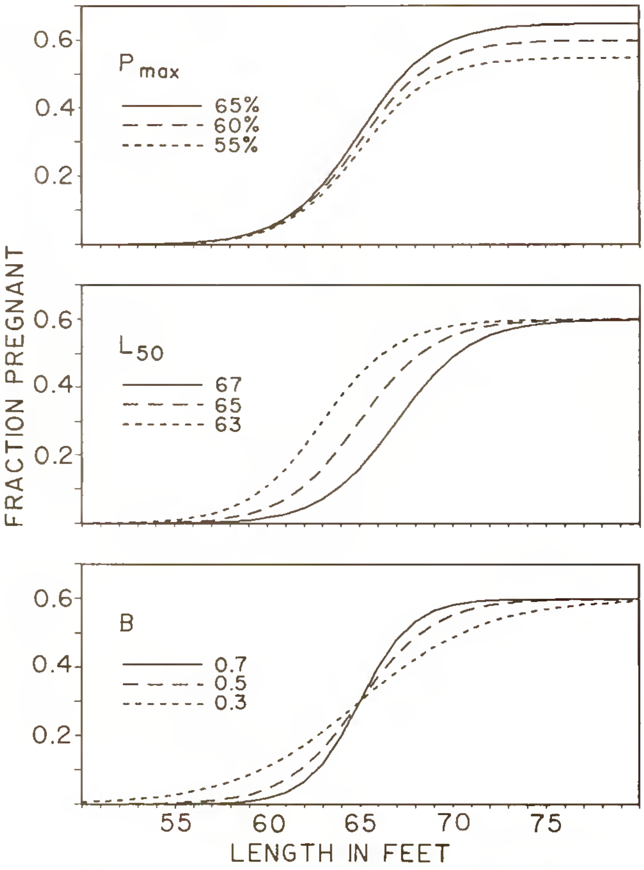


Fig. 2. Logistic equation for pregnancy rate versus length. The pregnancy rate versus length relationship was modelled by a symmetric logistic equation with a variable upper asymptote,

$$\text{Fraction Pregnant} = P_{max}/\{1+\exp[-B(\text{Length}-L_{50})]\}$$

with parameters (P_{max}, B and L_{50}). This figure illustrates how the three parameters control the shape of the curve.

The regression coefficients at each step provide adjustments to the current estimates for P_{max}, B and L_{50}. Iteration continues until there is no further change. This procedure, if it converges, yields the maximum likelihood estimates for P_{max}, B and L_{50}.

The deviance,

$$2\sum_{L}\{R(L)\ln[R(L)/\hat{R}(L)]+$$
$$[N(L)-R(L)]\ln([N(L)-R(L)]/[N(L)-\hat{R}(L)])\},$$

provides a measure of goodness of fit (McCullagh and Nelder, 1983). It is used to assess the adequacy of a particular parameter set and to measure improvements in the fit when parameters are changed. It is analogous to the residual sum of squares in linear regression. If the appropriate statistical model has been chosen, the deviance is distributed approximately as a chi-square random variable with degrees of freedom equal to the number of [R(L)/N(L)] observations less the number of estimated parameters.

The computations were all carried out using ‘macro’ programs in the GLIM 3.77 computing package (Baker and Nelder, 1985). Program listings of the macros are available from the author.

SELECTING SIGNIFICANT FACTORS

There are at least six factors which may affect the relationship between pregnancy rate and length: Season, Month, Latitude, Area, Nation and Expedition. A procedure is required which will assess their importance as explanatory variables. At one extreme, a single parameter set (P_{max}, B, L_{50}) may adequately describe the data. At the other extreme, the data may have little structure and it may be unreasonable to simplify them beyond separate parameter sets for every combination of the factors.

The fin whale lengths (recorded to the nearest foot) and the pregnancy states (pregnant or not) were aggregated by Season / Month / Latitude (by 10° intervals) Area / Nation / Expedition. Finer scales of aggregation were not considered. For each sample there is a length frequency distribution of pregnant animals and a length frequency distribution of all females, the R(L) and the N(L).

Some samples contain little information about the relationship between pregnancy rate and length. In order to estimate the three parameters there must be observations for at least four different length classes and they must be sufficiently spread. Also, within each length class there must be enough animals to permit identification of the fraction pregnant. These constraints and computational considerations make it difficult to estimate parameter sets for every sample; backward elimination (McCullagh and Nelder, 1983) is not a feasible method for assessing the importance of the different factors. However, a forward selection procedure can be used.

One begins by estimating parameters for the minimal model, a single parameter set (P_{max}, B, L_{50}) for all the samples. This set is used to estimate the R(L) for each sample and from these the total deviance is obtained. It has degrees of freedom equal to the number of [R(L)/N(L)] observations in all samples less three for the parameter estimates. Next, parameter sets are calculated one factor at a time for each level and the factor deviances and degrees of freedom are obtained by adding across the levels. As the number of parameter sets increases, the deviance and the degrees of freedom decrease. The reductions in the deviance and degrees of freedom provide a measure of the importance of each factor. The reduction in deviance is distributed approximately as a chi-square random variable with degrees of freedom equal to the reduction in the degrees of freedom.

If significant unexplained variation remains after fitting parameter sets for a particular factor, then the parameters are allowed to change with the levels of the other factors. This process is continued until parameter sets are found which account for a sufficient amount of the variability. One seeks a balance between a complete description of the observations, the data themselves, and a description which leaves inexplicable variability.

The minimal model, a single pregnancy rate versus length relationship for all the samples, does not adequately describe the data (the minimal model is labelled Total in Table 2.1). Expedition is the single factor which best accounts for the variability in the relationship between pregnancy rate and length; the Total deviance is reduced most significantly by parameter sets $(P_{max}, B, L_{50})_i$ which vary between Expeditions, i=1,2,...,71. However, Nation is also a very significant explanatory variable, it has considerably fewer levels than Expedition, and Expedition is nested within Nation. Much of the variability associated with Expedition might be attributable to Nation and, furthermore, the model with Nation rather than Expedition is much simpler. For the second step in this stepwise process I chose Nation as the primary factor and tested the other factors within each level of Nation (Table 2.2).

For the major whaling nations, Norway, Japan, Britain and the USSR, there is considerable and statistically significant unexplained variability in the samples even after the relationship between pregnancy rate and length is allowed to vary with the levels of the other factors (Table 2.2A). The most significant additional factor is either Season or Expedition. For the six other whaling nations, the addition of Season or Expedition reduces the variability to levels consistent with sampling error. For Dutch, South African and Panamanian samples, Season is the most significant additional factor. For German samples, Expedition is the most significant additional factor, but German expeditions operated for only three whaling seasons.

At the next step in the analysis I controlled for either [Nation * Season] or [Nation * Expedition] and fitted the remaining factors to the samples from the major whaling nations (Table 2.3). ([X * Y] denotes the combinations of factors X and Y.) For all four nations the models with separate parameter sets for each season and expedition are the most significant. For all but the Japanese samples the variability is consistent with sampling error. Of the 128 Japanese [Expedition * Season] samples only 11 had unexplained variability that was significant at the 5% significance level; for 91% of the Japanese samples the variability is consistent with sampling error.

Based on these results it appears that Expedition and Season are the major determinants of the relationship between pregnancy rate and length. Variability associated with factor Nation is an artefact of the correspondence between Expedition and Nation. For the four major whaling nations the factors Nation and Season are not sufficient to explain the variability in the data; the factor Expedition is required. Variability associated with factors Month, Latitude and Area is indistinguishable from sampling error.

ALTERNATIVE TEST OF [EXPEDITION * SEASON] SIGNIFICANCE

A difficulty with any stepwise scheme for model identification is the possibility that it will fail to locate other combinations of factors which are as good or better than the one chosen. For example, the analysis in the preceding section selected Expedition and Season as the dominant factors but the combination of Area and Month (or Month and Latitude) was not examined. An alternative strategy for model identification is to consider all possible combinations of factors and to select that combination which provides an adequate fit and has a small number of parameters. This is not feasible for these data; too many samples contain very little information.

One can overcome the problem of small samples by aggregating the length distributions across levels within a factor. The significance of the factor Season may be related to an underlying temporal trend, either a response to the declining population size or to shifts in the whaling grounds. Pooling the data across adjacent Seasons will not grossly distort such a trend.

The data were re-aggregated into three Season Groups, early, middle and late (Table 1), and by the Month / Latitude / Area / Expedition factors, a total of 1,863

Table 2

Analysis of deviance, fin whale pregnancy rate versus length

Stepwise forward selection of significant factors that affect the relationship between pregnancy rate and length.

The deviances and degrees of freedom (d.f.) have been transformed to approximate standard normal deviates in the columns labelled 'Z',

$$Z = (2\ \text{Deviance})^{1/2} \text{-} (2\ \text{d.f.-}1)^{1/2},$$

Abramowitz and Stegun (1964) equation 26.4.13.

In the right hand 'Z' column, values greater than about 1.65 indicate factors or factor combinations which explain significant variation (5% significance level) in the observed data. The largest values within a given step in the analysis are marked with a '<'.

In the left hand 'Z' column, values less than about 1.65 indicate factors or factor combinations for which the unexplained variation is not significant (5% significance level). These values are marked with a '*'. No additional factors are required to explain the observed variability in the data.

The column labelled 'Lev' is the number of levels within each factor; there were data for 39 different whaling Seasons.

The column labelled 'NC' is the number of levels within each factor for which the parameter estimation algorithm did not converge; there were insufficient data to obtain parameter estimates. The column labelled 'NF' is the total number of females in these non-convergent samples. For these samples, the deviances were computed using the parameter estimates from the preceding step in the analysis. For example, the deviances for each of the six non-convergent Expeditions were calculated by means of the parameter estimates that were obtained from the 'Total' model. This removes these particular expeditions from the test for a significant Expedition factor but still allows them to contribute to the 'Total' parameter estimates.

2.1 Total and single factor models

Factor	Deviance	d.f.	Z	Reduction in deviance	d.f.	Z	Lev	NC	NF
Total	74122.8	56062	50.2	Total no. females = 256759					
Season	68905.2	55948	36.7	5217.6	114	87.1	39	0	0
Nation	66470.0	56035	29.8	7652.8	27	116.4	11	1	1
Expedition	61686.3	55873	17.0	12436.6	189	138.3<	71	6	564
Month	73673.2	56047	49.1	449.6	15	24.6	7	1	25
Area	72898.1	56047	47.0	1224.8	15	44.1	6	0	0
Latitude	73579.7	56053	48.8	543.1	9	28.8	7	3	8

2.2A Two factor models controlling for nation
(In the samples for the following four nations, significant unexplained variability remains even after fitting with the best two factor models).

Factor	Deviance	d.f.	Z	Reduction in deviance	d.f.	Z	Lev	NC	NF
Norway	24665.4	21900	12.8	Total no. females = 96412					
Season	22491.1	21813	3.2	2174.3	87	52.8<	30	0	0
Expedition	23411.1	21846	7.4	1254.0	54	39.7	21	2	223
Month	24466.4	21888	12.0	199.0	12	15.2	7	2	105
Area	24496.2	21885	12.1	169.2	15	13.0	6	0	0
Latitude	24578.0	21891	12.5	87.3	9	9.1	6	2	7
Japan	15115.7	11968	19.2	Total no. females = 59589					
Season	13906.1	11881	12.6	1209.6	87	36.0	35	5	1929
Expedition	13870.6	11926	12.1	1245.1	42	40.8<	16	1	46
Month	14719.7	11953	17.0	396.0	15	22.8	6	0	0
Area	14650.6	11953	16.6	465.2	15	25.1	6	0	0
Latitude	14888.9	11959	17.9	226.8	9	17.2	5	1	1
Britain	12239.0	10104	14.3	Total no. females = 45857					
Season	11441.0	10029	9.6	798.0	75	27.7	26	0	0
Expedition	11005.3	10062	6.5	1233.8	42	40.6<	17	2	613
Month	12102.7	10092	13.5	136.3	12	11.7	7	2	114
Area	12079.6	10092	13.4	159.4	12	13.1	6	1	294
Latitude	12189.8	10098	14.0	49.2	6	6.6	4	1	6
USSR	8584.3	6822	14.2	Total no. females = 27867					
Season	7371.9	6741	5.3	1212.4	81	36.6<	30	2	155
Expedition	7847.6	6813	8.6	736.7	9	34.3	4	0	0
Month	8496.5	6813	13.6	87.8	9	9.1	6	2	67
Area	8496.9	6807	13.7	87.4	15	7.8	6	0	0
Latitude	8523.8	6813	13.8	60.5	9	6.9	4	0	0

2.2B Two factor models controlling for nation
(In the samples for the following six nations, the observed variability in the relationships between pregnancy rate and length is consistent with sampling error. No further factors are required.)

Factor	Deviance	d.f.	Z	Reduction in deviance	d.f.	Z	Lev	NC	NF
Holland	2261.4	2065	3.0	Total no. females = 9655					
Season	1929.5	2014	-1.3*	331.9	51	15.7<	18	0	0
Expedition	2261.4	2065	3.0				1	0	0
Month	2217.0	2053	2.5	44.4	12	4.6	6	1	44
Area	2213.0	2053	2.5	48.4	12	5.0	6	1	41
Latitude	2249.6	2062	2.9	11.8	3	2.6	3	1	4
S Africa	1377.9	1141	4.7	Total no. females = 8034					
Season	1126.5	1111	0.3*	251.4	30	14.7<	12	1	148
Expedition	1341.4	1138	4.1	36.4	3	6.3	3	1	148
Month	1306.0	1132	3.5	71.9	9	7.9	6	2	32
Area	1327.6	1132	4.0	50.3	9	5.9	4	0	0
Latitude	1349.3	1138	4.3	28.6	3	5.3	3	1	1
Panama	1111.8	943	3.7	Total no. females = 5529					
Season	902.6	919	-0.4*	209.2	24	13.6<	9	0	0
Expedition	1071.4	937	3.0	40.4	6	5.7	3	0	0
Month	1069.1	934	3.0	42.7	9	5.1	4	0	0
Area	1034.9	931	2.4	76.9	12	7.6	5	0	0
Latitude	1104.1	937	3.7	7.8	6	0.6	3	0	0
Germany	888.7	799	2.2	Total no. females = 2866					
Season	882.3	793	2.2	6.4	6	0.2	3	0	0
Expedition	796.7	790	0.2*	92.0	9	9.4<	5	1	185
Month	881.7	790	2.3	7.0	9	-0.4	6	2	2
Area	867.9	796	1.8	20.8	3	4.2	3	1	35
Latitude	886.2	796	2.2	2.5	3	0.0	2	0	0
Denmark	56.3	68	-1.0*	Total no. females = 198					
USA	168.5	224	-2.8*	Total no. females = 751					

2.3 Three factor models, controlling for [Nation * Season] or [Nation * Expedition]

Factor	Deviance	d.f.	Z	Reduction in deviance	d.f.	Z	Lev	NC	NF
Norway				Total no. females = 96412					
Season	22490.7	21813	3.2				30		
Expedition	19763.1	21255	-7.4*	2727.6	558	40.5<	243	27	3329
Month	22076.9	21609	2.2	413.8	204	8.6	132	34	1426
Area	21937.9	21663	1.3	552.8	150	16.0	99	19	444
Latitude	22230.8	21735	2.4	259.9	78	10.3	71	15	443
Japan				Total no. females = 59543					
Expedition	13818.1	11901	12.0				15		
Season	12058.0	11637	2.7	1760.1	264	36.4<	128	25	4804
Month	13335.3	11811	9.6	482.8	90	17.7	69	24	1459
Area	13081.1	11805	8.1	737.0	96	24.6	59	12	1231
Latitude	13201.8	11844	8.6	616.3	57	24.5	43	9	268
Britain				Total no. females = 45244					
Expedition	10658.5	9897	5.3				15		
Season	8947.3	9651	-5.2*	1711.2	246	36.3<	112	15	2140
Month	10395.3	9715	4.8	263.2	182	3.9	75	26	2035
Area	10341.8	9840	3.5	316.7	57	14.5	43	9	515
Latitude	10490.1	9790	4.9	168.4	107	3.8	31	7	604
USSR				Total no. females = 27712					
Season	7296.0	6682	5.2				28		
Expedition	6504.2	6595	-0.8*	791.8	87	26.6<	63	6	500
Month	6819.3	6550	2.3	476.7	132	14.7	113	41	3698
Area	6922.8	6568	3.1	373.2	114	12.3	99	33	2613
Latitude	7085.2	6607	4.1	210.8	75	8.3	73	20	1660

samples. The factor Nation was not examined in this part of the analysis; the information associated with Nation is already contained within factor Expedition. Also, the data from the miscellaneous minor expeditions (Table 1) were excluded from this part of the analysis. Parameter estimates were obtained for 732 samples. These samples accounted for 199,000 of the 244,000 female fin whales in all the samples examined. The fitting algorithm did not converge for the other samples; they had too few length classes or animals.

The expeditions' parameters were analysed in groups according to the seasons in which they operated; any Season effects should be of approximately the same magnitude for all expeditions within a group. The estimated L_{50} and P_{max} values within each grouping were examined for significant factor effects by analysis of variance with weights inversely proportional to the estimated variances of the $\hat{L}_{50}$ and $\hat{P}_{max}$. The resulting sums of squares and degrees of freedom for all possible three factor models are given in Table 3.

In all 10 cases (2 parameters for each of 5 Expedition groupings) the models which had the least significant residual sums of squares included either Season or Expedition. In six cases the best three factor models included both Season and Expedition. The other factors, Month, Area and Latitude, occurred only in combination with either Season or Expedition. If these other factors were important explanatory variables, then they should have entered the forward selection (above) during the second or third steps of that analysis.

The results from this analysis support the conclusion drawn from the forward selection; Season and Expedition are the dominant factors affecting the relationship between pregnancy rate and length.

TRENDS IN THE PARAMETERS FOR PREGNANCY RATE VERSUS LENGTH

The parameter estimates from the forward selection, $\hat{L}_{50}$, $\hat{B}$ and $\hat{P}_{max}$ for each [Expedition * Season] combination, were analysed for significant trends with Season. The estimates were put into five Expedition groups on the basis of similarity in the expeditions' seasons of operation (Table 1). Within each group, analyses of covariance were performed in order to test whether the expeditions' parameter estimates conformed to parallel or coincident linear trends. In all but one case the hypothesis of coincident trends must be rejected; there are significant differences in the trends in $\hat{L}_{50}$, $\hat{B}$ and $\hat{P}_{max}$ between expeditions (Table 4). In some cases the trends may be parallel.

Separate linear trends with Season were fitted to each Expedition's parameter estimates by weighted least squares with weights inversely proportional to the estimated variances of the parameter estimates (Table 5 and Fig. 3). There were no indications of appreciable curvature in the data series. There is considerable scatter about the fitted trends and few of the individual trends are significantly different from zero. But, 30 of the 45 trends in $\hat{L}_{50}$ are negative and 31 of the trends in $\hat{P}_{max}$ are positive. Because the slope estimates for each expedition are independent, one would expect, at the 5% significance level, to find less than about 28 of 45 negative (or positive) slopes if the true slopes in $L_{50}(t)$ and $P_{max}(t)$ were zero. If there were no trends in L_{50} and P_{max}, then it is very unlikely (less than one chance in 50) that one would find so many negative estimates for L_{50} or so many positive estimates for P_{max}. There has been a statistically significant decrease with whaling season in L_{50} and increase with whaling season in P_{max}. The parameter B does not appear to have any significant trend with whaling season.

Table 3

Alternative analysis of significant factors

Catches in adjacent seasons were combined into three Season Groups and the parameters for pregnancy rate versus length were estimated for each combination of factors; the factors were Season Group (S), Expedition (E), Month (M), Area (A) and Latitude by 10 degrees (L). The variability in the estimates of P_{max} and L_{50} was then examined by analysis of variance with weights inversely proportional to the estimated variances. This provides a method for ranking the relative importance of the different factor combinations.

The three factor sums of squares (SS) and degrees of freedom (df) are tabulated below. The columns labelled 'Z' are the sums of squares and degrees of freedom after transformation to standard normal deviates. The 'Z' values marked with '⇦' indicate those models which best explain the observed data.

	P_{max}			L_{50}		
Model	SS	df	Z	SS	df	Z
Major expeditions operating only before World War 2						
S * E * M	4.8	9	-1.04 ⇦	4.7	9	-1.10 ⇦
S * E * A	33.0	41	-0.87	47.1	41	0.71
S * E * L	32.2	36	-0.39	38.3	36	0.35
S * M * A	323.8	58	12.56	222.3	58	9.19
S * M * L	343.2	73	12.29	285.6	73	10.49
S * A * L	341.0	74	12.17	261.9	74	9.62
E * M * A	59.5	32	2.84	44.7	32	1.50
E * M * L	56.9	34	2.40	66.9	34	3.21
E * A * L	82.3	51	2.69	69.1	51	1.68
M * A * L	334.6	71	12.15	282.9	71	10.52
Major expeditions operating before and after World War 2						
S * E * M	264.4	85	9.04	174.7	85	5.36
S * E * A	289.0	102	8.94 ⇦	178.7	102	4.45
S * E * L	307.0	111	9.07	261.9	111	7.45
S * M * A	331.8	92	10.91	287.5	92	9.45
S * M * L	393.7	112	11.73	431.7	112	12.79
S * A * L	354.0	115	10.39	290.4	115	8.27
E * M * A	386.5	75	13.41	134.3	75	3.99 ⇦
E * M * L	465.0	96	14.43	183.5	96	5.06
E * A * L	483.1	106	14.42	178.8	106	4.20
M * A * L	420.9	101	13.04	231.5	101	6.84
Major expeditions operating only during 1945–67						
S * E * M	343.6	169	7.40	345.2	169	7.45
S * E * A	339.2	193	6.13 ⇦	397.1	193	8.05
S * E * L	378.6	216	6.45	522.8	216	10.72
S * M * A	1044.9	222	21.39	546.7	222	11.11
S * M * L	1232.7	250	23.58	762.0	250	15.12
S * A * L	1032.9	249	20.34	648.8	249	12.62
E * M * A	353.8	151	8.59	249.1	151	4.77 ⇦
E * M * L	598.0	198	13.33	517.1	198	11.29
E * A * L	455.5	205	9.30	477.2	205	9.91
M * A * L	1118.9	238	22.13	688.9	238	13.94
Major expeditions operating only after 1955						
S * E * M	123.7	49	5.44	83.5	49	2.96
S * E * A	127.6	53	5.32	98.8	53	3.63
S * E * L	156.2	65	5.86	134.4	65	4.74
S * M * A	319.3	56	12.55	87.0	56	2.58 ⇦
S * M * L	491.3	71	16.24	137.5	71	4.46
S * A * L	454.8	75	15.18	156.2	75	5.14
E * M * A	96.7	40	4.67	102.5	40	5.02
E * M * L	100.9	50	4.02 ⇦	119.2	50	5.11
E * A * L	137.5	57	5.53	126.0	57	4.91
M * A * L	332.0	63	12.52	140.0	63	5.20
Miscellaneous major expeditions						
S * E * M	146.2	55	6.13 ⇦	86.8	55	2.65 ⇦
S * E * A	171.5	69	6.30	123.6	69	3.83
S * E * L	209.9	79	7.31	146.3	79	4.35
S * M * A	437.4	84	14.31	398.5	84	13.28
S * M * L	597.3	97	17.45	447.1	97	13.92
S * A * L	556.9	96	16.61	378.6	96	12.10
E * M * A	142.1	46	6.64	86.4	46	3.43
E * M * L	227.8	64	9.00	130.9	64	4.63
E * A * L	202.7	69	7.67	143.1	69	4.91
M * A * L	539.9	88	16.58	395.5	88	12.99

DISCUSSION AND CONCLUSIONS

The variability in the observed relationships between fin whale pregnancy rate and length can be adequately accounted for by variations between whaling seasons and between expeditions. A statistically significant majority of the expeditions have increasing trends with season in the maximum pregnancy rates, the P_{max} parameter, and decreasing trends with season in the lengths at half of P_{max}, the L_{50} parameter. Fin whales of a given length are more frequently pregnant in more recent years. The supposition that month, area and latitude of capture are significant determinants of pregnancy rate is not supported by the data for Southern Hemisphere fin whales.

It is slightly puzzling that Expedition should be a significant factor in the relationship between fin whale pregnancy rate and length. Its importance could be due to differing whale measurement procedures between factory ships, but one would not expect large season to season changes in the operational characteristics of any particular factory ship. And yet, there is as much variability between Expeditions for a given Season as there is variability about the trends in L_{50} and P_{max} with Season for a given Expedition. An alternative explanation for the significant Expedition effect is that pregnant fin whales do not randomly mix with non-pregnant females. Whales of a given pregnancy condition may tend to occur in loose concentrations. During some seasons an expedition may encounter a disproportionately large number of pregnant animals; during other seasons it may encounter relatively few.

Table 4

Analysis of trends in pregnancy rate versus length

Test for parallel and coincident trends in the parameter estimates for pregnancy rate versus length. The F test is based upon the difference in the weighted sums of squares for parallel lines (or coincident lines) versus separate lines within an Expedition group.

		P_{max}		L_{50}		B	
Source	df	SS	F	SS	F	SS	F
Major expeditions operating only before World War 2							
Separate lines	49	137.7		146.6		31.9	
Parallel lines	63	287.1		206.9		40.2	
Difference	14	149.4	3.80**	60.3	1.44	8.3	0.91
Coincident lines	77	744.0		443.5		78.9	
Difference	28	606.3	7.71**	296.9	3.54**	47.0	2.58**
Major expeditions operating before and after World War 2							
Separate lines	96	615.4		257.2		97.2	
Parallel lines	100	636.5		262.4		104.5	
Difference	4	21.1	0.82	5.2	0.49	7.4	1.82
Coincident lines	104	711.8		517.0		115.4	
Difference	8	96.4	1.88	259.8	12.12**	18.3	2.25*
Major expeditions operating only during 1945–67							
Separate lines	177	1163.0		585.1		249.2	
Parallel lines	186	1575.0		701.1		281.2	
Difference	9	412.0	6.97**	116.0	3.90**	32.0	2.53**
Coincident lines	195	2805.0		849.7		325.0	
Difference	18	1642.0	13.88**	264.6	4.45**	75.8	2.99**
Major expeditions operating only after 1955							
Separate lines	60	301.6		245.9		78.5	
Parallel lines	65	449.9		284.0		96.6	
Difference	5	148.3	5.90**	38.1	1.86	18.0	2.76*
Coincident lines	70	697.1		329.1		107.6	
Difference	10	395.5	7.87**	83.2	2.03*	29.1	2.22*
Miscellaneous major expeditions							
Separate lines	45	235.2		117.0		59.9	
Parallel lines	53	450.9		156.7		70.9	
Difference	8	215.7	5.16**	39.7	1.91	11.0	1.03
Coincident lines	61	872.4		445.8		137.7	
Difference	16	637.2	7.62**	328.8	7.90**	77.8	3.65**

* Significant at 5% ** Significant at 1%

If the Expedition effect is due to non-random mixing of pregnant and non-pregnant females, then this implies that accurate measurement of temporal changes in fin whale pregnancy rates will be limited by one's ability to collect adequate samples. The selection of a representative sample of females requires the identification of the pregnancy conditions and lengths for large numbers of females from a range of lengths and from widely dispersed geographic regions. This is the type of sampling that the commercial whaling operations performed, albeit haphazardly. It is probably unreasonable to consider 'scientific' sampling of fin whale populations for the assessment of changes in the relationship between fin whale pregnancy rate and length. Sampling coverage would almost certainly be inadequate.

The analysis of pregnancy rate versus length suggests the following about the reproductive cycle in southern fin whales. First, in spite of expectations to the contrary, there are no significant changes within whaling seasons in the relationship between pregnancy rate and length; there is no evidence of a Month effect. There are at least three possible explanations for this: (1) fin whale calves were weaned prior to each whaling season's start; (2) lactating females were as likely to be pregnant as other females; or (3) whalers ignored the restriction against the harvest of lactating females. The first of these seems the most plausible. Second, the maximum pregnancy rates, those which occur in the longer animals, are too large to be consistent with a two year reproductive cycle; larger fin

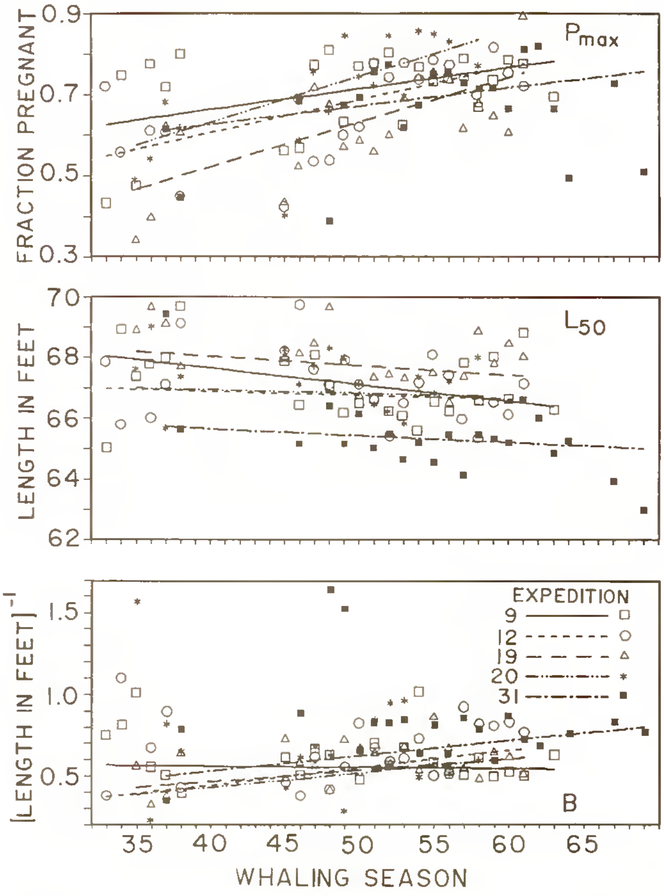


Fig. 3. Temporal trends in pregnancy rate versus length. The parameter estimates for the relationship between pregnancy rate and length are plotted by whaling season for the five major expeditions that operated before and after World War 2. The fitted lines were estimated by weighted least squares with inverse variance weighting.

whales in more recent years were successfully breeding about twice in three years. Both Mackintosh (1942) and Laws (1961) cited evidence that fin whales were capable of breeding more rapidly than once in two years. They both found lactating females that were also pregnant.

With regard to the non-significant Month effect, Laws (1961) estimated that weaning in fin whales occurs on average during December and that over 80 percent of females have weaned their calves before entering the pelagic whaling grounds. If this is true in general for southern fin whales, then it is entirely reasonable that the relationship between pregnancy rate and length shows no appreciable change during a whaling season. It would be useful to examine in detail the relationship between pregnancy rate and length for catches taken prior to the ban on the harvest of whales with calves.

Table 5

Temporal trends in pregnancy rate versus length

The estimates for each expedition's parameters (P_{max}, L_{50}, B) were tested for significant temporal trends. Expeditions were grouped according to similarities in their seasons of operation; weighted linear regressions were done with weights inversely proportional to the estimated variances of the parameter estimates.

The columns labelled 'Slo' are the slopes of the fitted straight lines. Positive values indicate increases with whaling season in P_{max}, L_{50} or B.

The temporal variable Season was scaled to the midrange within each group; the columns labelled 'Int' are the estimated parameter values at the 'Season Midrange'.

The columns labelled 'SE' are the estimated standard errors.

	P_{max}				L_{50}				B			
Exp	Slo	SE	Int	SE	Slo	SE	Int	SE	Slo	SE	Int	SE
Major expeditions operating only before World War 2												
Season Midrange 1934												
1	.049	.022	.525	.049	.325	.427	66.2	1.12	.035	.014	.308	.038
2	.057	.031	.586	.065	-.841	.368	70.7	.86	-.028	.025	.505	.079
3	-.028	.101	.449	.343	.129	2.39	67.9	8.39	.113	.118	.111	.371
4	.008	.051	.480	.103	-.697	.621	70.2	1.31	.070	.128	.772	.246
5	.014	.024	.524	.065	-.190	.372	67.9	.98	.014	.034	.447	.067
6	-.016	.042	.774	.104	-.200	.354	70.5	.85	.034	.039	.596	.088
7	.057	.039	.317	.096	-.978	.795	68.4	2.24	-.093	.089	.621	.259
8	.035	.030	.618	.083	-.443	.339	66.8	.81	-.002	.054	.626	.179
10	.090	.022	.338	.057	-1.10	1.18	69.7	4.06	.014	.053	.482	.185
11	.001	.025	.561	.056	.223	.422	66.9	.94	-.015	.041	.521	.106
13	.027	.021	.725	.044	.048	.268	69.0	.47	-.042	.030	.573	.059
14	-.013	.054	.367	.086	.347	1.26	67.7	1.97	.011	.025	.300	.049
15	-.114	.022	.822	.032	1.514	.546	64.7	1.01	-.005	.016	.341	.043
16	.017	.034	.232	.071	.793	.786	68.1	1.80	-.028	.067	.614	.168
17	.020	.021	.530	.055	-.064	.314	68.7	.84	-.003	.032	.481	.075
Major expeditions operating before and after World War 2												
Season Midrange 1951												
9	.005	.003	.719	.019	-.055	.022	67.0	.18	-.001	.003	.557	.024
12	.008	.003	.695	.022	-.013	.025	66.7	.20	.011	.004	.567	.029
19	.011	.004	.642	.026	-.031	.039	67.7	.22	.007	.003	.547	.026
20	.011	.005	.756	.030	-.011	.046	66.8	.26	.009	.006	.531	.038
31	.005	.002	.675	.020	-.022	.026	65.4	.19	.009	.004	.638	.034
Major expeditions operating only during 1945–67												
Season Midrange 1956												
48	.004	.005	.668	.025	-.053	.047	66.7	.25	-.004	.007	.589	.035
50	-.006	.006	.487	.034	.073	.062	68.0	.41	.005	.007	.465	.045
52	.009	.003	.654	.020	-.027	.035	67.4	.21	-.001	.007	.620	.032
53	.028	.004	.562	.025	.148	.058	68.5	.27	-.010	.009	.536	.028
54	.005	.005	.572	.019	.212	.054	67.4	.21	.021	.004	.523	.024
55	.008	.005	.726	.023	-.123	.049	66.4	.22	.001	.006	.504	.027
56	.034	.006	.475	.024	.011	.054	67.7	.22	.019	.006	.511	.026
58	.004	.009	.635	.032	.018	.088	67.2	.33	.006	.008	.542	.038
59	-.006	.004	.698	.022	-.015	.044	67.1	.22	.002	.007	.580	.032
60	-.001	.006	.710	.024	-.113	.060	67.0	.24	.011	.007	.518	.032
Major expeditions operating only after 1955												
Season Midrange 1965												
39	-.005	.005	.570	.022	-.061	.052	64.3	.30	-.024	.007	.630	.049
67	.016	.006	.499	.025	-.029	.074	65.2	.32	-.015	.017	.652	.062
68	-.003	.007	.535	.029	-.014	.090	64.9	.43	.002	.022	.680	.081
69	.010	.008	.697	.031	-.067	.077	65.4	.26	-.058	.018	.875	.073
70	-.024	.006	.649	.024	-.189	.081	64.7	.36	.041	.022	.799	.092
71	-.002	.008	.534	.033	-.282	.078	64.7	.32	-.015	.020	.565	.069
Miscellaneous major expeditions												
Season Midrange 1955												
27	-.022	.004	.694	.021	-.128	.044	65.2	.18	.003	.013	.749	.053
36	-.035	.011	.849	.062	-.019	.127	65.7	.62	-.048	.022	.959	.135
47	.075	.019	1.032	.127	-.519	.217	64.2	1.41	.038	.041	.857	.284
49	.091	.110	1.225	.898	.920	.976	80.4	7.49	-.010	.050	.316	.369
57	.104	.072	1.219	.418	-1.25	.596	59.3	3.59	-.210	.308	-.208	1.69
61	.042	.037	.489	.113	.061	.536	70.2	1.34	-.004	.019	.381	.051
62	.013	.026	.660	.069	.366	.217	68.5	.47	.013	.033	.683	.084
64	.015	.015	.712	.042	-.079	.146	66.0	.39	.001	.026	.684	.078
66	-.029	.009	.724	.056	-.246	.108	66.2	.57	.029	.022	.613	.098

In their analysis of fin whale pregnancy rates Mizroch and York (1985) found that Month was a significant factor, but its effect was very small relative to the Season and Length effects. In their analysis of the Norwegian data (their Table 3) the Month effect only accounted for 1.5% of the total deviance in Area II and 1.6% in Area III, whereas the Length and Season effects accounted for 81% in Area II and 77% in Area III. They found similar results in their analysis of British and Japanese data.

The monthly declines in pregnancy rates that were observed in catches at South Georgia (Mackintosh, 1942) were probably caused by the increase in the proportion of smaller fin whales later in the whaling season.

At the Whaling Commission conference on cetacean reproduction, held in La Jolla in 1981, the following potential problems were identified with regard to the use of commercial whaling data for the estimation of reproductive parameters: under-representation of lactating females; deliberate selection by whalers of large animals; and temporal changes in the whaling grounds (Perrin and Donovan, 1984). By explicitly modelling the dependence of pregnancy rate on length and by measuring the effects of the factors Month and Area/Latitude, my analysis addresses these problems. However, several authors have questioned the validity of the pregnancy rate data reported by the whaling industry.

Laws (1959) abstained from examining the foetal length data from the International Whaling Statistics on the grounds that 'small foetuses are almost invariably missed'. However, if this was actually occurring, then as the foetuses grew during the course of each whaling season the pregnancy rates would increase. But, there are no significant changes with Month. Furthermore, fin whale foetuses are of such large sizes during the months of whaling that it is unlikely that many would be missed.

For the period 1933–7 a total of 10,100 fin whale foetal length measurements are recorded in the Southern Hemisphere catch data. Of these lengths, slightly more than 94% are three or more feet. For the period 1956–60 a total of 26,400 foetal lengths are recorded and of these, again, slightly more than 94% are three or more feet. It seems unlikely that such large foetuses would not be seen during processing. Also, given the shape of the observed distributions of foetal lengths (Fig. 4), it is difficult to believe that the true proportion of small foetuses during the whaling seasons was appreciably larger than what was recorded.

Best (1989) presented evidence which suggests that a large proportion of sei whale foetuses were missed during the whaling operations at Donkergat prior to 1963. But, the great majority of the sei whale foetuses in these catches were less than one foot in length (Best's Fig. 4). There were very few sei whale foetuses that were between three and four feet in length and there were none that were four or more feet in length. Best did not have fin whale foetus data available for analysis.

Gaskin (1982) complained that some whalers 'were not above filling in some of the data on foetus presence and size "at the end of the shift"'. However, he presented no direct

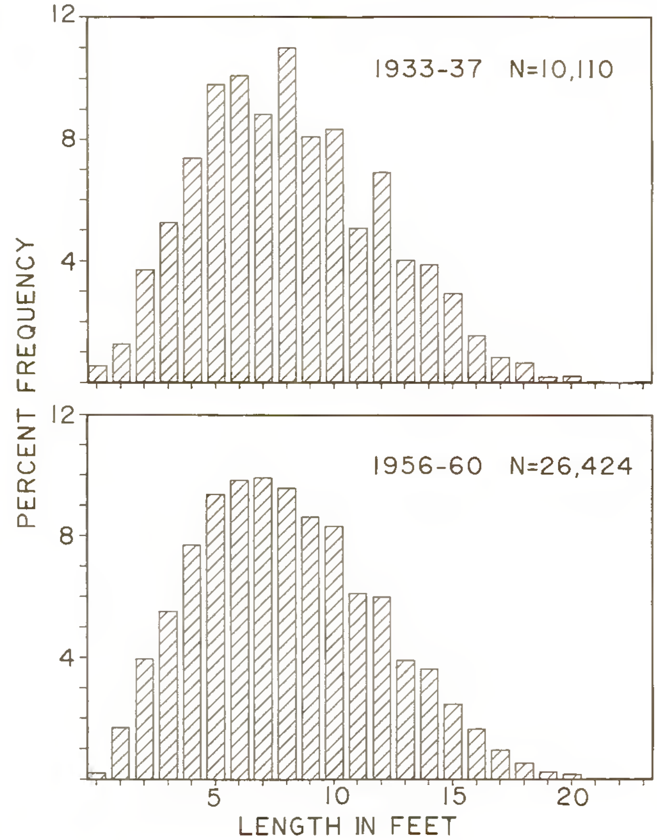


Fig. 4. Fin whale foetal length distributions. The pregnancy rates derived from whaling statistics are dependent on the correct determination that a female was carrying a foetus. Very small foetuses are likely to be missed. For the smaller species of baleen whale, and at certain times of year for fin whales, this can result in appreciable under-estimates of the true pregnancy rates. However, there are relatively few small fin whale foetuses during the months of whaling, December through April; almost 95% of the foetuses are at least three feet in length.

evidence and there are no indications in the data themselves that they were recorded in such an arbitrary manner. If there were an appreciable number of gross errors in the recording of pregnancy conditions, then it is improbable that the data would conform well to the smooth relationship between pregnancy rate and length. For example, if the data were concocted, one would expect to find reports of small females that were pregnant. In order to generate the observed pregnancy condition and length data the whalers would have to guess the pregnancy conditions in such a manner that (1) the data would agree with the curved relationship between pregnancy rate and length and (2) their guesses for the number of pregnant animals of a given length would appear to be binomially distributed. This seems unlikely.

It is almost inevitable that there should be some problems with such a large dataset. The extent of the difficulties is unknown and is probably unknowable. Best (1989) provides some specific examples of errors in the whaling statistics; there is no doubt that others will be identified and that many will remain undocumented. Nevertheless, the present examination suggests that the data for fin whale lengths and pregnancy conditions are of an acceptable quality and that the analysis presented here is an appropriate statistical treatment of them.

Lockyer (1981) prepared energy budgets for female fin whales. Reproduction, particularly the seven months of lactation, incurs sizeable energetic costs upon females; the energy requirements for lactating females are 60–70% higher than for other females. The balance between the energetic costs of growth and successful reproduction may regulate the L_{50} pregnancy rate parameter. Females which have not yet attained physical maturity cannot afford to reproduce as frequently as animals that have ceased growing (Lockyer, 1984). If there is more food per capita, which may occur as whales are harvested, then growing females can more readily recover from calf rearing. Increased food could also permit physically mature animals to reduce the time required to recovery from a pregnancy; this could account for the increase in P_{max}.

The parameter L_{50} should not be confused with the average length at sexual maturity. Animals can be sexually mature but not pregnant. But, animals that are pregnant must be sexually mature. As a consequence, the curve for pregnancy rate versus length always lies below the curve for sexual maturity versus length. The L_{50} parameter is bounded below by the average length at sexual maturity. The observed temporal changes in the L_{50} parameter are not inconsistent with the observation that for female fin whales the average length at sexual maturity has not changed appreciably during the course of exploitation (Gambell, 1976).

The six whaling sectors in the Southern Hemisphere have had very different histories of exploitation. Pelagic whaling operations began in Areas II and III in the mid 1920s and by 1940 more than 100,000 fin whales had been taken. During this same period there were few fin whales taken from Areas V, VI and I. If the temporal changes in the relationship between fin whale pregnancy rate and length are due to declines in the numbers of animals, then, during a given whaling season, one would expect the relationships to differ between Areas. However, there are no significant differences between Areas; either the fin whale stocks were mixing on the whaling grounds (but, recoveries of tagged fin whales indicate little mixing (Brown, 1962)) or all the stocks were affected simultaneously by the factor(s) which promoted the temporal change in pregnancy rates. If food limitation is the mechanism which regulates fin whale reproduction (Lockyer (1981) estimated that consumption of krill accounted for more than 80% of a female fin whale's annual intake of food), then the whales' primary prey, Antarctic krill *Euphausia superba*, may consist of a single circumpolar population from which each of the separate whale populations draw their sustenance. Morphological and biochemical analyses of samples from the major krill concentrations have found no evidence of genetically separate krill populations (Chittleborough, 1987).

ACKNOWLEDGEMENTS

I owe particular thanks to Mrs E.J.Snell and Professor D.R.Cox, of the Department of Mathematics, Imperial College, for their many helpful suggestions regarding a strategy for the analysis of these data. I also thank Dr J.R. Beddington, of the Renewable Resources Assessment Group, Imperial College, London, Dr G.P. Kirkwood, of CSIRO, Division of Fisheries, Hobart, Tasmania, and two anonymous reviewers for their comments on earlier drafts.

Support for this research was provided by the Natural Environment Research Council and by The People's Trust for Endangered Species. My thanks to both institutions.

REFERENCES

Abramowitz, M. and Stegun, I.A. (ed.). 1964. *Handbook of Mathematical Functions*. National Bureau of Standards, Applied Mathematics Series No. 55, US Government Printing Office, Washington, DC. 1,046pp.

Baker, R.J. and Nelder, J.A. 1985. *The GLIM System Release 3.77*. Numerical Algorithms Group Ltd, Oxford. 305pp.

Best, P.B. 1989. Some comments on the BIWS catch record data base. (Published in this volume).

Brown, S.G. 1962. The movements of fin and blue whales within the Antarctic zone. *Discovery Rep*. 33:1–54.

Chittleborough, R.G. 1987. A rationale for conservation areas within Antarctic waters. Paper SC-CAMLR-VI/BG/23 presented to the Scientific Committee of the Commission for the Conservation of Antarctic Marine Living Resources, October 1987. (Unpublished). 15pp.

Clark, W.G. 1983. Apparent inconsistencies among countries in measurements of fin whale lengths. *Rep. int. Whal. Commn* 33:431–4.

Cox, D.R. 1970. *The Analysis of Binary Data*. Methuen & Co. Ltd, London. 142pp.

Draper, N.R. and Smith, H. 1981. *Applied Regression Analysis*. 2nd Edition. John Wiley & Sons, New York. 709pp.

Fienberg, S.E. 1977. *The Analysis of Cross-Classified Categorical Data*. The MIT Press, Cambridge, Mass. 151pp.

Gambell, R. 1976. Population biology and the management of whales. pp.247–343 *In:* T.H. Coaker (Ed.) *Applied Biology*, Vol.1. Academic Press, New York. 358pp.

Gaskin, D.E. 1982. *The Ecology of Whales and Dolphins*. Heinemann Educational Books, London. 459pp.

Laws, R.M. 1959. The foetal growth rates of whales with special reference to the fin whale, *Balaenoptera physalus* Linn. *Discovery Rep*. 29:281–308.

Laws, R.M. 1961. Reproduction, growth and age of southern fin whales. *Discovery Rep*. 31:327–486.

Lockyer, C. 1981. Growth and energy budgets of large baleen whales from the Southern Hemisphere. *FAO Fish*. Ser. 5 *Mammals in the Seas* 3:379–487.

Lockyer, C. 1984. Review of baleen whale (Mysticeti) reproduction and implications for management. *Rep. int. Whal. Commn* (special issue 6):27–50.

Mackintosh, N.A. 1942. The southern stocks of whalebone whales. *Discovery Rep*. 22:197–300.

Mackintosh, N.A. 1965. *The Stocks of Whales*. Fishing News (Books) Ltd, London. 232pp.

McCullagh, P. and Nelder, J.A. 1983. *Generalized Linear Models*. Chapman and Hall Ltd, London. 261pp.

Mizroch, S.A. 1980. Some notes on Southern Hemisphere baleen whale pregnancy rate trends. *Rep. int. Whal. Commn* 30:561–74.

Mizroch, S.A. 1981. Further notes on Southern Hemisphere baleen whale pregnancy rate trends. *Rep. int. Whal. Commn* 31:629–33.

Mizroch, S.A. and York, A.E. 1985. Have pregnancy rates of Southern Hemisphere fin whales, *Balaenoptera physalus*, increased? *Rep. int. Whal. Commn* (special issue 6):401–10.

Perrin, W.F. and Donovan, G.P. 1984. Report of the workshop. *Rep. int. Whal. Commn* (special issue 6):2–17.

Pregibon, D. 1980. Goodness of link tests for generalized linear models. *Appl. Statist*. 29:15–24.

SC/40/Ba4

Stock Trajectories for the East Greenland/Iceland Fin Whale Stock Based on Revised Catch Statistics, 1883 – 1987

Th. Gunnlaugsson[1], K. G. Magnússon[2] and J. Sigurjónsson[1]

Programme for Whale Research, Iceland

ABSTRACT

In this paper the available fin whale catch data for Iceland from 1883–1987 are used to calculate population trajectories from an initial 1883 stock size. A Pella-Tomlinson population model is used to calculate the trajectory with two alternative target values of present stock size. The question of whether the stock could have recovered to its pristine level by 1948 is discussed, and the implications of various values of maximum sustainable yield rates (MSYR) are investigated in the light of crude catch per unit of effort (CPUE) measures available for the early period of whaling off Iceland and the recent CPUE values obtained since 1962. It is found that a relatively high MSY rate is required to explain the catch history for this stock.

INTRODUCTION

The history of modern whaling in Iceland has been described by several authors (Risting, 1922; Jónsson, 1965; Tønnesen, 1967; Rørvik, Jónsson, Mathiesen and Jonsgård, 1976; Tønnesen and Johnsen, 1982; Einarsson, 1987). Although experiments with explosive harpoons in the waters around Iceland started as early as 1867, the catch of whales was insignificant in the years following. Modern whaling is considered to have started in Iceland in 1883, when the first land station at Langeyri, Alftafjördur, NW Iceland, started operation with new whaling vessels equipped with the recently invented explosive harpoon developed by the Norwegian pioneer Svend Foyn. This first period of modern whaling in Iceland lasted until 1915, when the Icelandic Althing banned all whaling from land stations. During these years, a number of stations operated in the Vestfirdir peninsula (NW Iceland) as well as in eastern Iceland after the turn of the century (see Fig.1). The total catches numbered over 17,000 whales, primarily fin (*Balaenoptera physalus*), blue (*B. musculus*) and humpback whales (*Megaptera novaeangliae*). As many as 1,305 whales were landed by 30 catchers in a single season (1902). The total catch of fin whales from 1883 to 1915 has been estimated as 7,956.

The second phase lasted from 1935 to 1939, when a single station located in the Vestfirdir peninsula (Talknafjördur) operated with 2–3 catchers and caught a total of 459 whales (375 fin whales). Sixteen Norwegian pelagic expeditions operated in the North Atlantic during 1929–34 and 1937. Nine of these were examined by Jonsgård (1966) and who found catches of 560 fin whales in the area west of Iceland.

The third phase of land station activities in Iceland started in 1948 with the operation of the whaling station in Hvalfjördur, SW Iceland. This operation has been described in detail by Sigurjónsson (1988). A total of 8,887 fin, 2,574 sei (*B. borealis*), 2,886 sperm (*Physeter macrocephalus*), 163 blue and 6 humpback whales were caught in the years 1948–85. In addition a total of 156 fin and 60 sei whales were caught under special permits issued in the 1986 and 1987 seasons. The catch per unit effort (CPUE) relationship in the fishery has been studied by Jónsson (1965), Rørvik *et al.* (1976), Rørvik (1980), Rørvik and Sigurjónsson (1981), Sigurjónsson and Rørvik (1983) and Sigurjónsson and Gunnlaugsson (1985a).

According to the International Whaling Commission (IWC) stock divisions (IWC, 1977), fin whales off Iceland belong to the East Greenland/Iceland stock. When studying the development of the stock in recent decades, it has been generally assumed that the stock was near its pristine level prior to the catches in 1948, when whaling was resumed after the Second World War (see e.g. Rørvik *et al.*, 1976; IWC, 1983a; Magnússon, 1984). Similarly, by incorporating catches landed at the Talknafjördur station in 1935–39, Holt (1987) assumed that the stock was at its initial level in 1934. The significant catches taken in earlier years do however, cast some doubts on such assumptions.

Fig. 1. Iceland, showing whaling stations which have operated at some period since 1883. (1) 1883–1906. (2) 1883. (3) 1889–1901. (4) 1890–99. (5) 1893–1911 and 1935–39. (6) 1894–99 and 1902–15. (7) 1896–1903. (8) 1897–1903. (9) 1897–1904. (10) 1900–12. (11) 1900–13. (12) 1900–13. (13) 1903–05. (14) 1904–13. (15) 1948–present. (After Sigurjónsson, 1988).

---

[1] Marine Research Institute, Reykjavík, Iceland
[2] Science Institute, University of Iceland, Reykjavík, Iceland

This paper presents population trajectories of the stock through a 1987 population estimate using a Pella-Tomlinson population model, based on all available catch information. The question of whether the stock could have fully recovered by 1948 is discussed, and the implications of various values of the maximum sustainable yield rate (MSYR) are investigated in the light of available CPUE measures. No stock trajectories based on CPUE were calculated.

MATERIAL

Estimated catches of fin whales for the period 1889–1915 are prorated from known catches as a proportion of the total catch in the respective years (69% of the total catch known, Sigurjónsson, pers. comm.) and for the years 1883–88 we assume that fin whale catches have comprised approximately 45% of the reported total i.e. the same as in the following years. According to Tønnesen (1967) and Tønnesen and Johnsen (1982), a substantial proportion of whales killed during the years 1883–1907 were not retrieved, but this must have gradually decreased as catch techniques and equipment improved, together with increased crew experience. This has been taken into account in alternative computer runs in our analysis (see below). Catches prior to 1883 are excluded from the analysis, since they are regarded to be of no significance.

The catch totals for the pelagic operation off Iceland and East Greenland during 1929–34 are estimated from Jonsgård's (1966) mapping of 1,693 out of a total of 1,928 whales taken by the Norwegian pelagic operations. This gives an estimated total of 612 fin whales. In addition we include 198 animals taken off Iceland in 1937 (IWS, 1938).

Catch data by sex is available for the entire Hvalfjördur whaling operation (1948–1987). For the Talknafjördur operation (1935–39) the sex composition is only available for the 1936 and 1937 seasons, while the total catches are reported for all years (IWS, 1937; 1938). In the above periods the sex composition is 52:48 (females:males). This ratio has been assumed for the whaling operation around the turn of the century and in the 1935 and 1938–39 seasons. It is plausible that the female proportion was somewhat higher in 1883–1915, since lactating females were not protected until 1946. For the pelagic catches in the late 1920s and early 1930s, the sex composition is reported for part of the catches as 46.35% females (IWS, 1931) or approximately 46:54 (females:males), which accordingly is used here in our analysis.

The estimated total fin whale catches by sex for the period 1883–1987 are given in Table 1, together with the total number of vessels operating each year between 1883 and 1915. The fin whale catches and the pooled blue and humpback whale catches (1883–1915) are shown in Fig. 2.

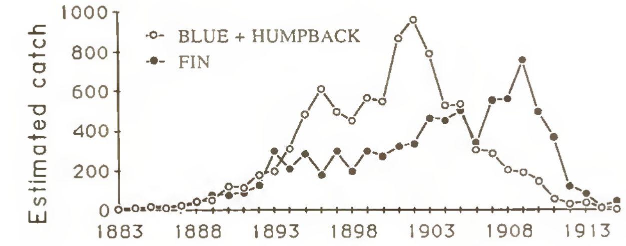


Fig. 2. Estimated catches of large whales 1883–1915.

Table 1

Estimated catches of male (M) and female (F) fin whales 1883–1987 and total number of boats per season (n) 1883–1915

Year	M	F	n	Year	M	F	n	Year	M	F
1883	1	2	1	1911	177	193	22	1960	81	79
1884	5	6	1	1912	58	63	20	1961	65	77
1885	6	8	1	1913	38	43	13	1962	165	138
1886	5	6	1	1914	9	11	3	1963	152	131
1887	10	11	2	1915	21	24	4	1964	109	108
1888	17	19	2	1929	37	32		1965	157	131
1889	36	41	4	1930	131	79		1966	163	147
1890	37	41	7	1931	89	76		1967	110	129
1891	44	48	8	1932	86	74		1968	100	102
1892	60	65	11	1933	106	92		1969	118	133
1893	142	155	13	1934	24	22		1970	140	132
1894	100	110	15	1935	12	13		1971	96	112
1895	137	149	16	1936	27	45		1972	118	120
1896	86	95	18	1937	137	117		1973	132	135
1897	143	155	21	1938	54	59		1974	145	140
1898	94	103	21	1939	52	57		1975	126	119
1899	144	158	23	1948	92	103		1976	132	143
1900	132	143	23	1949	109	140		1977	62	79
1901	155	169	27	1950	98	128		1978	108	128
1902	163	178	30	1951	122	190		1979	126	134
1903	224	243	30	1952	97	127		1980	116	118
1904	218	238	27	1953	98	109		1981	119	135
1905	242	263	25	1954	69	108		1982	96	98
1906	164	178	25	1955	117	119		1983	68	74
1907	265	288	25	1956	115	150		1984	67	99
1908	268	291	29	1957	149	199		1985	74	87
1909	363	394	30	1958	140	149		1986	27	49
1910	240	261	32	1959	95	82		1987	38	42

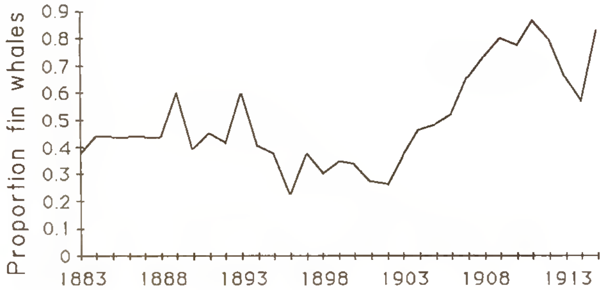


Fig. 3. Ratio of fin whales in the catch 1883–1915.

The ratio of fin whales in the catch did not show any upward trend until after the turn of the century (see Fig. 3).

During the first period, at the turn of the century, catches from the west coast stations were primarily taken in shallow and deep waters off the west and north coasts of Iceland, but also as far away as to the Westmann Islands in the south. From the east coast stations catches were mainly taken in deep and shallow waters off the northeast to southeast coasts. Catches from the Talknafjördur and Hvalfjördur stations were taken at and outside the continental edge southwest to northwest of Iceland.

Information on vital rates used in this work was derived from studies made on whales landed at Hvalfjördur station. Some of these studies have been published (e.g. Lockyer and Butterworth, 1984; Martin, 1982) and others are unpublished in the possession of the Marine Research Institute.

METHODS AND BASIC ASSUMPTIONS

Population model

The program Hitter/Fitter (written by J. Cooke and W. de la Mare; made available through the IWC Secretariat) was used for our computer runs.

The model used in the program is an age structured version of the Pella-Tomlinson population model:

$$N_{t+1}=(N_t-C_t)S+(1-S)(1+A(1-(N_{t-T}/K)^z)N_{t-T}.$$

Here N_t is the recruited stock at time t, C_t is the catch in year t, K is the unharvested equilibrium population (i.e. the carrying capacity) and S is the annual survival rate. The age at maturity, T, is assumed constant in the model; all the compensation is assumed to come from increased pregnacy rates and increased pre-recruitment survival. If the age at maturity decreases with decreasing population size, then the model is not exact. However, such an effect is incorporated to some extent into the the resilience coefficient A. The exponent z is taken to be 2.39, giving an MSY level at 60% of carrying capacity.

Biological parameters

The model is not very sensitive to the age at maturity. We use 8 years for the female age at 50% maturity and 11 for 95% maturity; close to the present day values (Lockyer and Butterworth, 1984).

In the present operation (1983–86) relatively few immature animals are taken and the peak age is 7 years. The situation was undoubtedly somewhat different during the operations at the turn of the century when there was no size limit on takeable whales and thus the age at recruitment was probably rather lower. Here we have used the value of 6 for age at 50% recruitment and 10 for age at 95% recruitment.

For the natural mortality M, the values 0.04 and 0.06 were used. The coefficient A is linearly related to the MSY rate (see below), which is usually assumed to lie somewhere between 1% and 4%. We will now briefly look at whether this assumption is reasonable or not.

MSY rate

Consider now the Pella-Tomlinson population model:

$$P_{t+1}=S(P_t-C_t/K)+(1-S)[1+A(1-(P_{t-T})^z)]P_{t-T}, \qquad (1)$$

where P=N/K. The latter term on the right hand side is the recruitment, denoted by R_1. At equilibrium we have

$$P=SP-SC/K+(1-S)P+A(1-P^z)P(1-S),$$

and hence

$$C/K=(1-S)A(1-P^z)P/S. \qquad (2)$$

C has a maximum at $P=(1/(z+1))^{(1/z)}$, the MSY-level, denoted by MSYL. The corresponding C/K, i.e. MSY, is MSY=(1-S)A[1–1/(z+1)]MSYL/S, and thus the MSY rate is

$$MSYR=MSY/MSYL=A(1-S)/S[z/(z+1)]. \qquad (3)$$

The recruitment can also be written as (assuming a 1:1 sex ratio among mature whales):

$$R_2=S^T\cdot(B(P)/2).\exp(-m_j).P, \qquad (4)$$

where B(P) is the birth rate at population level P, T is the age at recruitment (for the sake of simplicity taken here to be equal to the age at maturity) and m_j is the accumulated difference between the juvenile and adult mortality rates over the pre-recruitment years. We can assume that all the accumulated extra pre-recruitment mortality is concentrated in the first year of life, i.e. the annual survival rate in the first year is $\exp(-m_j)S$ and S subsequently. For small P, the recruitment R_1 can be written as

$$R_1=(1-S)[1+A]P+o(P). \qquad (5)$$

Let us now consider R_2; first we write the birth rate as $B(P)=B_o-B_1(P)$, where $B_1(P) \rightarrow 0$ as $P \rightarrow 0$. Furthermore, we write $\exp(-m_j)=S_{jo}+S_{j1}(P)$, where $S_{j1}(P) \rightarrow 0$ as $P \rightarrow 0$. Thus, B_o is the birth rate and $S_{jo}S$ is the annual juvenile survival rate at low population densities. Both B_o and $S_{jo}S$ are independent of P, the density dependent effects appear through $B_1(P)$ and $S_{j1}(P)$.

Then, R_2 can be written as

$$R_2=(S_{jo}S)S^{T-1}(B_o/2)P + o(P). \qquad (6)$$

Since $R_1=R_2$ for all P, we must have, (as $P \rightarrow 0$),

$$(1-S)[1+A]=(S_{jo}S)S^{T-1}(B_o/2), \text{ and thus}$$

$$A=(S_{jo}S)S^{T-1}(B_o/2)/(1-S)-1. \qquad (7)$$

Inserting into the equation for MSYR (equation 3), we get

$$\begin{aligned} MSYR&=(1-S)/S.[(S_{jo}S)S^{T-1}(B_o/2)/(1-S)-1](z/(z+1)) \\ &=[(S_{jo}S)S^{T-2}(B_o/2)-(1-S)/S](z/(z+1)). \qquad (8) \end{aligned}$$

Let us now examine some numerical examples. We will take T=8, z=2.39 (giving MSYL=60%) and S=exp(-0.04) or exp(-0.06) in accordance with the values used in the population model.

The MSYRs for different values of S_{jo} and B_o are given in Table 2.

Table 2

MSY-rate (%) for S=exp(-0.04) and for S=exp(-0.06)

	B_o			B_o	
$S_{jo}S$	0.75	0.5	$S_{jo}S$	0.75	0.5
S = exp(–0.04)			**S = exp(–0.06)**		
1*S	17.1	10.4	1*S	13.0	7.2
0.75	12.7	7.5	0.75	9.5	4.9
0.50	7.5	4.0	0.50	4.9	1.8

We take all combinations of B_o=0.75 and 0.5 (three calves every four years and one calf every second year) and $S_{jo}S$=S, 0.75 and 0.5 (no extra juvenile mortality, total survival during first year 75% and 50%). It should be noted that SS_{jo} and B_o are the values of juvenile survival and birth rates at very low population levels and thus are the maximum values of these parameters over the whole range of population levels.

The present pregnancy rate for fin whales has been estimated at 0.5 (Martin, 1982). B_o, which is the pregnancy rate as population levels become low, i.e. the maximum rate, is thus unlikely to be lower than 0.5. No information on juvenile survival exists, but for a value of 50%, an MSYR ranging from 1.8% to 4%, depending on the value of M, is obtained. In the case of 75% juvenile survival, MSYRs of between 4.9% and 7.5% are obtained. Thus, there seems to be no *a priori* biological reason to assume an upper bound of 4% for the MSY rate for fin whales. Note that if the extra juvenile mortality is spread evenly over the pre-recruitment years, then the average annual survival rate is

$$S_{pr}=[(S_{jo}S)/S]^{1/T}\,S.$$

If $S_{jo}S$=0.5 then S_{pr}=0.88 or 0.86 for S=exp(-0.04) and exp(-0.06) respectively.

In view of the above discussion, we have used three different values for MSYR; 1%, 4% and 7%.

Target stock

The 1987 target values for the stock trajectories were chosen on the basis of the results of NASS-87, the 1987 North Atlantic sightings surveys (Sigurjónsson, Gunnlaugsson and Payne, 1989). The estimate of total stock was 6,436 (IWC, 1989). The corresponding number for the recruited stock is between 4,500 and 5,000 (IWC, 1989). The numbers 5,000 and 3,000 were used as estimates of the recruited stock in 1987. The former is close to the estimate of recruited stock corresponding to a total stock of 6,436 and the latter is used as a low estimate of the recruited stock.

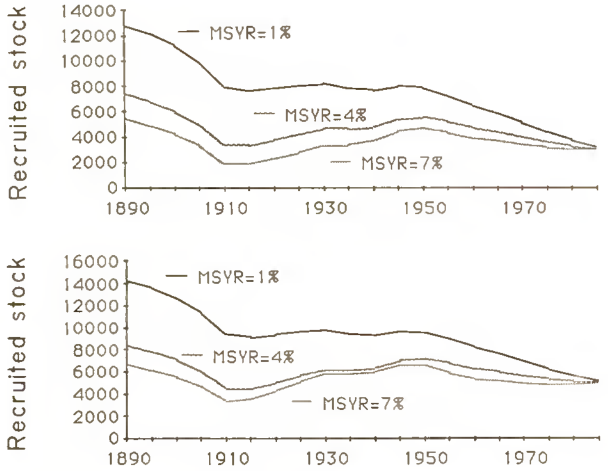
Catch series

All recorded fin whale catches off Iceland (see above) are used in the computer runs. An alternative set of catch statistics is also used for a second set of runs. This 'corrected' catch series is to account for the loss of whales in the first years of whaling. Tønnesen (1967) refers to statements by whalers, that during the first 20–25 years of whaling activities off Iceland (1867–1886/91), the number of whales reported caught can be doubled to get a correct estimate of killed animals and increased by 50% for the next 15–20 years. He further comments that this may be somewhat exaggerated although it gives an indication of the loss rates in this period. Our alternative set of 'corrected' catch statistics used here is based upon the assumptions that the losses during 1883–86 were 50% of the landed catch and those during 1887–1903 were 33%.

RESULTS AND DISCUSSION

Model runs

The results of the two sets of runs are summarised in Table 3, which gives the population sizes for selected years using the uncorrected (A) and the corrected (B) catch series. The values of the recruited stock are given for the following years: 1883 (initial stock); 1895 (peak total catch per boat 1883–1915); 1912 (in all runs the year of minimum stock size 1883–1915); 1929 (beginning of the Norwegian pelagic operation); 1940 (end of the pelagic operation and the operation from Talknafjördur land station); 1948 (beginning of the present phase); 1962 (first year in the unbroken CPUE series for the present operation); 1980 and 1987. The last column gives the replacement yield in 1988. Figs 4 and 5 show the stock trajectories for the uncorrected catch series and with M equal to 0.06.



Figs 4 and 5. Recruited stock of fin whales 1890–1985 with a 1987 stock size of 3,000 (top) and 5,000 (bottom).

It can be seen from Table 3 that for the uncorrected catch series, the 1948 population ranges from 62% to 100% of the original 1883 value. The only case when the population has recovered in 1948 is for a high MSYR (7%) and a high 1987 target value (5,000). For the corrected catch series, the values range from 57% to 90%, the population never quite having recovered in 1948. However, using the corrected catch series does not change the overall picture. As expected, the value of M makes little difference since the MSYR is fixed.

Table 3

Simulated population trajectories for different values of natural mortality (M), MSY-rate and final population size

M	MSYR(%)	1883	1895	1912	1929	1940	1948	1962	1980	1987	RY88
Uncorrected catch											
0.04	1	13523	12656	7607	8493	7911	8439	6558	3710	3000	48
0.06	1	12958	12136	7441	8228	7651	8128	6328	3648	3000	49
0.04	1	14916	14049	11630	10004	9480	10053	8253	5602	5000	65
0.06	1	14413	13591	8914	9789	9262	9781	8055	5553	5000	65
0.04	4	7677	6826	2767	4508	4669	5752	4755	3208	3000	120
0.06	4	7557	6750	2946	4595	4708	5690	4688	3193	3000	117
0.04	4	8616	7765	3808	5992	6296	7405	6244	4975	5000	166
0.06	4	8570	7764	4055	6088	6312	7313	6207	4981	5000	154
0.04	7	5659	4823	1325	3018	3435	4753	3917	2922	3000	167
0.06	7	5608	4817	1522	3250	3649	4833	3913	2929	3000	160
0.04	7	6852	6017	2811	5690	6065	6912	5200	4664	5000	206
0.06	7	6851	6061	3023	5705	5997	6823	5310	4704	5000	195
Corrected catch											
0.04	1	14700	13372	7435	8355	7813	8367	6536	3709	3000	48
0.06	1	14053	12795	7286	8102	7561	8063	6307	3647	3000	50
0.04	1	16005	14677	8768	9806	9334	9944	8212	5597	5000	66
0.06	1	15428	14170	8688	9608	9131	9683	8017	5547	5000	66
0.04	4	8527	7225	2452	4044	4207	5342	4611	3190	3000	122
0.06	4	8307	7074	2613	4148	4291	5334	4565	3176	3000	119
0.04	4	9079	7777	3105	5055	5437	6702	6014	4937	5000	167
0.06	4	8978	7745	3390	5278	5613	6761	6020	4949	5000	159
0.04	7	6484	5206	1048	2373	2568	3827	3601	2868	3000	175
0.06	7	6284	5075	1150	2502	2742	3949	3640	2884	3000	167
0.04	7	6853	5575	1571	3502	4224	5798	5227	4665	5000	206
0.06	7	6860	5651	1934	4036	4775	6155	5302	4702	5000	196

It should be noted that the recovery of the stock is unlikely to have been aided by immigration from other areas of known fin whale concentrations since the total catches of fin whales in the North Atlantic between 1920 and 1930 exceeded 1,000 in most years. The only areas of known concentrations of fin whales not exploited at that time were the East Greenland coastal waters and the deep waters of the Denmark Strait west and southwest of Iceland. (There was some exploitation by factory ships in this area in the 1930s, but only about 100 whales were taken (Jonsgård, 1966)). The stock estimate for this area from the NASS-87 sightings survey was 1,340 out of a total estimate of 6,436 for the East Greenland – Iceland stock (Gunnlaugsson and Sigurjónsson, 1988). The recovery of marks placed off East Greenland and east of Iceland is significantly lower than from markings placed on the whaling grounds (Sigurjónsson and Gunnlaugsson, 1985b). However, some marks have been recovered in the Icelandic catch and mixing has been demonstrated as one animal was tracked by radio from Iceland to the East Greenland coast (Watkins, Moore, Sigurjónsson, Wartzok and di Sciara, 1984). The slow mixing between the two areas could also explain the age distribution of the catch which shows a high mortality rate for the lower age classes, but nevertheless with quite a few old whales being caught. This is unexpected after such long and continuous exploitation.

Catch per boat series 1883–1915

The various population trajectories in Table 3 have to be viewed in the light of our knowledge of the various operational phases.

For the operation 1883–1915, no CPUE index is available, but the total number of boats operating in each season is known (Table 1). Assuming that the length of each season was relatively constant, this number can be used as a crude measure of the total effort. However, this operation was a multispecies fishery, since fin, blue and humpback whales were taken and there is no information available by which the effort can be divided among the three species.

A multispecies fishery can in fact be analysed on the basis of either of the two different assumptions given below concerning the operational pattern of the fishery. These assumptions correspond to the two extreme cases. In reality most operational patterns will be somewhere in between.

(1) The total effort E, is split into individual components representing the effort on each individual species, i.e. $E=\Sigma_i E_i$, where the index i refers to the species. This would apply in cases where the operational pattern is such that when one species is being hunted (searched for) then all other species are either not available or are ignored.

(2) All species are being hunted simultaneously i.e. $E=E_i$ for all i. The possibility that some species might be preferred to others, could be accommodated by incorporating such preferences into the catchability coefficient q_i, in the relation $(C_i/E)=q_i (N_i)^r$. Thus, if one of two species with equal catchability coefficients becomes the preferred species, then this would mean that the catchability of the other is decreased. Indeed, one is taking the view that if a whale of a species which is low on the preference list is encountered, it will not be taken due to the expectation that a species higher on the list will come along; this is equivalent to assuming that the whale was not seen at all.

If (1) holds and furthermore, the effort spent on each species is proportional to the respective catches; the total catch of all species, C, over the total effort, B (total number of boats), can be used as an index of fin whale abundance. This can be justified by setting total effort as B (total number of boats) and assuming that the fraction of the total effort spent on humpback and blue whales is $(C_b + C_h)/C$. Hence the effort on fin whales is

$$E_f=(1-(C_b+C_h)/C)B=(C_f/C)\ B,$$

and catch per unit effort for fin whales is $C_f/E_f=C/B$.

Thus we can use total catch over total number of catcher boats as a measure of the CPUE for fin whales. This CPUE series is shown in Fig.6. Due to a presumed initial period of learning and of technical improvements, we regard the peak year of 1895 as the end of this first phase of the fishery. By taking a regression line through the years 1895–1915 it follows that the CPB series has decreased by a total of 73% in this period, i.e. an almost fourfold drop in the CPUE.

As fin whales are becoming a larger proportion of the total catch through this period, another explanation for the drop in CPB could be that fin whales were much harder to catch than the other species, which would be reflected in the CPB when proportionally more fin whales were taken.

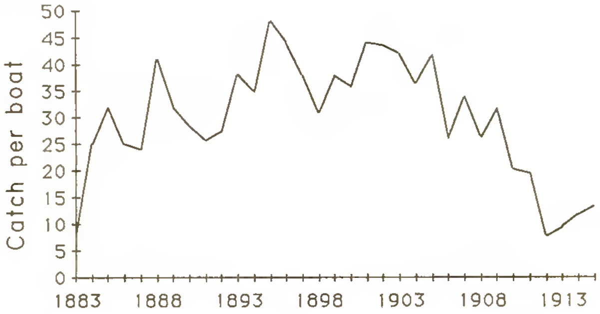


Fig. 6. Total catch per boat 1883–1915.

However, it is more likely that the smaller size of the fin whale caused the blue whale to be preferred, rather than less effort being required, as blue and fin whales in these areas are known to occur together and behave quite similarly. Furthermore, considering the CPB for the period after 1905 only, when fin whales became the dominant species, gives similar results, irrespective of whether the total catch or only the fin whale catch is used.

Any nonlinear effects in the relationship between stock abundance and a CPUE measure are likely to be much more severe for a crude CPUE series such as CPB, than for a more refined series such as the one for the present operation from the Hvalfjördur station. For one thing, when sailing time to the whaling grounds is included in the effort measure, saturation effects occur, making the relationship between the stock size and CPUE concave, i.e. making the exponent in the relationship CPUE=q(stock size)^r, closer to zero. Furthermore, limitations in the towing and processing capacity will contribute further to a concave relationship, as will the inclusion of chasing and handling times in the effort measure (Rørvik *et al.*, 1976; Cooke, 1985). Another factor which would tend to make the CPB series underestimate the actual decline in the stock, is the possibility discussed above of a high loss rate of killed whales. The loss rate will have decreased with time due to technical improvements and to increased crew experience. Therefore, the decline in CPB will be less than the actual population decline.

Compared to the present operation, the Norwegian land station operations from 1883–1915 had a much wider range and less time constraints. In addition, the range of the operations was not limited by the Iceland–Greenland midline [today, the highest concentrations of fin whales are observed at the rise of the shelf just west of the midline (Sigurjónsson, Gunnlaugsson and Payne, 1989)]. Thus, the whales were hunted wherever they were to be found, and so it seems evident that a far larger part of the stock was subject to exploitation in the past than in recent years. This would further increase the possibility that the stock could be severely depleted.

Fig. 7 shows the known location of the catches from the Mjóifjördur stations month by month for the years 1905 and 1909. The figures show that by 1909 the catches were taken much farther from the coast than in 1905, indicating the depletion of the coastal part of the stock. It should be noted that towing boats were gradually introduced as the catcher boats had to operate farther offshore.

The CPB is a very crude CPUE measure. For one thing we have a mixed fishery with CPB a measure of the total stock of three different species, and we have had to assume that the relative catches of the three species were equal to

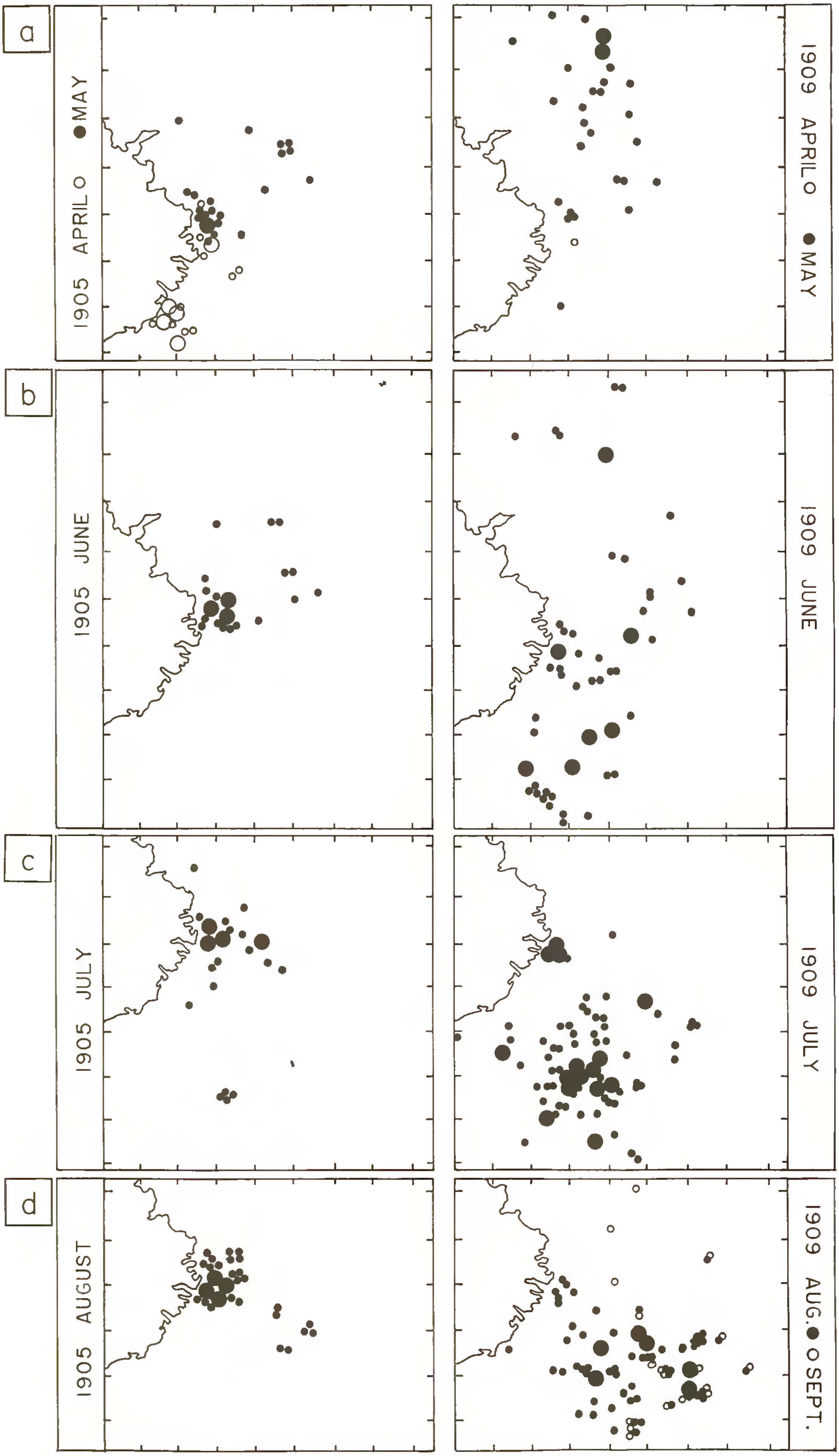


Fig. 7. Known locations of catches of fin whales from the Mjóifjördur stations in 1905 and 1909 by month.

their relative abundance. Also, the lengths of the seasons in different years have not been taken into account, and similarly it is not clear whether all boats were operational throughout the whole season. However, in view of the discussion above, it seems quite possible that the stock decreased by at least 75% from 1895 to 1915. A total of 6,981 fin whales (332 per year) were taken during this period. The hunting was most intense during the 13-year period from 1899–1911, when a total of 5,752 fin whales were taken (442 per year). The catch figures could be substantially higher if failures to retrieve killed whales were significant.

We note that if the operational pattern is such that assumption (2) above is satisfied, then the catch of fin whales over total effort would be the appropriate index to use. However, as can be calculated from Table 1, it turns out that the C_f/B index increased up to 1910, the decline only taking place in the last five or six years of whaling. Obviously therefore this ratio cannot be used as an index for the stock size of fin whales.

The possibility that the collapse of the stock at Iceland was aggravated by catches taken in other areas under exploitation cannot be ruled out. However, no new information is available to support a change of the accepted IWC stock boundaries. In fact there is evidence to support the claim that the East Greenland-Iceland stock and the Spain-Portugal-British Isles stock are distinct (Arnason and Jonsdottir, 1988). With the exception of a single mark placed off Canada in 1979, no marks placed in other areas have been recovered in Icelandic waters (Gunnlaugsson and Sigurjónsson, 1989). It is impossible to say beforehand, what effect the existence of a substantial mixing component between the North Atlantic stocks would have had, i.e. whether it would have aggravated the collapse off Iceland or lessened it. Furthermore, exploitation continued in these other areas after 1915, which would then have slowed the recovery of the stock in Icelandic waters.

Carrying capacity

The population numbers in Table 3 show that the 1948 stock size cannot be taken to be at its pristine (1883) level unless the MSYR is high and the present stock size relatively high.

If one makes the erroneous assumption that the 1948 stock size is at the carrying capacity of the environment when in actual fact the stock is increasing, the calculated decline in stock size from 1948 to the present will be higher than the true decline. This is because the 1948 stock will be used, instead of the true pristine level, as the value for the parameter K in the recruitment function in the Pella-Tomlinson population model. Thus at any population level, the calculated value of the recruitment will be lower than the value obtained if the correct value of the pristine level is used. As an example, let us take M=0.06, MSYR=4% and a 1987 stock of 5,000. Then, assuming that the stock was at the pristine level in 1948, we get a 1948 stock size of 8,303. Thus the present stock is 60.2% of the 1948 stock. However, from Table 3 it can be seen that for these values of the parameters, the 1948 stock is 7,313 and thus the present stock is 68.4% of the 1948 stock. This has of course nothing to do with where the present population is in relation to MSYL; it serves only to illustrate that the decline between any two years will be overestimated.

Consequently, the 1883 stock should be taken as the pristine level for this stock. However, this highlights one of the problems inherent in the IWC's current management procedure, the 'New Management Procedure'. The 100+ years catch history for the East Greenland-Iceland fin whale stock is relatively well known, but it is unreasonable to assume that the carrying capacity of the environment has remained unchanged for the entire period. For one thing the stocks of blue and humpback whales, which compete with fin whales for food were severely depleted at the turn of the century. In addition, the stocks of herring (*Clupea harengus*) and capelin (*Mallotus villosus*) have been heavily fished in recent decades. Both these species feature in the diet of fin and humpback whales, but they are also competitors for food, as they feed on krill (e.g. *Meganyctiphanes norvegica*). The changes in the stock sizes of these species are likely to have resulted in a change in the carrying capacity for fin whales. Another factor which could have resulted in a change in the carrying capacity is the gradual increase in sea temperatures around Iceland. This increase began in the 1920s and lasted until the 1960s since when the trend has reversed (Malmberg, 1985).

It is difficult to say exactly whether these changes in environmental conditions will have increased or decreased the carrying capacity for fin whales. Nevertheless, the inevitable conclusion is that if whales are to be managed on the basis of maintaining the stocks at a certain percentage of the carrying capacity, changes in the ecosystem of which they are an integral part, will have to be taken into account.

CONCLUSION

The stock trajectories presented here did not use either of the two CPUE series, i.e. no fitting process is involved; the MSYR is fixed and the population trajectory is made to pass exactly through an estimate of the 1987 population size. However, the behaviour of the population trajectory can, and has been *compared* to the observed trends in the two CPUE series. The early total catch per boat series show a sharp decline (73%) over the 20 year period 1895–1915 while the recent series has been relatively stable for the past 25 years (Sigurjónsson and Gunnlaugsson, 1985a).

Table 3 shows that the only case where the population decline between 1895 and 1915 is close to 73%, is when the MSYR is set at 7%. Furthermore, in this case, the population is shown to have been relatively stable since the 1960s, which is in agreement with the recent CPUE series. For other MSYR values, in particular 1%, the population decline in the early period is much less than is indicated by the decline in CPB, and the recent decline is much more severe than the recent CPUE series indicates.

The catch history for this stock thus shows that there are two basic possibilities: (a) the population suffered a great decline between 1895 and 1915 and has been relatively stable over the past 25 years, or (b) the early decline was less substantial, but a severe decline has taken place in recent years. Case (a) corresponds to a high MSYR and case (b) to a low one.

In light of the fact that both CPUE series are in agreement with case (a), it can be argued that the MSY rate is higher than 4%, which has hitherto been taken as an upper bound on the range of possible MSY rates. Furthermore, a value of 1% seems highly unlikely. In other words, if the stock collapsed shortly after the turn of the century as is indicated by the early CPUE series, then it could only have sustained the catches in the recent period if the MSYR was high. This argument is purely qualitative, in the sense that only the qualitative behaviour of the stock trajectory on the one hand, and the two CPUE series on the other hand are compared. In view of reservations about the early CPB series, and how the two series should be weighted, no attempt was made to fit to the CPUE data.

However, at the 40th Annual Meeting of the IWC Scientific Committee (IWC, 1989), the program Hitter/Fitter was used to fit a stock trajectory to one or both CPUE series. The trajectory was made to pass through an estimate of total population in 1987 of 6,436 animals and the MSYR was estimated by the program. Estimates were obtained by using either both the early, (i.e. CPB), and the recent CPUE series, and by using only the recent series. The inclusion of the early series made little difference to the results, which show that, irrespective of the early CPB series, the catch history for this stock requires a 'high' MSYR for the stock to have recovered sufficiently in order to sustain the catches since 1948. In all the runs performed, an estimate of MSYR of between 12% and 13% was obtained. This value does seem unrealistically high. However, one partial explanation for this might be that the calculated stock trajectory refers to the total stock, i.e. both the East Greenland component and the Iceland one, but that the two CPUE indices only refer to the Icelandic component which is likely to have declined more severely than the total in view of the incomplete mixing between the two components. The difference in the age at recruitment for the two major operations could also possibly contribute to this high MSYR estimate.

Attempts to estimate gross recruitment from catch-at-age data for the Icelandic fin whale stock were made by by the Scientific Committe in 1982 (IWC, 1983b). The results gave an increase in r_{II} from 4% to 7% between 1948 and 1960. These results are in no way contradictory to an MSY rate of 7%, since in that case the population size from 1948 to 1960 is well above MSY level, and hence the yield rate would be less than 7%. As pointed out by de la Mare (1985) the prospects of obtaining relieable estimates of net recruitment or changes in gross recruitment from age data are poor. In fact, in the case of the southern fin whale, Allen (1973) and Clarke (1984) failed to find any changes in recruitment as stocks collapsed.

Future studies

No additional runs have been made by the authors. A great deal of further work is required to refine the early CPB series and develop separate indices for the east and the west coast operations. With this in hand, a new problem arises of how to treat the two operations. Are they fishing from the same aggregation of whales, from completely separate aggregations or is the situation somewhere in between, which would require a new model? There exists no information on mixing rates between the east and west coasts and there are additional complications. As mentioned above, it has been demonstrated that mixing between the aggregations off East-Greenland and Iceland is slow or incomplete. The abundance of animals in the former area would be poorly reflected in the CPB series as well as in the modern CPUE series. This might result in an S-shaped stock CPUE relationship. Therefore, information about stock identities and mixing rates is required before more complex modelling is undertaken. Such information might for example be obtained by tracking animals and possibly by DNA analysis.

ACKNOWLEDGEMENT

We thank Carl Jacob Rørvik and two referees for their careful review of the manuscript and for useful comments.

REFERENCES

Allen, K.R. 1973. Analysis of the stock-recruitment relation in the Antarctic fin whales (*Balaenoptera physalus*). *ICES Rapport et P.-V.* 132–137

Arnason, A and Jonsdottir S. 1988. An electrophoretic study of cardiac esterases and proteins of fin whales (*Balaenoptera physalus*) from Icelandic and Spanish waters and sei whales (*Balaenoptera borealis*) caught off Iceland. Paper SC/39/Ba6 presented to IWC Scientific Committee, June 1987.

Clarke, W. G. 1984. Recruitment rates of Antarctic fin whales *Balaenoptera physalus*, inferred from cohort analysis. *Rep. int. Whal. Commn* (special issue 6): 411–15.

Cooke, J.G. 1985. On the relationship between catch per unit effort and whale abundance. *Rep. int. Whal. Commn* 35: 511–19.

De la Mare, W.K. 1984. On the power of catch per unit effort series to detect declines in whale stocks. *Rep. int. Whal. Commn* 34: 655–61.

De la Mare, W.K. 1985. On the estimation of the net recruitment rate from whale age data. *Rep. int. Whal. Commn* 35: 469–76.

Einarson, T. 1987. Hvalveidar vid Island 1600–1939. Menningarsjódur, Reykjavík, 177pp. [In Icelandic].

Gunnlaugsson, Th. and Sigurjónsson, J. 1989. NASS-87: Estimation of abundance of large cetaceans from observations made onboard Icelandic and Faroese survey vessels. Paper SC/40/O 30 presented to the IWC Scientific Committee, May 1988 (unpublished).

Gunnlaugsson, Th. and Sigurjónsson, J. 1989. Analysis of Icelandic fin whale markings 1979–1984 and recoveries up to and including the 1988 season. Paper SC/40/O 35 (published in this volume).

Holt, S. 1987. The status of the East Greenland fin whale stock. Paper SC/39/Ba2 presented to the IWC Scientific Committee, June 1987, (unpublished).

International Whaling Commission. 1977. Report of the working group on North Atlantic whales. Oslo, April 1976. *Rep. int. Whal. Commn* 27: 369–87.

International Whaling Commission. 1977. Report of the Scientific Committee. *Rep. int. Whal. Commn* 27:369–87.

International Whaling Commission. 1983a. East Greenland-Iceland fin whales: Results of modified BALEEN estimation. Report of the Scientific Committee, Annex F, Appendix 3. *Rep. int. Whal. Commn* 33: 134–5.

International Whaling Commission. 1983b. East Greenland-Iceland fin whales. Report of the Scientific Committee, Annex F. *Rep. int. Whal. Commn* 33: 125.

International Whaling Commission. 1989. Report of the Scientific Committee (published in this volume).

International Whaling Statistics. 1931. II: 68.

International Whaling Statistics. 1937. IX: 1–22.

International Whaling Statistics. 1938. XI: 1–36.

Jonsgård, Å. 1966. Biology of the North Atlantic fin whale, *Balaenoptera physalus* (L) – Taxonomy, distribution, migration and food. *Hvalrad. Skr.* 49:1–62.

Jónsson, J. 1965. Whales and whaling in Icelandic waters. *Norsk Hvalfangsttid.* 54:245–53.

Lockyer, C. and Butterworth, D.S. 1984. A note on age at maturity time-trends in Icelandic fin whales. Report of the Scientific Committee, Annex F, Appendix 4. *Rep. int. Whal. Commn* 34: 121.

Magnússon, K. 1984. Equilibrium and stability conditions for the East Greenland-Iceland fin whale stock. *Rep. int. Whal. Commn* 34: 425–30.

Malmberg, S.-A. 1985. The Watermasses between Iceland and Greenland. *Rit Fisk.* 9: 127–40.

Martin, A.R. 1982. Pregnancy rates of fin whales in the Icelandic catch. *Rep. int. Whal. Commn* 32: 325–9.

Risting, S. 1922. *Av Hvalfangstens Historie*. J. Petlitz Boktrykkeri, Kristiania, 625pp.

Rørvik, C.J. 1980. Catch per unit effort in the Icelandic fin whale fishery. *Rep. int. Whal. Commn* 30: 213–17.

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.

Rørvik, C.J., Jónsson, J., Mathiesen, O.A., and Jonsgård, Å. 1976. Fin whales, *Balaenoptera physalus* (L), off the west coast of Iceland, distribution, segregation by length and exploitation. *Rit Fisk.* 5(5): 1–30.

Sigurjónsson, J. 1988. Operational factors in the Icelandic coastal-based large whale fishery. *Rep. int. Whal. Commn* 38: 327–33.

Sigurjónsson, J. and Rørvik, C.J. 1983. Provisional data on catch per unit effort in the Icelandic fin whale fishery. *Rep. int. Whal. Commn* 33: 131-4.

Sigurjónsson, J. and Gunnlaugsson, Th. 1985a. Considerations on CPUE data for the Icelandic fin whale fishery. *Rep. int. Whal. Commn* 35: 108–12.

Sigurjónsson, J. and Gunnlaugsson, Th. 1985b. Further mark recapture analysis of fin whales caught off Iceland with a note on stock identity and movements of the East-Greenland/Iceland population. *Rep. int. Whal. Commn* 35: 357–62.

Sigurjónsson, J., Gunnlaugsson, Th. and Payne, M. 1989. NASS-87: Shipboard sightings surveys in Icelandic and adjacent waters June-July 1987. Paper SC/40/O 29 (published in this volume).

Tønnesen, J. 1967. *Den Moderne Hvalfangsts Historie.* II. Kommandor Chr. Christensens Hvalfangstmuseum, Sandefjord. 619 pp.

Tønnesen, J. and Johnsen, A.O. 1982. *The History of Modern Whaling.* C. Hurst & Co., London. 798 pp.

Watkins, W.A.,Moore, K.E., Sigurjónsson, J., Wartzok, D. and di Sciara, G.N. 1984. Fin whale (*Balaenoptera physalus*) tracked by radio in the Irminger Sea. *Rit Fisk.* 8(1):1–14.

SC/40/Ba5

Studies on Growth Layers in Tympanic Bullae of Fin Whales (*Balaenoptera physalus*) caught off Iceland

Atli Konrádsson and Jóhann Sigurjónsson

Marine Research Institute, Programme for Whale Research, P.O. Box 1390, Skúlagata 4, 121 Reykjavík, Iceland.

ABSTRACT

The paper presents results of investigations on growth layers in acid etched sections of tympanic bulla in fin whales (*Balaenoptera physalus*) caught off west Iceland. The number of growth layers in the bulla is compared with the number of growth layers in earplugs and the number of corpora in both ovaries of sexually mature females. The readability (difference between two independent readings equal or less than 2) of bulla layers is 71%, similar for both sexes. There are on average fewer bulla layers than the corresponding earplug layers. In sexually mature fin whales, the growth layers in bulla seem to form at a slower rate than the layers in earplugs; this is less the case in immature animals. For the ageing of mature animals in this species earplug growth layers seem more appropriate while the use of bulla growth layers may be justifiable when ageing immature animals.

INTRODUCTION

Since Klevezal and Mitchell (1971) described the growth layers in tympanic bullae of fin (*Balaenoptera physalus*) and sei whales (*B. borealis*), no studies have been carried out to evaluate the rate of growth layer formation in the bone of these species. While Christensen (1981) considered the rate of growth layer formation in the bullae of northeast Atlantic minke whales (*B. acutorostrata*) to be annual, Sigurjónsson (1980; 1988), Larsen and Kapel (1983) and Sukhovskaya, Klevezal, Borisov, Koltsov and Lagerov (1984) reported some inconsistencies when comparing the rates of growth layer formation in earplugs and bullae in minke whales from other regions. Sigurjónsson (1988) further suggested that layer formation in the bulla may slow down or stop as the animal grows older.

This paper presents results from studies made on the validity of using growth layers in the bulla for the age determination of fin whales caught off Iceland, by comparing earplug age and corpora counts with bulla growth layers.

MATERIALS AND METHODS

A total of 135 tympanic bullae (from 76 females and 59 males) were sampled during the 1986 and 1987 seasons from fin whales caught off west Iceland. The bones were cut at the medial wall in 9mm transverse sections by a modified water-cooled machine saw. The sections were etched in 10% formic acid for 20 minutes as in Christensen (1981) after the method had been tested on a limited sample of bullae from earlier seasons by varying the etching time.

After the etching, the bullae were washed in water for several minutes and then dried and stored at room temperature. The growth layers were located and counted (Christensen, 1981; Sigurjónsson, 1988) through a binocular microscope with x25 and x40 magnification, and a polarizing filter. The layers in each bulla were counted twice (randomly selected) by the same reader (the senior author) with at least several weeks between the two readings. The counts were made in the narrow periosteal zone at the medial and ventral part of the bone, where the largest numbers of layers are to be found (Christensen, 1981; Sukhovskaya *et al.*, 1984; Sigurjónsson, 1988). Of the 135 bullae examined, 126 were readable in the two independent layer counts, while the remaining 9 bones gave only one or did not yield any estimate of age.

Growth layers in both earplugs from the same animals were counted (in random order) by two independent readers after they had been preserved in 10% neutral formalin, cut along the central axis and examined under water using a magnifying lens as described by Lockyer (1972). For 124 of the 126 animals, layer counts in pairs of earplugs were in acceptable agreement (±1 layer for ≤10 layers; ±2 layers for 11–20 layers; etc.). These were compared with the corresponding bulla counts.

Ovaries were sectioned (4–5mm) in the laboratory and corpora counted. The reproductive condition of the females was determined from the presence or absence of a foetus, by examination of the ovaries and by histological examination of the uterine mucosa (Lockyer and Smellie, 1985).

The reproductive status of the males was assessed from microscopical examination of samples taken from testes according to Mackintosh and Wheeler (1929); histological data were available for all males.

The regression methods used (Sokal and Rohlf, 1969) were Bartlett's three-group method for Model II regression (used when both variables are subject to error) and ANOVA regression Model I, which gives the correlation coefficient, r. The parameters regressed were bulla growth layer counts, earplug growth layer counts and, for sexually mature females, number of corpora present in both ovaries.

Table 1

Readability of growth layers in tympanic bullae from fin whales as expressed by difference (D) between two independent layer counts

	Number analysed	D=0	D≤1	D≤2	D>2	One or no estimate
Males						
Number	60	14	27	43	12	5
% of total		23.3	45.0	71.7	20.0	8.3
Females						
Number	75	21	41	53	18	4
% of total		28.0	54.7	70.7	24.0	5.3
Total						
Number	135	35	68	96	30	9
% of total		25.9	50.4	71.1	22.2	6.7

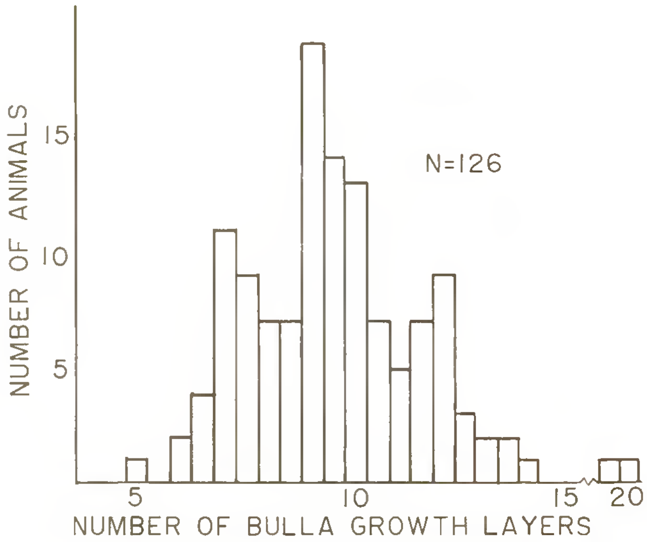


Fig. 1. Distribution of growth layer counts (average of two readings) from bullae.

RESULTS AND DISCUSSION

The difference between the two bulla counts for each animal was taken as the criterion for readability. Table 1 gives the readability of the sample. In 22.2% of the sample the difference was more than two layers while in 6.7% there was only one or no estimate; 71.1% of the sample had readings with differences of two layers or less ($D \leqslant 2$).

Fig. 1 shows the frequency distribution of the average of the two readings. The readings range between 5 and 19.5 layers with a median of 9.5 layers (SD=2.28).

The regression analysis of all successful bulla layer counts with (a) corpora numbers in both ovaries (if one or more corpora were present) and (b) earplug layer counts, are given in Table 2. The bulla layers are fewer on average than the earplug layers and the barely significant slopes of the regression lines indicate that the ratio bulla layers/ear plug layers, is disproportional with number of earplug layers. While there appears to be a strong correlation of the number of earplug growth layers against corpora number, the correlation is rather poor when earplugs are compared with bulla layers. The same applies when corpora numbers are compared with bulla layer counts.

Table 2

Comparison of age related parameters including all bulla readings; Bartlett's three group method for Model II and Model I (anova) regression, where $y=bx+a$. L1 and L2 are 95% confidence limits for b in Model II. ** = $P < 0.01$

			No. of	Model II				Model I		
	$\bar{x}$	$\bar{y}$	pairs	a	b	L1	L2	r	a	b
Earplug (x), Bulla (y)										
Males	13.31	9.52	55	8.25	0.10	0.19	0.00	0.368**	8.17	0.10
Females	14.53	9.56	69	7.41	0.15	0.26	0.05	0.214	8.62	0.06
All	13.99	9.54	124	7.68	0.13	0.20	0.07	0.261**	8.47	0.08
Corpora (x), Bulla (y)										
Females	5.71	9.89	55	9.47	0.07	0.25	-0.09	0.092	9.67	0.04
Earplug (x), Corpora (y)										
Females	16.14	5.71	55	-4.57	0.64	0.71	0.56	0.931**	-5.15	0.67

Table 3

Comparison of age related parameters – restricted criteria for bulla readings ($D \leq 2$); Bartlett's three group method for Model II and Model I (anova) regression, where $y=bx+a$. L1 and L2 are 95% confidence limits for b in Model II. ** = $P < 0.01$

			No. of	Model II				Model I		
	$\bar{x}$	$\bar{y}$	pairs	a	b	L1	L2	r	a	b
Earplug (x), Bulla (y)										
Males	12.74	9.41	43	8.58	0.07	0.18	-0.07	0.266	8.32	0.09
Females	14.87	9.60	52	8.01	0.11	0.23	0.00	0.181	8.82	0.05
All	13.91	9.51	95	7.86	0.12	0.21	0.04	0.205	8.67	0.02
Corpora (x), Bulla (y)										
Females	6.12	9.98	42	9.83	0.02	0.21	-0.15	0.04	9.88	0.02
Earplug (x), Corpora (y)										
Females	16.57	6.12	42	-4.62	0.65	0.57	0.72	0.932**	-5.12	0.68

Table 4

Comparison of age related parameters with respect to sexual maturity (only $D \leq 2$); Bartlett's three group method for Model II and Model I (anova) regression, where $y=bx+a$. L1 and L2 are 95% confidence limits for b in Model II. Parameters compared: earplug growth layers (×) with bulla growth layers (y). * = $P < 0.005$, ** = $P < 0.01$

			No. of	Model II				Model I		
	$\bar{x}$	$\bar{y}$	pairs	a	b	L1	L2	r	a	b
Matures										
Males	14.52	9.45	29	8.33	0.08	0.21	-0.04	0.239	8.41	0.07
Females	16.57	9.98	42	8.65	0.08	0.22	-0.04	0.069	9.66	0.02
All	15.73	9.76	71	8.51	0.08	0.18	-0.01	0.117	9.24	0.03
Immatures										
Males	9.07	9.32	14	3.42	0.65	1.29	0.11	0.644*	4.28	0.56
Females	7.70	8.00	10	2.23	0.75	1.71	-0.33	0.605	2.24	0.75
All	8.50	8.77	24	4.15	0.54	0.92	0.11	0.657**	3.24	0.65

In Table 3 the bullae with relatively poor readability ($D > 2$) are excluded from the analysis, but this does not improve the relationship between bulla and other age related parameters.

Figs 2 and 3 show the number of bulla growth layers as a function of earplug layer counts in mature and immature animals, respectively. Table 4 provides a separate analysis for sexually immature animals and sexually mature animals, respectively. The regression line for bulla counts on earplug counts is very different for the two categories of animals of both sexes. The slope for the sexually mature animals is not significantly different from zero. The slope is significantly different from zero for immature males (P>95%) but not for immature females. For immature animals the slope is highly significant for both sexes combined (P>99%). There seems to be a tendency for

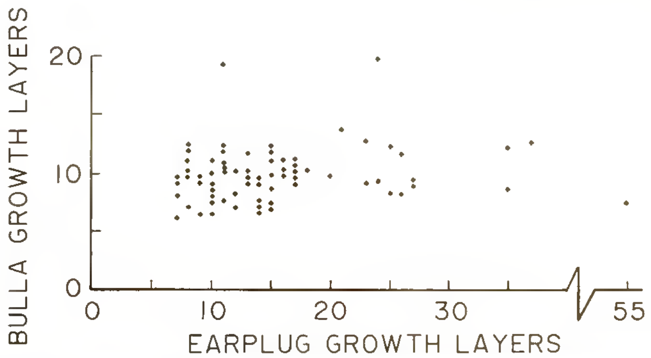


Fig. 2. Comparison of readings from bullae and earplugs for mature animals (n = 71, D ≤ 2).

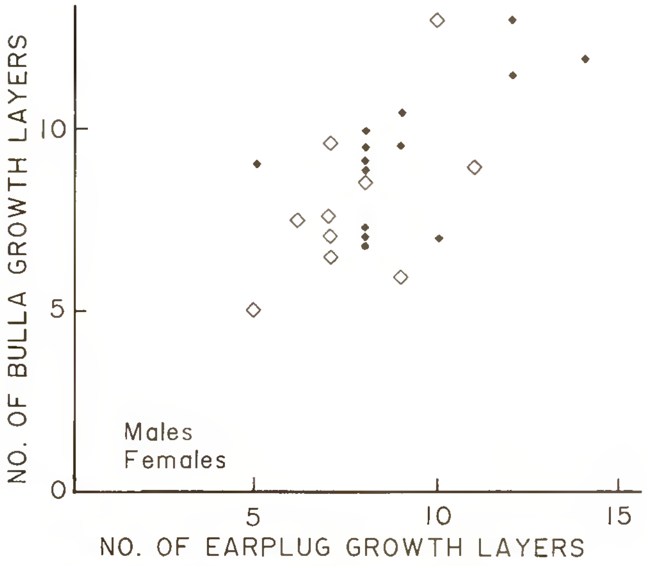


Fig. 3. Comparison of readings from bullae and earplugs for immature animals (n = 24, D ≤ 2).

larger number of layers in earplugs than in bulla, which is somewhat different from the good agreement between the two (up to 20 years) found in northeastern Atlantic minke whales (Christensen, 1981). Sukhovskaya *et al.* (1984) found consistently higher number of layers in haematoxylin-stained than acid-etched polished sections, while Christensen (1981) concluded that thin (30–50μ) prepared (unstained or stained) sections gave unsatisfactory results.

The results given here for fin whales off Iceland are similar to those reported for minke whales in Icelandic coastal waters (Sigurjónsson, 1988). In sexually mature fin whales, the growth layers in bullae seem to form at a slower rate than the layers in earplugs, while this is less so in immature animals. For the ageing of mature animals in this species, therefore, the use of earplug growth layers seems more appropriate. It may, however, be justifiable to use bulla layers for ageing immature animals when earplugs are not available or cannot be interpreted adequately. The method may also prove useful in species, such as minke whales, where readability is generally low or earplugs can simply not be obtained due to their fragility (e.g. Ivashin and Zinchenko, 1984; Sigurjónsson, 1988).

ACKNOWLEDGEMENTS

We would like to thank Ivar Christensen and Nils Øien of the Institute of Marine Research, Bergen, Christina Lockyer of Southwest Fisheries Center, La Jolla, and two anonymous reviewers for useful suggestions and critically reviewing the manuscript. Gísli Víkingsson, 'Arni Alfredsson and Eythór Thórdarson helped in collecting and preparing samples.

REFERENCES

Christensen, I. 1981. Age determination of minke whales, *Balaenoptera acutorostrata*, from laminated structures in tympanic bullae. *Rep. int. Whal. Commn* 31:245–53.

Ivashin, M.V. and Zinchenko, V.L. 1984. Processing of earplugs of the minke whale (*Balaenoptera acutorostrata bonaerensis* Burmeister, 1867). *Rep. int. Whal. Commn* 34:737 (abstract).

Klevezal, G.A. and Mitchell, E. 1971. On the annual layers in the bones of whalebone whales. *Zool. Zh.* 50: 1114–16

Larsen, F. and Kapel, F. 1983. Further biological studies of the West Greenland minke whale. *Rep. int. Whal. Commn* 33: 329–32.

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):276–294.

Lockyer, C. and Smellie, C.G. 1985. Assessment of reproductive status of female fin and sei whales taken off Iceland, from a histological examination of uterine mucosa. *Rep. int. Whal. Commn* 35: 343–8.

Mackintosh, N.A. and Wheeler, J.F.G. 1929. Southern blue and fin whales. *Discovery Rep.* 1: 259–539 (plus plates 25–54).

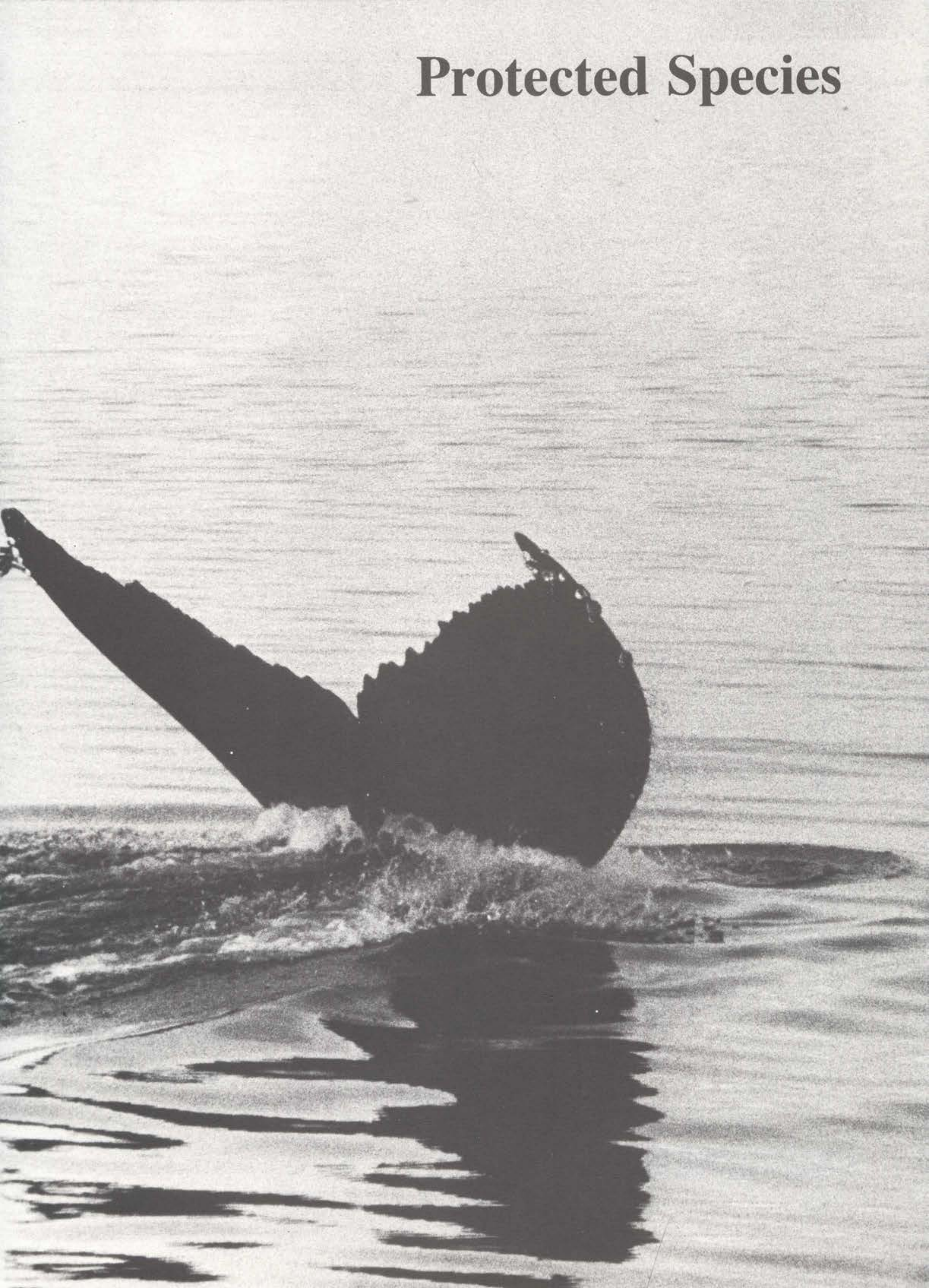
Sigurjónsson, J. 1980. Alderstudier over vagehval (*Balaenoptera acutorostrata* Lacepede) i islandske farvann. Thesis, University of Oslo, Norway, May 1980, 97 pp.

Sigurjónsson, J. 1988. Studies on age and reproduction in minke whale (*Balaenoptera acutorostrata*) in Icelandic waters. Paper SC/40/Mi22 presented to IWC Scientific Committee, May 1988 (unpublished), 33 pp.

Sokal, R.R. and Rohlf, F.J. 1969. *Biometry: The Principles and Practice of Statistics in Biological Research.* W.H.Freeman & Company, London, 776 pp.

Sukhovskaya, L.I., Klevezal, G.A., Borisov, V.I., Koltsov, N.K. and Lagerov, S.I. 1984. Use of bone layers for age determination of minke whales *Balaenoptera acutorostrata*. Paper SC/36/Mi6 presented to the IWC Scientific Committee, May 1984 (unpublished), 16 pp.

Protected Species



Humpback whale, southeast Alaska, summer 1984.
Photograph courtesy of Greg Donovan (IWC).

SC/40/PS2

Bowhead Whale (*Balaena mysticetus*) Spatial and Temporal Distribution in the Central Beaufort Sea During Late Summer and Early Fall 1979–86

Sue E. Moore and Janet T. Clarke
SEACO – A division of SAIC, 2845-D Nimitz Blvd., San Diego, CA 92106
Donald K. Ljungblad
Naval Ocean Systems Center, Code 514, San Diego, CA 92152

ABSTRACT

Bowhead whales were seen during aerial surveys in the eastern Alaskan and western Canadian Beaufort Sea from early August through mid-September 1979–86. Although the semi-monthly distribution and number of bowheads varied, whales were seen consistently along the coast near the US/Canadian border, and from 50 to 150km north and northeast of Barter Island, Alaska. The bowhead sighting rate (no. whales/survey hour) during the latter half of August (0.47) was less than half that calculated for the first half of August (1.17) or the first half of September (1.19), suggesting that the whales left the study area during the second half of August. Bowheads were primarily seen in water >200m deep in August (73%), with use of relatively shallow water (≤50m) habitat increasing from 21% during the latter half of August to 60% during the first half of September. Although mean swimming direction was northwest throughout August, headings were significantly clustered in that direction only during 1–15 September. Bowheads appear to alternate between swimming in a northwesterly direction and bouts of feeding, milling or resting throughout August and early September. Whales exhibiting feeding behaviour, 1980–86, were commonly seen in shallow (<20m) coastal water east of the US/Canadian border, with occasional sightings 3 to 60km offshore west of the border. Feeding whales were also seen north of Camden Bay (*ca.* 70°20′N, 144°30′W) in 1982 and 1984.

INTRODUCTION

The western Arctic population of bowhead whales (*Balaena mysticetus*), estimated to number 7,200 individuals (IWC, 1988), annually migrates around western and northern Alaska between wintering areas in the northern Bering Sea and summer feeding grounds in the Canadian Beaufort Sea (Braham, Fraker and Krogman, 1980). During these migrations, the whales pass through areas of the Alaskan outer continental shelf (OCS) that are planned for or currently undergoing exploration for oil and gas resources. The spring migration generally occurs along open-water lead systems in the pack ice that annually develop relatively close to shore (<10km) in the Chukchi Sea, but offshore (>50km) and well north of oil exploration activities in the Alaskan Beaufort Sea (Braham *et al.*, 1980; Ljungblad, Moore and Van Schoik, 1986c). In late summer and during the fall migration, however, bowheads commonly occur nearshore within or near oil lease areas in the Alaskan Beaufort Sea.

With the extension of planned industrial activities into OCS waters east of Prudhoe Bay, the importance of the eastern Alaskan Beaufort Sea to bowheads for feeding (Lowry and Frost, 1984; Ljungblad, Moore and Clarke, 1986a; Richardson, 1987), and as a potential staging area for the fall migration, has become a subject of concern for the Alaska Eskimo Whaling Commission, the Alaska Department of Fish and Game and the US Minerals Management Service (MMS). Aerial surveys for bowhead whales were conducted over this area, with some flights extending into Canadian waters, from August through October, 1979–86. Monthly distribution, abundance and behavioural data were summarised for the Alaskan Beaufort Sea study area (i.e. 140°-157°W, from shore to 72°N) for the 1979–83 database in Ljungblad *et al.* (1986c). These data were not specifically related to the portion of the Alaskan Beaufort Sea, east of 150°W longitude, where industrial activities have been most common (e.g. Johnson, Greene, Davis and Richardson, 1986; LGL and Greenridge, 1987). Noted in the earlier summary (Ljungblad *et al.*, 1986c) was a general lack of significant westerly movement on the part of bowheads prior to mid-September, indicating that whales seen in August and early September were not yet fully migratory. Thus, bowheads in the eastern Alaskan and western Canadian Beaufort Sea during August through mid-September may be whales that remain in the vicinity of OCS industrial activities and are the subject of the data analyses presented herein.

METHODS AND MATERIALS

Study area and aerial surveys

The Alaskan Beaufort Sea east of 150°W longitude represents a portion of a larger study area that included the northern Bering and eastern Chukchi Seas and the Beaufort Sea between 157°W and 140°W offshore to 72°N (Ljungblad *et al.*, 1986c). This area was divided into blocks for line transect surveys, with the eastern Alaskan Beaufort Sea comprising blocks 1, 2 and 4–10 (Fig. 1). Surveys in the Canadian Beaufort were generally confined to waters between the US/Canadian border and Mackenzie Bay (136°W). From 1979–81, survey effort was primarily in blocks 1–5. From 1982–86, coverage of blocks 6–10 and flights into Canadian waters were added.

Two types of aerial surveys were conducted. Random line transect surveys were flown in the survey blocks, and search surveys were flown along the coast while transiting to offshore survey blocks or along identifiable boundaries such as ice edges (Ljungblad *et al.*, 1986c). The primary survey aircraft, a *Grumman Turbo Goose G21G*, was dedicated to line transect coverage of the survey blocks. Additional aircraft (*Grumman Goose G21C*, and/or *de*

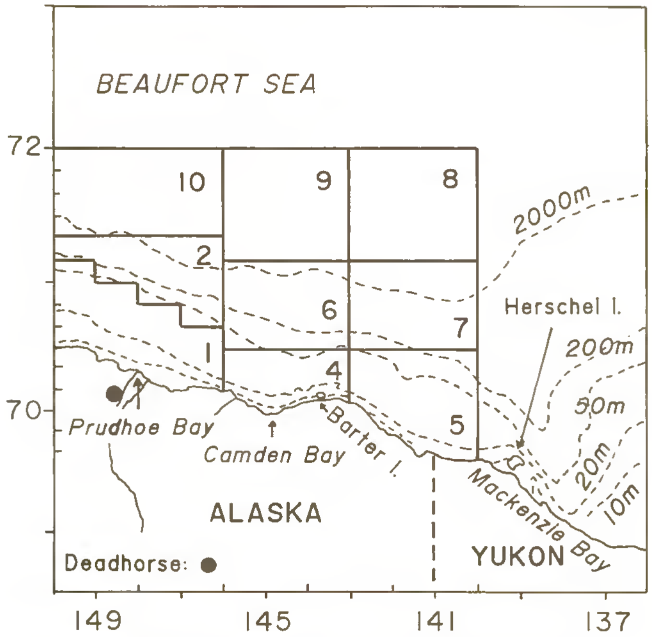


Fig. 1. Survey blocks and bathymetric contours within the study area. Dashed line (---) depicts US/Canadian Border.

Havilland Twin Otters) were used from 1982 through 1984 to study the interactions between bowhead whales and geophysical vessels in the Alaskan Beaufort Sea (Reeves, Ljungblad and Clarke, 1983; Ljungblad, Würsig, Reeves, Clarke and Greene, 1984; Ljungblad, Würsig, Swartz and Keene, 1988), and from 1985 to 1986 to monitor the status of the bowhead migration (Ljungblad, Moore, Clarke and Bennett, 1986b, 1987). Surveys were flown at 152 to 458m altitude, at speeds of 222 to 296km/hr. The higher altitudes were maintained, when weather permitted, to maximise visibility and reduce the likelihood of aircraft disturbance to whales. Each aircraft was equipped with a *Global Navigation System 500* that provided a continuous read out of position (0.6km/survey hour precision) and was programmable for transect turning points.

Table 1

Semi-monthly summary of survey effort (Hours), bowhead whale sightings (SI), total number of whales (BH) and sighting rate (WPUE = BH/Hours) east of 150°W longitude

	1-15 August				16-31 August			
Year	Hours	SI	BH	WPUE	Hours	SI	BH	WPUE
1979	10.7*	0	0	-	29.2*	4	7	0.24
1980	6.3*	0	0	-	6.6*	0	0	-
1981	4.4*	0	0	-	13.2*	1	2	0.15
1982	40.6	57	108	2.66	45.4	22	37	0.81
1983	26.3	25	49	1.86	72.1	8	11	0.15
1984	35.2	2	3	0.09	61.9	34	57	0.92
1985	29.5	8	9	0.31	37.5	3	3	0.08
1986	2.1*	6	12	5.71	44.6	15	29	0.65
Total	155.1	98	181	1.17	310.5	87	146	0.47

	1-15 September				16-31 September			
Year	Hours	SI	BH	WPUE	Hours	SI	BH	WPUE
1979	17.1	2	2	0.12	57.0	6	9	0.16
1980	27.7	9	12	0.43	40.6	9	12	0.29
1981	30.0	47	63	2.10	47.6	48	65	1.37
1982	46.3	49	116	2.51	132.3	128	261	1.97
1983	108.1	34	46	0.43	206.5	67	106	0.51
1984	45.6	30	64	1.40	142.7	66	124	0.87
1985	34.9	16	87	2.49	101.9	27	99	0.97
1986	53.1	23	40	0.75	99.8	44	81	0.81
Total	362.8	210	430	1.19	828.4	395	757	0.91

* = surveys not conducted over entire period.

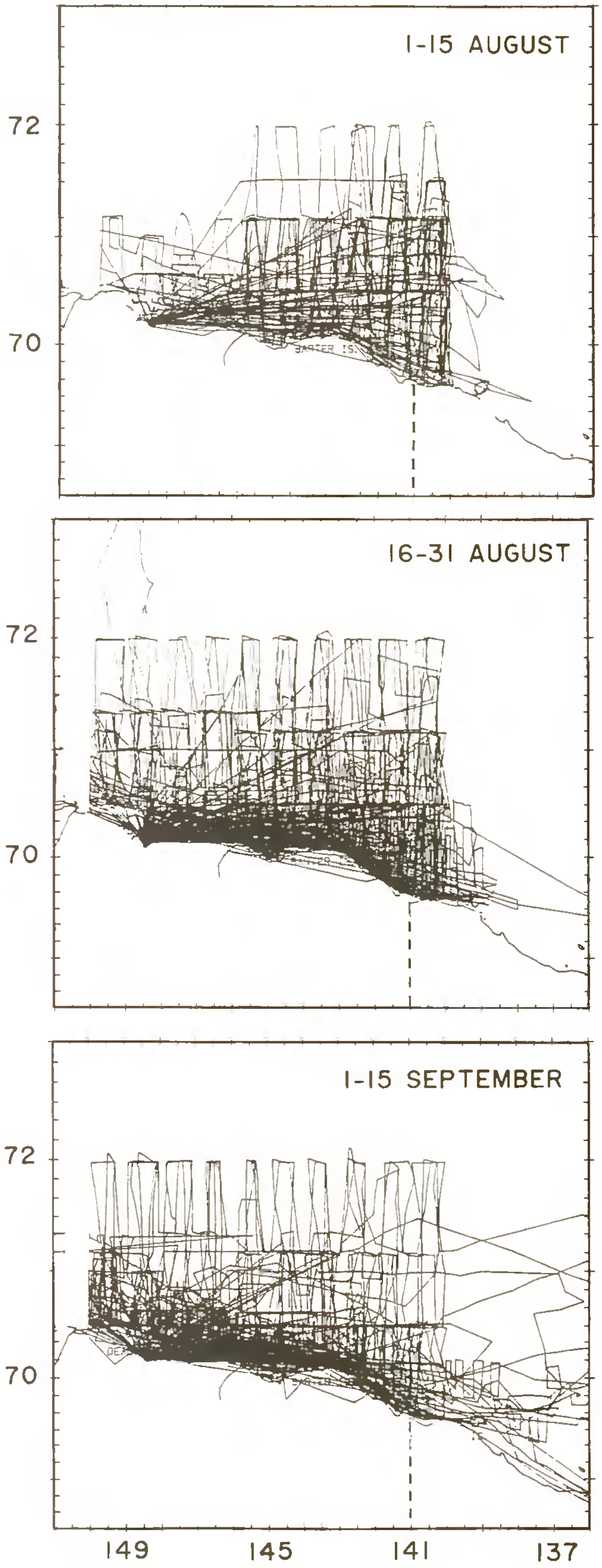


Fig. 2. Composite flight tracks depicting survey effort for 1–15 August (155.1hrs), 16–31 August (310.5hrs), and 1–15 September (362.8h), 1979–86. Dashed line (--) depicts US/Canadian Border.

Data collection and analyses

Data routinely logged on a microcomputer at the time of sighting included aircraft altitude, Greenwich Mean Time (GMT), latitude and longitude, random transect or search

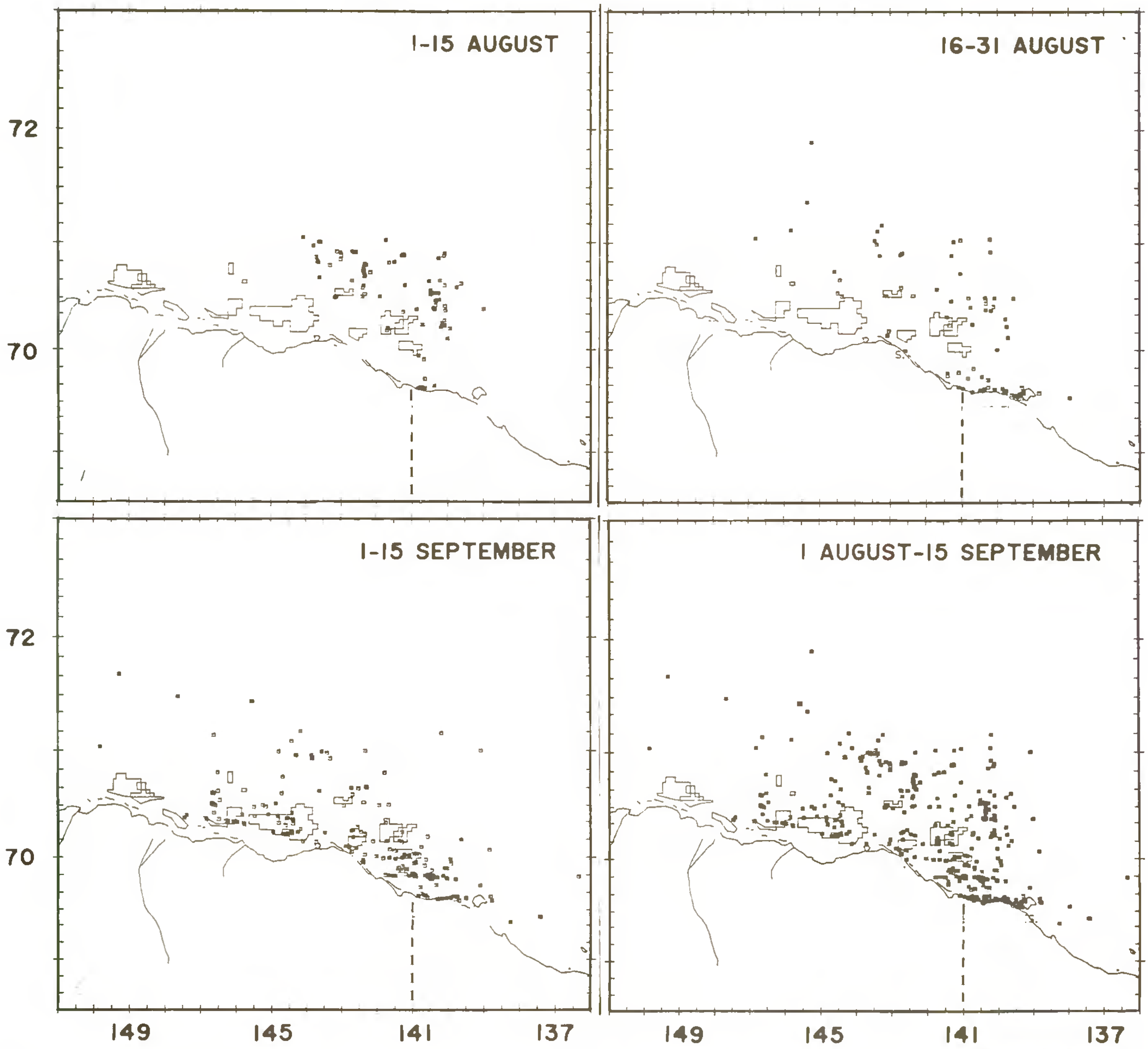


Fig. 3. Distribution of 98 sightings of 181 whales, 1–15 August; 87 sightings of 146 whales 16–31 August; 210 sightings of 430 whales, 1–15 September; and 395 sightings of 757 whales 1 August-15 September, 1979–86. Polygons depict Alaskan OCS oil and gas lease areas. Dashed line (---) depicts US/Canadian Border.

survey sighting, percent ice cover, sea state, visibility range (estimated), species, number of whales, initial swim direction and behaviour. Behaviour classifications included swimming, diving, resting, milling, display, cow-calf association and feeding (inferred based on criteria described in Ljungblad *et al.*, 1986a). Displays included flipper and tail slaps, breaches and underwater blows. Whale behaviours were recorded in a different manner during behavioural response experiments (Ljungblad *et al.*, 1988) and were omitted from this analysis.

Bowhead distribution east of 150°W was plotted relative to planned Alaskan OCS oil and gas lease areas in three half-month periods, and for the entire period from 1 August – 15 September. Annual and overall sighting rates (WPUE=no. whales/survey hour) were calculated for the same periods for the survey blocks and Canadian waters. Swimming direction was analysed using descriptive statistics for circular distributions as presented in Zar (1984), where 'a' represents the mean vector direction and 'r' is the mean length of the vector. Because whales that are milling, feeding or resting often change headings several times while at the surface, swimming direction for whales exhibiting those behaviours were omitted from the analysis. Sighting data from both random transect and search surveys were used in distribution, sighting rate and swimming direction analyses, and the tabulation of observed behaviour. In contrast, only random transect sightings were used for bathymetric analysis to avoid bias introduced by search surveys conducted solely over shallow-water habitat. Bathymetric habitat association was indexed as percentage of random bowhead sightings per depth class (0–10m, 11–20m, 21–50m, 51–200m, 200–2,000m and >2,000m; Fig. 1).

RESULTS

Survey effort

A total of 828.4hrs of surveys were flown east of 150°W, with 155.1hrs (19%) of this effort from 1–15 August, 310.5hrs (37%) from 16–31 August and 362.8hrs (44%) from 1–15 September (Table 1, Fig. 2). Line transect surveys were routinely conducted in the Alaskan Beaufort

Table 2

Semi-monthly summary of survey effort (Hours), number of bowhead whales (BH) and sighting rate (WPUE = BH/Hours) for survey blocks in the eastern Alaskan Beaufort Sea. Y/B = Year/Block, C = Canada

	1-15 August			16–31 August			1-15 September			Total		
Y/B	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE	Hours	BH	WPUE
1979												
1	7.33	0	–	13.35	0	–	11.30	0	–	31.98	0	–
2	0	–	–	2.15	0	–	0	–	–	2.15	0	–
4	2.47	0	–	9.16	0	–	3.10	0	–	14.73	0	–
5	0	–	–	0	–	–	0	–	–	0	–	–
6	0.90	0	–	4.23	7	1.65	2.70	2	0.74	7.83	9	1.15
7	0	–	–	0	–	–	0	–	–	0	–	–
8	0	–	–	0	–	–	0	–	–	0	–	–
9	0	–	–	0	–	–	0	–	–	0	–	–
10	0	–	–	0.36	0	–	0	–	–	0.36	0	–
1980												
1	3.47	0	–	4.00	0	–	10.46	3	0.29	17.93	3	0.17
2	0.31	0	–	0.05	0	–	0.09	0	–	0.45	0	–
4	0.99	0	–	0.90	0	–	3.41	0	–	5.30	0	–
5	1.54	0	–	1.01	0	–	6.08	8	1.32	8.63	8	0.93
6	0	–	–	0	–	–	0	–	–	0	–	–
7	0	–	–	0	–	–	0	–	–	0	–	–
8	0	–	–	0	–	–	0	–	–	0	–	–
9	0	–	–	0	–	–	0	–	–	0	–	–
10	0	–	–	0	–	–	0	–	–	0	–	–
C	0.02	0	–	0.64	0	–	7.77	1	0.13	8.43	1	0.12
1981												
1	0.83	0	–	5.93	0	–	9.63	0	–	16.39	0	–
2	0	–	–	0.26	0	–	0.29	0	–	0.55	0	–
4	1.70	0	–	2.49	0	–	5.08	0	–	9.27	0	–
5	0.88	0	–	1.06	0	–	8.87	62	6.99	10.81	62	5.74
6	0	–	–	0	–	–	1.45	0	–	1.45	0	–
7	0	–	–	0.55	0	–	0.57	0	–	1.12	0	–
8	0	–	–	0	–	–	1.30	0	–	1.30	0	–
9	0	–	–	0	–	–	0.12	0	–	0.12	0	–
10	0	–	–	0.53	0	–	0	–	–	0.53	0	–
C	1.00	0	–	2.24	2	0.89	2.64	1	0.38	5.88	3	0.51
1982												
1	3.12	0	–	7.25	0	–	8.30	19	2.29	18.67	19	1.02
2	0.79	0	–	2.91	0	–	1.52	0	–	5.22	0	–
4	7.19	0	–	7.07	0	–	13.00	50	3.85	27.26	50	1.83
5	7.21	6	0.83	11.93	10	0.84	10.75	31	2.88	29.89	47	1.57
6	8.77	37	4.22	6.42	6	0.93	3.98	0	–	19.17	43	2.24
7	8.19	62	7.57	4.18	13	3.11	3.68	0	–	16.05	75	4.67
8	4.86	0	–	0.04	0	–	1.55	0	–	6.45	0	–
9	0.31	0	–	3.42	2	0.58	3.11	4	1.29	6.84	6	0.88
10	0	–	–	0.54	0	–	0	–	–	0.54	0	–
C	0.16	3	18.75	1.64	6	3.66	0.36	12	33.33	2.16	21	9.72
1979–86												
1	24.95	0	–	61.34	0	–	93.44	31	0.33	179.73	31	0.17
2	1.84	0	–	11.41	1	0.09	12.49	4	0.32	25.74	5	0.19
4	29.99	0	–	64.70	2	0.03	75.25	83	1.10	169.94	85	0.49
5	34.73	65	1.87	74.00	48	0.65	71.29	223	3.13	180.02	336	1.87
6	20.37	37	1.82	30.13	14	0.46	27.19	19	0.70	77.69	70	0.90
7	27.93	71	2.54	23.53	23	0.98	20.53	13	0.63	71.99	107	1.49
8	8.68	0	–	10.44	0	–	12.49	0	–	31.61	0	–
9	3.01	0	–	10.75	2	0.19	6.92	5	0.72	20.68	7	0.34
10	0	0	–	6.87	0	–	7.21	2	0.28	14.08	2	0.14
C	3.61	8	2.22	17.30	56	3.24	35.73	50	1.40	56.64	114	2.01
1983												
1	2.37	0	–	10.43	0	–	21.33	0	–	34.03	0	–
2	0.23	0	–	2.68	1	0.37	5.12	1	0.20	8.03	2	0.25
4	2.36	0	–	12.29	0	–	18.77	1	0.05	33.42	1	0.03
5	6.54	38	5.81	20.31	0	–	12.18	3	0.25	39.03	41	1.05
6	3.00	0	–	4.26	0	–	9.12	17	1.86	16.38	17	1.04
7	6.93	8	1.15	8.27	10	1.21	6.34	12	1.89	21.54	30	1.39
8	1.73	0	–	3.19	0	–	3.34	0	–	8.26	0	–
9	2.29	0	–	2.16	0	–	2.66	1	0.38	7.11	1	0.14
10	0	–	–	5.22	0	–	7.04	2	0.28	12.26	2	0.16
C	0.82	3	3.66	3.26	0	–	22.29	9	0.40	26.37	12	0.46
1984												
1	3.12	0	–	11.41	0	–	14.13	2	0.14	28.66	2	0.07
2	0.50	0	–	1.70	0	–	1.28	3	2.34	3.48	3	0.86
4	7.45	0	–	11.93	2	0.17	13.24	32	2.42	32.62	34	1.04
5	9.41	1	0.11	18.03	28	1.55	8.87	27	3.04	36.31	56	1.54
6	4.74	0	–	3.80	0	–	2.74	0	–	11.28	0	–
7	7.56	0	–	2.62	0	–	1.57	0	–	11.75	0	–
8	1.12	0	–	1.87	0	–	1.50	0	–	4.49	0	–
9	0.40	0	–	2.52	0	–	0.79	0	–	3.71	0	–
10	0	–	–	0.06	0	–	0.10	0	–	0.16	0	–
C	0.91	2	2.20	7.96	27	3.39	1.40	0	–	10.27	29	2.82
1985												
1	4.41	0	–	6.25	0	–	7.43	6	0.81	18.09	6	0.33
2	0.01	0	–	1.66	0	–	1.42	0	–	3.09	0	–
4	7.22	0	–	9.53	0	–	8.25	0	–	25.00	0	–
5	7.96	8	1.01	9.56	3	0.31	11.95	67	5.61	29.47	78	2.65
6	2.96	0	–	4.59	0	–	0.93	0	–	8.48	0	–
7	5.25	1	0.19	3.45	0	–	2.06	0	–	10.76	1	0.09
8	0.97	0	–	2.03	0	–	2.29	0	–	5.29	0	–
9	0.01	0	–	0.07	0	–	0	–	–	0.08	0	–
10	0	–	–	0.16	0	–	0.06	0	–	0.22	0	–
C	0.68	0	–	0.23	0	–	0.52	14	26.92	1.43	14	9.79
1986												
1	0.30	0	–	2.72	0	–	10.96	1	0.09	13.98	1	0.07
2	0	0	–	0	–	–	2.77	0	–	2.77	0	–
4	0.61	0	–	11.29	0	–	10.40	0	–	22.30	0	–
5	1.19	12	10.08	12.10	7	0.58	12.59	25	1.99	25.88	44	1.70
6	0	–	–	6.83	1	0.15	6.57	0	–	13.40	1	0.07
7	0	–	–	4.46	0	–	6.31	1	0.16	10.77	1	0.09
8	0	–	–	3.31	0	–	2.51	0	–	5.82	0	–
9	0	–	–	2.58	0	–	0.24	0	–	2.82	0	–
10	0	–	–	0	–	–	0.01	0	–	0.01	0	–
C	0.02	–	–	1.33	21	15.79	0.75	13	17.33	2.10	34	16.19

Sea, while coastal search surveys were most common in Canadian waters, with some systematic search grids flown around working geophysical boats in 1983. Most of the survey effort (683.2hrs, 82%) was conducted in 1982–86 when surveys were routinely flown in August (see *, Table 1). Annual survey effort was greatest in 1983 (206.5hrs, 25%) and least in 1980 (40.6hrs, 5%).

Distribution and sighting rate

Ninety-eight sightings of 181 bowheads were made during the first half of August (Table 1, Fig. 3). They were seen along the coast at the US/Canadian border (141°W), and from approximately 30–120km offshore between 139°W and 144°W. Eighty-seven sightings of 146 whales were made during the latter half of August, mainly along the coast from Herschel Island to the US border, with a few sightings near the barrier islands east of Barter Island; whales were also seen up to 170km offshore between 139°30′W and 147°W. A total of 210 sightings of 430 whales were made during the first half of September, mainly along the coast from Herschel to Barter Island, with a relatively nearshore distribution continuing west across outer Camden Bay to waters just northeast of Deadhorse. They were also seen up to 140km from shore between 139°W and 150°W, with scattered sightings east of 139°W. The overall distribution of bowheads from 1 August – 15 September (395 sightings of 757 whales) overlapped OCS lease areas in the Alaskan Beaufort Sea (Fig. 3). Whales were seen in and near lease areas north and east of Barter Island during the entire period, but were seen near areas west of Barter Island primarily from 1–15 September.

The annual bowhead sighting rate for the entire study area was highest in 1982 (WPUE=1.97) and lowest in 1979 (WPUE=0.16), with an overall index of 0.91 whales/survey hour (Table 1). Sighting rate was comparatively low in 1979 (WPUE=0.16), 1980 (WPUE=0.29) and 1983 (WPUE=0.51). Notably, survey effort in 1979–80 was less extensive than in latter years, and whales north of blocks 1-5 would have been missed. In addition, 1980 and 1983 were years of heavier–than-normal ice cover, which may have affected observers' ability to see surfaced whales. Annual sighting rates were similar in 1984–86 when survey coverage and ice conditions were also similar.

Cumulative semi-monthly sighting rate was higher during the first half of August (WPUE=1.17), and the first half of September (WPUE=1.19), than during the latter half of August (WPUE=0.47; Table 1). This pattern was true of each year for which early August data were available (1982–86), except for 1984 when the sighting rate steadily increased over the course of the season. In 1982, 1983 and 1986, WPUE from 1–15 August was 3–12 times that calculated for 16–31 August. In 1983 and 1986, WPUE remained 4–8 times lower than 1–15 August values through mid-September.

Table 3

Number and percent (%) of random bowhead sightings in each depth category depicted in Fig. 1B. Depth calculated in meters for bowheads seen on random transect survey in the eastern Alaskan and western Canadian Beaufort Sea, 1982–86

	1-15 August		16–31 August		1-15 September		Total	
Year	No.	%	No.	%	No.	%	No.	%
1982								
0–10	0		0		0		0	
11–20	0		0		0		0	
21–50	0		2	11	9	70	11	19
51–200	3	12	2	11	2	15	7	12
201–2,000	23	88	11	57	0		34	59
≥ 2,000		0	4	21	2	15	6	10
1983								
0–10	0		0		0		0	
11–20	0		0		0		0	
21–50	1	9	0		1	10	2	7
51–200	1	9	1	17	0		2	7
201–2,000	6	55	1	17	5	45	12	43
≥ 2,000	3	27	4	66	5	45	12	43
1984								
0–10	0		1	17	0		1	9
11–20	0		1	17	1	20	2	18
21–50	0		2	33	3	60	5	46
51–200	0		2	33	1	20	3	27
201–2,000	0		0		0		0	
≥ 2,000	0		0		0		0	
1985								
0–10	0		0		0		0	
11–20	0		1	50	0		1	8
21–50	3	43	1	50	3	100	7	59
51–200	0		0		0		0	
201–2,000	4	57	0		0		4	33
≥ 2,000	0		0		0		0	
1986								
0–10	0		0		0		0	
11–20	0		0		0		0	
21–50	1	50	0		7	88	7	54
51–200	1	50	0		1	12	1	8
201–2,000	0		5	100	0		5	38
≥ 2,000	0		0		0		0	
1982–86								
1–10	0		1	3	0		1	1
11–20	0		2	5	1	2	3	2
21–50	5	11	5	13	23	58	33	27
51–200	5	11	5	13	4	10	14	11
201–2,000	33	72	17	45	5	12	55	44
≥ 2,000	3	6	8	21	7	18	18	15

Cumulative survey block sighting rate during the 1–15 August period was highest in block 7 (WPUE=2.54), followed by Canadian waters (WPUE=2.22), and blocks 5 (WPUE=1.87) and 6 (WPUE=1.82; Table 2). Sighting rate during the first half of August was particularly high in block 7 (WPUE=7.57) and block 6 (WPUE=4.22) in 1982, and in block 5 in 1983 (WPUE=5.81) and 1986 (WPUE=10.08). During the 16–31 August period, cumulative sighting rate was highest in Canadian waters (WPUE=3.24), while sighting rate was only 0.46–0.98 for survey blocks 5–7, and even lower for blocks 9 (WPUE=0.19), 2 (WPUE=0.09) and 4 (WPUE=0.03). The highest single-year sighting rate for this time period was in block 7 (WPUE=3.11) in 1982. During 1–15 September, bowheads were seen in all areas surveyed, except block 8. Highest sighting rates were calculated for block 5 (WPUE=3.13), Canadian waters (WPUE=1.40) and block 4 (WPUE=1.10). Annual sighting rate for early September was particularly high in block 5 in 1981 (WPUE=6.99) and 1985 (WPUE=5.61). Cumulative sighting rate for the 1 August to 15 September period was highest in Canadian waters (WPUE=2.01), and survey block 5 (WPUE=1.87), block 7 (WPUE=1.49) and block 6 (WPUE=0.90).

Inferences about annual variation in bowhead distribution can be drawn from comparisons of survey block sighting rates (Table 2). For example, whales were seen further north and west in August 1982 (blocks 6 and 7) than for any other year when this period was fully sampled (i.e. 1983–85). In 5 of 8 years, sighting rates were highest in block 5 during the first half of September. During this period in 1982, sighting rate was highest in block 4; in 1979, bowheads were seen only in block 6; and in 1983, sighting rates were relatively high in blocks 6 and 7, corresponding to the offshore shift in migratory route described for that year (Moore, Bennett and Ljungblad, 1988).

Bathymetric habitat and behaviour

Water depths from shore to greater than 2,000m were routinely sampled during random transect surveys from 1982–86. Bowheads seen on random transects were primarily in water deeper than 200m (78%, n=36) during 1–15 August, with 11% (n=5) in water 51–200m deep and 11% (n=5) in water 21–50m deep (Table 3, Fig. 4). The proportion of sightings in relatively shallow water (≤50m) increased to 21% (n=8) during 16–31 August and to 60% (n=24) during 1–15 September. Over the entire period, the proportion of random sightings was highest in water 201–2,000m deep (44%, n=55), or 21–50m deep (27%, n=33).

Annual variation in depth at sighting locations reflected some of the afore-mentioned differences in bowhead distribution and sighting rates. For example, the northwest distribution of whales and high WPUE in blocks 6 and 7 in August 1982 resulted in the high proportion (88%, n=23) of sightings in water 201–2,000m deep (Table 3). Conversely, most sightings (60% to 100%) during 1–15 September were in waters 21–50m deep, except in 1983 when the bowhead sighting rate remained high in blocks 6 and 7 corresponding to the 90% (n=10) of all random sightings in water >200m deep (Table 3) and to the offshore distribution along the migratory route that year (Moore *et al.*, 1988).

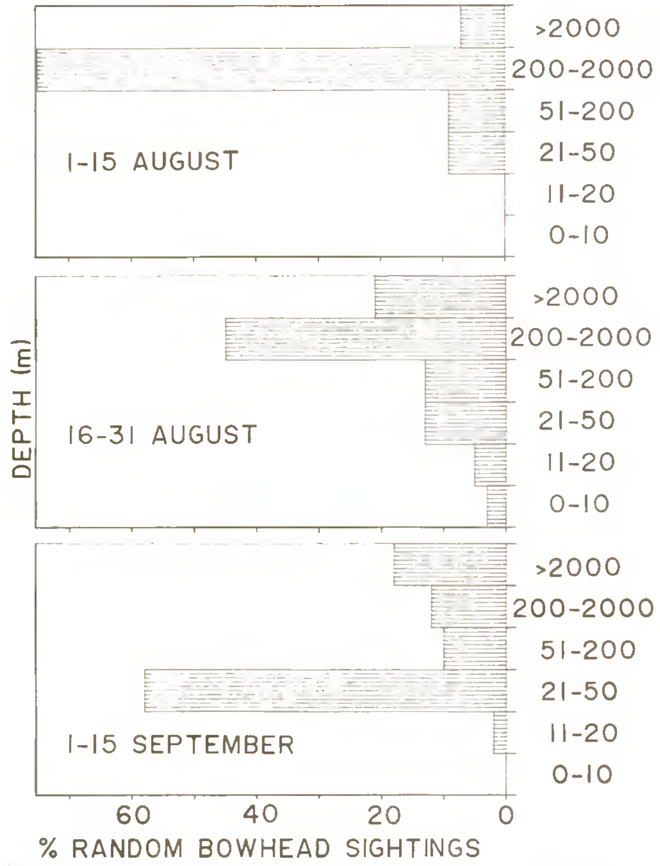


Fig. 4. Index of bowhead whale semi-monthly bathymetric habitat preference, August through mid-September 1982–86.

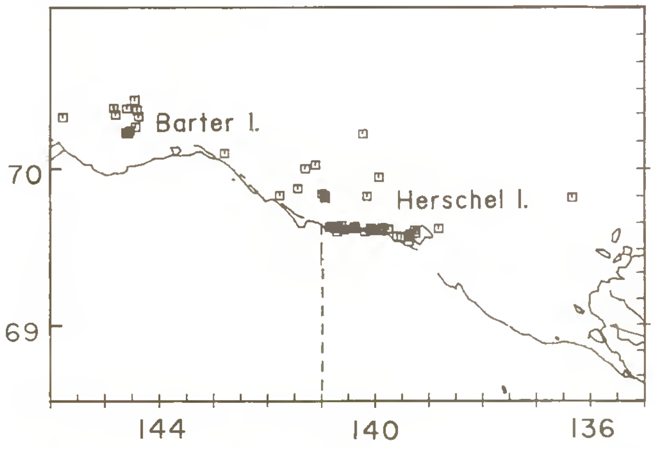


Fig. 5. Distribution of 53 sightings of 193 feeding bowhead whales, 1 August to 15 September, 1980–86. Dashed line (---) depicts US/Canadian Border.

Table 4

Number and annual percent (%) of bowheads east of 150°W in each behavior category, 1979–86

	1–15 August		16–31 August		1–15 September		Total	
Year	No.	%	No.	%	No.	%	No.	%
Swim								
1979	0		1	14	1	50	2	23
1980	0		0		7	70	7	70
1981	0		2	100	40	67	42	68
1982	64	59	4	11	11	10	79	31
1983	32	65	8	73	12	29	52	51
1984	2	66	34	64	32	52	68	58
1985	5	55	3	100	3	3	11	11
1986	1	8	5	17	24	60	30	37
Dive								
1979	0		6	86	1	50	7	78
1981	0		0		6	10	6	10
1982	5	5	5	14	10	9	20	8
1983	1	2	0		5	12	6	6
1984	0		1	2	5	8	6	5
1986	0		2	7	3	8	5	6
Rest								
1981	0		0		6	10	6	10
1982	18	17	5	14	19	17	42	16
1983	8	16	0		5	12	13	13
1984	1	33	2	4	1	2	4	3
1985	1	11	0		2	2	3	3
1986	2	17	1	3	0		3	4
Feed								
1980	0		0		3	30	3	30
1981	0		0		8	13	8	13
1982	0		0		41	36	41	16
1983	2	4	0		5	12	7	7
1984	0		15	28	13	21	28	24
1985	0		0		70	80	70	71
1986	8	67	18	62	10	25	36	44
Mill								
1982	11	10	10	27	8	7	29	11
1984	0		0		4	7	4	3
1985	0		0		8	9	8	8
1986	0		1	3	1	2	2	2
Display								
1982	0		2	5	8	7	10	4
1983	3	6	1	9	5	12	9	9
1984	0		1	2	0		1	1
1985	2	22	0		0		2	2
1986	0		0		2	5	2	2
Cow-calf								
1982	10	9	11	30	16	14	37	14
1983	3	6	2	18	9	22	14	14
1984	0		0		6	10	6	5
1985	1	11	0		4	5	5	5
1986	1	8	2	7	0		3	4
Total								
1979	0		7		2		9	
1980	0		0		10		10	
1981	0		2		60		62	
1982	108		37		113		258	
1983	49		11		41		101	
1984	3		53		61		117	
1985	9		3		87		99	
1986	12		29		40		81	

Observed behaviours varied annually (Table 4). Swimming was the most common behaviour recorded, except during periods when feeding and milling behaviours were proportionally higher. For example, between 1982–86 swimming was the predominant behaviour during the 1–15 August period, except in 1986 when 67% (n=8) of the whales seen were feeding nearshore in block 5 resulting in the high WPUE there (see Table 2). From 16–31 August 1986, whales continued to feed nearshore (62%, n=18), but most had shifted to coastal Canadian waters with feeding dropping to 25% (n=10) by 1–15 September. The semi-monthly proportion of milling or feeding whales was also relatively high from 16–31 August 1984 and from 1–15 September 1982 and 1985, corresponding to relatively low indices of swimming whales (Table 4). Feeding whales were common along the coast from Herschel Island to roughly 141°W, with fewer sightings from about 3–60km offshore between 140°W and 143°W (Fig. 5). Feeding whales were also seen north of Camden Bay in 1982 and 1984 (Fig. 5). This distribution is similar to that reported for feeding whales over the entire fall season (Ljungblad *et al.*, 1986a).

Semi-monthly swimming direction for whales not feeding, milling or resting was northwest (315°T) from 1–15 August and more westerly (264°T) from 16–31 August, but was significantly clustered about a mean vector only during

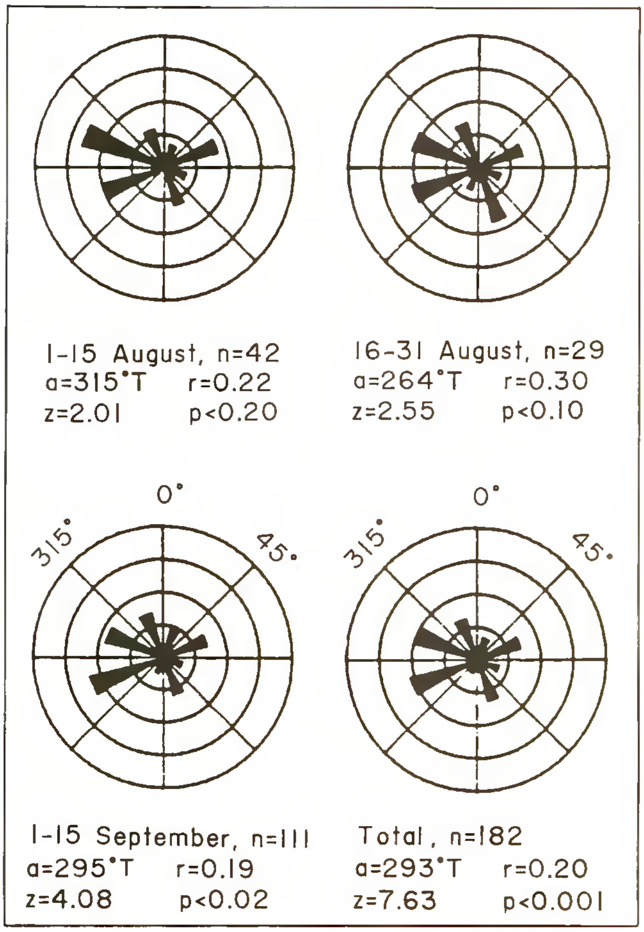


Fig. 6. Semi-monthly bowhead swimming directions in the eastern Alaskan and western Canadian Beaufort seas (i.e. longitudes 150°W-136°W), 1979–86.

1–15 September (ā=295°T, r=0.19, z=4.08, p<0.02) for combined 1979–86 data (Fig. 6). When annual swimming direction was tested for the 1–15 September period, headings were significantly clustered only in 1983 (ā=282°T, r=0.52, z=5.51, p<0.005) and 1984 (ā=311°T, r=0.57, z=6.72, p<0.001). Swimming direction was significantly clustered from 1–15 August 1982 (ā=315°T, r=0.36, z=4.24, p<0.02) when milling and resting whales were added to the sample (see Ljungblad, 1986c), but this was the only instance for this. Swimming direction was significantly clustered about 293°T (r=0.20, z=7.63, p<0.001) for the combined 1 August to 15 September period (Fig. 6).

DISCUSSION

Although bowhead distribution, sighting rate, bathymetric associations and behaviour varied annually, several trends can be identified. First, bowhead sighting rates were relatively high from 1–15 August, dropping during 16–31 August and were relatively high again from 1–15 September. This indicates that some whales leave the western Canadian and eastern Alaskan Beaufort Sea in late August, possibly to either begin their westward migration, or to return to feeding areas elsewhere in Canadian waters. Secondly, bowheads were primarily found relatively far offshore over continental slope waters (>200m) in August, with a shift towards continental shelf waters (≤50m) in late August through mid-September. Feeding bowheads were seen in shallow (<20m) coastal waters between 139°W and 141°W, or from 3–60km offshore between 140°W and 143°W, each year from 1980–86, and north of Camden Bay in 1982 and 1984. Lastly, bowheads were seen in and near OCS lease areas north and northeast of Barter Island, Alaska, from August through mid-September, and in OCS areas northeast and west of Barter Island from 1–15 September.

The distribution, sighting rate and bathymetric data summarised here complement and expand upon those of previous reports. The annual distribution of bowheads from August through 10 September 1980–84 in the Canadian Beaufort Sea (126°W to 141°W) was described in Richardson, Davis, Evans, Ljungblad and Norton (1987). In general, their distribution plots complement those presented here and allow an expanded review of semi-monthly bowhead distribution for years in which the two studies overlapped. For example, although bowhead distribution in the Canadian Beaufort Sea differed markedly between years, areas of peak whale concentration were generally closer to shore in mid– to late August than in early August when whales were seen relatively far offshore. This shift towards shore was most dramatic for years 1981–84, and corresponds to the onshore shift reported here for late August and early September. Further, bowhead distribution in early to mid-September varied less than in August, with most whales found over the continental shelf. Richardson *et al.* (1987) noted that whales were seen as far east as 126°W in early to mid-September in all years (1981, 1983, 1984) that surveys were conducted there.

As suggested in Richardson *et al.* (1987), it is likely that zooplankton prey availability strongly influences bowhead distribution and abundance. Bowheads feeding in the Alaskan Beaufort and northeastern Chukchi Seas in fall 1979–84 were seen in significantly larger groups, shallower water and in lighter ice cover than non-feeding whales (Ljungblad *et al.*, 1986a). In addition, particularly large aggregations of feeding whales were reported for nearshore shallow (<20m) waters off Tuktoyaktuk, Canada in 1980 (Richardson *et al.*, 1987), along the Yukon coast in 1983–86 (Richardson *et al.*, 1987) and northeast of Point Barrow, Alaska, in 1974, 1976, 1978 and 1984 (reviewed in Ljungblad *et al.*, 1986a). These large aggregations are periodic in nature and probably occur in years when particularly large and dense zooplankton assemblages are present. Unusually high prey concentrations have recently been demonstrated at several locations where bowheads were concentrating to feed (Bradstreet, Thomson and Fissel, 1987; Richardson, 1987). Prey availability has been reported to affect the distribution of other baleen whales (Nemoto, 1959; Whitehead and Carscadden, 1985).

In summary, it appears that bowheads arrive and disperse offshore in the Canadian Beaufort Sea in June-July, and remain offshore through mid-August, with some whales moving westward into eastern Alaskan Beaufort Sea. Whales generally move towards shore and over the continental shelf during the latter half of August and through early September, and appear to alternate swimming in a northwesterly direction with bouts of feeding, milling or resting. Although most whales are not strongly migratory until the latter half of September and October (Ljungblad *et al.*, 1986c; Richardson *et al.*, 1987), the direction of movement is westerly after early August.

The migration route in the eastern Alaskan Beaufort Sea during September-October was demarcated by the 20–50m isobaths for all years 1982–86, except 1983 when the route was roughly 50km further from shore in water *ca.* 200m deep (Moore *et al.*, 1989). The cause for the onshore shift in distribution in 1983 is unclear, but might have been related to variations in feeding opportunities or to restrictions to their movements caused by the heavier-than-normal ice cover in the Alaskan Beaufort Sea that year.

As OCS development activities increase in intensity east of the Prudhoe Bay field and farther offshore, it becomes more likely that these activities will be carried out near bowheads. Richardson *et al.* (1987) described the problems associated with interpreting within and between-year variations in bowhead distribution and abundance near OCS activities in the Canadian Beaufort Sea. Long-term, broadscale monitoring surveys remain the best method of detecting cumulative affects of long-term industrial activities over a number of years, and may be used, in association with direct behavioural studies to detect and interpret the impact of industrial activities on bowhead whales.

ACKNOWLEDGEMENTS

This work was supported by the Minerals Management Service, US Department of the Interior, Alaska OCS Region, Anchorage, AK. Individuals who have contributed to the success and safety of the field seasons include aerial survey crew members E. Barrowclough, A. Fowler, R. O'Hara, M. Platter Reiger, T. Rickman, F. Shipp, R. Van Schoik and C. Vrolijk of SEACO and pilots G. Candee, D. Moore and J. Warren of the Office of Aircraft Services, Anchorage, AK. R. O'Hara, J. Bennett and K. Fearon of SEACO provided software and analysis. We especially thank K. Frost and L. Lowry of Alaska Department of Fish and Game, 1300 College Rd., Fairbanks, AK 99701, W.J. Richardson of LGL, Fisher St., P.O. Box 457, King City, Ontario, Canada LOG 1KO and Howard Braham and David Rugh of National Marine Fisheries Service, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115 for their professional review and helpful comments. Special thanks to G. Young of SEACO for typing numerous drafts of the manuscript.

REFERENCES

Bradstreet, M.S.W., Thomson, D.H. and Fissel, D.B. 1987. Zooplankton and bowhead whale feeding in the Canadian Beaufort Sea, 1986. *In:* Environmental Studies. No. 50. Dept. of Indian and Northern Affairs, Ottawa, Canada. 204pp.

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.

International Whaling Commission. 1988. Report of the Sub-Committee on protected species and aboriginal subsistence whaling (Annex H). *Rep. int. Whal. Commn* 38: 109–16.

Johnson, S.R., Greene, C.R., Davis, R.A. and Richardson, W.J. 1986. Bowhead whales and underwater noise near the Sandpiper Island Drillsite, Alaskan Beaufort Sea, Autumn 1985. Final Report to Shell Western Exploitation and Production Inc., Anchorage, AK, prepared by LGL Limited. 130pp.

LGL and Greenridge, 1987. Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea, autumn 1986. Report from LGL Ltd., King City, Ontario, Canada, and Greenridge Sciences Inc., Santa Barbara, CA, for Shell Western Exploration and Production, Inc., Anchorage, AK. 371pp.

Ljungblad, D.K., Moore, S.E., Clarke, J.T. and Bennett, J.C. 1987. Distribution, abundance, behaviour and bioacoustics of endangered whales in the Alaskan Beaufort and eastern Chukchi Seas, 1979–86. NOSC TR 1177, prepared for MMS Alaska OCS Region. 391pp. (NTIS AD-A183 934/9)*

Ljungblad, D.K., Moore, S.E. and Clarke, J.T. 1986a. Assessment of bowhead whale (*Balaena mysticetus*) feeding patterns in the Alaskan Beaufort and northeastern Chukchi Seas via aerial surveys, Fall 1979–84, *Rep. int. Whal. Commn* 36: 265–72.

Ljungblad, D.K., Moore, S.E., Clarke, J.T. and Bennett, J.C. 1986b. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1985: with a seven year review, 1979–85. NOSC TR 1111, prepared for MMS Alaska OCS Region. 409pp.

Ljungblad, D.K., Moore, S.E. and Van Schoik, D.R. 1986c. Seasonal patterns of distribution, abundance, migration and behaviour of the western Arctic stock of bowhead whales, *Balaena mysticetus*, in Alaskan seas. *Rep. int. Whal. Commn* (special issue 8): 177–205.

Ljungblad, D.K., Würsig, B., Reeves, R.R., Clarke J.T. and Greene, C.R. 1984. Fall 1983 Beaufort Sea seismic monitoring and bowhead whale behaviour studies. Final Report prepared for MMS Alaska OCS Region, prepared by SEACO, Inc. 180pp. (NTIS PB86–196912)*

Ljungblad, D.K., Würsig, B., Swartz, S. and Keene, J.M. 1988. Observations on the behavioural responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. *Arctic* 41(3): 183–94.

Lowry, L.F. and Frost, K.J. 1984. Foods and feeding of bowhead whales in western and northern Alaska. *Sci. Rep. Whales Res. Inst., Tokyo* 35:2–16.

Moore, S.E., Bennett, J.C. and Ljungblad, D.K. 1989. Bowhead whale fall migration: analyses of bathymetrically defined route *J. Wildl. Manage.*: in press.

Nemoto, T. 1959. Food of baleen whales with reference to whale movements. *Sci. Rep. Whales Res. Inst., Tokyo* 14: 149–290.

Reeves, R.R., Ljungblad, D.K., and Clarke, J.T. 1983. Report on studies to monitor the interaction between offshore geophysical exploration activities and bowhead whales in the Alaskan Beaufort Sea, Fall 1982. Final Report prepared for MMS Alaska OCS Region, prepared by SEACO, Inc. 80pp. (NTIS PB86–168903)*

Richardson, W.J. (ed.). 1987. Importance of the eastern Alaskan Beaufort Sea to feeding bowhead whales, 1985–86. Final Report prepared for US MMS, prepared by LGL Ecol. Res. Assoc. Inc. 547pp.

Richardson, W.J., Davis, R.A., Evans, C.R., Ljungblad, D.K. and Norton, P. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980–84. *Arctic* 40(2): 93–104.

Whitehead, H. and Carscadden, J.E. 1985. Predicting inshore whale abundance — whales and capelin off the Newfoundland coast. *Can. J. Fish. Aq. Sci.* 42 (5): 976–81.

Zar, S.H. 1984. *Biostatistical Analysis*. Prentice Hall, Inc., Englewood Cliffs, N.J. 620pp.

* NTIS: available from National Technical Information Service, 5285 Port Royal Rd, Springfield, VA 22161, USA.

SC/40/PS3

Use of Passive Acoustics in Conjunction with Aerial Surveys to Monitor the Fall Bowhead Whale (*Balaena mysticetus*) Migration

Sue E. Moore and John C. Bennett
SEACO – A Division of SAIC, 2845-D Nimitz Blvd., San Diego, CA 92106, USA
Donald K. Ljungblad
Naval Ocean Systems Center, Code 514, San Diego, CA 92152, USA

ABSTRACT

Passive acoustics were used in conjunction with aerial surveys to detect bowhead whales (*Balaena mysticetus*) during the westward fall migration in 1986 and 1987. In 1986, 7,152 bowhead calls were recorded over a 37-day period using sonobuoys modified for extended transmission life and moored approximately 5km north of Barter Island, Alaska. In 1987, 531 bowhead calls were recorded over a 34-day period from standard drifting sonobuoys deployed from the survey aircraft near Barrow, Alaska. Three periods of peak calling activity were recognised over the course of each season. The temporal pattern of the bowhead migration represented by daily bowhead calling rates was similar to that described by aerial survey sighting rates. Acoustic monitoring, unlike aerial surveys, is fully operational during darkness and bad weather, thereby providing robust data to supplement visual sightings.

INTRODUCTION

Bowhead whales (*Balaena mysticetus*) annually migrate between summer feeding grounds in the Canadian Beaufort Sea, and wintering areas in the northern Bering Sea (Braham, Krogman and Carroll, 1984). Aerial surveys have been conducted over the Alaskan Beaufort Sea since 1979 to document bowhead whale distribution, abundance and migratory timing (Ljungblad, Moore and Van Schoik, 1986b). Passive acoustic monitoring for bowhead calls has been routinely conducted from the survey aircraft during flights to provide an additional indicator of bowhead presence. In addition, acoustic studies conducted in association with ice-based visual censusing near Point Barrow, Alaska during the bowhead spring migration have enhanced descriptions of whale distribution, movements and habitat relationships (Clark, Ellison and Beeman, 1985, 1986a, 1986b; Cummings and Holliday, 1985). Perhaps more importantly, passive acoustic studies have provided call localisation data that were incorporated with visual sighting data in population size estimates (Zeh, Turet, Gentleman and Raftery, 1988).

Passive acoustic monitoring from shore-based field stations was used in conjunction with aerial surveys in 1986 and 1987 to detect calling bowhead whales during the fall migration across the Alaskan Beaufort Sea. In 1986, a field station dedicated to recording bowhead calls via moored sonobuoys was established on Barter Island, Alaska to detect whales as they entered the Alaskan Beaufort Sea. In 1987, sonobuoys were routinely dropped from the survey aircraft near Barrow, Alaska to detect bowheads as they entered the northeastern Chukchi Sea. The goals of the monitoring stations were to (1) listen for and record bowhead calls during the migration period, (2) integrate acoustic data with aerial survey sighting data when possible and (3) assess passive acoustics as a tool for detecting migrating whales.

METHODS AND MATERIALS

Placement of sonobuoys for acoustic monitoring differed between years. In 1986, sonobuoys (model *AN/SSQ-41B*), modified with external batteries to extend transmission life to 72 hours, were moored approximately 5km north of Barter Island, Alaska, and replaced every 1 to 3 days using a small skiff. In 1987, standard sonobuoys (model *AN/SSQ-57A*), each with an 8-hour transmission life, were routinely dropped from the survey aircraft approximately 3km west of Barrow, Alaska and monitored for as long as they remained within transmission range (*ca.* 5–7km). Both sonobuoy models have flat frequency responses of 10Hz to 20kHz ± 2dB.

In both years, sounds received at the sonobuoy hydrophone were transmitted to a receiving antenna (*Motorola: TAD6043A*) externally mounted on a building at the shore station, and connected to a *Defense Electronics* VHF broadband receiver. The output from the receiver was recorded on a *RCA VLP 950 HF* video recorder using 6 hour VHS tape speed. The overall response of the recording systems was 20Hz to 10kHz ± 2dB, well within the frequency band of bowhead calls (Ljungblad, Thompson and Moore, 1982).

Call reception limits of 10 and 20km were estimated for both stations to approximate the areas monitored by the sonobuoy systems (Fig. 1). The 10km radius was the conservative radial limit of the monitoring station based upon estimates of bowhead call signal/noise ratio approaching zero at a median distance of 10km (Cummings and Holliday, 1983). The 20km radial limit was considered a secondary zone in which calling bowheads could be detected based upon their ability to produce sounds with estimated source levels as high as 189dB re 1 μPa (Cummings and Holliday, 1983). Although bowhead calls with source levels of 189dB could hypothetically be detected at ranges greater than 20km, local variation in

Table 1

Hours of recording, number of bowhead calls, call rate, and sighting rate (WPUE = no. whales/hour aerial survey) for days on which whales were recorded in 1986 and 1987. * = no flight; [1] = r 0.3, $p < 0.5$ when datum removed

Date	Hours	No. calls	Call rate	WPUE	Date	Hours	No. calls	Call rate	WPUE
Barter Island, 1986					**Barrow, 1987**				
3 Sep	10.3	1	0.10	2.99	18 Sep	7.1	34	4.79	0
9 Sep	23.4	2	0.09	0	30 Sep	11.8	3	0.25	0.60
11 Sep	10.0	1	0.10	1.54	3 Oct	3.9	48	12.31	0
12 Sep	8.6	2	0.23	0	5 Oct	8.7	76	8.74	0.46
18 Sep	23.0	32	1.39	*	6 Oct	11.6	238	20.52[1]	12.76[1]
19 Sep	14.6	106	7.26	0.37	15 Oct	8.7	27	3.10	0
20 Sep	23.9	119	4.98	0	16 Oct	7.5	81	10.80	0.90
25 Sep	8.2	52	6.34	1.88	19 Oct	7.8	15	1.92	0
27 Sep	23.1	661	28.61	*	20 Oct	8.7	2	0.23	0
28 Sep	23.8	2,100	88.24[1]	5.52[1]	21 Oct	8.7	7	0.80	0
29 Sep	21.7	534	24.61	0					
30 Sep	7.4	55	7.43	*					
1 Oct	22.3	1,566	70.22	2.41					
2 Oct	21.9	1,373	62.69	*					
3 Oct	23.2	375	16.16	*					
6 Oct	9.4	136	14.47	2.54					
7 Oct	22.1	35	1.58	*					
9 Oct	6.6	2	0.30	0					

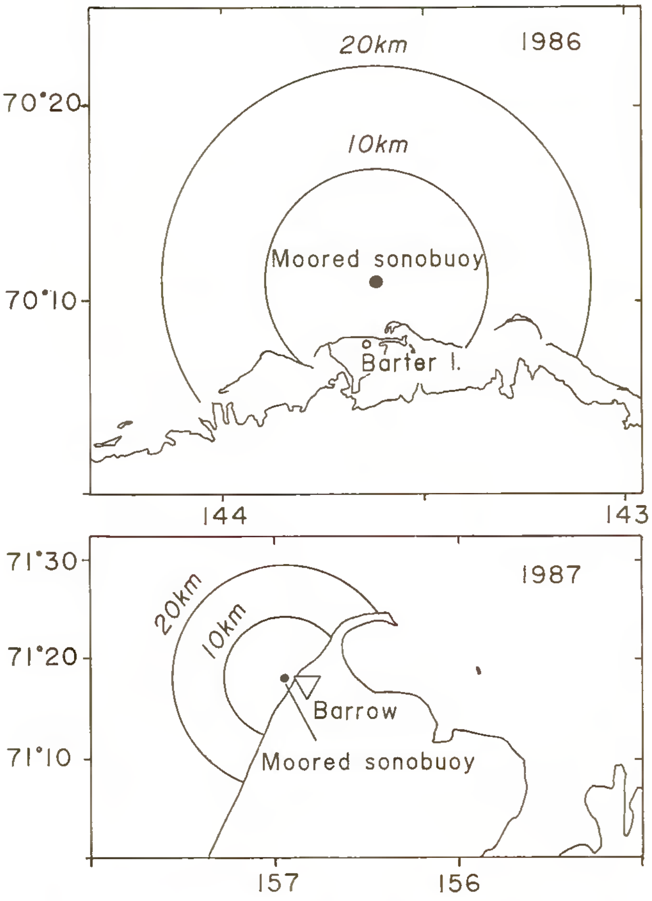


Fig. 1. Acoustic monitoring study area at Barter Island, Alaska, in 1986, and at Barrow, Alaska, in 1987. The location of the moored sonobuoy (1986) and the sonobuoy drop site (1987) are depicted, with 10km and 20km proposed radial limits of hydrophone reception.

ambient noise levels and sound transmission characteristics made it unlikely. Further, Clark *et al.* (1986a) report that the 'most common types' of bowhead calls are produced at an average estimated source level of 150 ± 9.4 SD dB re 1 μPa/100Hz, supporting the 20km radius as a reasonable estimate of bowhead call transmission limits under quiet ambient conditions.

Acoustic data were recorded continuously whenever sonobuoys were operational. All recordings were monitored in the field for bowhead calls by an experienced technician, and were augmented by a written daily log describing local weather conditions and notations on industrial or other biological sounds heard. Later, tapes containing bowhead calls were carefully monitored in the lab using the *RCA* recorder set at original recording speed. The audio signal was played through a *Hewlett Packard* dynamics signal analyser and a visual image of each call was displayed on a monitor set at 50 to 850Hz. Simultaneously, the tape was amplified using a *Pioneer 5A 608* pre-amplifier and monitored through headphones. Notation of bowhead calls included date, tape number and count, and sometimes an aural description of the call. Calls produced by white whales (*Delphinapterus leucas*) and bearded seals (*Erignathus barbatus*) were also noted.

Daily bowhead call rate (CR) was derived as the number of calls recorded per hour of recording effort. Subsequently, daily sighting rates (WPUE=no. whales/hour aerial survey) were correlated with daily CR, and a description of bowhead occurrence near each acoustic station was summarised as a combination of daily WPUE and CR. Daily sighting rates (WPUE) used were from aerial surveys for each year (Ljungblad, Moore, Clarke and Bennett, 1987b; 1988) and represent a sampling effort that included, but was not confined to, the boundaries approximated for the acoustic monitoring areas.

RESULTS

Recording effort and bowhead call rates

In 1986, over 590 hours of recordings were made on 42 days between 25 August and 11 October with over 166 hours of recordings collected on 26 days between 9 September and 21 October in 1987 (Fig. 2). In 1986, recordings were gathered during some portion of each field day except six, and were interrupted only when the moored sonobuoys were destroyed by sea ice, or when storms prevented the replacement of the external battery pack. In 1987, strong easterly winds sometimes carried the aircraft-deployed sonobuoy out of reception range within a few hours, but sonobuoys often stayed within recording range during calm periods for over eight hours. Recording periods longer than eight hours were obtained by dropping a sonobuoy at the beginning and end of a flight.

The total number of bowhead calls recorded were 7,152 in 1986 and 531 in 1987 (Table 1). The types of calls recorded were similar to those previously described as either tonal frequency modulated (FM) 'moans', or amplitude modulated (AM) 'growls' and 'trumpets' (Ljungblad *et al.*, 1982; Clark and Johnson, 1984). In 1986, the moored sonobuoy site was directly in the path of the bowhead migratory route. In contrast, the sonobuoy drop site in 1987 was dictated by water depth and reception range of the equipment and, due to acoustic shadowing by the Point Barrow peninsula, probably was sub-optimal for reception of bowhead calls originating northeast of Barrow (see Fig. 1). Nearly all calls recorded in 1987 were very low level, indicating that passing whales were either >10km from the hydrophone or that nearby whales were producing relatively low-level calls.

Three periods of calling activity were recognised over the course of each season (Fig. 2). In 1986, an initial period of very low call rates began on 3 September and ended on 12 September; a second period with intermediate call rates

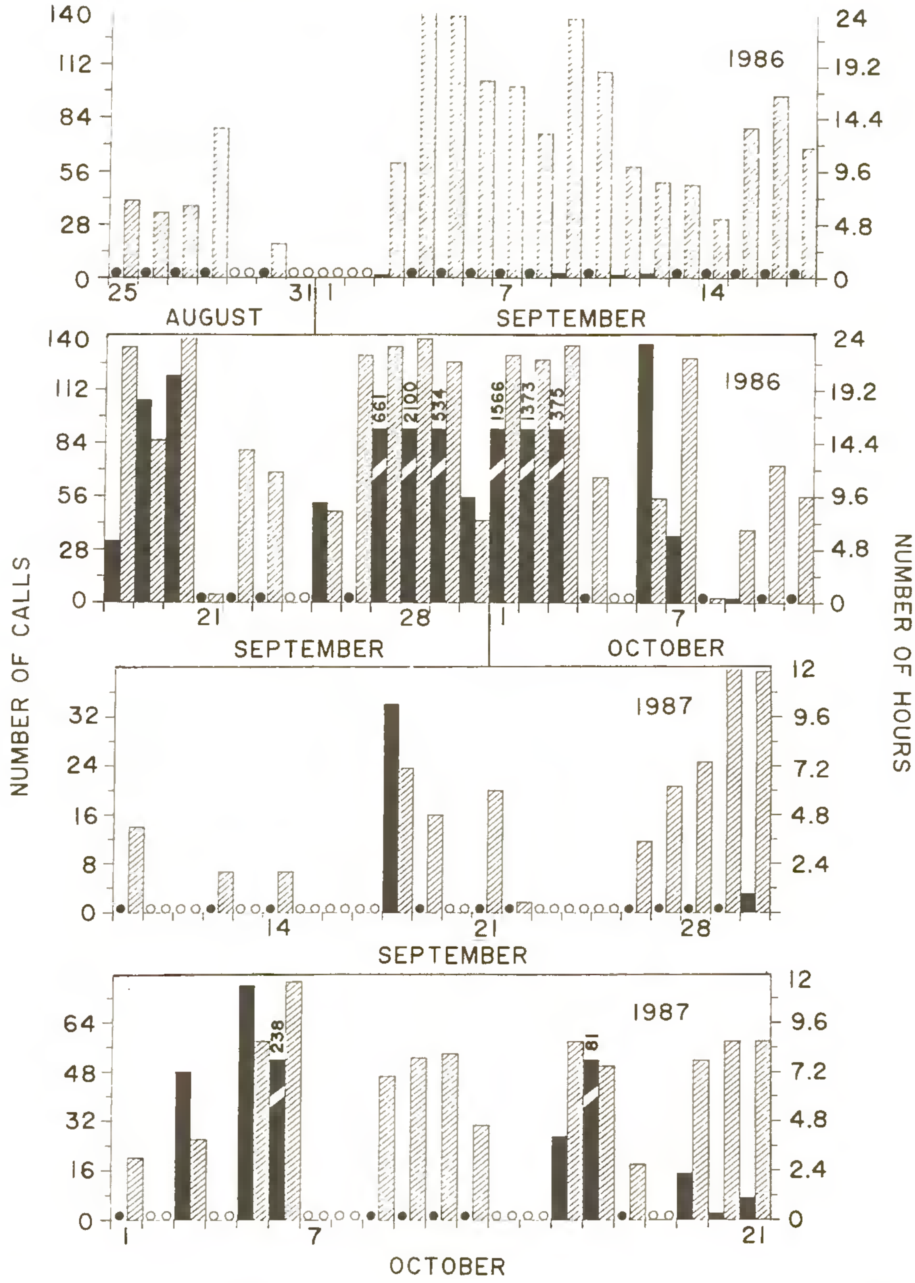


Fig. 2. Hours of recording effort (▨) and number of bowhead calls (■) recorded at the Barter Island (1986, 590.4 hrs) and Barrow (1987, 166.5 hrs) acoustic monitoring stations. Open circles = no effort, closed circles = no calls.

occurred from 18–20 September; and a third period of very active calling began on 25 September and ended on 9 October (Table 1). The majority of calls (n=6,664, 93%) were recorded during the third period, with peak call-rate days on 28 September (CR=88.24), 1 October (CR=70.22) and 2 October (CR=62.69). In 1987, bowhead calls were first recorded on 18 September, followed by a second period of relatively high call rates recorded from 30 September-6 October; with a third phase of intermediate calling between 15 and 21 October (Fig. 2, Table 1). The majority of calls (n=365, 69%) were recorded during the second period of calling activity, with peak call-rate days on 3 October (CR=12.31) and 6 October (CR=20.52). A final peak day occurred on 16 October 1987 (CR=10.80), during the last phase of calling. Recording efforts were terminated in both years due to ice conditions that prevented the continued deployment of sonobuoys.

Association of bowhead call rates with aerial survey sighting rates

Although there was a significant correlation between bowhead calling rates (CR) and aerial survey sighting rates (WPUE) in 1986 ($r=0.700$, $df=10$, $p<0.02$) and in 1987 ($r=0.764$, $df=8$, $p<0.02$), the correlation rested on one datum pair in both years (see footnote 1 in Table 1). It is important to emphasise that bowhead daily WPUE were derived from surveys conducted over a study area that included the acoustic monitoring sites, but were not confined to sightings within those areas. Although only 16 whales were seen within 20km of the acoustic station in 1986, and none were seen within the estimated 20km boundaries of the acoustic station in 1987, the temporal pattern of the bowhead migration was similarly represented by both visual and acoustic methods.

Thus, although WPUE and CR were correlated each year, the whales seen were not necessarily those recorded.

Table 2

Total number of calls recorded at the acoustic stations from a moored sonobuoy (1986) and from routine sonobuoy drops during aerial surveys (1987). * = no recording effort, 0 = no data recorded

Hour (local)	1986: Barter Is.	1987: Barrow	Hour (local)	1986: Barter Is.	1987: Barrow
0000–0100	392	*	1200–1300	314	0
0100–0200	401	*	1300–1400	257	3
0200–0300	283	*	1400–1500	239	1
0300–0400	328	*	1500–1600	497	32
0400–0500	315	*	1600–1700	252	17
0500–0600	225	*	1700–1800	227	50
0600–0700	250	*	1800–1900	322	11
0700–0800	312	*	1900–2000	309	75
0800–0900	256	*	2000–2100	240	151
0900–1000	183	0	2100–2200	298	171
1000–1100	219	0	2200–2300	451	19
1100–1200	230	0	2300–0000	352	1

Comparisons of the time of sightings versus the time that calls were recorded supports this supposition. In 1986 aerial survey sightings were generally made between 1000 and 1600hrs local time, when only 25% ($n=1,756$) of bowhead calls were recorded (Table 2). In addition, in 1986 mean night-time (1800–0600) CR tended to be higher ($\bar{x}=326$, $SD=65$) than mean daytime (0600–1800) CR ($\bar{x}=270$, $SD=80$), but not significantly so ($t=0.51$, $p<0.50$). In 1987, 75% ($n=397$) of all calls were recorded between 1900 and 2200, several hours after surveys were terminated due to darkness. Notably, in 1986, the first calls recorded occurred when bowheads were not seen within the 20km boundaries of the acoustic monitoring area, and in 1987, were recorded three days before the first bowhead sighting of the season.

Other marine mammals recorded

White whale calls were recorded on four days at the Barter Island acoustic station, but were not recorded during monitoring at Barrow. White whales make a variety of relatively high-frequency calls (300Hz to 20kHz) (Fish and Mowbray, 1962; Sjare and Smith, 1986). Such high-frequency calls are attenuated over much shorter distances than lower frequency bowhead calls (Urick, 1983) which, when combined with the relative offshore distribution of white whales during the fall season (Ljungblad, Moore, Clarke and Bennett, 1986a), probably accounts for the infrequent recording of their calls at the nearshore recording sites.

Bearded seal calls were recorded at both acoustic monitoring stations from September through October. Bearded seal 'trills' have been associated with breeding behaviour in the spring, with June reported as the period of highest call rates recorded in the Canadian High Arctic (Stirling, Calvert and Cleator, 1983).

DISCUSSION

These preliminary results suggest that acoustic monitoring, conducted in conjunction with aerial surveys, can provide important additional information on bowhead whale near shore occurrence during the fall migration. Passive acoustics reliably indicated the presence of bowheads and extended the data acquisition effort through periods of darkness and bad weather when aerial surveys could not be conducted. Although daily calling rates could be statistically correlated with daily sighting rates, there was no strong relationship that would allow the prediction of one from the other with confidence. Notably, acoustic results in 1987 were similar in periodicty to those in 1986, even though sampling effort in 1987 was restricted by the transmission life of the free-floating sonobuoys.

It is important to differentiate between the results reported here and those of the passive acoustic tracking work conducted during the bowhead spring migration by Clark *et al.* (1986a, 1986b). While it is tempting to interpret seasonal peak periods of bowhead calling, or daily peaks within these periods, as corresponding to aggregations or pulses of whales passing the monitoring site, these inferences cannot be supported by data gathered from a single omni-directional hydrophone. Without information on the locations of calling whales, it is impossible to determine if 'more' calls corresponds to 'more' whales, or to just a few calling whales that remain within range of the hydrophone for a relatively long time. It seems likely that at least some bowheads were socialising and calling within range of the hydrophone and not actively migrating past the monitoring site on peak call-rate days in both years because amplitude modulated 'growls' and 'trumpets' were commonly recorded. Such calls tend to be recorded more often near socialising rather than migrating whales (Ljungblad *et al.*, 1986a; Würsig, Clark, Dorsey, Fraker and Payne, 1985). In addition, 'growls' were positively correlated with call rate ($r=0.216$ $df=85$, $p<0.05$) in a sample of calls recorded during aerial surveys over several seasons (Ljungblad *et al.*, 1986a).

Although it is not possible to infer bowhead number or rate of passage from acoustic data collected from a single omni-directional hydrophone, the significant correlation of calling and sighting rates, and the extended period of acoustic data gathering, supports the contention that passive acoustic monitoring could be developed as a valuable and cost-effective tool to assess the timing of the bowhead fall migration. It is important to note that the success of any acoustic detection study will depend on environmental conditions that are conducive to maintaining the necessary field equipment. The 1986 field season was unusually mild, with ample periods between storms that usually allowed the moored sonobuoy system to be replaced at timely intervals. In 1987, open water conditions persisted near Barrow until well into October facilitating sonobuoy deployment. A season of prolonged storms or heavy ice could have resulted in sparse acoustic data in both years.

Passive acoustics is becoming an important supplemental technique for detecting cetaceans, assessing their distribution and inferring something about their behaviour. Clark *et al.* (1985, 1986) have used passive acoustic tracking to provide important insights on the distribution of bowheads migrating past Point Barrow, Alaska, in spring. In other studies, Thompson and Friedl (1982) documented the seasonal occurrence of five cetacean species in Hawaiian waters by long term monitoring of two bottom-mounted hydrophones. Watkins and Moore (1982) and Whitehead and Gordon (1986) described passive acoustical tracking of sperm whales (*Physeter macrocephalus*) from research vessels, and Thomas, Fisher, Ferm and Holt (1986) acoustically identified eight cetacean species and increased the overall detection of cetaceans by 32% using an array of hydrophones towed behind a research vessel. In all cases, the use of passive acoustics has enhanced accuracy and often extended data gathering through periods of darkness or inclimate weather when visual techniques would not work. The continued use of acoustics in the study of cetacean populations seems certain to expand our understanding of animals that spend most of their lives underwater and rely heavily on the acoustic modality.

ACKNOWLEDGEMENTS

This work was funded by the Minerals Management Service (MMS), US Department of the Interior, Alaska OCS Region, Anchorage, AK. We thank J. Imm, C. Cowles and J. Montague of MMS Anchorage, AK for their support of the project; John Hayne and Kim Fearon of SEACO, for their dedicated work in the field and lab, respectively; the personnel of the Barter Island DEW line site, and the Bensons at Barrow, AK, for their logistic support; and Gloria Young of SEACO for typing the manuscript. We especially thank Dr Clifford Hui, Naval Ocean Systems Center, Code 512, San Diego, CA 92152 and Dr Marilyn Dahlheim of National Marine Fisheries Service, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115 for reviewing and providing many helpful comments on the draft manuscript.

REFERENCES

Braham, H.W., Krogman, B.D. and Carroll, G.M. 1984. Bowhead and white whale migration, distribution and abundance in the Bering, Chukchi and Beaufort Seas, 1975–78. NOAA Technical Report NMFS SSRF-778, 39p.

Clark, C.W., Ellison, W.T. and K. Beeman. 1985. Acoustic tracking and distribution of bowhead whales, *Balaena mysticetus*, off Point Barrow, Alaska in the spring of 1984. Paper SC/37/PS11 presented to the IWC Scientific Committee. June 1985. (Unpublished), 25pp.

Clark, C.W., Ellison, W.T. and Beeman, K. 1986a. An acoustic study of bowhead whales, *Balaena mysticetus*, off Point Barrow, Alaska during the 1984 spring migration. Final report to the North Slope Borough under Contracts 83–66 and 84–137. 145pp.

Clark, C.W., Ellison, W.T. and K. Beeman. 1986b. A preliminary account of the acoustic study conducted during the 1985 spring bowhead whale *Balaena mysticetus* migration off Point Barrow, Alaska. *Rep. int. Whal. Commn* 36: 311–6.

Clark, C.W. and Johnson, J.H. 1984. The sounds of the bowhead whale (*Balaena mysticetus*) during the spring migrations of 1979 and 1980. *Can. J. Zool.* 62(7): 1,436–41.

Cummings, W.C. and Holliday, D.V. 1983. Source level of bowhead whale sounds determined by acoustical array localisation. *J. Acoust. Soc. Am.* (Suppl. 1) 74: 555.

Cummings, W.C. and Holliday, D.V. 1985. Passive acoustic location of bowhead whales in a population census off Point Barrow, Alaska. *J. Acoust. Soc. Am.* 78(4): 1,163–9.

Fish, M.P. and Mowbray, W.H. 1962. Production of underwater sound by the white whale or beluga, *Delphinapterus leucas*. *J. Mar. Res.* 20(2): 149–62.

Ljungblad, D.K., Moore, S.E., Clark, J.T. and Bennett, J.C. 1986a. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1985: with a seven year review 1979–85. Final Report prepared by NOSC, for the US MMS 443pp.

Ljungblad, D.K., Moore, S.E., Clark, J.T. and Bennett, J.C. 1987b. Distribution abundance, behaviour and bioacoustics of endangered whales in the Alaskan Beaufort and eastern Chukchi Seas 1979–86. Final Report prepared by NOSC, for the US MMS 391pp.

Ljungblad, D.K., Moore, S.E., Clark, J.T. and Bennett, J.C. 1988. Distribution, abundance, behaviour and bioacoustics of endangered whales in the western Beaufort and northeastern Chukchi Seas, 1979–87. Final Report prepared by SEACO, for the US MMS 231pp.

Ljungblad, D.K., Moore, S.E. and Van Schoik, D.R. 1986b. Seasonal patterns of distribution, abundance, migration and behaviour of the western Arctic stock of bowhead whales, *Balaena mysticetus* in Alaskan Seas. *Rep. int. Whal. Commn* (special issue 8): 177–205.

Ljungblad, D.K., Thompson, P.O. and Moore, S.E. 1982. Underwater sounds recorded from migrating bowhead whales, *Balaena mysticetus*, in 1979. *J. Acoust. Soc. Am.* 71(2): 477–82.

Sjare, B.L. and Smith, T.G. 1986. The vocal repertoire of white whales, *Delphinapterus leucas*, summering in Cunningham Inlet, Northwest Territories. *Can. J. Zool.* 64: 407–15.

Stirling, I., Calvert, W. and Cleator, H. 1983. Underwater vocalisations as a tool for studying the distribution and relative abundance of wintering pinnipeds in the high arctic. *Arctic* 38(3): 262–74.

Thomas, J.A., Fisher, S.R., Ferm, L.M. and Holt, R.S. 1986. Acoustic detection of cetaceans using a towed array of hydrophones. *Rep. int. Whal. Commn* (special issue 8): 139–48.

Thompson, P.O. and Friedl, W.A. 1982. A long term study of low frequency sounds from several species of whales off Oahu, Hawaii. *Cetology* 45:1–19.

Urick, R.J. 1983. *Principles of Underwater Sound*, 3rd ed. McGraw-Hill Book Co., New York, NY. 423pp.

Watkins, W.A. and Moore, K.E. 1982. An underwater acoustic survey for sperm whales (*Physeter catadon*) and other cetaceans in the southeast Carribbean. *Cetology* 46: 1–7.

Whitehead, H. and Gordon, J. 1986. Methods of obtaining data for assessing and modelling sperm whale populations which do not depend on catches. *Rep. int. Whal. Commn* (special issue 8): 149–65.

Würsig, B., Clark, C.W., Dorsey, E.M., Fraker, M.A. and Payne, R.S. 1985. Normal behaviour of bowheads, 1980–84. pp. 13–88 *In:* W.J. Richardson (ed.) Behaviour, Disturbance Responses and Distribution of Bowhead Whales (*Balaena mysticetus*) in the Eastern Beaufort Sea, 1980–84. Final Report by LGL Ecol. Res. Assoc., Inc. for the US MMS, 306pp.

Zeh, J.E., Turet, P., Gentleman, R. and Raftery, A.E. 1988. Population size estimation for the bowhead whale *Balaena mysticetus* based on 1985 and 1986 visual and acoustic data. *Rep. int. Whal. Commn* 38: 349–64.

SC/40/PS4

Numbers and Distributions of Bowhead Whales, *Balaena mysticetus*, Based on the 1986 Acoustic Study off Pt. Barrow, Alaska

Christopher W. Clark
Cornell University, Sapsucker Woods Road, Ithaca, NY, 14850, USA
William T. Ellison
Marine Acoustics Inc., 240 Oxford Drive, Cotuit, Mass. 02635, USA

ABSTRACT

Multiple channel tape recordings of bowhead whale, *Balaena mysticetus*, sounds were obtained during the whales' migration off Point Barrow, Alaska in the spring of 1986. Acoustic location analysis was completed on 231hrs of tapes resulting in 4,636 locations. Locations were converted into tracks and from these, numbers of vocalizing whales and the distribution of their closest point of approach relative to the visual observation perch were estimated. These data were corrected to take into account the effects of array geometry, distance to a calling whale, whales that swim in pairs, and time periods when calls were recorded but not analyzed. The results indicate that there were 4,726 vocalizing bowheads detected in 1986 between 17 April to 2 June during the 841hr of acoustic observation. This estimate is further corrected to 6,132 whales when time periods during the season with no acoustic monitoring (287hr) are taken into account.

INTRODUCTION

Acoustic studies of migrating bowhead whales have been conducted in close coordination with visual census studies in 1982, 1984, 1985 and 1986 (Clark, Ellison and Beeman, 1986a, 1986b, 1986c; Clark and Ellison, 1988; Cummings and Holliday, 1985). The 1984 study (Clark *et al.*, 1986a) primarily demonstrated the effectiveness of the acoustic methods during periods when visual observations were restricted by poor visibility conditions (heavy ice, fog, snow etc.). It also gave the first good indications that a sizeable percentage of whales were too far offshore to be seen and that many of the whales within 4km of the visual observation perch were not seen by visual observers, even under good or very good visibility conditions. The 1985 study (Clark *et al.*, 1985b; 1986c; Ellison, Clark and Beeman, 1986; Clark and Ellison, 1988) was the first to provide a fairly complete acoustic analysis of the entire seven week season, and these acoustic data were merged with the visual sighting data to yield a population estimate (Zeh, Turet, Gentleman and Raftery, 1988). This paper presents the results of the acoustic census analysis based solely on the 1986 acoustic data in a manner similar to that for the 1985 acoustic study (Clark and Ellison, 1988). These are the acoustic location data used by Zeh, Raftery and Styer (1988) and Raftery, Zeh and Styer (1988) in order to compute bowhead population estimates. Here we provide results showing the numbers and distributions of whales for the different parts of the 1986 season before and after correction for the effects of geometry, distance from the array and pairs of whales. The total numbers from each of these parts are corrected for periods that were not analyzed for locations, and the total number of vocalizing whales migrating off Point Barrow in the spring of 1986 is estimated.

METHODS

Field methods and acoustic locations

The major objective of the acoustic field study was to monitor and record the sounds of the whales on linear arrays of 3–4 hydrophones throughout as much of the migration as possible. Later, a representative portion of these acoustic data tapes was analyzed for acoustic locations. These basic field methods, as well as the methods for acoustic location and analysis, are described in Clark *et al.* (1986b). Acoustic analysis began with the conversion of each tape into a continuous stereographic visual display of two audio channels, referred to as a *stereogram* (see Clark *et al.*, 1986b, Fig. 1). Bowhead calls were identified as to type and time of occurrence from these visual representations of sounds, which also served as a guide for the computer operator during the sound location process. The location of a vocalizing whale was computed only for a sound with a bearing within ± 60° of a line originating at the visual observation perch and perpendicular to the axis of the array. This area in which acoustic locations were obtained is referred to as the 120° sector.

The area over which reliable locations are obtained is particularly sensitive to the geometry of the hydrophone array, which is arranged as an approximate line of sensors along the edge of the ice, approximately parallel to the whales' migration path. An appreciation of the effect of array geometry on the efficiency of the acoustic location method is critical to the process of deriving a correction term for those whales that were heard but not located, and will be discussed under the heading 'Correction factors' below.

In all further discussion the terms 'sound' and 'call' are equivalent and refer to a bowhead vocalization and not to bowhead songs (Ljungblad *et al.*, 1982; Clark and Johnson, 1984). By this procedure sound counts do not include song notes, but song notes were located in order to locate and track singing whales, which are included in counts of the numbers of whales. Counts of bowhead calls refer to the numbers of sounds tallied over a given time period. There are two types of counts referred to here, 'field counts' and 'lab counts'. Field counts are the numbers of calls noted by acoustic observers in the field at the time of monitoring and recording. Lab counts are the numbers of calls found on the tapes as a result of acoustic analysis.

Blocks of time selected for location analysis are referred to as 'segments'. For each segment, all tapes were converted into stereograms and an effort was made to locate every sound in the 120° sector. Blocks of time for which acoustic monitoring or recordings were made but location analysis was not performed are referred to as 'non-segments'. Periods of time within the season with similar array and environmental conditions are referred to as 'parts'.

Acoustic tracks and CPA distributions

All sound locations were analyzed for acoustic tracks using the bowhead tracking procedures (Sonntag, Ellison, Clark, Corbit and Krogman, 1986; Sonntag, Ellison and Corbit, 1987). In all acoustic tracking, the angle of migration was parallel to the axis of the hydrophone array, swimming speeds ranged from a minimum of 2km/hr to a maximum of 7km/hr, the angle of deviation from the migratory direction was ±15° and the consolidation parameters were 240sec and 150m, respectively (*T2* and *R* in Sonntag *et al.*, 1988). An 'acoustic track' is defined as one or more acoustic locations, and it is assumed that there is only one whale per track. Closest point of approach (CPA) distributions, also referred to as distributions, were computed by projecting the first location in a track onto the line originating at the visual observation perch and perpendicular to the direction of migration.

Correction factors

We are presenting the numbers and distributions of whales based solely on acoustic information. These acoustic analyses provide numbers and distributions only for a portion of the actual population passing by the acoustic observation area. The proportion of the *vocalizing* population counted during the season is primarily affected by factors related to spatial and temporal sampling limitations. Spatial sampling limitations affect the proportion of the *vocalizing* whales that are actually detected and located during an acoustic segment. Temporal sampling limitations affect the proportion of vocalizing whales counted during the periods of acoustic analysis relative to the total duration of the season. In order to take these limitations into account and estimate numbers and distributions of vocalizing whales for the entire migration period, the numbers and distributions computed from the tracking algorithm are corrected to account for the following factors:

(a) the acoustic location method does not sample the entire area through which the migration flows with equal certainty (the probability of locating a vocalizing whale as it passes by the array is dependent upon where, relative to that array, the whale makes the sound);

(b) acoustic methods cannot detect two whales in the same track; i.e., two or more whales that are swimming so close to each other that their acoustic locations overlap can not be acoustically distinguished as different whales.

(c) periods of time when acoustic observations were made but acoustic location analysis was not performed; and

(d) periods of time during the migration when no acoustic observations were made.

Five separate acoustic correction factors are applied to the numbers and distributions of whales computed for each part of the season, in a manner similar to that for the 1985 data (Clark and Ellison, 1988). The order and procedure by which these correction factors are determined is as follows.

Geometric correction factor

This factor consists of a set of values that correct for whales that are under-sampled in the 120° sector between 0–4.5km. We assume that the probability of detecting a whale is proportional to the amount of time a whale spends in the 120° sector. The longer a whale is within the 120° sector of the array, the greater the chances it will call and the greater the chances it will be acoustically located. By this logic, it is clear that the acoustic behavior of a whale affects the chances of its being located; whales that call more often and make louder calls will have a greater chance of being detected and located. This year we studied the acoustic location data in order to investigate various relationships between acoustic behavior, acoustic track length and distance from the array. The relationship between calls per track/hr/km as a function of distance offshore suggested that there was no tendency for whales to change their calling rate as a function of CPA distance. Furthermore, we found that the distributions of received sound pressure levels for calls showed a consistent relationship with the distance to the calling whale. Specifically, call level distributions were attenuated *ca.* 3dB per each doubling of distance indicating that the whales were producing sounds at equivalent output levels independent of where they were relative to the visual observation perch and the array. Therefore, from all analysis to date there is every indication that the acoustic behavior of the whales in terms of call rates and call levels is independent of where they are relative to the array. This does not rule out the possibility, however, that acoustic behavior is influenced by social factors such as proximity to other vocalizing whales, density of calling etc.

Because the area over which whales are located is a truncated cone, whales that are close to the array near the edge of the shorefast ice will have less chance of being located than whales that are further offshore of the array. Last year (Clark and Ellison, 1988) we assumed a geometric correction factor which was a direct function of the straight line distance between the borders of the 120° sector out to a distance of 5km. This year we use the acoustic location data to test the effects of array aperture on the number of whales tracked, and we empirically derive a geometric correction factor. The procedure for doing this is as follows. The acoustic observation area is a 120° sector, and the effects of this angled sector are eliminated if the observation area were an aperture of constant width, such as is typically used in line transect analysis. In practice the maximum aperture width is the length of the array, and reducing our observation area to widths of our present array sizes (2–3km) would severely

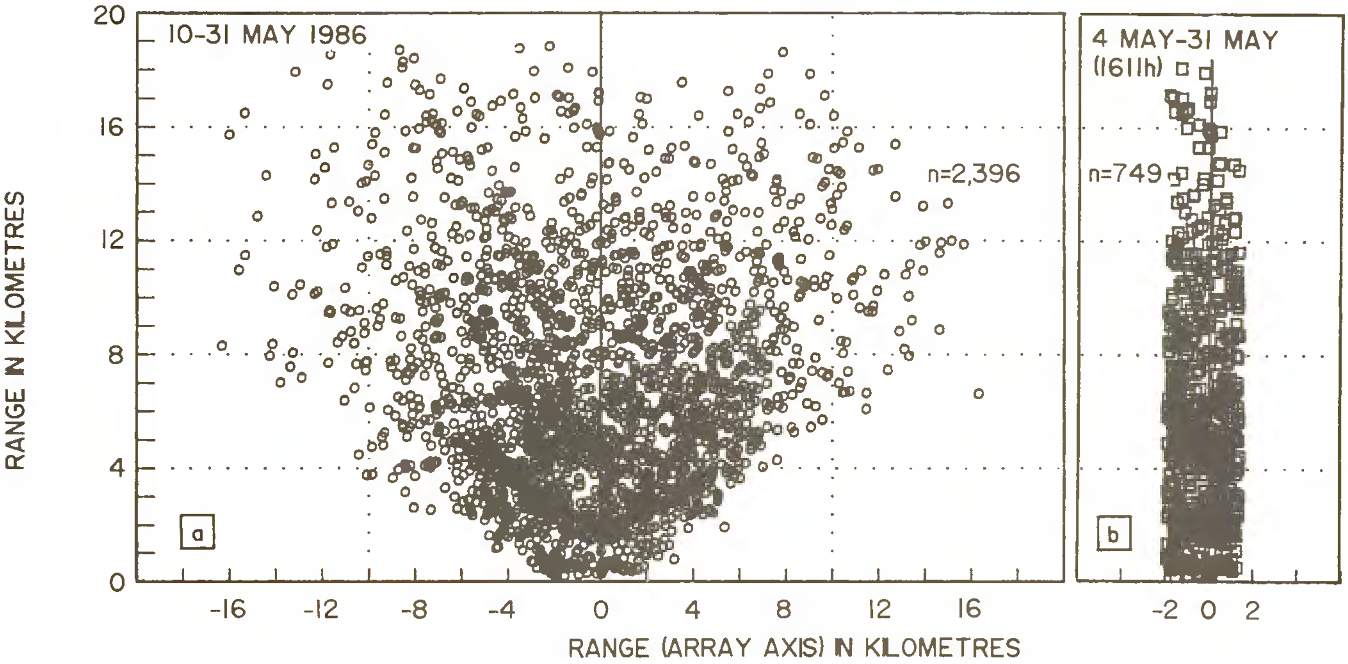


Fig. 1. Scatterplot of acoustic locations for Polar 2 period for (a) the full 120° sector and (b) only in the aperture that was the 3,050m width of the array.

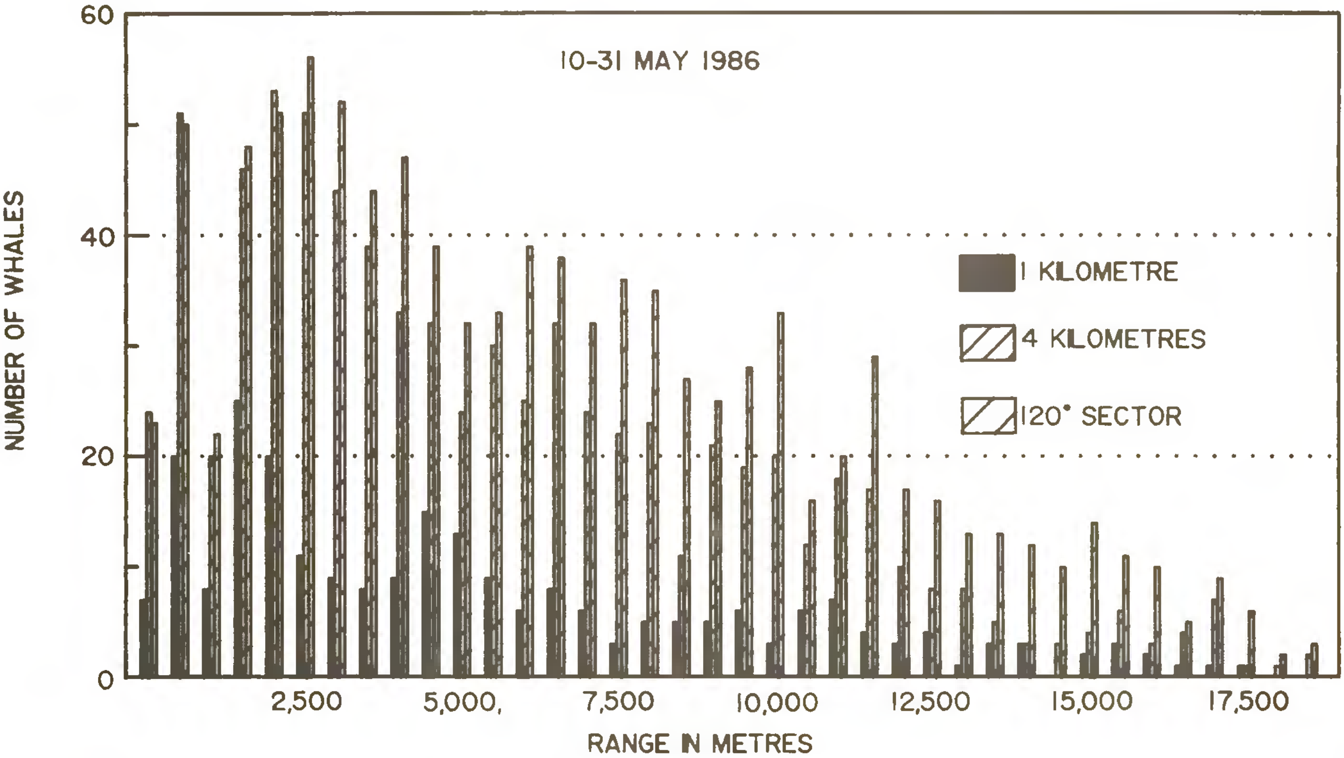


Fig. 2. CPA distributions based on all acoustic locations for the Polar 2 period 120 sector, and based on just those locations within an aperture of 1km and 4km.

reduce our chances of locating calling whales. In order to study the effects of the 120° sector on our ability to locate and therefore count vocalizing whales, we use apertures of 2, 3, 4, 8 and 16km and compare the resulting CPA distributions with the distribution from the 120° sector. An example of this procedure is shown in Fig. 1 where 1A shows all acoustic locations within the 120° sector and 1B shows all the locations within an aperture equal to the length of the array (3,050m). Fig. 2 shows the CPA distributions for the 1km and 4km apertures compared to the 120° sector. It illustrates how the number of whales detected increases with increasing aperture. The geometric correction factor for an aperture is determined by first computing the ratio between the number of whales within the aperture and the number of whales within the 120° sector. This ratio is computed for each 0.5km CPA distance bin from 0–20km using data only for CPA distances that satisfied the condition:

$$\text{CPA distance} \geq \text{Tan}(30)*\text{Aperture}/2 \qquad (1)$$

The set of ratio values for all CPA distances that satisfy equation (1) are averaged to yield the geometric correction factor for that particular aperture.

Distance correction factor

For distances greater than 4.5km no geometric-correction factor is applied, but we know that the ability of the acoustic method to detect and locate a call is a function of the distance between the calling whale and the array. For simplicity, we assume that the probability of locating a vocalizing whales is 1 between 5–10km offshore and that this probability decreases to 0 at 20km. By comparing the offshore distributions from the acoustic data and the aerial data (Nerini and Rugh, 1986) the best present estimate is that for distances >10km, acoustic methods are missing ca. 50% of the whales. Therefore, the effect of the distance correction factor is to multiply the total number of whales in the distribution that are further than 10km offshore by a factor of 2. It is important to note that the original number of whales in the 5–10km range is not changed by either the geometric or distance correction factors, and it is assumed we are counting all vocalizing whales that pass through the area 5–10km offshore of the array.

Pairs correction factor

The total numbers of whales in the distributions (after correction for geometry and distance) are corrected for the percentage of tracks expected to contain two or more whales. The pairs correction factor is different for different periods of the season and is determined from visual observation data for those periods. A pairs correction factor of 1.2 for example, means that *ca.* 20% of all visually distinct groups during that part of the season consisted of two or more whales travelling within several body lengths of one another and could not be acoustically distinguished as more than one whale using the present acoustic methods. This correction factor assumes that the numbers of whales travelling in such groups is independent of their proximity to the nearshore lead edge. It also does not adjust for the fact that the resolution of the acoustic location method is not constant with range but instead degrades geometrically with range.

Non-segment correction factor

The non-segment correction factor is computed for each part of the season using the following procedure. The total field count for the part and the field count for just the analyzed segments within the part are tabulated, and are referred to as 'field count' and 'segment count', respectively. The field counts for the three hours before and the three hours after each segment are summed to yield a term referred to as the 'pre– and post-segment count'. This is added to the 'segment count' to yield a 'corrected segment count'. This procedure of adding back sounds from three-hour periods that are never actually analyzed but which are contiguous with analyzed segments is a conservative means of reducing the chances of counting a whale twice; once when it is actually located within a segment and once when it is heard during an adjacent non-segment. The non-segment correction factor, is thus the ratio of the field count to the corrected segment count and is calculated for each part of the season.

Not-monitored correction factor

In 1986 there was a total of 286.75hrs (11.95 days) during the migration when we were unable to record or monitor bowhead vocalizations. These hours of no monitoring effort were primarily a result of environmental conditions that prevented us from safely deploying and maintaining the acoustic recording equipment. For each part of the season a correction is applied to account for the percentage of that part for which no acoustic data were collected. The not monitored correction factor is the ratio of total hours in a part of the season to hours monitored for that part.

RESULTS

In 1986 the first bowhead call was heard at 1600hrs on 17 April and the last call was heard at 0700hrs on 2 June when the acoustic study ceased. For all of 1986, a total of 50,552 bowhead calls were noted by acoustic observers during 841.25hrs of acoustic monitoring. There were 573.8hrs of tapes recorded when an array was functioning. Location analysis was performed on 231hrs of these array

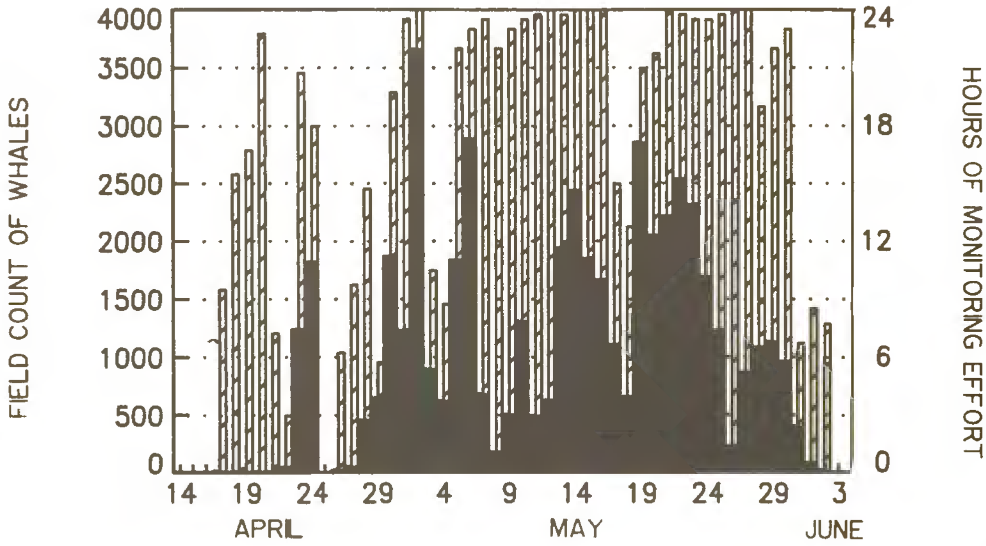


Fig. 3. Daily field counts of bowhead calls (black bars) and numbers of hours of acoustic monitoring effort (hatched bars) during the 1986 season.

recordings. This analysis resulted in 4,636 acoustic locations. Fig. 3 shows a histogram plot of the daily field counts and acoustic monitoring effort for the 1986 season.

The season was divided into four acoustic analysis parts, referred to as 'Soda Pop' (17–24 April), 'Deep Six' (25 April-3 May), 'Polar 1' (4–8 May) and 'Polar 2' (9 May-2 June); named after the different visual observation perch sites and arrays established at those sites. A summary of the acoustic analysis effort and results for the different segments within the four parts of the season is given in Table 1.

Table 1

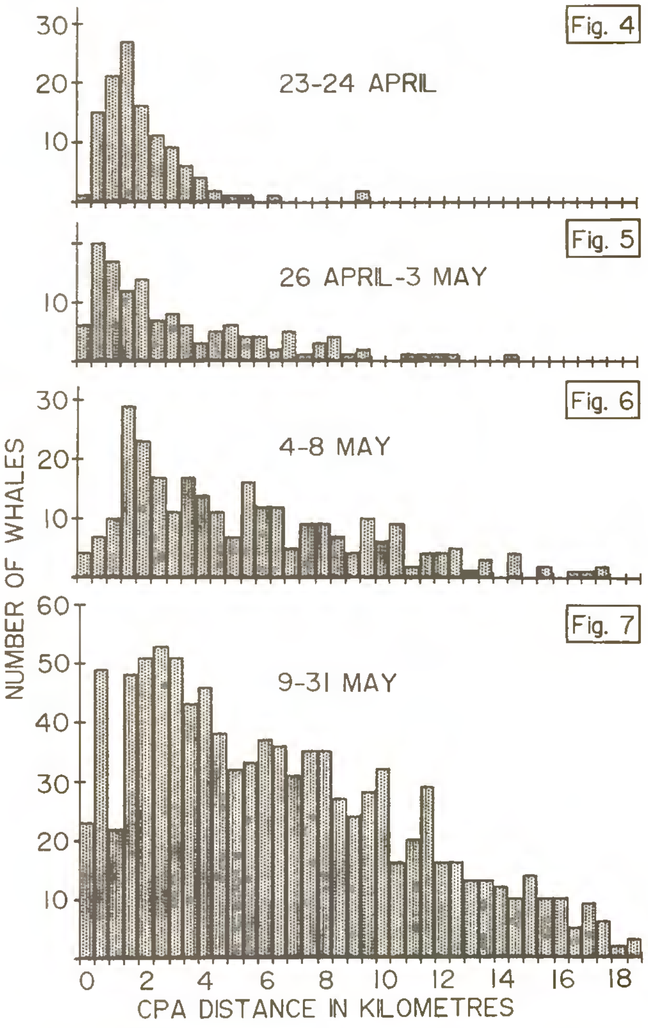
Summary of 1986 acoustic analyses results for segments

Date	Perch	Acoustic condition	Hours analyzed	Lab counts	Acoustic locations	Whales
4/23	Soda Pop	fair	6	983	327	98
4/24	Soda Pop	fair	5	248	55	19
4/29–30	Deep Six	poor	6	1,671	63	21
5/1–2	Deep Six	fair	13	3,870	250	93
5/2	Deep Six	fair	5	864	32	21
5/4	Polar 1	fair	8	830	55	29
5/6–7	Polar 1	poor	32	3,489	589	231
5/8	Polar 1	poor	4	162	59	18
5/10	Polar 2	poor	9	999	180	62
5/10	Polar 2	poor	10	395	93	42
5/12	Polar 2	good	13	427	93	52
5/13	Polar 2	good	9	462	81	40
5/14–15	Polar 2	good-fair	19	2,330	384	112
5/15–17	Polar 2	fair	42	3,515	718	236
5/19–20	Polar 2	fair	16	3,175	959	181
5/21–22	Polar 2	poor	5	479	120	50
5/22	Polar 2	poor	4	701	96	41
5/23	Polar 2	fair	8	1,112	248	72
5/24	Polar 2	poor	4	523	76	33
5/26	Polar 2	poor	5	115	35	14
5/28	Polar 2	poor	4	327	78	19
5/30	Polar 2	poor	4	255	45	24
Total			231	26,932	4,636	1,508

Tracking analysis of the 4,636 acoustic locations yielded a total of 1,508 whales. Figs 4–7 show the uncorrected distributions for the four parts.

The final results of the geometric correction factor analysis are given in Fig. 8 which shows the empirically derived geometric correction factor values for the five different apertures and the interpolated values for 0.5km increments. Here aperture has been converted to its equivalent CPA distance using the equality expressed in (1) above. By this conversion, apertures of 2, 3, 4, 8 and 16km are equivalent to CPA distances of 0.58, 0.87, 1.15, 2.31, and 4.62km, respectively. This figure shows, for example, that with an array length of 2km and sampling restricted to a 120° sector, the number of whales tracked in the first 500m offshore of the array should be multiplied by a factor of 4.5 in order to correct for the shortness of time that the whales are actually within the 120° sector. For whales that are further offshore, and hence spend more time within the 120° sector, the geometric correction factor decreases exponentially. By 4.5km offshore the geometry of the array does not appear to have any affect on our chances of locating vocalizing whales.

Corrected CPA distributions are computed from the original distributions for each of the four parts using the geometric and distance correction factors. Figs 9–12 shows the corrected distributions for the four parts. These figures correspond to the uncorrected distributions as shown in Figs 4–7. Figs 13 and 14 show the original and corrected distributions for all four parts combined, respectively.



Figs 4–7. Acoustic CPA distributions in 1986: (4) Soda Pop period; (5) Deep Six period; (6) Polar 1 period; (7) Polar 2 period.

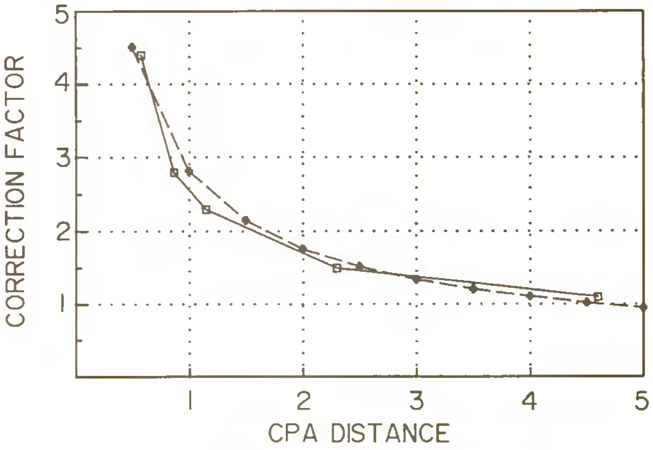
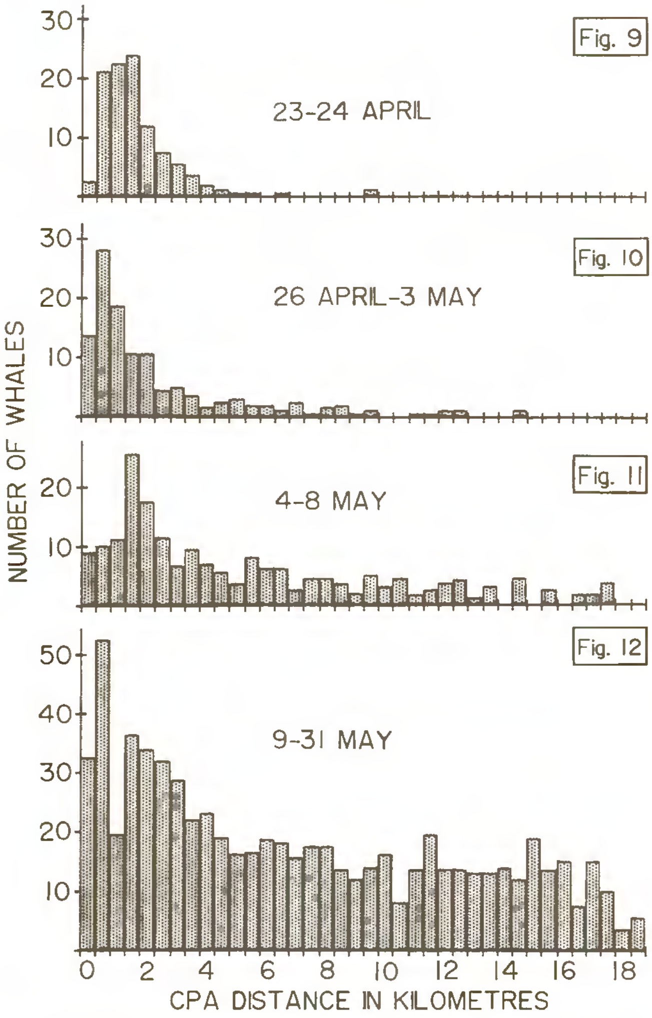
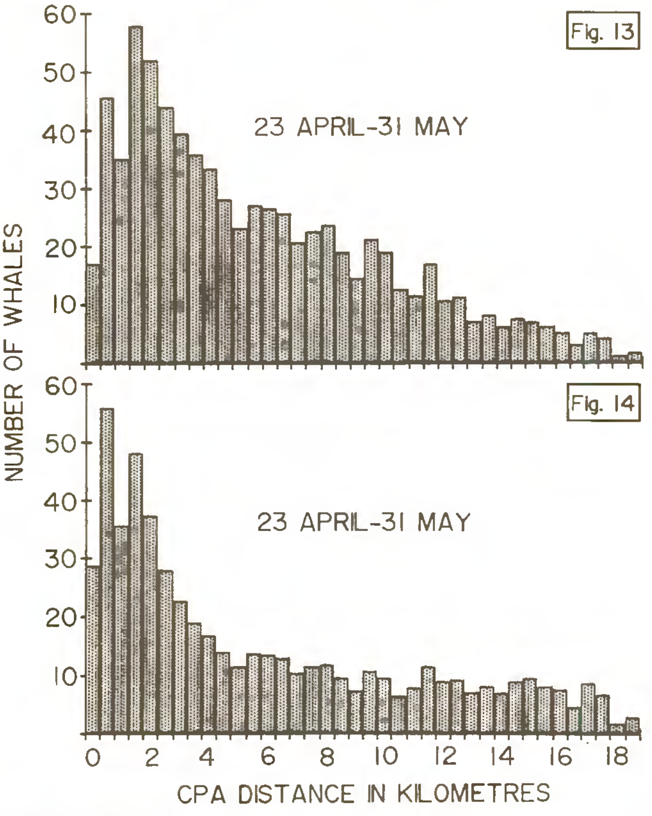


Fig. 8. Emperical (□) and resultant (+) interpolated values of the geometric-correction factor for 1986.

The pairs correction factors for 1986 are 1.2 for the 17 April-3 May period (Soda Pop and Deep Six), 1.1 for the 4 May-8 May period (Polar 1), and 1.2 for the 9 May-2 June period (Polar 2). These factors were the same factors as used in Zeh, Turet, Gentleman and Raftery (1987). The pairs correction factor is applied to the total number of whales detected in each part after correction by the geometric and distance correction factors.



Figs 9–12. Corrected CPA distributions in 1986: (9) Soda Pop period; (10) Deep Six period; (11) Polar 1 period; (12) Polar 2 period.



Figs 13 and 14. CPA distributions for all of 1986: (13) uncorrected; (14) corrected.

Table 2

Call counts and the non-segment correction factor

Part name	Total field count	Segment count	Pre and Post segment count	Corrected segment count	Non-segment correction factor
Soda Pop	3,171	803	758	1,561	2.031
Deep Six	8,846	3,892	1,757	5,649	1.566
Polar 1	6,225	2,677	848	3,525	1.766
Polar 2	32,310	11,745	5,834	17,579	1.838
Totals	50,552	19,117	9,197	28,314	

Table 3

Number of possible hours, hours monitored and the not-monitored correction factor

Part name	Dates covered	Total hours	Hours monitored	Not-monitored correction factor
Soda Pop	17 Apr - 24 Apr	192	113.50	1.692
Deep Six	25 Apr - 3 May	216	114.25	1.891
Polar 1	4 May - 8 May	120	99.50	1.206
Polar 2	9 May - 2 Jun	600	514.00	1.167
Totals		1,128	841.25	

Table 4

Resultant number of whales after application of the correction factors

Part name	Numbers of vocalizing whales				
	Geometric	Distance	Pairs	Non-segment	Not-monitored
Soda Pop	117	207	249	506	856
Deep Six	135	237	284	445	841
Polar 1	278	391	430	759	915
Polar 2	978	1,367	1,641	3,016	3,520
Totals	1,508	2,202	2,604	4,726	6,132

The non-segment correction factor is computed from call counts. These call counts and the resultant non-segment correction factor for each part of the season are listed in Table 2 where the non-segment correction factor is calculated as described above.

The not-monitored correction factor is computed from the field effort data. Total number of possible hours, total hours monitored and the resultant not-monitored correction factor for each of the four different parts of the season are listed in Table 3.

A summary of the resultant numbers of whales per part after application of each of the five different correction factors is given in Table 4. The final total estimate for the entire 1986 season is 6,132 whales.

DISCUSSION

These results indicate that a substantial number of whales were vocalizing as they migrated off Point Barrow in 1986. The results also further support the previous findings from the 1984 and 1985 acoustic studies which showed that a sizeable proportion of whales are not within range of the visual observation perches. For the entire 1986 season, 58% of the whales were >3km from the perch at their closest point of approach after correction for the geometry and distance factors (see Figs 9–12). This compares with a value of 34% for 1985. These values are interesting when compared to those based upon aerial survey transect data (see Zeh *et al.*, 1988, Table 5 based upon Withrow and Goebel–Diaz, 1989) which show that in 1986, 84% of the whales were >3km offshore. Aerial data suffer from small sample sizes, but nonetheless do not contradict the high proportions of offshore whales as presented here based upon a large acoustic sample.

The proportion of whales >3km offshore is not constant throughout the season but increases as the season progresses. In the early part of the season at Soda Pop, only 14% are >3km offshore and this increases to 28% for Deep Six, 57% for Polar 1 and 70% for Polar 2. It might appear that this increase in the number of offshore whales is related to the number of migrating animals; as the density of the migration increases more animals are found offshore. However, it is not substantiated by the actual numbers since the highest density of passage, when averaging number of whales per hour for a given period, occurred during Soda Pop. Therefore, the notion that high proportions of offshore whales are a result of density displacement must be viewed with caution until the variation in the distribution can be studied in detail and not lumped into such large time periods as we have done here.

From the results of the 1985 study we know that acoustic conditions can affect our ability to locate and track vocalizing whales. In 1986 acoustic conditions were generally poor and this is partially reflected in the low proportion of sounds we were able to locate (only 4,636 locations from 19,117 calls). We also believe that some of this inefficiency is a result of so many whales being >10km offshore. For this reason several areas of improvement for the acoustic methods include increasing the size of the array so that our accuracy at these greater distances is improved, and quantifying the ambient noise conditions so that ambient noise can be factored into our acoustic correction procedures. A further area of improvement involves the tracking algorithm which processes acoustic locations into tracks and from which all numbers and distributions as presented here are derived. We know that this program is most sensitive to the values of two parameters; range of swimming speed and deviation in migration direction (Sonntag *et al.*, 1988). The choice of parameter values are presently based on limited visual observation data. Recently, one of us (CWC) presented a procedure for determining tracks based upon the specific acoustic characteristics of bowhead calls (Clark, 1989). These call tracks provide important information about the speed and deviation parameters which, when incorporated into the algorithm, should improve the reliability of future estimates.

ACKNOWLEDGEMENTS

Funding for these studies was provided by the State of Alaska (through the Department of Natural Resources to the North Slope Borough) and by the North Slope Borough, P.O. Box 69, Barrow, Alaska, USA 99723. Thomas Albert (North Slope Borough, Department of Wildlife Management) was a constant source of advice, support and encouragement and was instrumental in the planning and successful completion of this research. We are very grateful to Mayor George Ahmaogak and all the people of Barrow for their support and hospitality during this project. John Craighead George, Luke George, Brendon Kelly, Donna McDonald, Lori Quakenbush and Richard Yackley provided invaluable assistance during the field effort. John Bower, Jane Moon Clark, Susan Minges, Zywia Wojnar and Miriam Wolfenstein were extraordinarily competent assistants during the laboratory analysis and write up.

REFERENCES

Clark, C. W. 1989. The use of bowhead whale call tracks based on call characteristics as an independent means of determining tracking parameters. Report of the Scientific Committee, Annex G, Appendix 2. (Published in this volume).

Clark, C.W., Ellison, W.T. and Beeman, K. 1986a. An acoustic study of bowhead whales, *Balaena mysticetus*, off Point Barrow, Alaska during the 1984 Spring migration. A Report to the North Slope Borough, Department of Wildlife Management. Marine Acoustics. 145pp.

Clark, C.W., Ellison, W.T. and Beeman, K. 1986b. A preliminary account of the acoustic study conducted during the 1985 spring bowhead whale, *Balaena mysticetus*, migration off Point Barrow, Alaska. *Rep. int. Whal. Commn* 36: 311–16.

Clark, C.W., Ellison, W.T. and Beeman, K. 1986c. Acoustic tracking of migrating bowhead whales. *IEEE Oceans '86 Conf. Proc*: 341–6.

Clark, C.W. and Ellison, W.T. 1988. Numbers and distributions of bowhead whales, *Balaena mysticetus*, based on the 1985 acoustic study off Pt. Barrow, Alaska. *Rep. int. Whal. Commn* 38: 365–70.

Clark, C.W. and Johnson, J.H. 1984. The sounds of the bowhead whale, *Balaena mysticetus*, during the spring migrations of 1979 and 1980. *Can. J. Zool.* 62: 1,436–41.

Cummings, W.C. and Holliday, D.V. 1985. Passive acoustic location of bowhead whales in a population census off Point Barrow, Alaska. *J. Acoust. Soc. Am.* 78: 1,163–69.

Ellison, W.T., Clark, C.W. and Beeman, K. 1986. Acoustic location techniques and calibration methods used during the spring 1984 and 1985 bowhead whale, *Balaena mysticetus*, migrations. Paper SC/37/PS11 presented to the IWC Scientific Committee, June 1986. (Unpublished).

Ljungblad, D.K., Thompson, P.O. and Moore, S.E. 1982. Underwater sounds recorded from migrating bowhead whales, *Balaena mysticetus*, in 1979. *J. Acoust. Soc. Am.* 71:477–82.

Nerini, M.K. and Rugh, D.J. 1986. Distribution of bowhead whales in the vicinity of Point Barrow, Alaska: aerial observations, 1984 and 1985. *Rep. int. Whal. Commn* 36: 359–61.

Raftery, A.E., Zeh, J.E. and Styer, P. 1988. Bayes empirical Bayes interval estimation of bowhead whale, *Balaena mysticetus*, population size based upon 1985 and 1986 combined visual and acoustic censuses off Point Barrow, Alaska. Paper SC/40/PS6 presented to the IWC Scientific Committee, May 1988. (Unpublished).

Sonntag, R.M., Ellison, W.T. Clark, C.W., Corbit, D.R. and Krogman, B.D. 1986. A description of a tracking algorithm and its application to bowhead whale acoustic location data during the spring migration near Point Barrow, Alaska 1984–85. *Rep. int. Whal. Commn* 36: 299–310.

Sonntag, R.M, Ellison, W.T. and Corbit, D.R. 1988. Parametric sensitivity of a tracking algorithm to the migration of bowhead whales, *Balaena mysticetus*, near Pt. Barrow, Alaska. *Rep. int. Whal. Commn* 38: 337–47.

Withrow, D. and Goebel-Diaz, C. 1989. Distribution of bowhead whales near Point Barrow, Alaska, 1984–1986. (Published in this volume).

Zeh, J.E., Turet, P., Gentleman, R. and Raftery, A.E. 1987. Population size estimation for the bowhead whale, *Balaena mysticetus*, based on 1985 and 1986 visual and acoustic data. Paper SC/39/PS7 presented to the IWC Scientific Committee, June 1987. (Unpublished).

Zeh, J.E., Turet, P., Gentleman, R. and Raftery, A.E. 1988. Population size estimation for the bowhead whale, *Balaena mysticetus*, based on 1985 visual and acoustic data. *Rep. int. Whal. Commn* 38: 349–64.

Zeh, J.E., Raftery, A.E. and Styer, P. 1988. Mark-recapture estimation of bowhead whale, *Balaena mysticetus*, population size and offshore distribution from 1986 visual and acoustic data collected off Point Barrow, Alaska. Paper SC/40/PS5 presented to the IWC Scientific Committee, May 1988. (Unpublished).

SC/40/PS11

Distribution of Bowhead Whales near Point Barrow, Alaska, 1984–1986

David Withrow and Camille Goebel-Diaz

National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service,
National Oceanic and Atmospheric Administration, 7600 Sand Point Way, Bin C15700,
Seattle, Washington 98115–0070, USA

ABSTRACT

Aerial surveys were flown over the nearshore lead near Point Barrow, Alaska, each spring from 1984–86, to determine the distribution of migrating bowhead whales *Balaena mysticetus* and to evaluate the relative proportion of the population missed by the ice-based census. Data from transects flown in 1979, 1981 and 1984 showed that 19% of the whales passed beyond the effective distance of the ice-based census observer's visual range (i.e. further than 3km from the shorefast ice edge). In 1985, 61% of the whales seen on transects were beyond 3km from the shorefast ice edge (N=33) and in 1986, 84% (N=31). However, an analysis of data collected during the same period in 1986 on surveys designed to photograph and determine the length structure of the population, showed that 42% of the whales photographed were beyond 3km (N=80). This figure is still substantially higher than in previous years, but significantly less than observed during the transect surveys. Data collected during systematic transect surveys should be less biased than the pooled photogrammetric data. However, it was our subjective opinion that the transect distribution did not reflect the distribution of the whales we observed. Although the photogrammetric distribution data could be biased, it provides an alternative data set useful for estimating abundance. These differences are important since the proportion of the population that migrates beyond the visual range of the ice-based observers will significantly affect any population estimate.

In 1986, immature whales were located significantly further offshore (p=0.0001) than other size categories of whales. No significant segregation by size class was found for 1985.

INTRODUCTION

The spatial distribution of bowhead whales (*Balaena mysticetus*) during the spring migration past Point Barrow, Alaska, is of critical importance to the estimation of population size. The percentage of the population that migrates beyond the visual range of the North Slope Borough ice-based observers must be determined before a statistically reliable estimate of missed whales can be made.

Previous analyses have attempted to examine the apparent decline in visual sightings as sighting distance increased (Krogman, Ko, Zeh, Grotefendt and Sonntag, 1983; Hammond, 1984; Krogman, George, Carroll, Zeh and Sonntag, 1987; George and Carroll, 1987). Acoustic studies have localized the positions of vocalizing whales as they migrated past the census observers (Cummings and Holiday, 1985; Clark, Ellison and Beeman, 1986), as an indirect means to determine the distribution beyond the census camps. Two problems with these approaches are that the accuracy and number of localizations decrease with distance (Nerini and Rugh, 1986).

The National Marine Mammal Laboratory has conducted aerial photogrammetric and transect surveys of bowhead whales in the vicinity of Point Barrow since 1984. The objective of the transect surveys was to estimate the spatial distribution of whales travelling in the nearshore lead. These results were to be used in conjunction with the results of the ice-based visual and acoustic censuses to estimate the abundance of bowhead whales. Aerial observations offer uniform sighting capability along a transect line, thus eliminating the major bias described above. Drawbacks to this method, however, include small sample sizes and the inability to see whales travelling under the ice. Increased density of ice might decrease the sightability of whales, because of the increased probability whales will be travelling under the ice, thus rendering a downward bias with increased ice coverage. However, the opposite could also be true because observers concentrate their search on the few open areas where whales could surface.

This paper addresses the distribution of whales across the lead system in 1984–86 near Point Barrow, Alaska, to help develop correction factors for the proportion of missed whales by the ice census observers. Our objective is to point out possible biases in the existing data and the need for dedicated aerial surveys as a way to support current methods used to estimate the population size of bowhead whales.

METHODS

Aerial surveys were usually conducted between 15 April and 7 June during the spring migration when whales pass Point Barrow, except in 1986 when surveys began on 1 May. In 1985 and 1986, a *DeHavilland Twin Otter* aircraft was used equipped with a *Global Navigation System* (GNS), bubble windows, an onboard computer interfaced with the GNS, a radar altimeter and photogrammetric and photo-identification camera systems. In 1984, the aircraft used was an *Aero Commander Shrike*. Transects were flown at 305m (1,000ft) altitude (ceiling permitting) at an airspeed of 170km/hr (90 knots). Two parallel transect lines, separated by 4km, were flown starting from and perpendicular to the ice edge and extending 30km offshore. The first transect leg began 4km NE of the northernmost active census camp, and the second leg terminated at the shorefast ice edge over the census camp. The viewing strip on each side of the aircraft was 2km.

We also conducted a photogrammetric study in addition to the transect surveys in which precise, high resolution photographs were taken to determine the length of individual whales. More detailed descriptions of both these methodologies appear in Nerini and Rugh (1986) and Nerini, Withrow and Strickland (1987).

The positions of individual whales were plotted (by computer) by size class and location. The distance from each whale to the shorefast ice edge was calculated using a digitizer and computer.

RESULTS AND DISCUSSION

Distribution of whales offshore

The distributions of bowhead whales from the shorefast ice edge for the years 1984, 1985 and 1986 are illustrated in Figs 1a-c, respectively. Ice-based observers can accurately detect whales out to 3km but only rarely are observers able to detect whales 5km and beyond (Zeh, Raftery and Styer, 1988).

Fig. 1a (1984) is typical of results from aerial surveys made in previous years, with 94% of the whales being sighted within 3km of the ice-edge (Withrow and Nerini, 1987; Nerini and Rugh, 1986). Results from 1979, 1981 and 1984 combined indicated that 81% of the whales sighted during transects were within 3km of the shorefast ice edge. However, results in 1985 and 1986 were significantly different (Figs 1b and c), with 39% and 16% of the whales sighted within 3km of the shorefast ice edge, respectively. In other words, 61% of the whales in 1985 and 84% in 1986 could have passed beyond the effective visual range of the ice-based observers.

In 1986, the mean distance whales were seen from the shorefast ice edge was 11.9km and the furthest sighting offshore was 28km, much further than in any previous year. The total sample size for 1986 was small ((N=31) although 51 transect legs were flown covering 1,510km. This distribution however was not representative, in our subjective opinion, of the distribution we saw during the photogrammetric surveys (which made up 90% of our survey time), when the proportion of whales seen nearshore was larger.

One would expect that data collected using standard transect methods (strip census) would be less biased than the pooled photogrammetric data where surveys were conducted to maximise the number of whales photographed. However, if the transect sample size is small, then the estimate of the distribution may be imprecise. It is our opinion that this was the case for the 1986 transect data. To further examine this and provide an alternative data set for the offshore distribution of bowhead whales, sightings from the 1986 photogrammetric database were plotted and the distance to the shorefast ice edge measured. The sample area began at the southernmost census camp in use (either 'Polar Perch' or 'Deep Seven') and extended approximately 42km northeast (to 71°28.6′N, 156°51.0′W). Lead conditions in this area resembled those seen from the census site. The nearshore lead becomes less well defined further north and east of this point in all years. We did not survey south of the census camp at the request of the whalers.

Fig. 1d reveals that for the 1986 photogrammetric database, 58% of the bowhead whales were observed within 3km of the ice edge, thus 42% were seen beyond 3km (mean=4.9km). Although the proportion seen beyond 3km is higher than in previous years, it is substantially less than the 84% observed during transect surveys.

There are several factors that might bias the calculated distribution from the pooled photogrammetric data: (1) there is no indication of lead width at the point of each sighting; (2) only whales that could be measured were included in the analysis (although some whales were missed, this should have occurred with equal frequency regardless of distance from the lead edge); and (3) compared to transect data, effort is not as quantifiable. Photogrammetric operations occurred out to 75km from

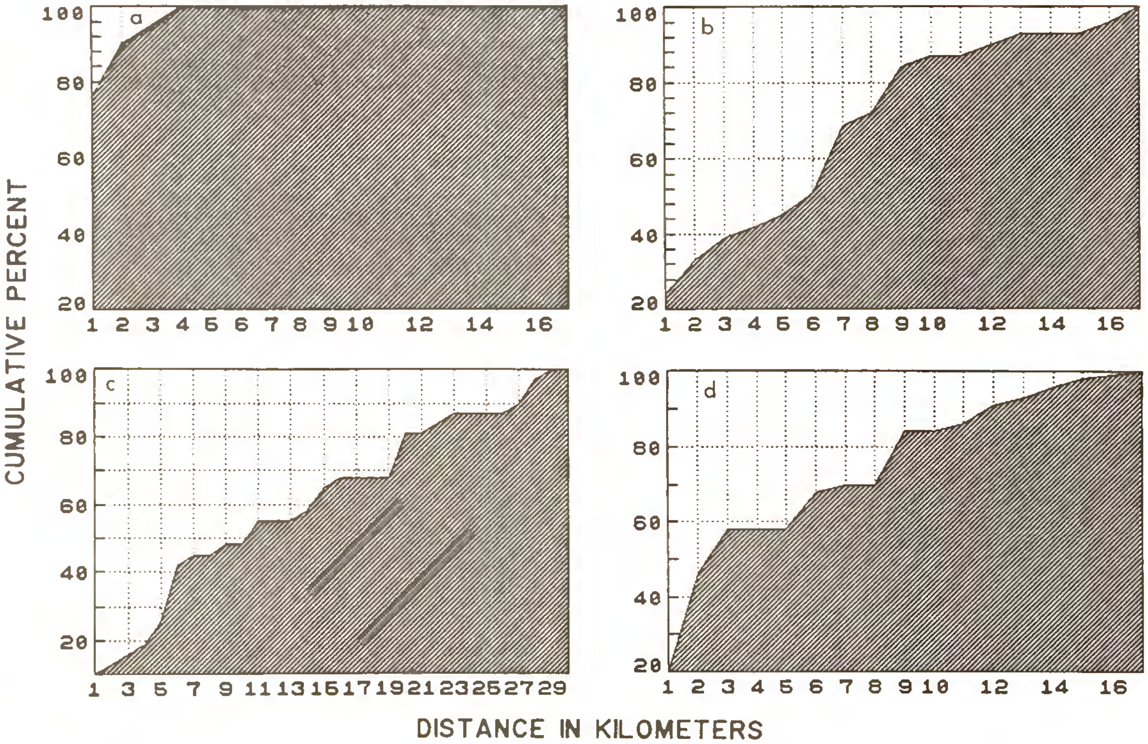


Fig. 1. Bowhead whale offshore distribution. The shaded area represents the cumulative percent of whales found within each 1km distance category seaward from the shorefast ice-edge, while the unshaded area above represents the proportion beyond that distance. (a) 1984 transect survey, N=21. (b) 1985 transect survey, N=33. (c) 1986 transect survey. (d) 1986 photogrammetric survey.

the shorefast ice edge; however, much of the time was spent in the productive nearshore lead where whales were consistently found and open water was more prevalent.

Distribution by size class

The 1985 (Fig. 2a) and 1986 (Fig. 2b) photogrammetric data were divided into four size classes of whales and plotted against the distance from the shorefast ice edge. The size categories were cows with calves (calf <6.8m), yearlings (6.8–8.49m), immatures (8.5–12.99m), and adults (⩾13.0m) based on Nerini *et al.* (1987). The data were grouped by 5km distance intervals by size class. For 1985, no significant differences in distance from the shorefast ice edge by size class were found (chi-square=1.87, p=0.60, N=294). In 1986 however, immatures were significantly further from the shorefast ice edge in the survey area than adults and cows with calves (Chi-square=23.96, p=0.0001; the yearling category was dropped because of low sample size, N=2). This difference may be real or an artifact of small sample sizes (1986, N=78).

In 1986 conditions were unusual in that from 2–15 May, the migratory corridor was completely open, without significant ice, out to at least 20km offshore. As the season progressed, the weather became colder and the distances across the lead narrowed, in contrast to the normal situation. By 15 May, over half of our photogrammetric images were taken, over half of the whales had passed Point Barrow (George and Carroll, 1987) and 84% of our transect sightings had occurred. Usually, the shore lead is much narrower, especially during peak migration around mid-May and the whales do not migrate through the thick pack ice further offshore when the lead is well defined.

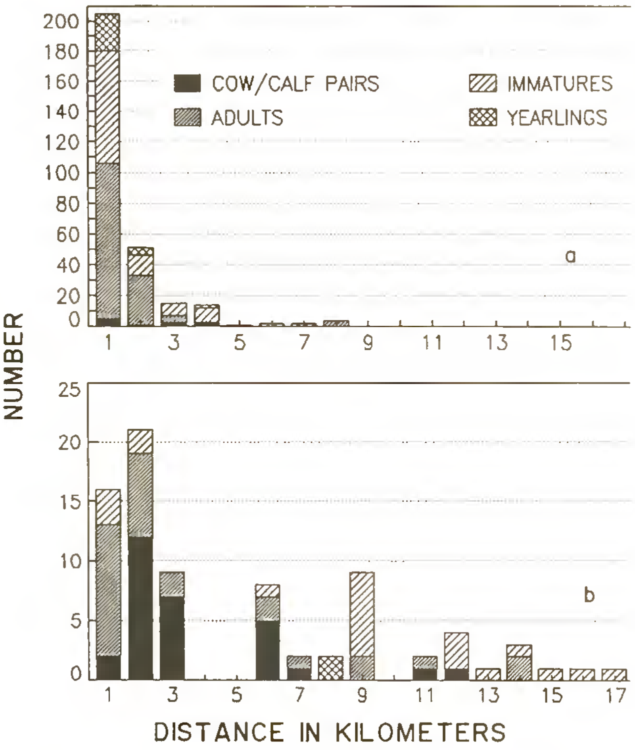


Fig. 2. Bowhead whale distribution offshore by size class. (a) 1985 Cows with calves N=11; adults N=143; immatures N=106; yearlings N=34. (b) 1986 Cows with calves N=29; adults N=28; immatures N=21; yearlings N=2.

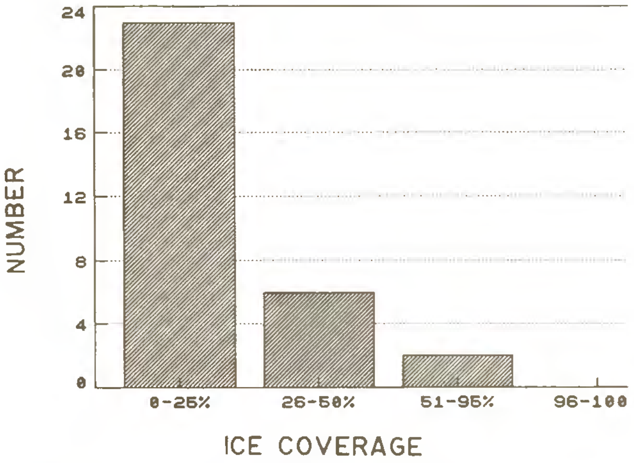


Fig. 3. Distribution of bowhead whale sightings in 1986 as a function of percent ice coverage.

Distribution by ice cover

Of the whales seen during transects in 1986, 74% (N=23) were in areas with 0–25% ice coverage (Fig. 3). The degree of ice cover did not increase uniformly with distance from the shorefast ice-edge and whales were seen in regions of lighter ice regardless of the distance from the shorefast ice edge. In the latter part of the season, the ice cover was often denser near the shorefast ice edge than it was further offshore. Whales at these times were seen in light ice both near and far from the shorefast ice edge, as well as in the dense ice near the shorefast ice edge. Therefore, there was an unusually wide distribution of whales in 1986 since the lead conditions were less well defined than in other years and the whales migrated past in areas where the ice coverage and thickness was minimal.

CONCLUSION

An accurate estimate of abundance and trends in the bowhead population requires a statistically reliable estimate of the number of whales missed by the ice based observers. Aerial survey is the only current method which can give independent and unbiased estimates of the distribution of whales within and beyond the effective range of both visual and acoustic detection methods. It is our opinion that aerial surveys should be dedicated solely for the purpose of obtaining systematic transect data throughout the entire season to ensure proper sample sizes are obtained.

This paper provides an additional dataset for the 1986 offshore distribution of bowhead whales. We realise the numerous potential biases with using data from photogrammetric surveys to predict the offshore distribution, but it is our opinion that the 1986 photogrammetric dataset better represents the actual distribution. Future population studies should include systematic aerial surveys (line or strip census methods) of sufficient sample size to ensure precise estimates of the offshore distribution.

ACKNOWLEDGEMENTS

Howard Braham, Linda Jones, Dale Rice, Anne York, Jeff Breiwick and Judy Zeh provided helpful reviews of this paper. Mary Nerini's ideas and direction were invaluable. David Rugh contributed his knowledge, field expertise and a critical review of the manuscript. Kathy Strickland and Joanna Flanders helped collect and process the data. Tom Albert, Craig George and Geoff Carroll of the North Slope Borough provided additional field assistance.

REFERENCES

Clark, C.W., Ellison, W.T. and Beeman, K. 1986. A preliminary account of the acoustic study conducted during the 1985 spring bowhead whale *Balaena mysticetus* migration off Point Barrow, AK. *Rep. int. Whal. Commn* 37: 311– 17.

Cummings, W.C. and Holiday, D.V. 1985. Passive acoustic locations of bowhead whales in a population census off Point Barrow, Alaska. *J. Acoust. Soc. Am.* 78(4): 1163–9.

George, J.C. and Carroll, G.M. 1987. Overview of the 1985 and 1986 visual and acoustic census of bowhead whales off Point Barrow, Alaska with observations on the subsistence harvest. Abstract in the Fourth Conf. on the Biol. of the Bowhead Whale, *Balaena mysticetus*. March 4–6, 1987. Anchorage, Alaska. 6pp.

Hammond, P.S. 1984. On the application of line transect sampling to estimation of the number of bowhead whales passing the Point Barrow ice camps. *Rep. int. Whal. Commn* 34: 465–7.

Krogman, B., Ko, D., Zeh, J., Grotefendt, R. and Sonntag, R. 1983. Experimental design considerations for the use of acoustic data to correct for whales missed by the ice-based census. *Rep. int. Whal. Commn* 35: 445– 56.

Krogman, B., George, J., Carroll, G., Zeh, J. and Sonntag, R. 1987. Preliminary results of the 1985 spring ice-based census of the bowhead whale, *Balaena mysticetus*, conducted near Point Barrow, Alaska. *Rep. int. Whal. Commn* 37: 343–52.

Nerini, M.K. and Rugh, D.J. 1986. Nearshore distribution of bowhead whales in the vicinity of Point Barrow, Alaska from aerial observations 1984–1985. *Rep. int. Whal. Commn* 36: 359–61.

Nerini, M., Withrow, D. and Strickland, K. 1987. Length structure of the bowhead whale population derived from aerial photogrammetry with notes on recruitment, spring 1985 and 1986. Paper SC/39/PS14 presented to the IWC Scientific Committee, May 1987 (unpublished). 22pp.

Withrow, D. and Nerini, M. 1987. Bowhead whale distribution within the lead in the vicinity of Point Barrow, Alaska, May 1986 as determined by aerial survey. Abstract in the Fourth Conf. on the Biol. of the Bowhead Whale, *Balaena mysticetus*. March 4–6, 1987. Anchorage, Alaska. 4pp.

Zeh, J.E., Raftery, A.E. and Styer, P.E. 1988. Mark-recapture estimation of bowhead whale, *Balaena mysticetus*, population size and offshore distribution from 1986 visual and acoustic data collected off Point Barrow, Alaska. Paper SC/40/PS5 presented to the IWC Scientific Committee, May 1988, (unpublished). 31pp.

SC/40/PS13

A Note on the Spatial Distribution of Gray Whales off Chukotka

S.A. Blokhin

Pacific Research Institute of Fisheries and Oceanography (TINRO), 690600 Vladivostok, USSR

ABSTRACT

The sex, length composition and reproductive data for gray whales taken off Chukotka from July-November 1980–87 are presented. The data suggest a heterogeneous distribution of whales off Chukotka. Males predominate among whales feeding in summer in the Chukchi Sea. Immature whales feed mainly in inshore waters. Pregnant females feed more at greater depths where the density of prey is probably greatest. Non-pregnant females are distributed relatively evenly over the feeding grounds. Some pregnant females may remain off Chukotka as late as November.

INTRODUCTION

Most of the California-Chukotka population of gray whales feed off Chukotka in summer-autumn, but their distribution patterns there are not well understood.

Previous investigations (Bogoslovskaya *et al.*, 1981, 1982; Krupnik *et al.*, 1983; Blokhin, 1983; 1986) only allow the conclusion that younger animals, as a rule, keep closer to the shore, at lesser depths. This paper examines the 1980–87 catch data to see if they can provide further information on the distribution pattern.

MATERIALS AND METHODS

Data were collected during the subsistence hunting of gray whales from 1980–87 (e.g. see Blokhin, 1982–87). Most of the whales were examined during flensing in the village of Lorino where 70–80 animals (41–47% of all taken whales) are annually taken. In addition observations were carried out at the villages of Yanrakynnot and Sireniki. The whaling areas off Chukotka have been divided into nine main sub-areas in which the sites with the highest number of whales killed were marked (Fig. 1).

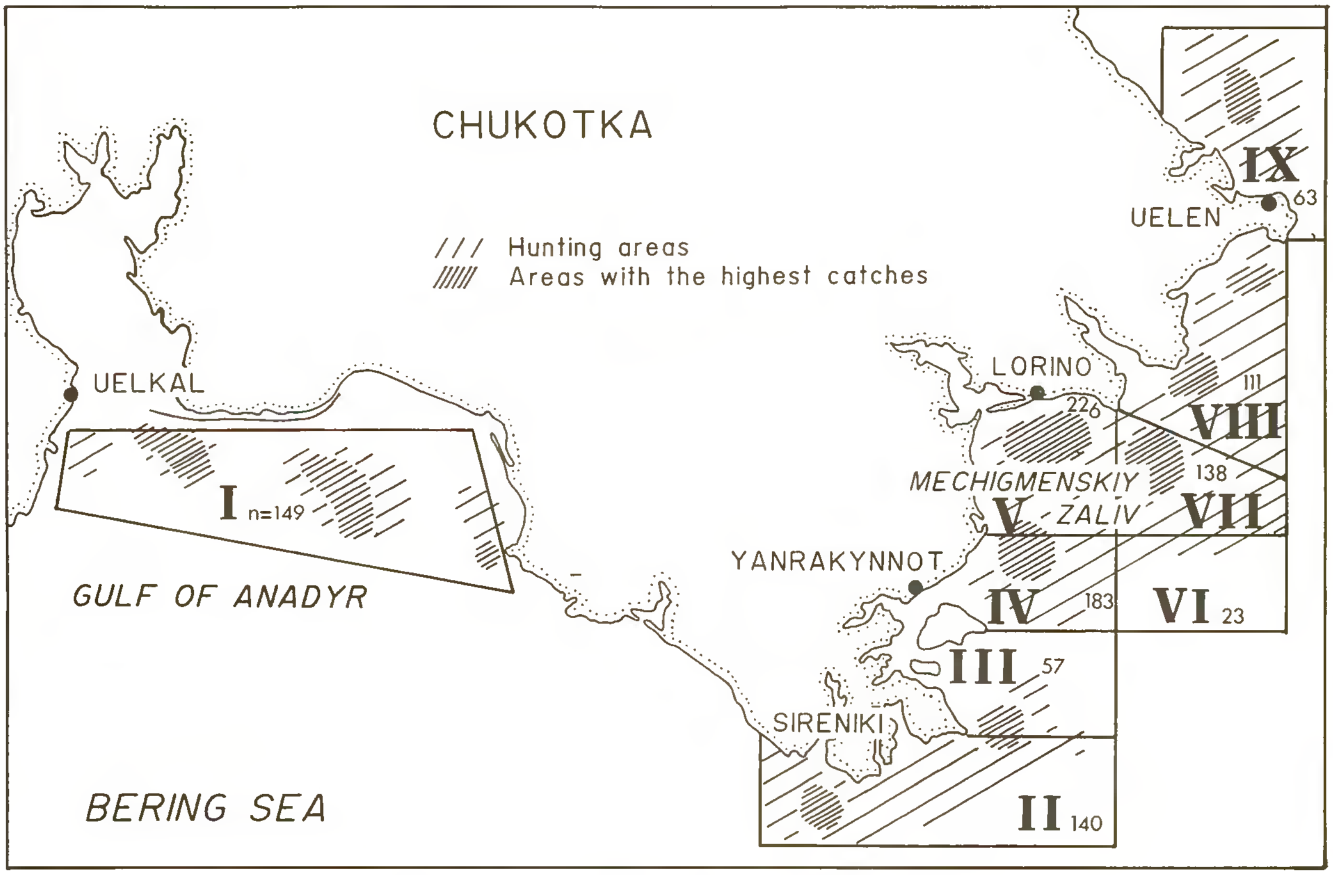


Fig. 1. Hunting areas of gray whales off Chukotka in 1980–1987.

The preferential kill of larger whales and the changing needs of the native population by year and month makes a non-biased evaluation of certain characteristics difficult. Therefore some of the data given in the tables, especially those with small sample sizes, are not discussed below.

RESULTS AND DISCUSSION

Analysis of the data of commercial operations showed that females predominated in the catch in the Bering Sea (sub-areas I-VIII, Table 1). This pattern was observed for all years where whales were taken by the modern catcher boat (Blokhin, 1979, 1982–87; Zimushko and Ivashin, 1980).

As it is impossible to determine the sex of a whale in the water, the prevalence of females in the kill is mainly related to their larger size (Blokhin, 1979; Zimushko and Ivashin, 1980). However, despite this, there is evidence to suggest a heterogenous distribution of the sexes in the foraging range. Differences in the sex ratio in the catch in the more offshore areas were not as great as in the inshore areas (Blokhin, 1983; 1984) while the values for 1980 revealed considerable variation in the sex ratio by month (Blokhin, 1982). However, pooling the catch data over eight years (1980–87) presents a somewhat different picture (Table 1).

Table 1

Percentage of females in the catch in various areas and at various times off Chukotka (1980–87). n = sample size

Area	n	% Females	Month	% Females
I	149	73.2	July	74.2
II	140	65.7	August	69.2
III	57	63.2	September	70.7
IV	183	75.9	October	71.7
V	226	75.7	November	69.2
VI	23	74.0		
VII	138	73.2		
VIII	111	76.6		
IX	63	50.8		
Total	1,090	71.8		

The percentages of females in the catch in the sub-areas of the Bering Sea (I-VIII, Fig. 1) were similar both among each other and by month (females always predominant). However the sex ratio in the catch in the Chukchi Sea was 1:1 over the 8 years, and in some years males even predominated. This suggests that the sexes do distribute unevenly over the feeding grounds, with possibly most males spending the summer in the Chukchi Sea, where the highest numbers of feeding whales are found in August (Blokhin, 1988). A further pointer to the uneven distribution by sex is that from the catch data, with females predominating, an 'excess' of males of the order of over 1,500 should have occurred in the population since 1969. If they were distributed evenly over the feeding grounds then this should have been reflected in the sex ratio of the catch.

As noted above, young whales tend to be found in inshore areas with shallow waters. The available data reveal some differences in the mean lengths of whales taken by sub-area. The largest mean lengths for both sexes were in sub-areas II, VII and VIII (Table 2). The range in lengths, however, is similar for all areas. The smallest mean lengths for both sexes were in sub-areas III and V. For benthos feeders, it is easier for young animals to feed in shallow waters (<25m) such as those found in Mechigmenskiy Zaliv (sub area V). In the other sub-areas the whales mainly stay in waters of 35–50m deep.

Table 2

Mean size (in metres) of gray whales taken off Chukotka in various areas (1980–87). n = sample size

	Females		Males			Females		Males	
Area	n	Size	n	Size	Area	n	Size	n	Size
I	19	11.6	5	11.3	VI	–		–	
II	13	12.6	9	11.8	VII	73	12.1	34	11.7
III	5	11.4	7	11.1	VIII	21	12.3	17	11.5
IV	106	12.0	23	11.2	IX	1	12.2	1	12.3
V	130	11.5	58	10.7					

There are insufficient sample sizes for some areas and this precludes any detailed comparison among them. Here only sub-areas V, IV and VII are examined. The sex ratio was similar for each area (73.2–75.9% females). The highest percentages of immature and resting females were in the shallow waters (sub-area V) with pregnant females occurring relatively more often in deeper waters (sub-areas IV and VII) (Table 3). Pregnant females have greater energetic requirements and probably choose the deeper waters which are rich in food biomass.

Table 3

Breeding state of females (%) taken in various areas off Chukotka (1980–87). n = sample size

Area	n	Immature	Non-pregnant	Pregnant
I	19	57.9	10.5	31.6
II	11	18.2	72.7	9.1
III	9	33.3	55.6	11.1
IV	98	28.6	48.0	23.4
V	134	43.3	41.0	15.7
VI	2	50.0	–	50.0
VII	78	25.6	43.6	30.8
VIII	32	40.6	34.4	25.0
IX	1	–	100	–

An examination of the occurrence of females by reproductive state by month (Table 4) shows that the percentages of immatures was around 30–37% from July–October for the pooled data, although there was significant variation by month among years. Pregnant females were most often taken in July-August. The previously expressed view that in general pregnant females leave the feeding grounds first on their migration to the calving regions (Rice and Wolman, 1971; Blokhin, 1982) is confirmed by these data. However, the fact that some

Table 4

Breeding state (%) of gray whales taken in various months off Chukotka (1980–87). n = sample size. Ranges are given in parentheses. * = of mature whales

Month	n	Immature	Non-pregnant	Pregnant
July	23	30.4 (25.0–35.3)	17.0 (5.9–25.0)	52.6 (0–58.0)
August	68	33.8 (7.7–62.5)	36.8 (12.5–53.8)	29.4 (10.0–45.5)
September	135	37.0 (10.0–53.8)	43.7 (28.6–66.7)	19.3 (0–41.7)
October	114	33.3 (25.0–100)	47.4 (0–66.7)	19.3 (5.0–37.5)
November	16	62.5 (25.0–100)	25.0 (0–63.7)	12.5 (0–25.0)
For Season	356	36.0	41.0 64.0*	23.0 36.0*

pregnant females are still taken even as late as November (up to 25% of the female catch in that month) shows that some of them may stay off Chukotka up to the arrival of the ice (the latest capture data for a pregnant female was in sub-area V on 8 November). These late-stay pregnant females may be ensuring that they have sufficient food reserves for the high energy demands of the coming months and may be females who conceived late in the season. Assuming a mean rate of southerly travel of 185km a day on the 9,000km journey to the breeding areas (Rice and Wolman, 1971), means that gray whales could in fact remain off Chukotka until December, and still arrive at the calving areas by middle January – early February, i.e. at parturition time (Rice and Wolman, 1971).

CONCLUSIONS

This brief analysis of the whaling data for the eight years 1980–87 does not give a complete picture of the distribution pattern of gray whales off Chukotka. However, it does provide some useful information:

(1) most males feed in the Chukchi Sea whilst females predominate in the inshore areas of the Bering Sea;
(2) whales of a wide length range feed off Chukotka, with immatures keeping closer to the shore, and adults in deeper waters;
(3) pregnant females are distributed relatively evenly over deeper (and richer) areas;
(4) although in general pregnant females are the first to leave the feeding grounds this is not true for all pregnant females with some remaining as late as November.

REFERENCES

Blokhin, S.A. 1979. On the status of the gray whale stocks in the coastal waters of the Chukotka peninsula. *Rep. int. Whal. Commn* 29: 335–6.

Blokhin, S.A. 1982. Investigation of gray whales taken off Chukotka in 1979. *Rep. int. Whal. Commn* 32:375–80.

Blokhin, S.A. 1984. Investigation of gray whales taken off Chukotka in 1982. *Rep. iint. Whal. Commn* 34: 461–3.

Blokhin, S.A. 1985. Investigations of gray whales taken off Chukotka in 1983. *Rep. int. Whal. Commn* 35: 371–4.

Blokhin, S.A. 1986. Investigations of gray whales taken off Chukotka in 1984. *Rep. int. Whal. Commn* 36: 287–90.

Blokhin, S.A. 1987. Investigations of gray whales taken off Chukotka in 1985. *Rep. int. Whal. Commn* 37: 337–9.

Blokhin, S.A. and Vladimirov, V.L. 1983. Investigations of Gray whales taken off Chukotka in 1981. *Rep. int. Whal. Commn* 33: 553–5.

Bogoslovskaya, L.S., Votrogov, L.M. and Semenova, T.N. 1981. Feeding habits of the gray whales of Chukotka. *Rep. int. Whal. Commn* 31: 507–10.

Bogoslovskaya, L.S., Votrogov,L.M. and Semenova, T.N. 1982. Distribution and feeding of gray whales off Chukotka in the summer and autumn of 1980. *Rep. int. Whal. Commn* 32: 385–9.

Krupnik, I.I., Bogoslovskaya, L.S. and Votrogov, L.M. 1983. Gray whaling off the Chukotka Peninsula: past and present status. *Rep. int. Whal. Commn* 33: 557–62.

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.

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.

Small Cetaceans

Long-finned pilot whale off Spain, summer 1983.

SC/40/SM1

Composition of the 1987 Incidental Kill of Small Cetaceans in the US Purse-Seine Fishery for Tuna in the Eastern Tropical Pacific

Susan J. Chivers, Aleta A. Hohn, and Ruth B. Miller

Southwest Fisheries Center, National Marine Fisheries Service,
NOAA, P.O. Box 271, La Jolla, California 92038 USA

ABSTRACT

Data are presented for the 1987 incidental kill of small cetaceans by US-registered purse-seine vessels collected by the Inter-American Tropical Tuna Commission and the National Marine Fisheries Service on 123 vessel-trips. Composition of the kill is reported by area, species, sex, length and, for females, reproductive condition.

INTRODUCTION

Dolphins have been incidentally killed in the eastern tropical Pacific (ETP) tuna purse-seine fishery since 1959. In 1968, the National Marine Fisheries Service (NMFS) began to monitor mortality and estimate reproductive rates for the purpose of assessing the effects of the fishery on dolphin stocks. This program is on-going and includes the sampling of all US-registered vessels. In January 1979, the Inter-American Tropical Tuna Commission (IATTC) began a complementary program to collect data on both US-registered and non-US-registered vessels. The incidental kill of small cetaceans by the international fleet has been documented by Hall and Boyer (1986; 1987).

The species most frequently killed as a result of fishery operations are spotted dolphins (*Stenella attenuata*), spinner dolphins (*S. longirostris*) and common dolphins (*Delphinus delphis*). Several other species of small cetaceans are also incidentally killed, although in relatively low numbers. The composition of the US kill of small cetaceans from 1979–1986 has been documented in a series of five reports (Perrin and Oliver, 1982; Oliver, Walker and Miller, 1983; Wahlen, Walker, Miller and Oliver, 1986; Wahlen, Miller and Macky, 1987; and Wahlen, Miller and Ladrana, 1988). The purpose of this report is to document the incidental kill of small cetaceans by US-registered vessels during 1987.

METHODS

Data were collected by both IATTC and NMFS biological technicians (observers) aboard US-registered tuna purse-seine vessels fishing in the ETP. These include US-registered vessels chartered by non-US companies. In previous years, selection of a sample of vessels has been determined using methods described by Lo, Powers and Wahlen (1982). However, beginning on 1 January 1987, observers were placed on all US-registered purse-seiners operating in the ETP. The only US-registered vessels operating in 1987 without observers were those that were out at sea prior to 1 January 1987 and remained at sea into calendar year 1987.

The observers collect information about the schools of dolphins involved in the fishery, as well as about individual animals. The tally data collected by the observers include the number of dolphins incidentally killed during fishing operations by geographic location, species, stock and sex. The life history data are a subset of the observed kill as they are the biological data (e.g., specimen length and reproductive condition) collected from individual dead animals. Specimen collection procedures for life history data have been described by Perrin, Coe and Zweifel (1976). The data forms used to collect life history and tally information are included as appendices in Perrin and Oliver (1982), while Henderson, Perrin and Miller (1980) describe the methodology for producing this report.

Life history and tally data have been summarized for all observed trips made in 1987. The life history data were summarized by species, sex and total specimen length, and for females, by reproductive condition. The tally data, which is the observed kill, were summarized by geographic area, species and sex. For spotted and spinner dolphins, the tally and life history data were stratified by stock [for stock designations, see Perrin, Sloan and Henderson (1979) for spinner dolphins and Perrin, Scott, Walker and Cass (1985) for spotted dolphins]. The incidental kill of other small cetaceans was compiled by species.

RESULTS

A total of 123 trips was made by US-registered vessels with biological technicians aboard in 1987, including 2 trips by US-registered seiners chartered by non-US companies. Of the observed trips, 118 reported dolphin kills. The observed incidental kill of 14,206 small cetaceans comprised 8,599 spotted, 3,601 spinner, 1,525 common, 8 striped (*Stenella coeruleoalba*), 52 bottlenose (*Tursiops truncatus*), 24 rough-toothed (*Steno bredanensis*), 5 Pacific white-sided (*Lagenorhyncus obliquidens*) and 392 dolphins unidentified to species. The geographical distribution of purse-seine sets with kill observed is shown in Fig. 1. The observed kill has been reported by statistical blocks [5° square areas (see Perrin and Oliver, 1982 for a complete

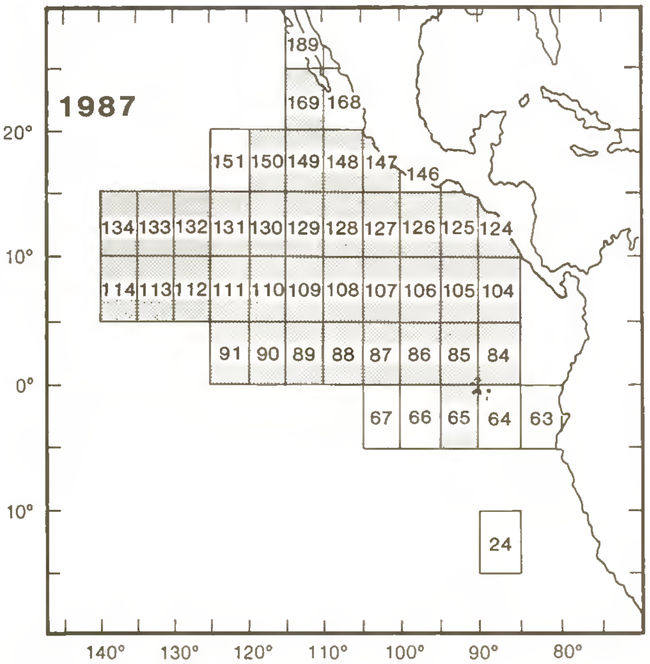


Fig. 1. Geographic distribution of the observed incidental kill of dolphins during 1987 reported for US-registered vessels by five-degree squares. The numbered blocks without shading are regions where only tally data were collected; the stippled blocks with numbers had both tally and life history data collected.

map of statistical reporting blocks)] and by sex, if available, for each species (Tables 1 and 2).

Life history data were collected for spotted, spinner, common, bottlenose and rough-toothed dolphins from 97 of the 123 observed trips. Total specimen length was recorded for 1,536 females and 1,338 males (Table 3) and reproductive data were recorded for 914 females (Table 4).

DISCUSSION

Data on observed kill and life history have been collected for dolphins from the ETP since 1968, providing a time series which has been used to assess population status of *Stenella* species (Smith, 1983). Reproductive parameters for *Stenella* species have also been estimated from the data (see, e.g., Barlow, 1984; Hohn, Chivers and Barlow, 1985; Myrick, Hohn, Barlow and Sloan, 1986; Perrin *et al.*, 1976; Perrin and Henderson, 1979; Perrin, Holts and Miller, 1977; Perrin *et al.*, 1979).

The observed kill data are used to estimate dolphin mortality [for techniques, see Wahlen (1986) and Hall and Boyer (1986)]. The data collected for 1987 are unique because observers were placed on almost all US-registered vessels fishing in the ETP during the calendar year. These mortality data will be used to evaluate sub-sampling schemes and techniques for estimating biweekly mortality (R. Holt, pers. comm.[1]).

Despite the placement of observers on nearly all US-registered vessels during 1987, the number of animals for which life history data were collected did not appreciably increase. Review of the incidental kill data collected since 1979 shows that there has been a marked decline in the fraction of the observed kill with life history data collected (Table 5). Although the absolute number of individual animals sampled is high for some years, a majority of the specimens did not have accompanying reproductive data. Observers are encouraged to collect gonad samples from individual male and female animals whenever possible as these samples are essential for reproductive studies. In addition, for females, pregnant and lactating condition must be determined at the time of collection. When the data are stratified by geographic area, sex and reproductive condition (for example, see Table 4), the sample becomes much smaller, and therefore, much less useful for estimating life history parameters. The prevalence of small sample sizes raises the question of how accurately the collected sample represents the life history characteristics of all the animals killed and, more importantly, the population. The effects of data collection biases, noted by Stuntz (1980), Perrin and Oliver (1982), Hohn and Scott[2], Chivers and Hohn[3], and Barlow (1984; 1985), on life history parameter estimation are currently unknown.

ACKNOWLEDGEMENTS

We thank the staffs and biological technicians of both the Inter-American Tropical Tuna Commission and the National Marine Fisheries Service for preparing the data used in this report, C. Fried, K. Peltier and M. Schwartz for assisting with the processing of specimens and R. Allen for preparing the figure. We are grateful to M. Hall (Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, La Jolla, California, 92093, U.S.A.), D. DeMaster, R. Holt and W. Perrin (Southwest Fisheries Center, P. O. Box 271, La Jolla, California, 92038, U.S.A.) for reviewing the manuscript.

REFERENCES

Barlow, J. 1984. Reproductive seasonality in pelagic dolphins (*Stenella* spp.): implications for measuring rates. *Rep. int. Whal. Commn* (special issue 6): 191–8.

Barlow, J. 1985. Variability, trends, and biases in reproductive rates of spotted dolphins (*Stenella attenuata*). *Fish. Bull., US* 83(4):657–69.

Hall, M.A. and Boyer, S.D. 1986. Incidental mortality of dolphins in the eastern tropical Pacific tuna fishery: description of a new method and estimation of 1984 mortality. *Rep. int. Whal. Commn* 36:375–81.

Hall, M.A. and Boyer, S.D. 1987. Incidental mortality of dolphins in the eastern tropical Pacific tuna fishery in 1985. *Rep. int. Whal. Commn* 37:361-2.

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, La Jolla, CA, *Admin. Rep.* LJ-80–02, 51pp.

---

[1] Holt, R.S. Southwest Fisheries Center, P.O. Box 271, La Jolla, California 92038, USA, April 1988.

[2] Hohn, A.A. and Scott, M.D. 1983. Segregation by age in schools of spotted dolphins in the eastern tropical Pacific. Abstract, Fifth Biennial Conference on the Biology of Marine Mammals, Boston, MD, U.S.A.

[3] Chivers, S.J. and Hohn, A.A. 1985. Segregation by maturity state and sex in schools of spinner dolphins in the eastern Pacific. Abstract, Sixth Biennial Conference on the Biology of Marine Mammals, Vancouver, B.C., Canada.

Hohn, A.A., Chivers, S.J. and Barlow, J. 1985. Reproductive maturity and seasonality of male spotted dolphins, *Stenella attenuata*, in the eastern tropical Pacific. *Mar. Mammal Sci.* 1(4):273–93.

Lo, N.C.H., Powers, J.E. and Wahlen, B.E. 1982. Estimating and monitoring incidental dolphin mortality in the eastern tropical Pacific tuna purse seine fishery. *Fish. Bull., US* 80(2):396–401.

Myrick, A.C., Jr., Hohn, A.A., Barlow, J. and Sloan, P.A. 1986. Reproductive biology of female spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. *Fish. Bull., US* 84(2):247–59.

Oliver, C.W., Walker, G.J. and Miller, R.B. 1983. Time/area distribution and composition of the incidental kill of small cetaceans in the US purse-seine fishery for tuna in the eastern tropical Pacific during 1981. *Rep. int. Whal. Commn* 33:603–15.

Perrin, W.F., Coe, J.M. and Zweifel, J.R. 1976. Growth and reproduction of the spotted porpoise, *Stenella attenuata*, in the offshore eastern tropical Pacific. *Fish. Bull., US* 74:229–69.

Perrin, W.F., Holts, D.B. and Miller, R.B. 1977. Growth and reproduction of the eastern spinner dolphins, a geographical form of *Stenella longirostris* in the eastern tropical Pacific. *Fish. Bull., US* 75:725–50.

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, La Jolla, CA. *Admin. Rep.* LJ-79–29, 13pp.

Perrin, W.F., Sloan, P.A. and Henderson, J.R. 1979. Taxonomic status of the 'southwestern stocks' of spinner dolphin *Stenella longirostris* and spotted dolphins *S. attenuata*. *Rep. int. Whal. Commn* 29:175–84.

Perrin, W.F. and Oliver, C.W. 1982. Time/area distribution and composition of the incidental kill of dolphins and small whales in the US purse-seine fishery for tuna in the eastern tropical Pacific, 1979–80. *Rep. int. Whal. Commn* 32:429–44.

Perrin, W.F., Scott, M.D., Walker, G.J. and V.L. Cass. 1985. Review of geographical stocks of tropical dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific. NOAA-TM-NMFS-SWFC-28, 28pp.

Smith, T. D. 1983. Changes in size of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. *Fish. Bull., US* 81(1):1–13.

Stuntz, W.E. 1980. Variation in age structure of the incidental kill of spotted dolphins, *Stenella attenuata*, in the US tropical purse-seine fishery. Southwest Fisheries Center, La Jolla, CA. *Admin. Rep.* LJ-80–06, 29pp.

Wahlen, B.E. 1986. Incidental dolphin mortality in the eastern tropical Pacific tuna fishery, 1973 through 1978. *Fish. Bull., US* 84(3):559–69.

Wahlen, B.E., Walker, G.J., Miller, R.B. and Oliver, C.W. 1986. Composition of the incidental kill of small cetaceans in the US purse-seine fishery for tuna in the eastern tropical Pacific, 1982 through 1984. *Rep. int. Whal. Commn* 36:369–74.

Wahlen, B.E., Miller, R.B. and Macky, C.J. 1987. Composition of the incidental kill of small cetaceans in the US purse-seine fishery for tuna in the eastern tropical Pacific during 1985. *Rep. int. Whal. Commn* 37:353–5.

Wahlen, B.E., Miller, R.B. and Ladiana, S.J. 1988. Composition of the incidental kill of small cetaceans in the US purse-seine fishery for tuna in the eastern tropical Pacific during 1986. *Rep. int. Whal. Commn* 38:403–5.

Table 1

Total kill of spotted and spinner dolphins by stock, sex (M=male, F=female) and 5° square. No kill was reported for coastal spotted dolphins; animals not identified to stock (1 spotted and 55 spinner dolphins) were not included in the table.

	Spotted dolphins						Spinner dolphins								
	Northern offshore			Southern offshore			Eastern			Northern whitebelly			Southern whitebelly		
5° block	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
24	0	0	0	1	5	10	0	0	0	0	0	0	0	0	0
63	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
64	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
66	0	1	1	0	1	1	0	0	0	0	0	0	1	0	1
67	0	0	0	3	2	9	0	0	0	0	0	0	0	3	3
84	1	3	44	0	0	0	1	3	4	0	1	7	0	0	0
85	39	73	165	0	0	0	0	0	0	9	17	48	0	0	0
86	26	40	99	0	0	0	0	0	0	1	2	5	0	0	0
87	9	12	295	0	0	0	0	0	0	0	0	1	0	0	0
88	5	3	306	0	0	0	0	0	0	0	0	53	0	0	0
89	14	22	362	0	0	0	0	0	0	2	2	53	0	0	0
90	26	23	112	0	0	0	0	0	0	4	0	10	0	0	0
91	18	16	322	0	0	0	0	0	0	2	1	52	0	0	0
104	25	24	120	0	0	0	0	0	0	2	0	2	0	0	0
105	81	121	319	0	0	0	2	6	8	4	1	11	0	0	0
106	211	242	958	0	0	0	17	6	60	8	2	13	0	0	0
107	82	91	416	0	0	0	21	23	57	2	5	51	0	0	0
108	53	43	271	0	0	0	2	0	5	1	3	17	0	0	0
109	37	48	133	0	0	0	8	5	15	11	13	29	0	0	0
110	77	70	402	0	0	0	1	1	10	10	12	60	0	0	0
111	102	123	539	0	0	0	23	10	33	43	36	126	0	0	0
112	158	225	710	0	0	0	1	0	4	38	28	114	0	0	0
113	31	30	151	0	0	0	0	0	0	6	5	17	0	0	0
114	1	1	3	0	0	0	0	0	0	1	2	7	0	0	0
124	3	5	12	0	0	0	4	3	7	0	0	2	0	0	0
125	160	229	1,049	0	0	0	269	224	1,191	5	6	15	0	0	0
126	21	21	151	0	0	0	22	22	133	0	0	0	0	0	0
127	38	41	230	0	0	0	34	36	147	1	0	5	0	0	0
128	85	123	396	0	0	0	42	44	300	0	0	0	0	0	0
129	37	37	413	0	0	0	34	35	320	0	0	0	0	0	0
130	18	48	105	0	0	0	38	38	96	1	9	10	0	0	0
131	33	30	139	0	0	0	27	14	111	2	2	5	0	0	0
132	23	23	92	0	0	0	4	9	22	15	14	53	0	0	0
133	16	16	68	0	0	0	15	10	28	21	23	78	0	0	0
134	2	1	37	0	0	0	0	0	0	5	4	105	0	0	0
146	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
147	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
148	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0
149	5	19	70	0	0	0	1	5	8	0	0	0	0	0	0
150	26	20	72	0	0	0	0	0	2	5	2	28	0	0	0
151	1	2	3	0	0	0	0	0	0	0	2	3	0	0	0
168	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
169	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Total	1,465	1,832	8,578	4	8	20	566	494	2,562	199	192	980	1	3	4

Table 2

Total kill of common, striped, bottlenose, rough-toothed and unidentified dolphin species by sex (M=male, F=female) and geographic location (number of the corresponding 5° square). There were no dolphins unidentified to species with known sex.

	Common			Striped			Bottlenose			Rough-toothed			Pacific White-sided			Unidentified
5° block	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total	Total
65	124	146	480	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
85	71	74	171	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
89	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
104	9	5	56	0	0	0	0	0	0	0	0	0	0	0	0	0
105	12	19	41	0	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	1	0	3	0	0	3	0	0	0	0	0	0	4
107	0	0	0	3	0	3	2	0	2	1	2	3	0	0	0	2
108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
124	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	1
125	13	14	55	0	0	1	5	4	34	5	8	21	0	0	0	296
126	0	0	0	0	0	0	1	4	7	0	0	0	0	0	0	29
127	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1
129	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	26
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
132	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	7
149	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
168	3	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
169	30	44	141	0	0	0	0	0	0	0	0	0	0	0	0	0
189	78	139	544	0	0	0	0	0	0	0	0	0	0	2	5	0
Total	340	442	1,525	5	0	8	9	11	52	6	10	24	0	2	5	392

Table 3

Length frequencies for all dolphin species with life history data collected. No kill was reported for coastal or southern offshore spotted dolphins or for southern whitebelly spinner dolphins. Twenty-two (22) spinner dolphins unidentified to stock were not included.

Length (cm)	N. offshore spotted		Eastern spinner		N. whitebelly spinner		Common		Striped		Rough-toothed		Bottlenose	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
0–74	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75–79	2	0	3	1	0	0	0	0	0	0	0	0	0	0
80–84	2	2	2	2	1	1	1	0	0	0	0	0	0	0
85–89	6	4	3	0	0	0	0	1	0	0	0	0	0	0
90–94	6	2	3	2	0	0	0	1	0	0	0	0	0	0
95–99	9	7	4	4	0	2	0	0	0	0	0	0	0	0
100–104	6	6	3	3	1	2	1	1	0	0	0	0	0	0
105–109	1	4	5	1	1	1	0	0	0	0	0	0	0	0
110–114	5	7	2	3	1	0	0	0	0	0	0	0	0	0
115–119	5	7	6	6	1	0	1	1	0	0	0	0	0	0
120–124	6	8	2	4	3	0	0	1	0	0	0	0	0	0
125–129	9	8	3	2	0	1	0	0	0	0	0	0	0	0
130–134	13	9	3	0	1	0	1	0	0	0	0	0	0	0
135–139	17	7	3	4	2	1	0	1	0	0	0	0	0	0
140–144	13	19	5	10	1	0	0	1	0	0	0	0	0	0
145–149	16	17	16	11	4	4	1	0	0	0	0	0	0	0
150–154	24	24	11	27	9	5	1	1	0	0	0	0	0	0
155–159	46	42	37	36	8	3	1	0	0	0	0	0	0	0
160–164	70	60	53	43	3	12	2	2	0	0	0	0	0	0
165–169	66	68	49	53	8	19	1	4	0	0	0	0	0	0
170–174	70	78	45	66	19	16	3	7	1	0	0	0	0	0
175–179	69	93	49	40	19	12	3	4	1	0	0	0	0	0
180–184	69	124	33	11	17	12	7	3	1	0	0	0	0	0
185–189	59	167	11	2	7	10	4	2	0	0	0	0	0	0
190–194	56	146	2	1	2	2	2	10	0	0	0	0	0	0
195–199	56	74	1	0	3	0	5	6	0	0	0	0	0	1
200–204	46	34	0	0	0	0	1	3	0	0	0	0	0	0
205–209	38	7	0	0	0	0	1	3	0	0	0	0	0	0
210–214	19	4	0	0	0	0	1	0	0	0	1	1	0	0
215–219	7	0	0	0	0	0	0	0	0	0	0	0	0	0
220–224	1	0	0	0	0	0	0	0	0	0	0	0	0	0
225–229	0	0	0	0	0	0	0	0	0	0	0	1	0	1
230–234	1	0	0	0	0	0	0	0	0	0	0	0	0	1
235–239	0	0	0	0	0	0	0	0	0	0	0	0	1	1
240–244	0	0	0	0	0	0	0	0	0	0	0	0	0	1
245–249	0	0	0	0	0	0	0	0	0	0	0	0	3	1
250–254	0	0	0	0	0	0	0	0	0	0	0	0	0	0
255–259	0	0	0	0	0	0	0	0	0	0	0	0	0	1
260–264	0	0	0	0	0	0	0	0	0	0	0	0	2	0
265–269	0	0	0	0	0	0	0	0	0	0	0	0	2	0
270–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	814	1,028	354	332	111	103	37	52	3	0	1	2	8	7

Table 4

Reproductive condition of female dolphins with life history data collected. Percentages include females without reproductive information available. 'Maturity undetermined' indicates that only minimum life history data were collected.

	N. offshore spotted		Eastern spinner		N. whitebelly spinner		Common		Bottlenose		Rough-toothed	
Reproductive condition	N	%	N	%	N	%	N	%	N	%	N	%
Maturity undetermined	426	41.2	128	38.3	55	53.4	8	15.4	1	14.3	0	0.0
Sexually immature	258	25.0	131	39.2	23	22.3	18	34.6	1	14.3	1	50.0
Sexually mature:												
Condition undetermined	6	0.6	2	0.6	1	1.0	0	0.0	0	0.0	0	0.0
Pregnant only	83	8.0	11	3.3	8	7.8	7	13.5	0	0.0	0	0.0
Pregnant and lactating	29	2.8	4	1.2	0	0.0	6	11.5	0	0.0	0	0.0
Lactating only	173	16.7	46	13.8	14	13.6	9	17.3	3	42.9	1	50.0
Resting with corpus luteum	7	0.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Resting without corpus luteum	46	4.4	12	3.6	2	1.9	4	7.7	2	28.6	0	0.0
Post-reproductive	6	0.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	1,034	100.0	334	100.0	103	100.0	52	100.0	7	100.0	2	100.0

Table 5

The total observed kill (TOK) for US-registered purse-seine vessels from 1979 through 1987. Life history data collection is presented as (1) the number of specimens sampled, and (2) the fraction of the observed kill (FOK). 'Minimum data only' refers to those specimens for which only species, sex and total specimen length are available. The collection of gonads, in addition to minimum data, constitutes 'complete' data collection. Specimens unidentified to stock were included.

		Minimum data				Complete data			
		Total		FOK		Total		FOK	
Year	TOK	M	F	M	F	M	F	M	F
1979	4,900	964	1,197	0.20	0.24	603	694	0.12	0.14
1980	3,125	623	766	0.20	0.25	341	393	0.11	0.13
1981	3,297	573	687	0.17	0.21	379	387	0.11	0.12
1982	9,262	790	1,042	0.09	0.11	451	504	0.05	0.05
1983	2,999	327	423	0.11	0.14	148	192	0.05	0.06
1984	4,427	542	624	0.12	0.14	184	250	0.04	0.06
1985	8,996	1,095	1,198	0.12	0.13	553	559	0.06	0.06
1986	10,241	576	701	0.06	0.07	339	370	0.03	0.04
1987	14,206	1,338	1,536	0.09	0.11	786	959	0.06	0.07

SC/40/SM2

Estimates of Incidental Mortality of Dolphins in the Eastern Pacific Fishery for Tropical Tunas in 1987

M.A. Hall and S.D. Boyer

Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, La Jolla, California 92093, USA

ABSTRACT

Estimates of incidental dolphin mortality in the eastern Pacific have been made for 1987. Observers have collected data on 214 trips, distributed as follows: US (IATTC observers) 44, US (NMFS observers) 80, and other countries (IATTC observers) 90. Sampling coverage for the international fleet was 47.9% of all trips during which dolphin sets were made in the eastern Pacific. Ratio estimates, combined with a spatial stratification and re-sampling techniques, were used to produce the mortality estimates. The mortality estimates remain high; 99,187 using the mortality-per-set ratio and 112,901 using the mortality-per-ton ratio. With respect to 1986, estimated mortality has declined 13% to 25%, in spite of an increase of 20% in the number of sets on dolphins. Several possible causes of the reduction are mentioned.

INTRODUCTION

For several decades, tuna fishermen operating in the eastern Pacific Ocean have known that yellowfin tuna (*Thunnus albacares*) associate with dolphins of several species, especially spotted dolphins (*Stenella attenuata*), spinner dolphins (*S. longirostris*) and common dolphins (*Delphinus delphis*). They have taken advantage of this association to capture tunas, but in the process dolphins are killed. The Inter-American Tropical Tuna Commission (IATTC) has conducted an international observer program since 1979 to estimate the incidental mortality caused by the tuna fleet, which in 1987 included vessels flying the flags of Costa Rica, Ecuador, El Salvador, Mexico, Panama, Spain, the United States, Vanuatu and Venezuela. A US national agency, the National Marine Fisheries Service (NMFS) has been placing observers on US vessels since the early 1970s. Currently, the IATTC shares the sampling of the US fleet with the NMFS; IATTC observers on US boats contribute information in radio reports which are transferred to the NMFS for use in its national management scheme. In turn, the NMFS provides the IATTC with records of its observed US trips; these are used to compute the yearly mortality estimates for the international fleet (Hammond and Tsai, 1983; Hammond, 1984; Hammond and Hall, 1985; Hall and Boyer, 1986; 1987). Other estimates for the period prior to 1979 can be found in Lo and Smith (1986) and Wahlen (1986).

MATERIALS AND METHODS

The data base for 1987 includes 214 observer trips, distributed as follows: US (IATTC observers) 44, US (NMFS observers) 80 and other countries (IATTC observers) 90. Of those trips, 201 (93.9%) had dolphin sets. Table 1 gives the coverage by port of operations for trips with dolphin sets.

In 1987 the NMFS decided to increase sample coverage for the US fleet to 100% to study sampling problems and the performance of individual skippers. The first trips of the year by US boats were sampled fully by the NMFS and the remaining trips were shared equally by the NMFS and the IATTC. Coverage of the US fleet did not reach 100%, but, at 91.5% was very close to that figure. To coincide with the national legislation requirements, only vessels with a capacity of 400 tons or more were included in the calculation. In addition, the calculations of tonnage of tuna and dolphin kill-per-ton were made using only yellowfin tuna.

Table 1

Coverage of operations for trips with dolphin sets

	Observed trips	Total trips	% coverage
Ecuador (Flags of Ecuador, Spain and Vanuatu)	10	40	25.0
Mexico	49	166	29.5
Panama	2	11	18.2
USA	121	135	89.6
Venezuela (Flags of Costa Rica, El Salvador, Venezuela and chartered US vessels)	19	68	27.9
Totals	201	420	47.9

The statistical methods described by Hall and Boyer (1986) were used. Basically, the mortality, set and catch data obtained by the observers were combined to produce ratio estimates. Mortalities per set and per ton were computed for geographical strata corresponding to areas with different levels of effort. It is known (Anon., 1986, pp.55–6) that behavioural differences among areas result in heterogeneous mortality rates. The geographical stratification was different for those species that are found throughout the fishery and for those that are vulnerable only in restricted areas. After obtaining values of mortality per set and per ton for each stratum, they were extrapolated to the total amount of effort on dolphins in that stratum. Bootstrap procedures were used to reduce the bias of estimates and to obtain non-parametric variance estimates.

The extra coverage of the US fleet for 1987, however, greatly exceeded the coverage of the non-US fleet and possibly created a source of bias. When differences among flags were tested (Hall and Boyer, 1986), there were no differences for most areas; only two areas showed significant differences between US and non-US fleets, and these were in opposite directions. The imbalance in sample coverage caused by the increase to almost 100% coverage of the US fleet, if combined with one or two of those areas, could result in biased estimates. To prevent this, the

Table 2

Estimates of incidental mortality of dolphins in 1987. Standard errors are in parentheses.

	Using mortality per set	Using kill per ton
Offshore spotted dolphin		
Northern stock	51,684 (4,764)	56,573 (5,016)
Southern stock	3,285 (1,478)	4,029 (419)
Eastern spinner dolphin	10,277 (1,198)	11,638 (1,389)
Unidentified prorated as eastern spinners	131 (45)	147 (51)
Whitebelly spinner dolphins		
Northern stock	3,562 (1,012)	3,988 (1,206)
Unidentified prorated as northern whitebelly spinners	32 (11)	35 (12)
Southern stock	2,432 (1,225)	2,910 (544)
Common dolphins		
Northern stock	8,216 (4,954)	8,190 (5,135)
Central stock	9,659 (2,507)	12,198 (3,410)
Southern stock	6,759 (3,323)	9,616 (5,033)
Other dolphins	3,200 (1,140)	3,577 (1,270)
Totals	99,187 (8,485)	112,901 (9,693)

Notes:
(a) This table has been fully stratified by stock at the request of the International Whaling Commission.
(b) Other dolphins include the following species and stocks whose observed mortality is shown in brackets: Striped dolphins (*Stenella coeruleoalba*) [245], Bottlenose dolphins (*Tursiops truncatus*) [68], Coastal stock of spotted dolphins (*S. attenuata*) [37], Rough-toothed dolphins (*Steno bredanensis*) [16], Fraser's dolphins (*Lagenodelphis hosei*) [10], Short-finned pilot whales (*Globicephala macrocephalus*) [1], Costa Rican stock of spinner dolphins (*S. longirostris*) [1], Unidentified spotted dolphins (*S. attenuata*) [238] and unidentified dolphins [581]. There are not enough data to make separate estimates for these stocks on a consistent basis.

estimates for 1987 were obtained by stratifying by area and flag. The US data, essentially a full census, were separated from the rest of the data base, thus generating two sets of estimates. These estimates were later combined to provide the total figures presented in Table 2.

In previous years, we stratified by area rather than by flag because area was statistically more significant as a source of heterogeneity. Other stratification criteria, principally season, vessel capacity, and flag, could not be added because of sample size constraints. Of these, possible heterogeneities in performance by flags could be better handled by sampling all flags at basically the same level, and this is the direction towards which we have been heading.

RESULTS

Estimates for 1987 are shown on Table 2. The estimated mortality remains high, but has declined 10% – 24% as compared to 1986, despite an increase of 20% in the numbers of sets on dolphins in 1987. If the mortalities per set and per ton had remained at the 1986 levels, total mortality would have exceeded 150,000 animals.

Some of the factors contributing to the reduction in mortality rates were:

(1) significantly lower average catches of tuna in dolphin sets in 1987 (Van der Waerden test: $p<0.001$);
(2) slightly shorter sets, lasting an average of 2.77 hours in 1987, as compared to 2.97 hours in 1986 (Van der Waerden test: $p<0.001$);
(3) a reduction in the proportion of sets on common dolphins from over 7% in 1986 to 5% in 1987 (t-test: $p<0.01$), although these sets resulted in 17% of the mortality;
(4) a slight reduction (1.5%) in the proportion of night sets (t-test: not significant);
(5) an increase in the proportion of sets with zero mortality from 38.0% in 1986 to 46.1% in 1987 (t-test: $p<0.001$) – in addition the proportion of high mortality sets (>50 animals) declined from 5.7% to 3.2% (t-test: $p<001$);
(6) a decline in the average number of animals left in the net after backdown in both day sets (5.2 to 4.1) (Van der Waerden test: $p<0.001$) and night sets (12.8 to 6.9) (Van der Waerden test: $p<0.001$);
(7) a decline in the average number of dolphins captured (Van der Waerden test: $p<0.001$).

Factors 1 and 2 are highly correlated, so their effects are confounded.

Sets on common dolphins and night sets usually have much higher mortality rates than other types of sets; in addition, the larger the size of the group encircled, the greater the mortality rate.

Regardless of their statistical significance, these changes influence the estimates for total mortality.

ACKNOWLEDGEMENTS

The authors wish to thank Doug DeMaster, National Marine Fisheries Service, Southwest Fisheries Center, PO Box 271, La Jolla, CA 92038; Frank Alverson, Living Marine Resources, Porpoise Rescue Foundation, 7169 Construction Court, San Diego, CA 92121; and Michael Scott and William Bayliff, Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, La Jolla, CA 92093 for reviewing this manuscript.

REFERENCES

Anonymous. 1986. Annual Report of the Inter-American Tropical Tuna Commission, 1985. (In English and Spanish).

Hall, M.A. and Boyer, S.D. 1986. Incidental mortality of dolphins in the eastern tropical Pacific tuna fishery: description of a new method and estimation of 1984 mortality. *Rep. int. Whal. Commn* 36: 375–81.

Hall, M.A. and Boyer, S.D. 1987. Incidental mortality of dolphins in the eastern tropical Pacific tuna fishery in 1985. *Rep. int. Whal. Commn* 37: 361–2.

Hammond, P.S. 1984. Dolphin mortality incidental to purse-seining for tunas in the eastern tropical Pacific Ocean, 1982. *Rep. int. Whal. Commn* 34: 539-41.

Hammond, P.S. and Hall, M.A. 1985. Dolphin mortality incidental to purse– seining for tunas in the eastern tropical Pacific inflicted by the US fleet in 1983 and non-US fleet in 1979–83. *Rep. int. Whal. Commn* 35: 431–3.

Hammond, P.S. and Tsai, K.T. 1983. Dolphin mortality incidental to purse-seining for tunas in the eastern tropical Pacific Ocean, 1979–1981. *Rep. int. Whal. Commn* 33: 589–97.

Lo, N.C.H., Power, J.E. and Wahlen, B.E. 1982. Estimating and monitoring incidental dolphin mortality in the eastern Pacific tuna purse seine fishery. *Fish. Bull., US* 80(2): 396–400.

Lo, N.C.H. and Smith, T.D. 1986. Incidental mortality of dolphins in the eastern tropical Pacific, 1959–1972. *Fish. Bull., US* 84(1): 27–34.

Mann, F.E., Hall, M.A. and Scott, M.D. In prep. Changes in the behaviour of dolphins affected by the tuna purse-seine fishery.

Wahlen, B.E. 1986. Incidental mortality of dolphins in the eastern tropical Pacific tuna fishery, 1973 through 1978. *Fish. Bull., US* 84(3): 559–69.

SC/40/SM3

Reducing Bias in Trends in Dolphin Relative Abundance, Estimated from Tuna Vessel Data

A.A. Anganuzzi and S.T. Buckland*

Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, La Jolla, CA 92093, USA

ABSTRACT

The relative abundances of eastern tropical Pacific stocks of three dolphin species are estimated from tuna vessel data, using the methods of Buckland and Anganuzzi (1988), but with further refinements to reduce bias. Estimates corresponding to each year from 1975 to 1987 are given for the new procedure using two sets of stock boundaries. Conclusions are generally similar to those of Buckland and Anganuzzi (1988); the stocks for which we have most information (the eastern stock of spinner dolphin and the northern offshore stock of spotted dolphin) both appear to have been relatively stable in size during the 1980s, with evidence of reductions in the latter stock in the late 1970s.

INTRODUCTION

Incidental mortality of dolphins in the eastern tropical Pacific caused by the tuna fishery has been sufficient to affect adversely abundance of stocks of at least two species of dolphins, the spotted dolphin *Stenella attenuata* and the spinner dolphin *S. longirostris* (Smith, 1983). Although there is less information available on stocks of the common dolphin *Delphinus delphis*, recent estimates of mortality (e.g. Hall and Boyer, 1988) suggest that this species may have been affected to some degree as well. Line transect methodology has been applied by several authors in attempts to estimate trends in abundance of these stocks. Holt and Powers (1982) and Holt (1985) considered analyses of research vessel data alone and of tuna vessel data combined with research vessel data. Tuna vessel data alone were analysed by Hammond and Laake (1983), by Polacheck (1987) and by Buckland and Anganuzzi (1988).

The tuna vessel data are collected by scientific technicians placed on board tuna purse seiners by two organisations: the Inter-American Tropical Tuna Commission (IATTC), which places technicians on vessels of the international fleet (including US-registered vessels); and the National Marine Fisheries Service (NMFS) of the United States which places technicians on US-registered vessels only. Data were first collected by NMFS in 1974 and by IATTC in 1979. Relative to research vessel data, there are large numbers of sightings of the three target species of dolphin listed above, and the data span the entire period from 1974 to the present. Additionally, the data are collected at low cost, because technicians are placed on board vessels to monitor incidental mortality of dolphins. While there is therefore a strong need to develop methods that utilise tuna vessel data, all the major assumptions of the line transect method are violated to varying degrees by these data, and robust methods must be developed for analysing them. These problems were considered by Hammond and Laake (1983) for data spanning the period 1977–81 inclusive, by Polacheck (1987) for 1977–80 and by Buckland and Anganuzzi (1988) for 1975–86. The last of these three papers employed several methods to reduce bias and increase robustness of estimates, and we have further modified these methods to improve the reliability of the relative abundance estimates. These modifications take into account potential biases resulting from geographic variability in average school size and in the fishing and searching modes in the eastern tropical Pacific, by incorporating separate stratification schemes for each of the components of the estimator.

METHODS

Estimation

The number of dolphins in an area for a given stock and year may be estimated by

$$\hat{N} = A.\bar{s}.\hat{D}$$

where A is the size of the area, $\bar{s}$ is the average school size for the stock in area A and $\hat{D}$ is the estimated density of schools in area A.

The line transect method provides the estimate $\hat{D}$ (Burnham, Anderson and Laake, 1980). Suppose schools farther than a distance w from the trackline are discarded from the analyses. Then

$$\hat{D} = n.\hat{f}(0)/2L \qquad (1)$$

where n is the number of schools detected in the area that are within distance w of the trackline, $\hat{f}(0)$ is the estimated probability density function of the n perpendicular distances evaluated at perpendicular distance zero and L is the total distance covered within the area.

If we define the encounter rate E to be the expected number of sightings detected within w of the trackline per nautical mile of search, then $\hat{E}$=n/L, with L measured in nautical miles. Hence,

$$\hat{D} = \hat{E}.\hat{f}(0)/2 \qquad (2)$$

and

$$\hat{N} = \hat{E}.\hat{f}(0).\bar{s}.A/2 \qquad (3)$$

The above estimation is valid under the following assumptions:

(i) within each area or stratum, either the search effort of the tuna vessels is random or the dolphin schools are randomly distributed;
(ii) any movement of schools is slow relative to the speed of the vessel, at least before detection;
(iii) all schools on or very close to the trackline are detected and identified;

---

*Current address: SASS, Aberdeen Unit, Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen AB9 2QJ, Scotland.

(iv) sighting distances and angles are measured without error;
(v) sightings of schools are independent events;
(vi) school size is recorded without error (if the school contains more than one species, percent of each species is recorded without error);
(vii) probability of detection of a school is independent of its size, at least out to perpendicular distance w.

Further details, including methods for estimating the variance of $\hat{N}$, are given by Buckland and Anganuzzi (1988). We use here the nonparametric bootstrap, as described by them.

Stratification

As noted by Buckland and Anganuzzi (1988), assumption (i) above is particularly critical for the tuna vessel data, but if sub-areas can be defined within which the assumption holds to a reasonable approximation, then bias in the above estimation can be appreciably reduced. Buckland and Anganuzzi found that stratification by encounter rate worked well, and we use this method to estimate the encounter rate E for each sub-area created by the stratification, although we modify their method of smoothing from which the strata are created (see below). The encounter rate for the entire stock area is then estimated by taking the average of the stratum estimates, weighted by the area of each stratum.

We may stratify in different ways to obtain each of the three estimates ($\hat{E}$, $\hat{f}(0)$ and $\bar{s}$) required to allow equation (3) to be applied. We may therefore reduce the problem of abundance estimation to the three simpler problems of estimating, for a random point in the stock area, the expectations of encounter rate, of effective track half-width (and hence its inverse, $\hat{f}(0)$), and of average school size. Correlation between the estimates does not introduce bias into the abundance estimate, and its effect on variance estimation may be accounted for by using the nonparametric bootstrap and applying the full estimation routine to each bootstrap replication. The above procedure yields $\hat{E}$; we now require similar procedures to provide $\hat{f}(0)$ and $\bar{s}$.

If fishing effort on dolphins is correlated geographically with average school size and no stratification is used, estimated average school size will be biased towards that observed in areas of high effort. Stratification of 1° squares by recorded school size should overcome this problem. We first calculate the average of the recorded school sizes (adjusted for bias as in Buckland and Anganuzzi, 1988) for each 1° square for which there was at least one sighting. Because many squares have no sightings and many others have very few, we then smooth these average school size estimates using the smoothing procedure discussed below. The 1° squares are then listed from lowest smoothed school size estimate to the highest, and divided into strata using the same rule as Buckland and Anganuzzi (1988) used for encounter rates. Note that the smoothing procedure does not need to generate valid estimates of average school size, provided that the ordering of the 1° squares correlates well with the true average school size in each. Once the strata have been defined, school size is estimated within each, and the stratum estimates are combined by calculating their weighted average, with weights equal to the stratum areas. The weights are chosen in this way since we require an estimate of expected school size at a random point in the stock area, which is different from the expected size of a school selected at random from the stock. (If we were to estimate the latter quantity, we should weight our estimate by the estimated number of schools in each stratum.)

We implemented two approaches for estimating the expectation of effective track width at a random point in the stock area. In the first, the average perpendicular sighting distance from a detected school to the trackline was calculated for each 1° square, and smoothed as described below. Although the average sighting distance does not estimate the effective track width, it correlates well with the half-width, and should therefore generate strata that are relatively homogeneous with respect to half-width. We attempted using the average perpendicular distances truncated at 5.0 n.miles instead of untruncated radial distances. However, estimation of half-width was found to be less stable using this option, apparently as a result of sightings with very small sighting angles tending to congregate in the stratum with smallest average perpendicular distance. It seemed reasonable to assume that if the average of untruncated radial distances was large, the effective track width would also be large. One factor that might reduce this correlation is if helicopters tended to be used mostly beyond the 5 n.miles truncation distance, since this gives large radial distances, but not necessarily large effective track width, after truncation at 5 n.miles perpendicular distance. An examination of perpendicular distances of helicopter sightings showed that this did not occur; the detection curve for helicopter sightings appeared to be non-increasing, with the probability of detection for a school beyond 5 n.miles being substantially lower than for a school within 5 n.miles of the track line.

The above approach implicitly adjusts for the effects of factors such as fishing mode, use of helicopters, presence of birds and sea state on the effective track width, by creating strata within which the track width is more or less constant. We can instead take account of such variables explicitly, using a second method.

We first selected variables that were likely to be correlated with effective track width: proportion of sightings with birds as the 'primary' cue (i.e. sightings of birds which led to detection of dolphins); proportion of sightings first detected by a helicopter; proportion of sets that were dolphin sets; and average sea state as measured by the Beaufort scale. These variables were calculated for each 1° square, and smoothed using the procedure described below.

Both the use of birds as a cue for the presence of dolphins and the use of helicopters as a searching platform affect the characteristics of the detection process. The occurrence of birds associated with dolphin schools allows detection at distances beyond the horizon, which increases the detectability of schools away from the trackline. Helicopter sightings have a similar effect. The proportion of dolphin sets by area is assumed to be correlated with the predominant fishing mode in the area, and indicates the relative interest of the fishermen in dolphins. Fishing mode was used as a stratification factor by Hammond and Laake (1983). Sea state was found to affect encounter rate by Buckland and Anganuzzi (1988). It is also a measure of sighting conditions, and thus may affect the effective track width.

To classify the 1° squares using the information contained in the four variables selected, we have several possible choices. A cluster analysis can be performed based on some similarity matrix. However, to determine the number of clusters to retain is difficult, as generally some clusters correspond to groups of outliers comprising one or very few squares. We chose therefore to carry out a principal components analysis (PCA) on the correlation matrix for the selected variables. Scores were calculated for each 1° square for each of the four principal components and the squares were divided into strata using each of the components in turn; the squares were ordered from the lowest score on a given component to the highest and the list was divided as before. For each stratum, effective strip width was estimated using the hazard-rate model and the average score was calculated. The component that maximises correlation between the average score and estimated effective track width was selected as the final stratification factor. The estimated effective track widths from the stratification derived from the selected component are combined again using a weighted average, with weights equal to the areas of the strata. This procedure is flexible and allows us to incorporate more auxiliary variables if they are shown to have an effect on effective track width. It also allows investigation of the effects of various variables on the detection process.

In the old procedure (Buckland and Anganuzzi, 1988), for stocks in which the number of sightings is small, the effective strip width was estimated using all years combined. In practice, there is the disadvantage of having to update the estimate of f(0) for past years as new data are incorporated in the databases (therefore revising past years' estimates). Another disadvantage is that possible trends in the effective track width could be overlooked. To avoid this, under the new procedure, for any given year f(0) is estimated by pooling the data for the current year with those from the previous two years. For years earlier than 1970, a value for $\hat{f}(0)$ calculated for the period 1977–79 was used. Apart from this, the new and old procedures are identical if the same stock boundaries are used, since there were too few data to allow stratification of stocks for which there were few sightings.

Smoothing

Buckland and Anganuzzi (1988) smoothed 1° square estimates of encounter rate, using the following method. Assign a weight of one to the 1° square for which an estimate is to be calculated, and weights to neighbouring squares that decline linearly with distance. The weights become zero at radial distance d units say, where a unit is 1° of latitude or longitude. Subject to the constraint that d should be at least d_{min}, it is set equal to the smallest integer value such that at least a minimum number of detected schools n_{min} contributed to the smoothed encounter rate estimate. Buckland and Anganuzzi (1988) chose d_{min}=4 and n_{min}=50. The smoothed estimate for square i is given by:

$$\hat{e}_i = \sum_j (w_{ij}n_j) / \sum_j (w_{ij}f_j) \qquad (4)$$

where n_j is the number of schools detected in square j, f_j is the total distance searched in square j and w_{ij} is the weight for square j relative to square i and is calculated as:

$$w_{ij} = \begin{cases} 1 - (d_{ij}/d), & d_{ij} < d \\ 0, & d_{ij} \geq d \end{cases}$$

where d_{ij} is the distance between the centers of squares i and j in 1° square units.

Analyses were run for various values of n_{min}, and using smaller values for d_{min}. Small values of n_{min} did not lead to significant fragmentation of the strata but did generate peaks and troughs in encounter rate estimates that were inferred from very little information. Choice of n_{min} had little effect in areas with high effort. Examination of estimates and of contour plots lead us to retain the value n_{min} = 50. Choice of d_{min} by contrast had no effect in areas of low effort, but values less than four lead to less smooth contours in regions of high effort. This property seems desirable, since the apparent changes in encounter rate over a relatively short distance are estimated from adequate information, and we adopt d_{min} = 1 here.

Use of an elliptical smoothing region, with major axis in the east/west direction, was investigated, since this is the predominant direction of currents in the offshore area and the distribution of schools is probably related to oceanographic features. It did not seem to offer an improvement over use of a circular region however and we do not use it here.

The same smoothing procedure was applied for other variables. In the case of school size, n_j in equation (4) is replaced by n_j multiplied by the average size of detected schools in square j and f_j is replaced by n_j. If average school size is replaced by average perpendicular distance of detected schools in square j, then the smoothing procedure for the simpler approach for generating effective track width strata is obtained. If the principal component analysis is implemented, then for each variable, equation (4) is applied, with appropriate quantities substituted for n_j and f_j. For example, in the case of proportion of sets made on dolphins, n_j will be replaced by the total number of sets made on dolphins in square j, and f_j will be replaced by all sets made in square j.

Stock areas

For comparability with Buckland and Anganuzzi (1988), we used the stock boundaries of Perrin, Scott, Walker and Cass (1985). We also give estimates of stock size using the boundaries (termed the Status of Porpoise Stocks or SOPS boundaries) presented by Au, Perryman and Perrin (1979). Since we estimate encounter rate, effective track width and average school size for a random point within the stock boundaries, large strata influence estimation more than small strata. Large strata are created in areas that have few sightings however, so that the procedures developed here might be expected to yield more stable estimation if the narrower SOPS boundaries are used. This would exclude some of the more distant areas where both fishing effort and dolphin density are low but which were within the stock boundaries proposed by Perrin *et al.* (1985).

RESULTS

In Figs 1–3 we show the contours that arise from the encounter rate, school size and effective track width stratifications respectively for the 1987 data on the northern offshore stock of spotted dolphin, using SOPS boundaries. The track width stratification is based upon the simpler approach, in which average sighting distances are utilized. This method required less computer time than the PCA approach, and was found to yield higher precision and marginally smoother trend estimates for the northern offshore stock and was therefore used to generate the abundance estimates of this paper. The stratification using the PCA approach corresponding to Fig. 3 is shown in Fig. 4.

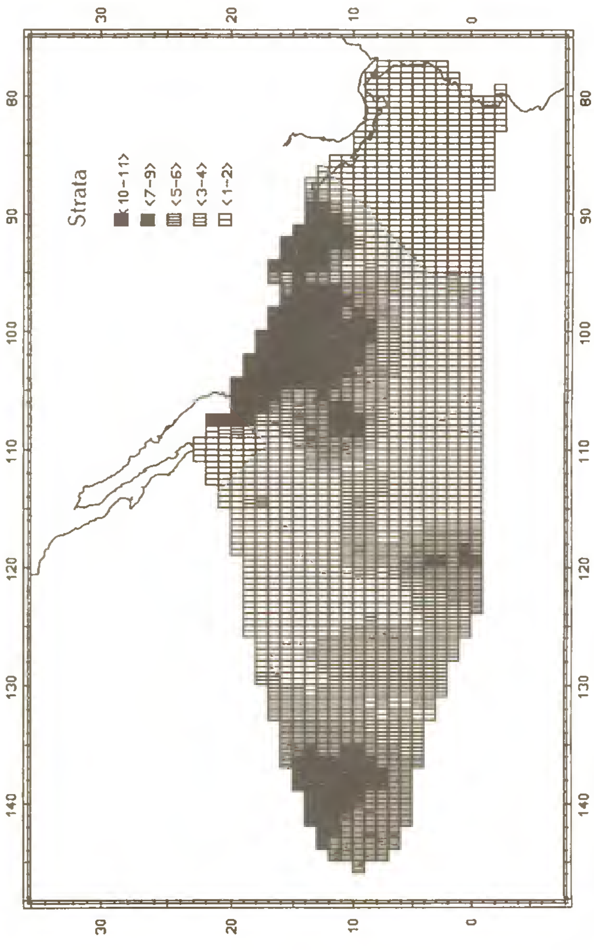


Fig. 1. Strata for estimation of encounter rate for the northern offshore stock of spotted dolphin, 1987 data. The different shadings indicate the strata to which the squares were assigned.

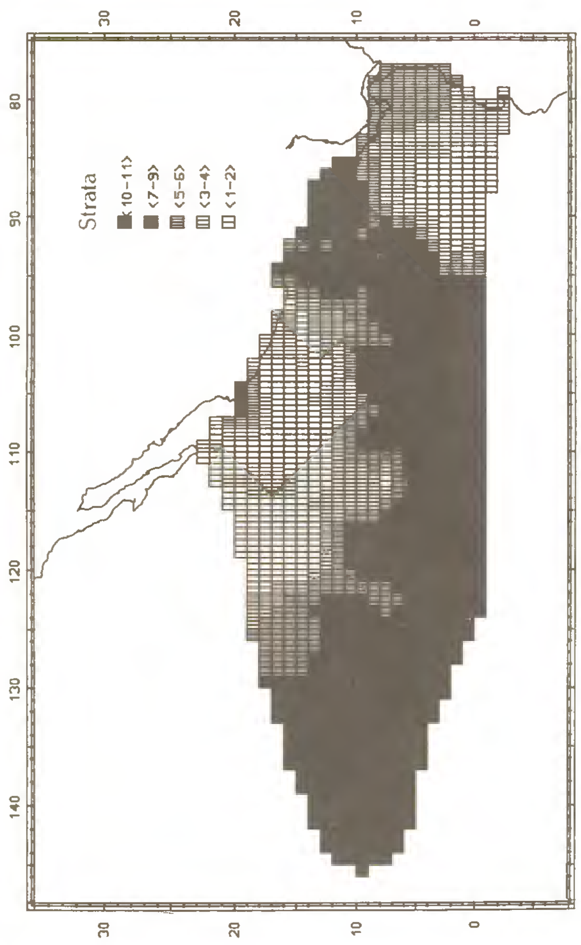


Fig. 2. Strata for estimation of average school size for the northern offshore stock of spotted dolphin, 1987 data. The different shadings indicate the strata to which the squares were assigned.

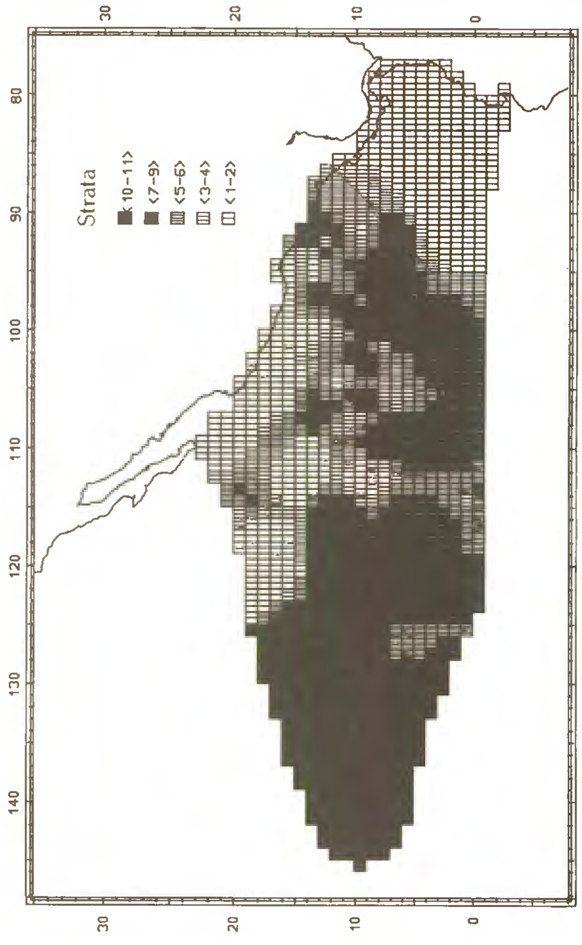


Fig. 3. Strata for estimation of effective track half-width for the northern offshore stock of spotted dolphin, 1987 data. The different shadings indicate the strata to which the squares were assigned.

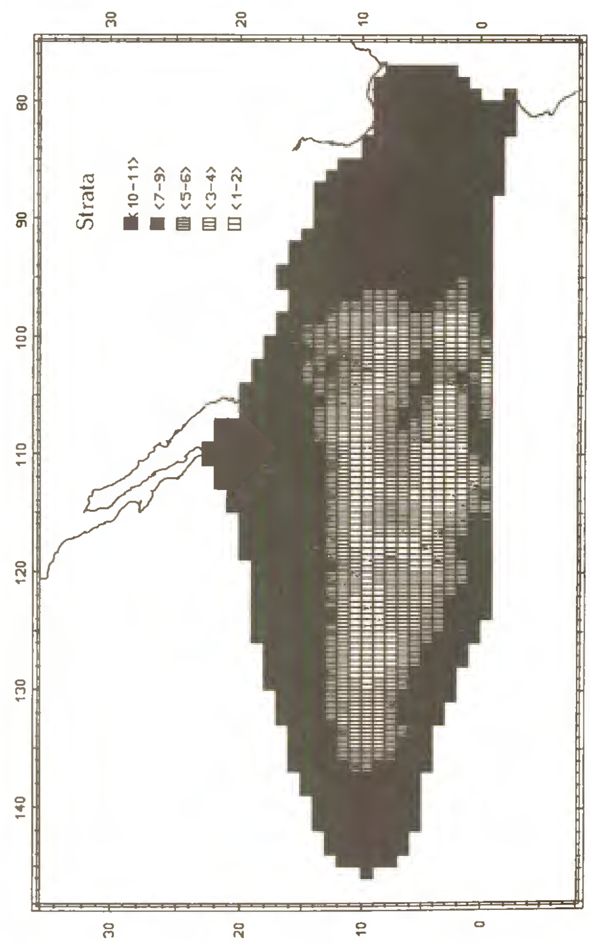


Fig. 4. Strata for estimation of effective track half-width for the northern offshore stock of spotted dolphin, 1987 data. The different shadings indicate the strata to which the squares were assigned. Stratification based on the PCA approach.

Using the PCA approach, the most effective component for estimating $\hat{f}(0)$ appeared to be one giving approximately equal weights to the four variables used in the analysis. An example is shown in Table 1. Note that the component that maximises the correlation between $\hat{f}(0)$ and average stratum scores may be of low order; the fourth and last component was selected in this instance, having a correlation of 0.63 with $\hat{f}(0)$. When strata were created on the basis of average sighting distances, the correlation between $\hat{f}(0)$ and average sighting distance was 0.76. Fig. 3 seems to show an east-west trend, while Fig. 4 shows a trend from the boundaries of the stock area towards the center. While the stratifications are very different, the effective track half-widths are 3.14 and 3.10 respectively, so that abundance estimation is not appreciably different.

Figs 5–13 show estimated trends in abundance for all stocks considered by Buckland and Anganuzzi (1988), using SOPS boundaries and the new procedures.

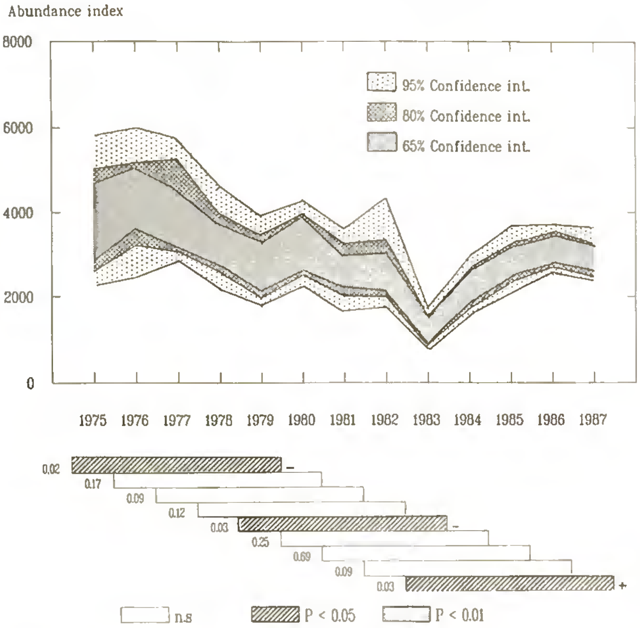


Fig. 5. Confidence intervals and test for trends for the northern stock of spotted dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. × Buckland and Anganuzzi (1988); + new procedure with Perrin *et al.* (1985) boundaries; ○ new procedure with SOPS boundaries.

Bootstrap standard errors and confidence limits were set using 79 replications. Since this is too few to provide reliable 95% confidence limits by the percentile method (Buckland, 1984), but CPU time is excessive if substantially more replications are used, we also calculated 80% and 65% confidence intervals, which are more reliably estimated from few bootstrap replications. The number 79 was taken since a 95% percentile confidence interval can then be obtained by taking the second largest and second smallest bootstrap estimates, an 80% interval by taking the eighth largest and smallest, and a 65% interval by taking the fourteenth largest and smallest estimates. These results are found by calculating $(b+1)\alpha$, where $b=79$ and $\alpha=0.025$, 0.1 and 0.175 respectively (Buckland, 1984). Figs 5–13 show regions corresponding to these three levels of confidence.

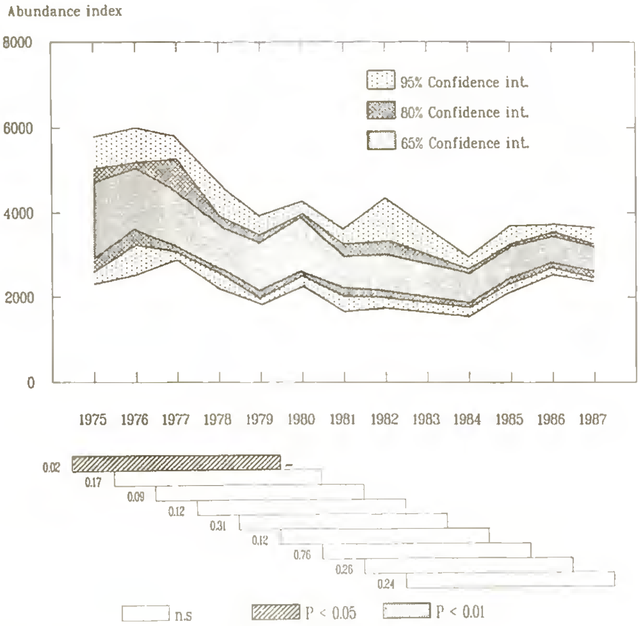


Fig. 6. Confidence intervals and test for trends for the northern stock of spotted dolphin, excluding 1983 estimate. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as in Fig. 5.

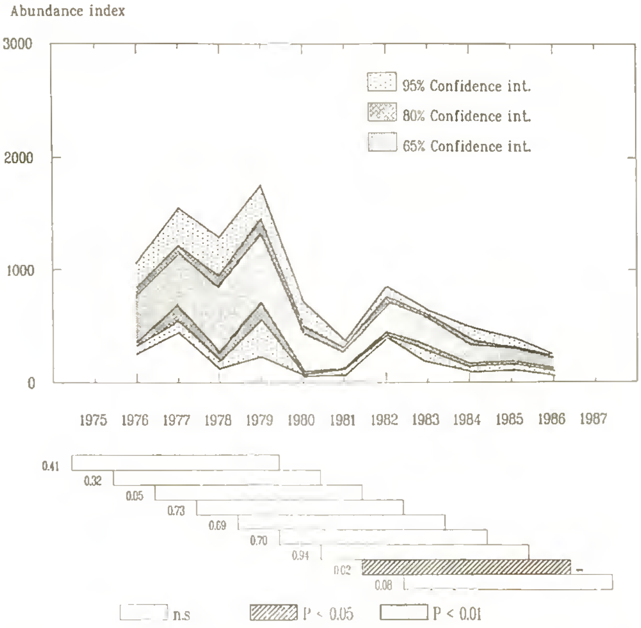


Fig. 7. Confidence intervals and test for trends for the southern stock of spotted dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

In Figs 14–21, we show estimates for the boundaries of Perrin *et al.* (1985) under both the old and the new procedure, and estimates for the narrower SOPS boundaries under the new procedure alone. The estimates from the old procedure are slightly different from those of Buckland and Anganuzzi (1988), as an error was detected in the smearing routine. This had the effect of deleting a small proportion of sightings, although conclusions were unaffected.

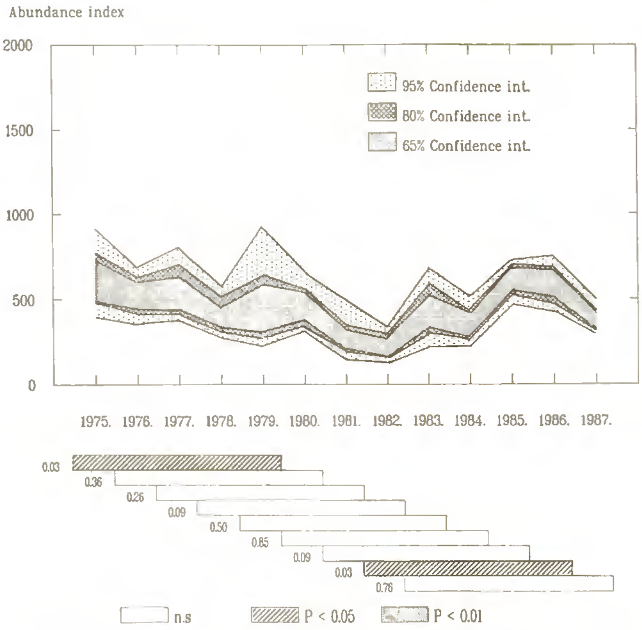


Fig. 8. Confidence intervals and test for trends for the eastern stock of spinner dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

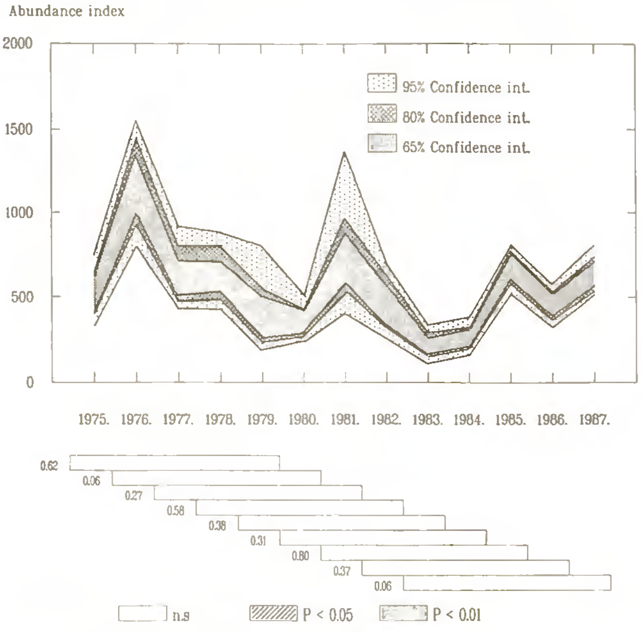


Fig. 9. Confidence intervals and test for trends for the northern whitebelly stock of spinner dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

Using the estimates derived from SOPS boundaries we tested for differences between mean estimates for 1975–80 and for 1981–87. Table 2 corresponds to Table 10 of Buckland and Anganuzzi (1988). We also carried out the five-year tests for linear trend described by them. The results are summarised in Figs 5–13.

Spotted dolphin

(i) Northern offshore stock

Fig. 14 suggests that the new estimation procedures considered here provide marginally more stable estimation of the northern offshore spotted dolphin stock than the procedure of Buckland and Anganuzzi (1988). Full estimates using the SOPS boundaries are shown in Table 3. The 1983 estimate, corresponding to a strong El Niño event, is still low, but is proportionately closer to the other estimates when the new procedure is used. Significant trends noted in Fig. 5 corresponding to 1979/83 and 1983/87 both have the very low El Niño estimate as an endpoint, and so should be viewed as unreliable. As a comparison, Fig. 6 shows the results when the 1983 estimate is excluded. The only significant trend is for the period 1975/79, when estimates decreased. This is consistent with the test of Table 2 which provides strong evidence of lower stock levels during 1981/87 relative to 1975/80.

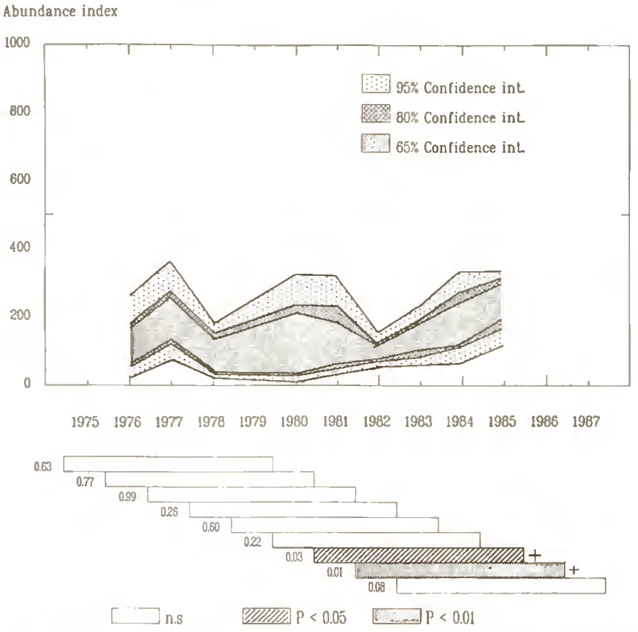


Fig. 10. Confidence intervals and test for trends for the southern whitebelly stock of spinner dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

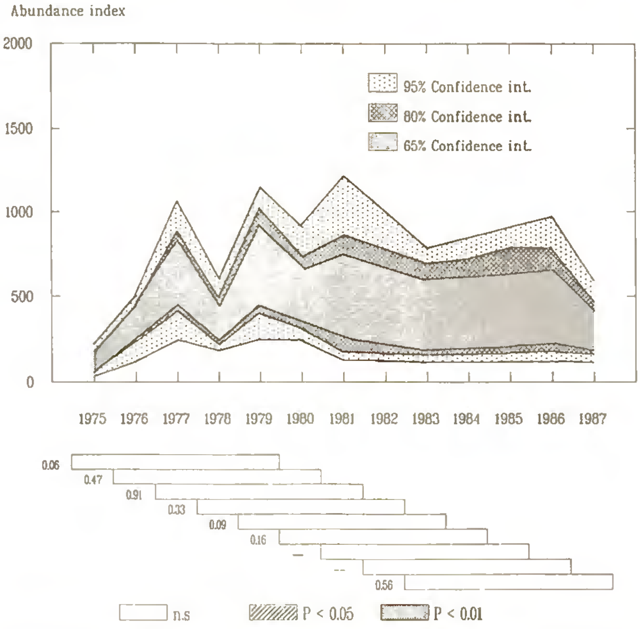


Fig. 11. Confidence intervals and test for trends for the northern stock of common dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

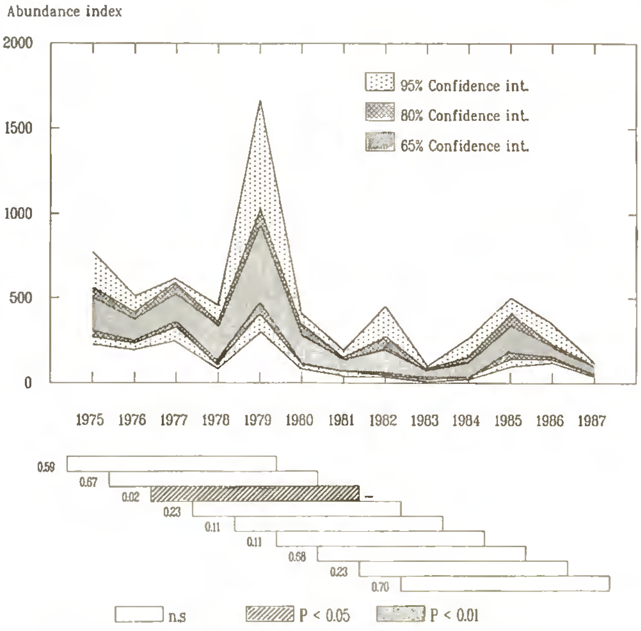


Fig. 12. Confidence intervals and test for trends for the central stock of common dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

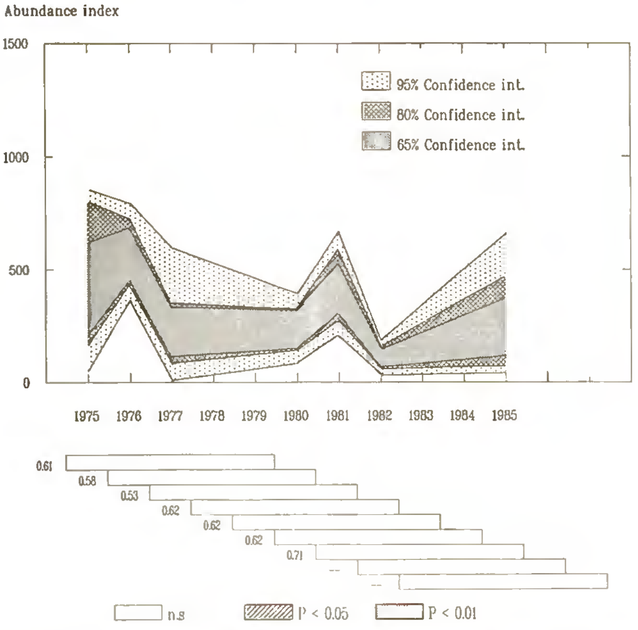


Fig. 13. Confidence intervals and test for trends for the southern stock of common dolphin. The bars summarise results on tests for linear trends for five-year periods. Numbers on the left of the bars are the corresponding p-values. If trends are significant a + or – sign at the right indicates the direction of trend. ×, + and ○ as Fig. 5.

Table 1

Stratification based on PCA analysis for estimation of effective strip width. 1987 data, the northern offshore stock of spotted dolphin, SOPS boundaries.

Variable	Comp. 1	Comp. 2	Comp. 3	Comp. 4
Proportion of sets made on dolphins	–0.78	–0.06	0.19	–0.59
Proportion of sightings for which cue was birds	0.52	–0.08	0.72	–0.45
Proportion of sightings made by helicopter	0.26	–0.64	–0.55	–0.46
Average Beaufort	0.22	0.76	–0.38	–0.49
Correlation between scores and f(0)	–0.30	–0.58	0.40	0.63

Table 2

Tests of whether average stock size estimates (using SOPS boundaries) for 1975–80 and for 1981–87 differ significantly.

Stock	Years used in analysis	Stock size estimate and S.E. (000's)		p
		1975/80	1981/87	
Northern offshore spotted dolphin	75/87	3588 (304)	2495 (161)	0.001
	75/82,84/87	3588 (304)	2708 (161)	0.010
Southern offshore spotted dolphin	76/86	676 (131)	314 (51)	0.010
Eastern spinner dolphin	75/87	486 (68)	396 (44)	> 0.1
Northern whitebelly spinner dolphin	75/87	509 (77)	474 (55)	> 0.1
Southern whitebelly spinner dolphin	76/78,80/85	127 (36)	159 (28)	> 0.1
Northern common dolphin	75/81,83,86/87	437 (69)	427 (118)	> 0.1
Central common dolphin	75/87	400 (61)	136 (26)	< 0.0001
Southern common dolphin	75/77,80/82,85	358 (96)	262 (120)	> 0.1

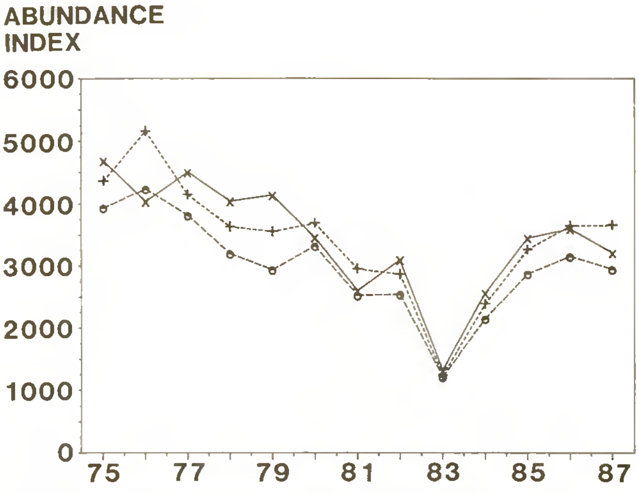


Fig. 14. Abundance estimates for the northern stock of spotted dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

As a result of using tighter boundaries, the estimates of Table 3 are lower than those using Perrin *et al.* (1985) boundaries, on average by roughly 500,000 animals. They are rather higher on average than those of Hammond and Laake (1983) for the same stock, and slightly lower than the average of their estimates that are stratified by fishing mode, which include the southern stock. The average of the abundance estimates for 1977–83 from Table 3 lies between the two estimates for this period given by Holt (1985), who also used the SOPS boundaries and used both research vessel and tuna vessel data from which to generate estimates; estimates based on research vessel data alone are appreciably lower than ours. See Buckland and Anganuzzi (1988) for more detailed comparison.

Table 3

Estimates for the northern offshore stock of spotted dolphin, using the SOPS boundaries. [] indicate that 1977 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	761	[2.74] (0.30)	9.00 (1.28)	634 (71)	6232 (1145)	3949 (996)
1976	876	[2.74] (0.30)	7.40 (0.92)	830 (92)	5127 (878)	4253 (908)
1977	1700	2.74 (0.30)	6.46 (0.52)	855 (73)	4476 (692)	3828 (751)
1978	720	2.65 (0.23)	6.58 (0.53)	680 (69)	4723 (551)	3212 (543)
1979	516	2.36 (0.32)	7.03 (0.67)	521 (54)	5661 (922)	2950 (559)
1980	1460	2.37 (0.28)	6.36 (0.39)	654 (80)	5098 (707)	3335 (582)
1981	1593	2.62 (0.24)	6.39 (0.37)	547 (44)	4633 (561)	2536 (443)
1982	1383	2.37 (0.57)	6.32 (0.34)	503 (54)	5072 (1341)	2550 (557)
1983	731	2.92 (0.37)	5.94 (0.64)	316 (44)	3863 (533)	1221 (249)
1984	636	3.19 (0.34)	8.81 (0.78)	411 (51)	5249 (742)	2158 (362)
1985	1976	2.78 (0.18)	8.96 (0.63)	471 (41)	6125 (562)	2884 (352)
1986	2197	2.76 (0.17)	9.11 (0.41)	504 (30)	6276 (498)	3165 (302)
1987	3529	2.85 (0.13)	8.82 (0.41)	502 (36)	5886 (423)	2953 (293)

Table 4

Estimates for the southern offshore stock of spotted dolphin, using SOPS boundaries. [] indicate that 1977–79 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	-	-	-	-	-	-
1976	54	[2.39] (0.49)	2.84 (0.72)	1032 (176)	557 (158)	574 (212)
1977	42	[2.39] (0.49)	4.79 (0.96)	985 (213)	938 (285)	924 (332)
1978	37	[2.39] (0.49)	4.02 (1.21)	743 (241)	786 (261)	584 (302)
1979	46	2.39 (0.49)	5.25 (1.65)	1011 (182)	1029 (375)	1040 (394)
1980	43	1.70 (0.38)	1.44 (0.64)	655 (181)	397 (186)	260 (168)
1981	59	1.91 (0.48)	1.47 (0.49)	551 (52)	361 (141)	199 (83)
1982	73	1.82 (0.41)	3.25 (0.43)	709 (122)	833 (204)	591 (180)
1983	55	2.04 (0.47)	3.94 (0.91)	507 (63)	905 (302)	459 (177)
1984	24	1.79 (0.42)	1.78 (0.52)	524 (109)	466 (171)	244 (115)
1985	43	2.01 (0.53)	2.45 (0.57)	418 (101)	570 (155)	238 (68)
1986	21	2.88 (0.78)	2.81 (0.60)	336 (57)	458 (169)	154 (60)
1987	-	-	-	-	-	-

(ii) Southern offshore stock

Since there were too few data to allow stratification of the southern offshore spotted dolphin, the new procedure is different from the old only in the number of years included to estimate f(0). Fig. 15 shows that the differences between the old and new procedure when using the same boundaries are very small. The tighter SOPS boundaries (Table 4) yielded estimates of abundance that are slightly more than half the estimates obtained using the Perrin *et al.* (1985) boundaries although estimated trends are similar (Fig. 15). On average, the estimates of Table 4 were close to those of Hammond and Laake (1983) and Holt (1985). Table 2 and Fig. 15 provide some evidence of a decline in this stock. However, the distribution of sightings is highly variable between years, and in some recent years 20–50% have been south of 11°S, and hence outside the SOPS boundary for the sock (M.D. Scott, pers. comm.). This may contribute to the large fluctuations in the estimates, and cause the apparent decline in numbers.

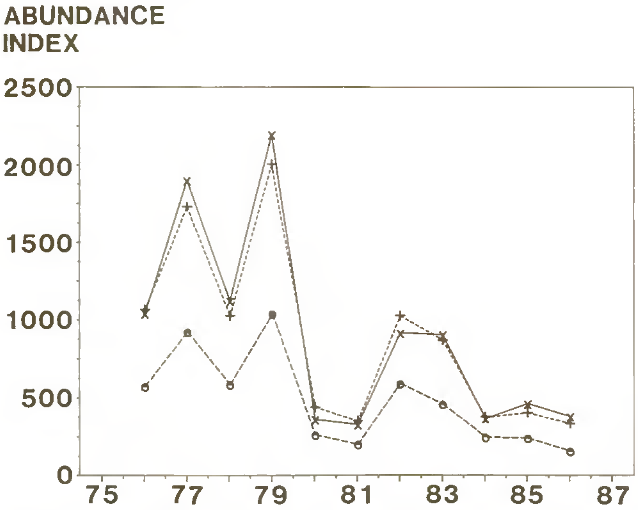


Fig. 15. Abundance estimates for the southern stock of spotted dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

Spinner dolphin

Estimates for the eastern and northern whitebelly stocks of spinner dolphin (including unidentified spinners) under the new estimation procedure are given in Table 5.

Table 5

Estimates for the eastern and northern whitebelly stocks of spinner dolphin, including unidentified, using SOPS boundaries. [] indicate that 1977 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	417	[2.69] (0.29)	3.99 (0.46)	376 (65)	2897 (458)	1088 (249)
1976	554	[2.69] (0.29)	5.34 (0.73)	448 (45)	3878 (700)	1739 (360)
1977	946	2.69 (0.29)	3.50 (0.29)	434 (47)	2540 (409)	1101 (225)
1978	402	2.49 (0.27)	4.00 (0.46)	322 (31)	3137 (431)	1008 (181)
1979	262	2.59 (0.58)	3.76 (0.53)	281 (40)	2832 (954)	794 (305)
1980	694	2.31 (0.25)	2.99 (0.22)	312 (33)	2530 (347)	789 (142)
1981	774	2.14 (0.68)	3.54 (0.29)	294 (36)	3222 (1274)	949 (345)
1982	605	2.58 (0.56)	3.39 (0.36)	240 (28)	2571 (682)	617 (163)
1983	462	2.53 (0.48)	3.47 (0.38)	236 (33)	2684 (569)	634 (161)
1984	324	3.15 (0.33)	4.26 (0.31)	224 (32)	2644 (323)	593 (120)
1985	1265	3.01 (0.23)	6.02 (0.39)	316 (34)	3904 (382)	1234 (143)
1986	1352	2.97 (0.23)	5.46 (0.36)	288 (28)	3593 (343)	1034 (145)
1987	2197	2.72 (0.14)	5.68 (0.44)	253 (21)	4081 (393)	1034 (115)

Table 6

Estimates for the eastern stock of spinner dolphin, using SOPS boundaries. [] indicate that 1977 estimate was used. Bootstrap standard errors are given in parentheses. * Unidentified spinner schools prorated between eastern and northern whitebelly stocks.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)	Number of dolphins* (000's)
1975	140	[2.68] (0.35)	0.94 (0.27)	564 (157)	398 (117)	225 (90)	599 (197)
1976	103	[2.68] (0.35)	1.14 (0.31)	569 (70)	485 (134)	276 (72)	535 (190)
1977	428	2.68 (0.35)	1.93 (0.19)	484 (62)	817 (130)	396 (89)	514 (152)
1978	141	2.06 (0.56)	1.35 (0.20)	463 (88)	747 (228)	346 (129)	395 (124)
1979	130	2.90 (0.52)	1.78 (0.29)	348 (99)	701 (185)	244 (103)	428 (202)
1980	248	2.25 (0.39)	1.13 (0.13)	479 (109)	570 (111)	273 (92)	447 (112)
1981	334	2.97 (0.49)	1.93 (0.23)	346 (57)	739 (153)	256 (67)	255 (165)
1982	204	2.78 (0.74)	1.29 (0.14)	367 (54)	527 (170)	193 (71)	202 (91)
1983	187	2.27 (0.34)	2.45 (0.30)	335 (61)	1225 (209)	410 (91)	423 (130)
1984	108	2.70 (0.66)	2.32 (0.48)	315 (51)	974 (200)	307 (62)	340 (85)
1985	714	2.75 (0.28)	3.31 (0.33)	395 (55)	1371 (199)	542 (114)	586 (124)
1986	667	3.02 (0.29)	2.99 (0.17)	362 (37)	1128 (116)	408 (60)	584 (108)
1987	1278	2.89 (0.17)	2.81 (0.15)	281 (19)	1102 (92)	310 (38)	384 (87)

Table 7

Estimates for the northern whitebelly stock of spinner dolphin, using SOPS boundaries. [] indicate that 1977 estimate was used. Bootstrap standard errors are given in parentheses. * Unidentified spinner schools prorated between eastern and northern whitebelly stocks.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)	Number of dolphins* (000's)
1975	53	[3.23] (0.56)	1.13 (0.26)	347 (67)	531 (169)	184 (63)	490 (181)
1976	176	[3.23] (0.56)	3.32 (0.70)	400 (74)	1554 (415)	622 (202)	1205 (293)
1977	325	3.23 (0.56)	2.45 (0.31)	396 (48)	1146 (304)	453 (150)	588 (163)
1978	150	2.58 (0.32)	3.13 (0.48)	292 (42)	1841 (321)	537 (109)	613 (150)
1979	64	2.33 (0.61)	1.39 (0.37)	231 (44)	905 (385)	209 (87)	366 (183)
1980	229	2.98 (0.46)	1.93 (0.22)	213 (30)	981 (187)	209 (45)	342 (99)
1981	311	1.27 (0.74)	2.46 (0.35)	237 (29)	2939 (2044)	696 (476)	694 (287)
1982	205	1.90 (0.73)	1.97 (0.31)	254 (39)	1567 (706)	398 (159)	416 (132)
1983	215	2.56 (0.76)	2.11 (0.36)	164 (38)	1250 (520)	204 (95)	211 (90)
1984	147	3.91 (0.49)	2.56 (0.32)	230 (41)	993 (158)	228 (64)	253 (72)
1985	229	2.99 (0.63)	4.03 (0.59)	294 (38)	2037 (469)	599 (157)	648 (128)
1986	358	3.05 (0.32)	2.75 (0.35)	231 (26)	1366 (248)	315 (75)	451 (95)
1987	320	2.94 (0.31)	3.42 (0.43)	297 (50)	1764 (323)	525 (153)	650 (105)

Separate estimates for the two stocks appear in Tables 6 and 7. The proration scheme for unidentified schools is described by Buckland and Anganuzzi (1988). Estimates for the southern whitebelly stock of spinner dolphin using both sets of boundaries, and including unidentified schools of spinner dolphin in the southern area, are in Table 8.

Table 8

Estimates for the southern whitebelly stock of spinner dolphin, using SOPS boundaries. [] indicate that 1977–79 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	–	–	–	–	–	–
1976	35	[2.63] (0.84)	1.56 (0.48)	333 (111)	345 (122)	115 (62)
1977	30	[2.63] (0.84)	3.09 (0.73)	297 (73)	683 (302)	203 (87)
1978	20	[2.63] (0.84)	1.88 (0.56)	156 (58)	417 (186)	65 (47)
1979	–	–	–	–	–	–
1980	25	1.10 (0.88)	0.72 (0.22)	330 (180)	377 (232)	124 (86)
1981	38	1.34 (0.70)	0.84 (0.27)	341 (164)	363 (139)	124 (80)
1982	38	1.68 (0.68)	1.35 (0.21)	213 (33)	467 (201)	100 (47)
1983	44	2.05 (0.53)	2.41 (0.67)	210 (46)	683 (258)	144 (47)
1984	24	1.62 (0.40)	1.42 (0.27)	357 (102)	508 (126)	182 (71)
1985	48	1.42 (0.40)	2.25 (0.47)	269 (35)	921 (230)	247 (64)
1986	–	–	–	–	–	–
1987	–	–	–	–	–	–

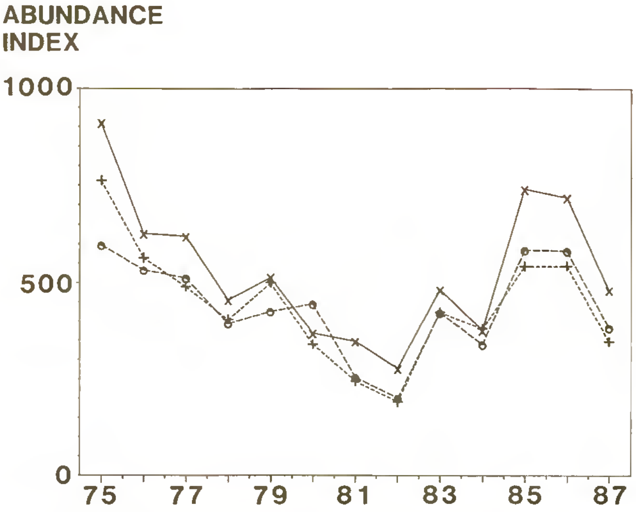


Fig. 16. Abundance estimates for the eastern stock of spinner dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

(i) Eastern stock

Abundance estimates for the eastern spinner dolphin seem very similar under the new procedure for either set of boundaries (Fig. 16 and Table 6). The 1977–83 estimates of Table 6 are slightly lower on average than those of Holt (1985), but the 1977–79 estimates are higher than those of Holt and Powers (1982). The various estimates of Hammond and Laake (1983) are generally lower than the corresponding estimates given here. Our 1987 estimates are similar to those for the early 1980s, suggesting that the higher estimates of abundance for 1985–86 may not indicate a real increase in stock size.

(ii) Northern whitebelly stock

Neither replacing the old procedure by the new nor changing the stock boundaries seemed to affect the estimates of the northern whitebelly stock of spinner

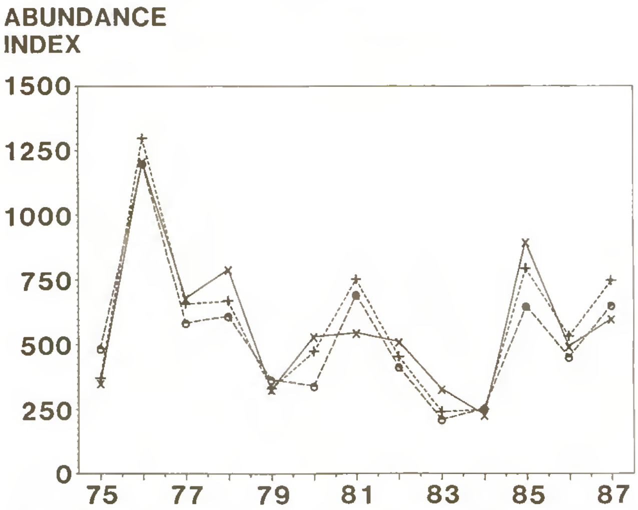


Fig. 17. Abundance estimates for the northern whitebelly stock of spinner dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

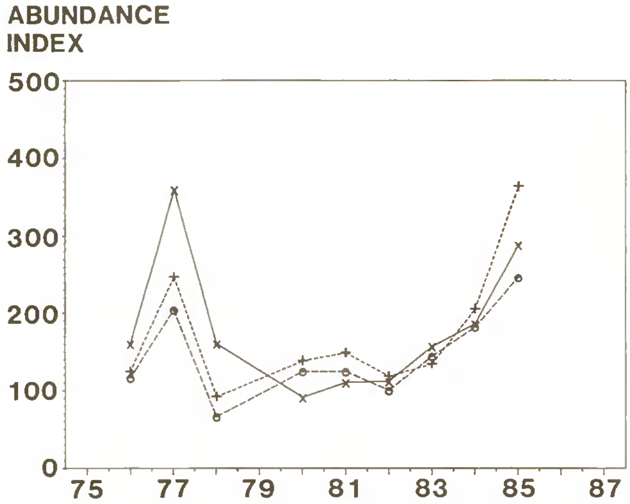


Fig. 18. Abundance estimates for the southern whitebelly stock of spinner dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

dolphin greatly, so that results were similar to those of Buckland and Anganuzzi (1988) (Fig. 17). Fig. 9 shows an apparent decline over 1976–80, and weak evidence of an increasing trend for 1983–87.

(iii) Southern whitebelly stock

The small number of sightings did not allow stratification for this stock. Estimates for the new procedure were similar when using the two different boundaries (Fig. 18), although estimates were slightly lower for the SOPS stock because the area encompassed is smaller than that of Perrin *et al.* (1985). When compared with estimates for the old procedure, they were lower on average and more stable. On average, they are also lower than those of Holt and Powers (1982) and considerably lower than those of Holt (1985), but are broadly similar to those of Hammond and Laake (1983) that include unidentified spinner dolphin schools. There may have been some increase in this stock during the early 1980s (Fig. 10).

Table 9

Estimates for the northern stock of common dolphin, using SOPS boundaries. [] indicate that 1977–79 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	36	[1.10]	1.52	287	427	122
		(0.17)	(0.28)	(104)	(107)	(51)
1976	40	[1.10]	1.48	827	416	344
		(0.17)	(0.25)	(251)	(104)	(130)
1977	84	[1.10]	2.35	967	658	637
		(0.17)	(0.65)	(199)	(204)	(200)
1978	29	[1.10]	1.24	1029	348	358
		(0.17)	(0.31)	(292)	(100)	(126)
1979	40	1.10	2.08	1116	583	650
		(0.17)	(0.45)	(382)	(145)	(248)
1980	112	1.35	1.72	1304	393	512
		(0.21)	(0.32)	(252)	(97)	(191)
1981	74	1.21	1.45	1392	369	513
		(0.20)	(0.40)	(555)	(124)	(330)
1982	–	–	–	–	–	–
1983	41	1.01	1.97	695	598	415
		(0.20)	(0.45)	(317)	(152)	(210)
1984	–	–	–	–	–	–
1985	–	–	–	–	–	–
1986	74	1.50	1.88	1233	385	475
		(0.36)	(0.46)	(365)	(136)	(237)
1987	106	1.62	1.93	831	366	304
		(0.33)	(0.47)	(167)	(108)	(123)

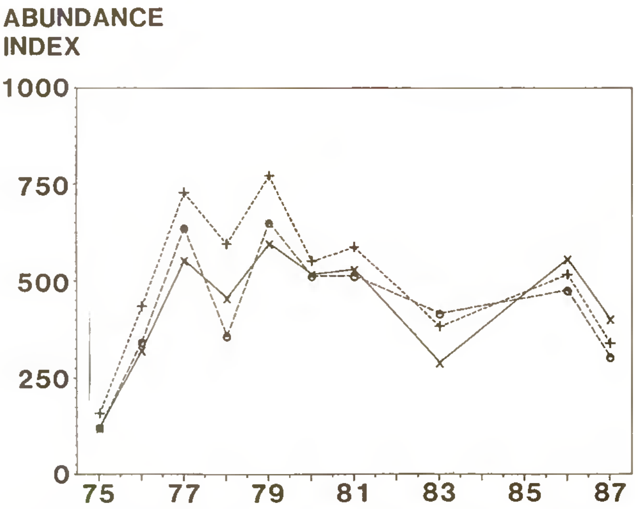


Fig. 19. Abundance estimates for the northern stock of common dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

Common dolphin

(i) Northern stock

Again, there were insufficient sightings to allow stratification. There were only minor differences between the old and the new procedure when using the same set of boundaries (Fig. 19). The change in boundaries made little difference to the estimates. Hence, our estimates remained surprisingly high relative to those of Holt (1985).

(ii) Central stock

Estimates of abundance for the central stock under the new procedure were very similar for the two sets of boundaries, and were broadly similar, but somewhat lower on average, than under the old procedure (Fig. 20). There is evidence

Table 10

Estimates for the central stock of common dolphin, using SOPS boundaries. [] indicate that 1977 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	142	[1.86]	1.69	406	994	404
		(0.25)	(0.14)	(129)	(164)	(138)
1976	164	[1.86]	1.04	468	614	287
		(0.25)	(0.14)	(103)	(130)	(80)
1977	319	1.86	1.26	628	742	466
		(0.25)	(0.14)	(111)	(105)	(90)
1978	117	1.57	0.72	653	505	329
		(0.58)	(0.16)	(130)	(159)	(105)
1979	68	1.32	0.99	815	815	664
		(0.50)	(0.17)	(199)	(298)	(287)
1980	74	0.83	0.45	427	588	251
		(0.26)	(0.05)	(255)	(125)	(85)
1981	46	1.49	0.26	583	191	111
		(0.45)	(0.07)	(118)	(69)	(35)
1982	94	1.42	0.48	634	367	232
		(0.55)	(0.09)	(169)	(105)	(101)
1983	38	2.54	0.48	211	205	43
		(2.03)	(0.28)	(132)	(144)	(22)
1984	24	1.01	0.39	167	425	71
		(1.70)	(0.16)	(56)	(816)	(91)
1985	168	1.60	0.90	434	611	265
		(0.66)	(0.19)	(170)	(224)	(105)
1986	196	1.77	0.86	319	531	169
		(0.44)	(0.14)	(60)	(139)	(50)
1987	132	2.74	0.45	332	180	60
		(0.70)	(0.08)	(56)	(50)	(18)

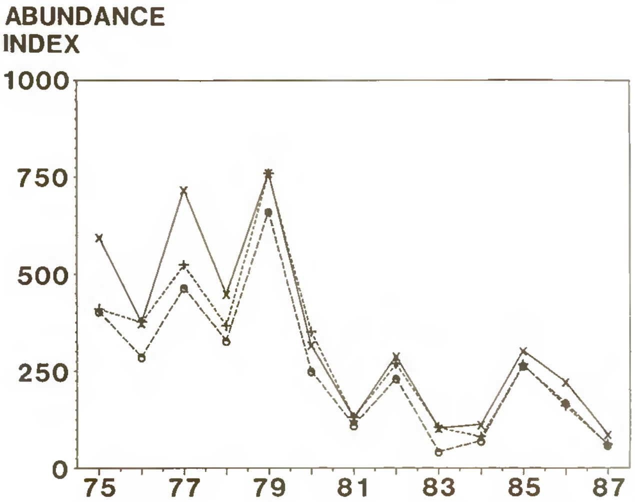


Fig. 20. Abundance estimates for the central stock of common dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

of a decline during 1977–81 (Fig. 12), supported by the strong evidence of a decline between the two periods 1975–80 and 1981–87 (Table 2). In marked contrast to the previous stock, our estimates are appreciably lower than those of Holt (1985).

(iii) Southern stock

No stratification was possible for the southern stock of common dolphin. For the same boundaries, estimates for the new procedure (Fig. 21) yielded slightly smoother trends. Estimates for the SOPS boundaries are presented in Table 11. Fig. 21 shows that the abundance estimates are smaller on average and more stable than those for the boundaries of Perrin *et al.* (1985). Too few data exist to detect any trends in abundance.

Table 11

Estimates for the southern stock of common dolphin, using SOPS boundaries. [] indicate that 1977–79 estimate was used. Bootstrap standard errors are given in parentheses.

Year	No. of sightings	Effective track half-width (nm)	Encounter rate (schools/ 1,000nm)	Average school size	Number of schools	Number of dolphins (000's)
1975	26	[1.36]	2.03	614	626	385
		(0.44)	(0.59)	(195)	(241)	(227)
1976	114	[1.36]	4.19	453	1295	586
		(0.44)	(1.04)	(132)	(553)	(223)
1977	25	[1.36]	1.48	500	458	229
		(0.44)	(0.74)	(415)	(279)	(162)
1978	-	-	-	-	-	-
1979	-	-	-	-	-	-
1980	50	1.27	1.13	613	375	230
		(0.54)	(0.25)	(139)	(194)	(139)
1981	48	1.48	1.08	1421	306	435
		(0.41)	(0.31)	(262)	(108)	(142)
1982	22	1.29	0.66	474	217	103
		(0.66)	(0.15)	(168)	(116)	(90)
1983	-	-	-	-	-	-
1984	-	-	-	-	-	-
1985	28	0.68	1.11	364	685	249
		(0.42)	(0.50)	(88)	(720)	(318)
1986	-	-	-	-	-	-
1987	-	-	-	-	-	-

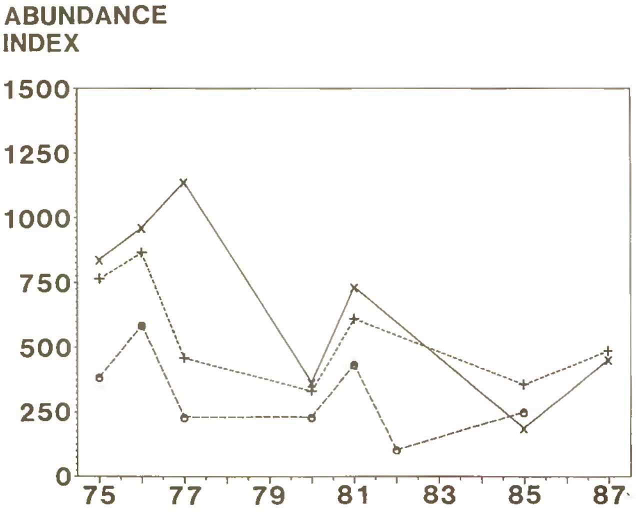


Fig. 21. Abundance estimates for the southern stock of common dolphin from Buckland and Anganuzzi (1988) and for the current procedure using Perrin *et al.* (1985) boundaries and SOPS boundaries.

DISCUSSION

Relative to the methods of Buckland and Anganuzzi (1988), the estimates presented here take account of bias resulting from geographic variability in average school size and in effective search width. However, the new procedure does not address the potentially serious problems of vessels turning on to schools before a sighting angle is recorded, or of non-random search for local, temporary concentrations of dolphin schools, in which case the assumption that sightings are independent events is violated. Biases arising from either effect would lead to overestimation of abundance (Buckland and Anganuzzi, 1988). We believe, therefore, that an attempt to calibrate our estimates against research vessel estimates should be made; the quantity of tuna vessel data over a long period of time seems to make them more appropriate for estimating trends in relative abundance, whereas research vessel data may yield a less biased estimate of absolute abundance, and, given enough research vessel cruises, may allow an assessment of whether trends exist in the bias in estimates from tuna vessels.

Buckland and Anganuzzi (1988) found that their estimates of trends were relatively insensitive to choice of stock boundaries. The new procedure is expected to be more sensitive to unreliable estimation in large strata with low densities of dolphins, since we estimate each component in the model (encounter rate, effective track width and average school size) for a random point within the boundaries. Hence, we might expect estimation to be more stable using the tighter SOPS boundaries than for the boundaries of Perrin *et al.* (1985). Estimates from research vessel data are based on SOPS boundaries (Holt and Powers, 1982; Holt, 1985), so that if calibration is to be carried out against them and future research vessel estimates, it seems more appropriate to use the SOPS boundary estimates presented here. The disadvantage is that dolphin abundance may be underestimated, as a result of dolphins occurring beyond the SOPS boundaries. We recommend that the estimated trends of Figs 5–13 are used for future work; that is, we propose that the new estimation procedures described here are used in conjunction with the SOPS boundaries.

Buckland and Anganuzzi (1988) gave figures showing geographic distribution of fishing effort by year and by season. They also examined the implications of seasonal movements by both the dolphins and tuna vessels, and concluded that bias from this source was slight. They noted that local concentrations of schools could lead to overestimation of density, and studies by Edwards and Kleiber (pers. comm.) have examined this effect. The low 1983 estimate for the northern offshore spotted dolphin might have arisen if concentrations of schools did not occur during the strong El Niño of that year. If this is so, the 1983 estimate might be relatively unbiased (which accords with the fact that it is similar in magnitude to research vessel estimates) and other estimates might be biased upwards.

Bias in our estimates might be greater for years in which the tuna vessel fleets fish predominantly on dolphins. However, correlations between our estimates and percentage of sets made on dolphins during 1975–87 were not significant for any stock.

Buckland and Anganuzzi (1988) suggest further avenues of research which might be followed, some of which have been implemented here. If tuna vessel estimates are used to examine trend only, then it is tempting to simplify estimation by using encounter rates, as did Polacheck (1987), rather than line transect methods. These provide relative density estimates under certain assumptions. In the context of dolphin stocks in the eastern tropical Pacific, the approach is likely to be seriously biased if temporal and spatial variation in both average school size and probability of detection is ignored. To address the latter source of bias, line transect methodology seems the most appropriate tool. If school size is ignored, the overall number of schools may be roughly stable, yielding a stable relative abundance estimate, when the number of animals is declining (see Buckland and Anganuzzi, 1988). Methods similar to those developed by Drummer and McDonald (1987) may enable the line transect approach to handle bias in school size estimation in a more sophisticated way than we use here, but will still be subject to the constraints imposed by the quality of the data.

ACKNOWLEDGEMENTS

We would like to thank the many people who have contributed to the collection of the tuna vessel data, including observers and scientific technicians, and a number of scientists and data processors employed by NMFS and IATTC. In addition, we have had useful discussions with several researchers, in particular J. Barlow, E. Edwards, M. Hall, R. Holt, W. Perrin, S. Reilly, M.D. Scott, and T. Smith, which have helped formulate our ideas for improving on the procedures for estimating abundance from tuna vessel data. We are also grateful to S. Boyer and K. Smith for computing support, to R. Holt for facilitating our access to the San Diego Supercomputer Center and to our colleagues at IATTC, for their tolerance when our jobs filled the computer queues! Both referees made helpful suggestions which improved the final paper.

REFERENCES

Au, D., Perryman, W.L. and Perrin, W. 1979. Dolphin distribution and the relationship to environmental features in the eastern tropical Pacific. NMFS, SWFC Admin. Rep. No. LJ-79-43. 59pp.

Buckland, S.T. 1984. Monte Carlo confidence intervals. *Biometrics* 40: 811–7.

Buckland, S.T. and Anganuzzi, A.A. 1988. Trends in abundance of dolphins associated with tuna in the eastern tropical Pacific. *Rep. int. Whal. Commn* 38: 411–37.

Burnham, K.P., Anderson, D.R. and Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72. 202pp.

Drummer, T.D. and McDonald, L.L. 1987. Size bias in line transect sampling. *Biometrics* 43: 13–21.

Hall, M.A. and Boyer, S.D. 1988. Incidental mortality of dolphins in the eastern tropical Pacific. *Rep. int. Whal. Commn* 38: 439–41.

Hammond, P.S. and Laake, J.L. 1983. Trends in estimates of abundance of dolphins (*Stenella* spp. and *Delphinus delphis*) involved in the purse-seine fishery for tunas in the eastern Pacific Ocean, 1977–81. *Rep. int. Whal. Commn* 34: 565–83.

Holt, R.S. 1985. Estimates of abundance of dolphin stocks taken incidentally in the eastern tropical Pacific yellowfin tuna fishery. NMFS, SWFC Admin. Rep. No. LJ-85-20. 32pp.

Holt, R.S. and Powers, J.E. 1982. Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys to 1979. NOAA Tech. Memo. NMFS, SWFC No. 23. 95pp.

Perrin, W.F., Scott, M.D., Walker, G.J. and Cass, V.L. 1985. Review of geographical stocks of tropical dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern Pacific. NOAA Tech. Rep. NMFS 28: 28pp.

Polacheck, T. 1987. Relative abundance, distribution and inter-specific relationship of cetacean schools in the eastern tropical Pacific. *Mar. Mamm. Sci.* 3(1): 54–77.

Smith, T.D. 1983. Changes in sizes of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. *Fish. Bull., US* 81: 1–14.

SC/40/SM4

Recent Harvests of Belukha Whales, *Delphinapterus leucas*, in Western and Northern Alaska and Their Potential Impact on Provisional Management Stocks

Lloyd F. Lowry[1], John J. Burns[2] and Kathryn J. Frost[1]

ABSTRACT

The average annual landed harvest and average annual total kill of belukha whales, made by Alaskans in the period 1980–6, is estimated at 241 and 345 respectively. The total kill represents an annual removal by Alaskans of 1.9% to 2.6% of the estimated 13,500 to 18,000 belukhas that occur in, or pass through, waters adjacent to western and northern Alaska. We partitioned the average annual total kill among four provisional management stocks and suggest probable removal rates due to netting and hunting. The postulated rates are 1.8% of the Bristol Bay; 6.7% of the Norton Sound-Yukon Delta, 3.8% of the eastern Chukchi; and 1.0% of the eastern Beaufort stocks. The latter stock is also hunted by Canadians. The combined average annual total kills by Alaskans and Canadians, from the eastern Beaufort stock, is estimated at about 3%. Estimated values for size of the provisional stocks, and for total annual kills, require further verification and refinement. Research is also needed to determine relationships among the provisional stocks.

INTRODUCTION

This paper concerns the harvest of belukha (or white) whales (*Delphinapterus leucas*) that occur in, or pass through, coastal waters of western and northern Alaska. In Alaska, belukhas are an important subsistence resource for coastal residents. They appear seasonally near several villages where they are hunted with rifles and harpoons, or caught in nets. The small population which resides primarily in Cook Inlet is not considered in this report. Most belukhas in Alaska occur in the Bering, Chukchi and Beaufort Seas, mainly overwintering in the Bering Sea. The belukhas in this region are considered to be separate from those elsewhere in the north and we refer to them as the Bering Sea population. A provisional estimate of the number of belukhas occurring in waters adjacent to western and northern Alaska is 13,500–18,000 (Seaman, Frost and Lowry, 1986). If belukhas that summer in far eastern waters of the USSR are included, the number of belukhas in the Bering Sea population probably exceeds 25,000 (Burns, 1984; Seaman *et al.*, 1986; Burns and Seaman, 1986).

The identity of management units or stocks within the Bering Sea population is poorly known. Based on a compilation of information on distribution, abundance and movements, Seaman *et al.* (1986) tentatively identified four provisional stocks: (1) the eastern Beaufort Sea stock, numbering a minimum of 11,500 (Davis and Evans, 1982); (2) the eastern Chukchi Sea stock, estimated at 2,500–3,000 (Seaman *et al.*, 1986); (3) the Norton Sound/Yukon Delta stock estimated at 1,000–2,000 (Seaman *et al.*, 1986); and (4) the Bristol Bay stock, numbering approximately 1,000–1,500 (Frost, Lowry and Nelson, 1984; Seaman *et al.*, 1986). Stock size estimates for the eastern Beaufort Sea and Bristol Bay are based on aerial surveys, while estimates for Norton Sound/Yukon Delta and the eastern Chukchi Sea are largely based on opportunistic observations, although limited aerial surveys were conducted in the Chukchi Sea in 1978, 1979 and 1981 (Seaman *et al.*, 1986).

There has never been an adequate program to monitor belukha harvests in Alaska, although personnel of the Alaska Department of Fish and Game (ADF&G) have gathered such data whenever possible. The effort devoted to this has varied with availability of funds and staff, and competing priorities and needs.

Information on the magnitude of belukha harvests in Alaska for 1977–9, and review of harvest data in earlier years, was presented by Seaman and Burns (1981). Monitoring of harvests at major hunting sites was continued from 1980–3 with results presented in Burns and Seaman (1986), who also reported a partial compilation of harvest records for 1984. In this paper we present additional data collected from 1984–6, reanalyse the previously reported data for 1980–4, and briefly discuss trends in belukha hunting and harvest levels in western and northern Alaska.

METHODS AND ASSUMPTIONS

Our harvest data come from a variety of sources. In some instances we observed and sampled the entire belukha harvest at a particular village and therefore knew how many whales were retrieved. Usually, such sampling was at the more productive hunting sites. More commonly, our information was derived from interviews with local residents or opportunistic observations of ADF&G staff biologists. In such cases, the numbers were usually estimates rather than exact counts, or may not have represented all hunters or the entire hunting season. Sometimes an informant knew only that a harvest was ‘poor’ or ‘good,’ or that ‘some’ or ‘many’ belukhas were taken. When harvests were reported in those general terms, we made numerical estimates based on the range of known past harvests at the village in question. In this paper, we continue the procedure used by Burns and Seaman (1986) and provide numbers for the known and/or estimated harvests (each category is identified) for all hunting sites. In cases where values for both known and estimated harvests are given, it is because we had a firm figure for a minimum number taken but knew that additional animals were harvested.

---

[1] Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701

[2] Living Resources, Inc., P.O. Box 83570, Fairbanks, AK 99708

To determine total kill, the extent of hunting loss must be known. Accurate estimates of hunting loss are difficult to obtain and there are few data available. The loss rate varies greatly with the method of harvest, of which there are several (Seaman and Burns, 1981). Belukhas may be caught in nets set specifically to catch them or may be taken incidentally in the course of fishing for salmon or other fishes. In either case, net-caught belukhas are treated as harvested animals in our data, since those caught incidentally are usually used for human food. We continue to assume a loss rate of 0% for netted whales. Whales are taken, often in large numbers, in organised nearshore hunts during the open-water season by driving them into shallow water where they are killed. We have no additional information that alters the previous conclusions of Seaman and Burns (1981) or Burns and Seaman (1986) that the loss rate during whale drives approximates 20% (i.e. 20% of the total animals shot are lost and 80% are retrieved.)

In the Yukon-Kuskokwim Delta and in Bristol Bay, whales may be pursued individually or in small groups by one or more boats in open water. Water in this area is sometimes deep and often very muddy. Given the factors of water conditions (negative) and the pursuit of individual whales (positive) we estimate the loss rate for such hunting to be 40%. This is intermediate between the deep open water estimate of 60% loss and the 20% loss for whales taken in shallow water during drives.

Belukhas are also hunted in spring as they pass through leads or drifting ice. Loss rates are estimated at 60% for these types of hunting (Seaman and Burns, 1981). In spring 1985 an unusual event occurred near Kivalina when a large harvest was taken from a group of whales entrapped in the ice. Since the whales were in a confined opening, within easy range of harpoons, we have assumed a loss rate of 20% for that event.

Sometimes our information did not indicate the technique used to effect a harvest. This has been a problem with data for Bristol Bay and the Yukon–Kuskokwim Delta and, to a lesser extent, for Norton Sound. For Bristol Bay and the Yukon-Kuskokwim Delta, we have assumed that half the whales are taken in nets (loss 0%) and half in open water (loss 40%) unless we have data indicating otherwise. For Norton Sound villages, whales were assumed to have been taken in drive hunts (loss 20%) unless we were specifically informed that they were caught in nets. Therefore, some netted whales may have been included as animals taken during drives. This may result in a slight overestimate of total kill in this region.

The harvest data reviewed and presented here are partitioned among the four provisional stocks previously indicated. This was done based on a knowledge of the seasonal distribution and movements of belukhas in waters adjacent to Alaska (Seaman *et al.*, 1986). Harvests south of Bering Strait are taken in late spring to early fall and they can be easily ascribed to one of the provisional stocks based on location. However, north of Bering Strait, though belukhas may be present from March to October, they mainly appear along the coast in two peak periods. The first whales pass through coastal leads in spring (March-May) on their way to summering areas in the eastern Beaufort Sea. The second wave of whales appears in coastal waters during and after breakup of the sea ice (June to mid-August) (Seaman *et al.*, 1986). Generally, a village takes belukhas from only one of these groups and the harvests can be ascribed to each based on knowledge of when and where the hunt occurred. Wainwright is the only village that takes belukhas from both the eastern Chukchi and eastern Beaufort management stocks, as successful hunting occurs in leads during spring and near shore during mid-summer.

We emphasise that estimates of annual total landed harvests, total kills and size of each of the provisional stocks are just that – estimates. Considerable future work is required to make such estimates more accurate. Nonetheless, it is useful to derive preliminary estimates of the significance of average annual hunting mortality on each of the provisional management stocks. We have done this by dividing the mean of the range of the seven-year average estimated total kill by the mean of the range of estimated stock size.

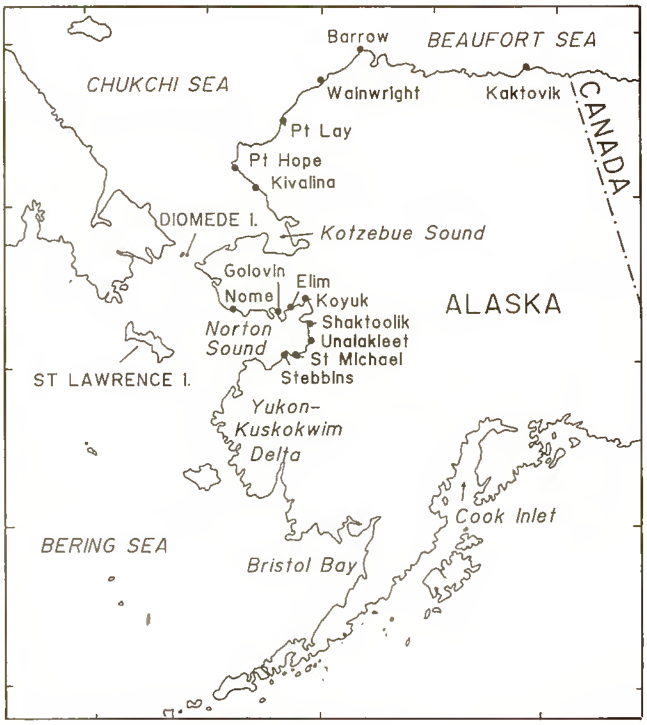


Fig. 1. Map of the Bering, Chukchi and Beaufort seas showing major locations mentioned in the text.

RESULTS

Estimated total annual landed harvests of belukhas in western and northern Alaska, from each of the provisional management stocks for the years 1980–6, are presented in Tables 1–4. Locations are shown in Fig. 1. Table 5 is an expansion of the landed harvests to estimated total annual kills (landed harvests + hunting losses), based on the loss rates previously discussed. For the four provisional management stocks combined, annual landed harvests during that seven-year period ranged from a low of 174–191 in 1986 to a high of 307-354 in 1982. The mean of the ranges for the seven years was 241, our value of the estimated average size of recent landed harvests in western and northern Alaska. Using similarly derived data about total kills, presented in Table 5, the mean of the ranges of total kills during 1980–6, was 345, or 1.9% to 2.6% of the estimated 13,500 to 18,000 belukhas that are in, or pass through, waters adjacent to Alaska.

Table 1

Known and estimated (in brackets) landings of belukhas from the provisional eastern Beaufort Sea stock of belukhas taken in western and northern Alaska, 1980–6

Year	Diomede	Kivalina	Point Hope	Barrow	Wain-wright	Kak-tovik	Total landings
1980[1]	2	3 (3–5)	23 (23–25)	0	(0)	11	39 (39–43)
1981[1]	(0)	3 (10–15)	(4–7)	5	(0)	0	8 (19–27)
1982[1]	1	4 (4–5)	17	3 (3–5)	(0)	0	25 (25–28)
1983[1]	0	24	30 (31)	0 (3)	(0)	0	54 (58)
1984[2]	(2–4)	27	(30)	0	(0)	0	27 (59–61)
1985	(2–4)	120–200	(30)	0	(0)	0	120–200 (152–234)
1986	(2–4)	7	(30)	0	1	0	8 (40–42)

[1] Harvest figures from Burns and Seaman (1986).

[2] Harvest figures, in part, from Burns and Seaman (1986), with additional estimates from this study.

Table 2

Known and estimated (in brackets) landings of belukhas from the provisional eastern Chukchi Sea stock, taken in western and northern Alaska, 1980–6

Year	Kotzebue Sound Southeast	Kotzebue Sound Northeast	Point Lay	Wainwright	Total landings
1980[1]	101	13	15 (15–18)	0	129 (129–132)
1981[1]	39	4	29 (29–38)	(0)	72 (72–81)
1982[1]	129	25	28 (28–33)	0	182 (182–187)
1983[1]	48	19 (19–24)	18	0	85 (85–90)
1984[2]	0	31	0	0	31
1985	2	13	18	0	33
1986	0	3	33	4	40

[1] Harvest figures from Burns and Seaman (1986).

[2] Harvest figures, in part, from Burns and Seaman (1986), with additional estimates from this study.

Table 6 includes information about average annual kills during 1980–6, made from each of the four provisional stocks, the estimated size of stocks and the percent annually removed by Alaskans. The annual rate of removal ranges from an estimated 1% for the provisional eastern Beaufort stock to 6.7% for the provisional Norton Sound-Yukon Delta stock.

DISCUSSION

Our data highlight the information needs for the four provisional stocks of belukhas that occur in, or pass through, waters adjacent to western and northern Alaska. A primary need is to understand relationships among the four provisionally recognised management stocks.

Table 4

Known and estimated (in brackets) landings of belukhas from the provisional Bristol Bay stock, taken in western and northern Alaska, 1980–6

Year	Landings	Year	Landings
1980[1]	8 (15–20)	1984[1]	6 (6–15)
1981[1]	(10–20)	1985	6 (10–15)
1982[1]	9 (15–20)	1986	6 (10–15)
1983[1]	22 (25–30)	Total	57 (91–135)

[1] Harvest figures from Burns and Seaman (1986).

Table 5

Summary of estimated total landings and estimated total kill of belukha whales in western and northern Alaska stocks 1980–6. ETL = Estimated total landings; EKL = Estimated total kill

Year	Eastern Beaufort ETL	Eastern Beaufort ETK	Eastern Chukchi ETL	Eastern Chukchi ETK	Norton Sound-Yukon Delta ETL	Norton Sound-Yukon Delta ETK	Bristol Bay ETL	Bristol Bay ETK
1980	39–43	98–107	129–132	165–174	50	75	15–20	20–27
1981	19–27	47–68	72–81	90–102	78–103	98–131	10–20	13–27
1982	25–28	62–68	182–187	223–239	85–119	109–153	15–20	20–27
1983	58	146	85–90	103–108	58	71	25–30	34–40
1984	59–61	123–128	31	36	90–104	114–130	6–15	8–20
1985	152–234	205–310	33	38	61–70	78–89	10–15	13–20
1986	40–42	75–80	40	50	84–94	101–114	10–15	13–20
Seven year total								
	392–493	756–907	572–594	705–747	506–598	646–763	91–135	121–181
Seven year average								
	56–70	108–130	82–85	101–107	72–85	92–109	13–19	17–26

Table 6

Potential magnitude (%) of average annual total kills of belukhas from the four provisional belukha whale stocks, made by Alaskans based on estimated total kills and estimated stock size. Total kills are the means of the ranges for the calendar years 1980–6

Parameter	E. Beaufort Range	E. Beaufort Mean	E. Chukchi Range	E. Chukchi Mean	Norton Sound - Yukon Delta Range	Norton Sound - Yukon Delta Mean	Bristol Bay Range	Bristol Bay Mean
Total kill	108–130	119	101–107	104	91–109	101	17–26	22
Stock size ('000s)	-	11.5	2.5–3.0	2.75	1.0–2.0	1.5	1.0–1.5	1.25
Estimated % removed annually		1.0		3.8		6.7		1.8

Table 3

Known and estimated (in brackets) landings of belukhas from the provisional Norton South-Yukon Delta stock, taken in western and northern Alaska, 1980–6

Year	Yukon – Kuskokwim Delta	Saint Michael	Stebbins	Unalakleet	Shaktoolik	Koyuk	Elim	Golovin	Nome	Total landings
1980[1]	9 (15)	(10)	(10)	(0)	(5)	(15)	(5)	(0)	(0)	9 (50)
1981[1]	17 (25–28)	11	10 (10–20)	(0)	7 (7–15)	21 (21–25)	3	(0)	1	70 (78–103)
1982[1]	29 (29–47)	4 (4–10)	6	(0)	16	13 (15–20)	14 (15–20)	(0)	(0)	82 (85–119)
1983[1]	6 (15)	4	7	2	7	11	10	2	0	49 (58)
1984[2]	5 (20)	(5–10)	(8–10)	(0)	(8–10)	38	(10–15)	1	0	44 (90–104)
1985	(25)	7	(8–10)	(0)	(8–10)	3	(10–15)	(0)	0	10 (61–70)
1986	(30–40)	6	4	(0)	4	10	30	(0)	0	54 (84–94)

[1] Harvest figures from Burns and Seaman (1986).

[2] Harvest figures, in part, from Burns and Seaman (1986), with additional estimates from this study.

Whether they are discrete stocks or not is a question central to their management. This is especially true for the Norton Sound-Yukon Delta stock which sustains a postulated kill rate estimated at 6.7%. More accurate estimates of stock size, landed harvests and hunting loss are also needed for this provisional stock.

The Bristol Bay stock is not intensively harvested at this time. A high proportion of the 17 to 26 whales taken annually are caught incidentally in the course of the intensive salmon fishery which is conducted with drift- and set-gillnets. The loss rate of killed whales is low. Surveys and observations in this area suggest that stock size has been stable over the last 30 years (Frost *et al.*, 1984).

Harvest data for both the provisional eastern Chukchi and eastern Beaufort stocks are relatively easy to obtain and are acceptably reliable. However, such records should continue to be compiled. Additional effort should be devoted to obtaining more accurate estimates of losses associated with belukha hunting in relatively deep water, as during the spring hunts in lead systems, and during the shallow-water drive hunts. It is especially important to obtain information about the relationship and extent of discreteness (if any) between the eastern Chukchi and eastern Beaufort management stocks. Better estimates of stock sizes are also needed, especially for belukhas that spend part of the summer in coastal waters of the eastern Chukchi Sea.

Recent harvests of belukhas in southeastern Kotzebue Sound have been reduced and irregular. Our present hypothesis is that this has resulted from partial displacement (reduced availability to hunters), rather than a decline in numbers of whales or a reduction in hunting effort. A hunting camp in northeastern Kotzebue Sound has been reoccupied in recent years and motor boat traffic between Kotzebue and the camp, through the area once intensively used by belukhas, has increased steadily. Local residents believe the use of new, large outboard motors with underwater exhaust contributes to the problem (P. Schaeffer, Kotzebue, AK, pers. comm.). In southeastern Kotzebue Sound, particularly in the early to mid-1980s, boat traffic associated with the belukha hunt increased greatly as people from other areas where belukhas were less numerous came to hunt. Traditionally, this hunt was highly coordinated and occurred on only a few days each summer, after which the whales were left undisturbed. Beginning in the early 1980s, hunting began to occur in a less coordinated fashion, resulting in much more boat activity in the areas used by belukhas.

Based on an estimate of 2,500 to 3,000 belukhas in the eastern Chukchi Sea provisional stock, the average kill rate of 3.8% is not excessive. Although overhunting cannot be entirely discounted, since stock size estimates are based on aerial photographic counts near Point Lay (the assumption is that Point Lay belukhas are the same as those seen several weeks earlier in Kotzebue Sound), we think it is unlikely. At Point Lay, there has been no recent change in hunting success relative to effort, or in the numbers of belukhas sighted in the area (Frost and Lowry, in review). It is possible that in recent years most belukhas have by-passed Kotzebue Sound and moved directly to the Point Lay area.

The provisional eastern Beaufort Sea stock is the only one hunted in waters of both Alaska and Canada. The current estimate of 11,500 animals (Davis and Evans, 1982) is probably conservative and additional effort will be required to further refine that estimate. The total annual kills made by Alaskan hunters, estimated to average 119, is 1.0% of the stock. Data on landed harvests and total kills of these belukhas from Canadian waters of the eastern Beaufort Sea and Amundsen Gulf have been obtained by the Canadian Fisheries Joint Management Committee since 1985. In 1985–87, the average annual landed harvest was 137 and the estimated total kill was 175. Data from previous studies indicate a similar average harvest of 135, but a substantially higher average number (225) struck and lost (Sergeant and Brodie, 1975; Hunt, 1976, 1977, 1979; Fraker, Sergeant and Hoek, 1978; Fraker, 1980; Fraker and Fraker, 1982; Finley, Norton and Davis, 1983). Based on the more recent data, the average annual total kills from Alaskan and Canadian waters in combination, estimated at 294 (119 Alaskan + 175 Canadian), is a little less than 3.0% of the current estimated stock size.

At present, little is known about the natural mortality sustained by the four provisional stocks. Recent incidents of entrapment suggest that, on occasion, it may be significant (Burns and Seaman, 1986; Ivashin and Shevlyagin, 1987). In some instances, savssat (whales entrapped in small pockets of open water in the sea ice) are taken by hunters as happened near Kivalina in 1985. The extent to which hunting of entrapped whales is additive to natural mortality is probably quite variable, though presently unknown. The fate of entrapped whales should be studied, though such an undertaking would have to be done on an opportunistic basis.

NOTE

On 4 March 1988, the first meeting of the 'Alaska and Inuvialuit Belukha Whale Committee' was held in Fairbanks, Alaska. The meeting was organised and funded by the North Slope Borough Department of Wildlife Management, a local government agency in northern Alaska. Participants included representatives from coastal belukha whale hunting communities, the United States National Marine Fisheries Service, the Alaska Department of Fish and Game, the Inuvialuit Game Council (representing Inuit hunters of the Canadian Beaufort Sea region), and the Canada Department of Fisheries and Oceans.

This Alaska and Inuvialuit Belukha Whale Committee was created with the following goals: (1) to develop an effective belukha whale management plan in consultation with subsistence hunters and the appropriate governmental agencies; (2) to promote hunter education and improved hunting techniques to reduce the number of animals struck and lost; (3) to advocate needed research; (4) to compile statewide harvest statistics; (5) to identify and encourage protection of important belukha whale habitat; and (6) to provide a contact point for the exchange of research and management information on belukha whales.

The committee met again in September 1988 and is currently developing by-laws, seeking funding for operational expenses, and soliciting input from residents of coastal communities and others regarding future actions needed to provide for the conservation of belukha whales in Alaska.

ACKNOWLEDGEMENTS

Our work on belukhas was funded by the Minerals Management Service, US Department of the Interior, through an interagency agreement with the National Oceanic and Atmospheric Administration, Department of Commerce, as part of the Alaska Outer Continental Shelf Environmental Assessment Program. Additional support was provided by the Alaska Department of Fish and Game, Division of Game. Harvest data for several villages for 1984–6 were provided by the North Slope Borough, Department of Wildlife Management. This compilation would not have been possible without the many observations made by people who live, work and hunt along the Alaskan coast. We thank them all for their contributions. The manuscript was reviewed by Dr Thomas F. Albert, North Slope Borough Department of Wildlife Management, P.O. Box 69, Barrow, AK 99723, USA; Dr Howard Braham, Director, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Building 32, Seattle, WA 98115, USA; and two anonymous reviewers. We thank them for their constructive comments.

REFERENCES

Burns, J.J. 1984. Living resources. pp.75–104. *In*: W.E. Westermeyer and K.M. Shusterich (eds.) *United States Arctic Interests: The 1980s and 1990s*. Springer-Verlag, Inc., New York.

Burns, J.J. and Seaman, G.A. 1986. Investigations of belukha whales in coastal waters of western and northern Alaska. II. Biology and ecology. Final Rep. NOAA, Outer Continental Shelf Environmental Assessment Program Contract NA-81-RAC-00049. Alaska Dept. Fish and Game, Fairbanks, AK. 129pp.

Davis, R.A. and Evans, C.R. 1982. Offshore distribution and numbers of white whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Unpubl. Rep. by LGL Ltd. for SOHIO Alaska Petroleum Co., Anchorage, AK and Dome Petroleum Ltd., Calgary, Alberta. 76pp.

Finley, K.J., Norton, P. and Davis, R.A. 1983. Status report on the white whale in the Beaufort Sea. Unpubl. Rep. by LGL Ltd., for Can. Dept. Fish. and Oceans, Ottawa, Ontario. 25pp.

Fraker, M.A. 1980. Status and harvest of the Mackenzie stock of white whales (*Delphinapterus leucas*). *Rep. int. Whal. Commn* 30:451–8.

Fraker, P.N. and Fraker, M.A. 1982. The 1981 white whale monitoring program, Mackenzie estuary. Unpubl. Rep. by LGL Ltd. Sidney, B.C., Canada. 74pp.

Fraker, M.A., Sergeant, D.E. and Hoek, W. 1978. Bowhead and white whales in the southern Beaufort Sea. Beaufort Sea Proj. Tech. Rep. No. 4. Dept. Fish. and Environ. Canada, Sidney, B.C. 114pp.

Frost, K.J., Lowry, L.F. and Nelson, R.R. 1984. Belukha whale studies in Bristol Bay, Alaska. pp.187–200. *In:* Proceedings of the workshop on biological interactions among marine mammals and commercial fisheries in the southeastern Bering Sea. October 18–21 1983, Anchorage, AK. Alaska Sea Grant Rep. 84–1.

Hunt, W.J. 1976. Domestic whaling in the Mackenzie Bay area, Northwest Territories. Fish. and Mar. Serv., Dept. Fish. and Environ., Canada. Enforcement Div., Inuvik, Northwest Territories. Data Rep. Ser. No. CEN/D-75–1.

Hunt, W.J. 1977. Domestic whaling in the Mackenzie Bay area, Northwest Territories. Fish. Mar. Serv. Tech. Rep., Dept. Fish. and Environ., Winnipeg., Manitoba. 9pp.

Hunt, W.J. 1979. Domestic whaling in the Mackenzie Estuary, Northwest Territories. Fish. Mar. Serv. Tech. Rep. 769. Dept. Fish. and Environ., Winnipeg, Manitoba. 14pp.

Ivashin, M.V. and Shevlyagin, K.V. 1987. The white whale (*Delphinapterus leucas* Pallas, 1776): Entrapment and escape in the ice of Senjavin Strait, USSR. *Rep. int. Whal. Commn* 37: 357–9.

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.

Seaman, G.A., Frost, K.J. and Lowry, L.F. 1986. Investigations of belukha whales in waters of western and northern Alaska. I. Distribution, abundance, and movements. Final Rep. NOAA, Outer Continental Shelf Environmental Assessment Program Contract NA-81-RAC-00049. Alaska Dept. Fish and Game, Fairbanks, AK. 60pp.

Sergeant, D.E. and Brodie, P.F. 1975. Identity, abundance, and present status of populations of white whales, *Delphinapterus leucas*, in North America. *J. Fish. Res. Bd Can.* 32:1,047–54.

SC/40/SM5

A Proposed Methodology for Field Testing Line Transect Theory for Shipboard Surveys of Cetaceans

Tom Polacheck and Tim D. Smith

National Marine Fisheries Center, Northeast Fisheries Center, Woods Hole, Mass. 02543, USA

ABSTRACT

A short survey planning cruise for harbor porpoise, *Phocoena phocoena*, was conducted by the Northeast Fisheries Center of the National Marine Fisheries Service in the western Bay of Fundy during August 1987. During the cruise transects were surveyed in which two independent teams of observers simultaneously collected sighting data from two different height sighting platforms aboard the vessel. The resulting data can be considered as two independent line transect surveys conducted simultaneously along the same trackline. The absolute density estimates from the two teams should be equal, except for sampling error, according to traditional line transect theory.

The study area in the western Bay of Fundy is easily accessible by small vessels and relatively inexpensive to survey. In the late summer, harbor porpoise congregate in this area. Large numbers of sightings can be made in a short time so that sufficient data can be collected to estimate sighting functions with large sample sizes under a variety of conditions. It is proposed that in this study area, the use of multiple simultaneous teams of observers provides a valuable methodology for field testing and validating line transect methods for cetaceans.

INTRODUCTION

Harbor porpoises (*Phocoena phocoena*) are directly or incidentally killed in fisheries in the Black Sea, North Atlantic and the North Pacific (Gaskin, 1984). While lack of information on both population abundances and the magnitudes of the kill has hampered quantitative assessments of the status of the various populations, Gaskin's (1984) worldwide review suggests that the kills may be significant in a number of regions and that there is a need for further research to evaluate the extent of the problem.

In the northwest Atlantic, recent research suggests that substantial numbers of harbor porpoises become entangled and drown in United States and Canadian bottom tending gillnet fisheries in the New England and Bay of Fundy areas (Gaskin, Read, Watts and Smith, 1985; Gilbert and Wynne, 1985; Read and Gaskin, 1988). Gaskin (1984) proposed that harbor porpoises in the region from south of Nova Scotia be considered as a distinct sub-division for assessment purposes. While precise estimates of the number of animals in the population and numbers killed do not exist, some interpretations of the limited available data suggest that the numbers killed could be greater than 1% of the population per year (J.R. Gilbert and K.M. Wynne, pers. comm.).

The available estimates of harbor porpoise abundances in this region do not, however, provide an adequate basis for assessment of the effect of these takes. A survey conducted in 1982 (Kraus, Prescott and Stone, 1983) did not extend seaward sufficiently and did not cover the entire Gulf of Maine and Bay of Fundy area. Further, the assumptions of line transect methods used in the analyses were not fully addressed. Similarly, other survey operations conducted in the Bay of Fundy have been concentrated in only a portion of the inhabited area (Gaskin *et al.*, 1985). To be able to assess the impact of the incidental kills, a reliable estimate of absolute abundance for the total population is needed for comparison with the estimates of the numbers killed.

Line transect surveys have been the most commonly used approach for estimating the abundances of cetaceans in recent years. While the general survey methods are well established, development and testing of specific field procedures has been necessary for each region and species complex. Species-specific behavior, vessel constraints and local geographic, oceanographic and atmospheric conditions all affect sighting performance. Survey procedures must be adapted to these features to avoid biases and to maximize efficiency. The Northeast Fisheries Center (NEFC) of the National Marine Fisheries Service (NMFS) conducted a short survey planning cruise in the Bay of Fundy from 20–22 August 1987 to develop procedures for conducting line transect surveys for harbor porpoises in the Gulf of Maine and Bay of Fundy region. The purpose of the present paper is to describe some results from this planning cruise that suggest that the field situation encountered is ideal for testing certain aspects of the use of line transect methods for cetacean surveys. The emphasis is on experimental tests of different factors rather than on obtaining the best estimate of density. Other results obtained from the planning cruise relevant to the design of a complete line transect survey for harbor porpoises in this region will be presented in a future paper.

MATERIAL AND METHODS

Study site

The study site for the planing cruise was in the western Bay of Fundy in the general vicinity of Campobello and Grand Manan Islands (Fig. 1). Harbor porpoises are known to congregate in this area in high densities in late summer and early autumn; the area has been used for numerous studies of harbor porpoises (e.g. Neave and Wright, 1968; Gaskin *et al.*, 1985; Kraus, Gilbert and Prescott, 1983; Gaskin, 1977; Kraus and Prescott, 1984). The area is easily accessible by small boats. Although the wind and sea state conditions can be highly variable, the geography of the region results in numerous sheltered areas where it is possible to test survey procedures even when general weather conditions are inappropriate for conducting a comprehensive survey. Additionally, the density of porpoises in this region is sufficiently high that the large numbers of sightings required to estimate the parameters of sighting distributions needed for line transect methods (Burnham, Anderson and Laake, 1980) can be obtained rapidly.

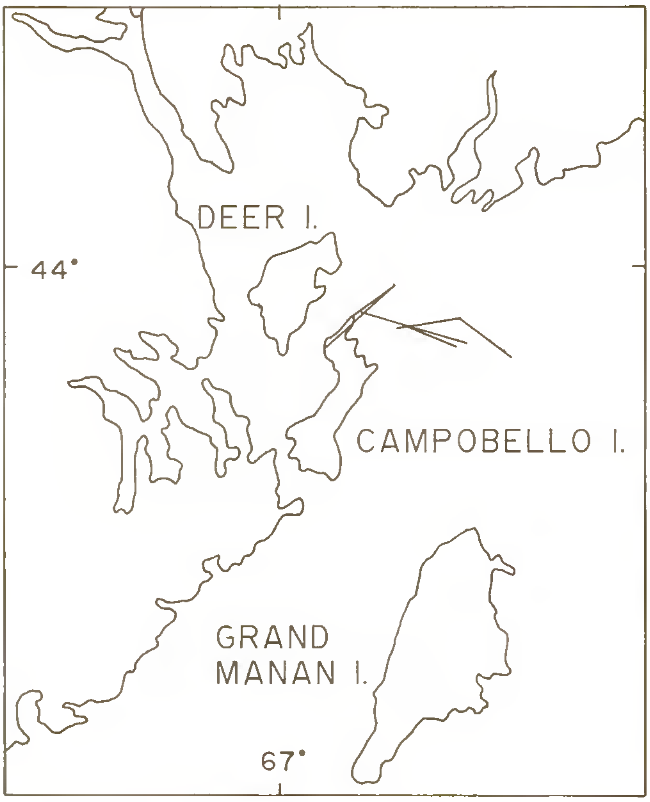


Fig. 1. Map showing general study area and location of transects surveyed.

Methods

A series of eleven trial transects ranging from one-half to one hour were conducted during the planning cruise. The surveys were conducted aboard the NMFS R/V *Gloria Michelle*, a 20m converted shrimp trawler, at a speed of 9 knots. A total of six observers were available, all of whom had previous experience in cetacean sighting surveys and four of whom had extensive experience with harbor porpoises. Standard line transect data were recorded including (1) the estimated radial sighting distance from the vessel at which porpoise were sighted; (2) the estimated sighting angle; (3) the estimated number of animals sighted in a group; (4) the time of the sighting; (5) the observer position, and (6) the observer making the sighting. Radial distances and angles were estimated visually; the planning nature of the cruise precluded adequate time for calibrating these estimates, however.

The R/V *Gloria Michelle* has three locations from which from which searching can conveniently be conducted (termed sighting platforms): (1) on the main deck forward of the wheel house (height above water=1.8m); (2) on top of the wheel house (height above water=4.2m); (3) from the crow's nest on the ship's mast (height above water=7.1m). During four of the transects, parallel and independent teams of observers collected sighting data from two of the different searching positions (the top of the wheel house and the crow's nest). While the initial impetus for conducting these transects was to gain information on the best height for observers during a survey, the resulting data can be considered as paired line transect surveys, conducted under identical conditions except for observer height. Because both teams of observers were transiting the same survey line at the same time, the difference in the estimated densities from the two sighting platforms should be zero. Simple t-tests can be used to compare the resulting density estimates, and the frequency distribution of the sighting angles and distances, and the calculated perpendicular distances were compared using chi square tests.

It should be noted that observers on the wheel house could be seen from the crow's nest if the crow's nest observers looked nearly straight down. Crow's nest observers were instructed not to look at the activity of the wheel house observers and participants felt that the independence of the data from the two heights was not a problem during this experiment.

During these four transects, all searching was done without binoculars. Observers had the use of binoculars to confirm any questionable sighting cues and to help with the estimation of group size. The crow's nest, as configured during the cruise, could accommodate two observers. Each of these observers searched one half of the track line plus an intentional overlap of the about 20° in the forward direction. One observer also acted as data recorder. A team of three observers plus a separate data recorder was used on the wheel house. The central observer searched directly ahead to cover the track line, while the two side observers searched their respective sides of the track line.

RESULTS

During the four transects, observers on top of the wheel house made a total of 24 sightings of harbor porpoises representing an estimated 47 individuals compared to 30 sightings and 67 individuals sighted by observers from the crow's nest. The frequency distribution of perpendicular sighting distances are similar in shape for the two sighting platforms (Fig. 2a; chi square=4.5, 4 df, P>0.25). For both sighting positions the perpendicular sighting distances were clustered around the track line and a high proportion of the sightings were within 50m of the trackline (63% for the crow's nest and 58% for the wheel house). This appears to be due to a high degree of effort being focused on the trackline.

To compare the overall results from the two sighting platforms, estimates of f(0) were calculated using both the Fourier series (Burnham *et al.*, 1980) and the generalized hazard rate function (Hayes and Buckland, 1983). Since the angle and sighting data exhibited rounding to convenient whole numbers, smearing of the data before fitting was also explored (Buckland, 1987). Because of the limited sample size and clustering of samples near the track line, the estimates of f(0) were sensitive to the choice of models and the choice of stopping rules for the number of parameters used for the Fourier series model. However, the estimates of f(0) for both models were generally similar for the two observer heights. As such, the density estimates for the crow's nest were about 25% greater than the estimates for the wheel house because of the greater number of sightings seen from the higher platform, although the differences were not statistically significant.

Comparison of the distribution of radial sighting distances and sighting angles indicates the similarity and differences in the sighting process from the two sighting platforms. The distribution of radial sighting distances from the wheel house and the crow's nest are markedly different, with sightings made out to 500m from the crow's nest, but only out to 300m from the wheel house (Fig. 2b;

chi square=14.2, 7 df, $P<0.05$). The distributions of sighting angles, in contrast, were very similar (chi square=4.2, 5 df, $P>0.50$), and were centered in a narrow sector around the track line (Fig. 2c).

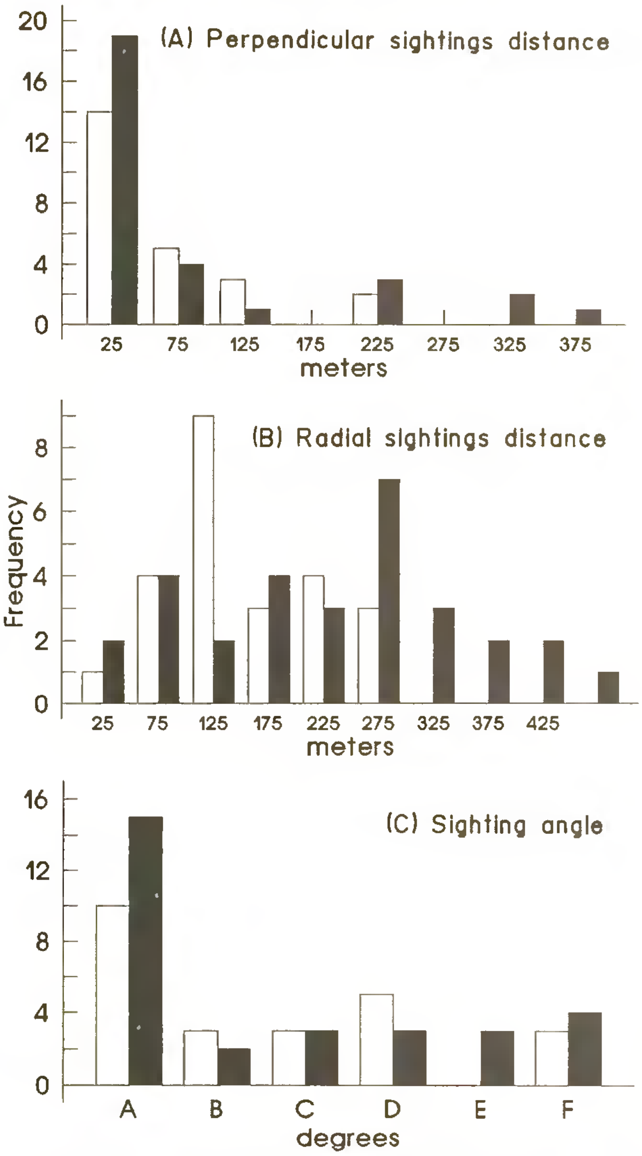


Fig. 2. Comparison of harbor porpoise sightings from two heights made aboard the R/V *Gloria Michelle* during transects surveyed in the Bay of Fundy: Perpendicular distances in 50 meter intervals (Frame A), radial sighting distances in 50 meter intervals (Frame B) and sighting angles (Frame C). Labels in frame A and B are the mid-points of the interval. Solid bars = crow's nest, open bars = wheelhouse. In Frame C, a = 0–5°, B = 6–10°, C = 11–30°, D = 31–45°, E = 45–60°, F = 60–90°.

Additional observations made during the cruise suggested changes in observer searching behavior at very high porpoise densities which could have significant effects on absolute abundance estimates from line transects. Two transects were conducted in a manner similar to the four described above but during which extremely high rates of sightings occurred (e.g., as great as six per minute) (Fig. 3). These high sighting rates resulted in the crow's nest observers missing some sightings because of data recording difficulties and hence the data could not be used to compare density estimates. However, the distributions of sighting angles and radial sighting distances during these two transects (Figs 3a and 3b) can be compared to those observed during the four transects with lower sighting frequencies (Figs 2b and 2c). The distributions of sighting angles (Figs 2c and 3c) are significantly different for observations made from the crow's nest (chi square=13.6, 5 df $P<0.025$) and from the wheel house (chi square=11.7, 5 df, $P<0.05$). The distribution of sighting angles during the higher density transects were more diffuse, suggesting that the relative probability of detecting an animal off the track line was greater (i.e. f(0) was smaller) at higher porpoise densities. The distribution of radial sighting distributions (Figs 2b and 3b) were not significantly different (chi square for the wheel house=7.6, 6 df, $P>0.25$; chi square for the crow's nest=7.3, 7 df, $P>0.25$). The resultant distribution of the perpendicular distances were significantly different for the crow's nest (chi square=10.0, 4 df, $P<0.025$), and were not significantly different for the wheel house (chi square=6.0, 4 df, $P>0.10$).

DISCUSSION

The results presented above demonstrate the feasibility and potential utility of having independent teams of observers conducting simultaneous transects from different sighting platforms aboard the same vessel. While the sample sizes from the four transects reported here are insufficient to determine whether the two platform heights yielded equivalent density estimates, the differences in the number of sightings and the similarity in the estimates of f(0) raise the possibility that the effect of observer height in this situation may not be fully accounted for with current line transect methods.

Such a problem may not be a difficulty if line transect estimates are treated only relatively, but would preclude their use for measuring absolute abundance. The problem may possibly be due to the interaction of the movement of the animals, the greater range of radial distances over which animals could be seen from the crow's nest (Fig. 2b), and the apparently narrow angle of view in which searching effort was concentrated by observers at both positions (Fig. 2c). The combination of these factors may have resulted in significant numbers of animals sighted from the crow's nest on or near the track line at far distances from the vessel having been missed by the wheelhouse observers. These animals may have had a low probability of being sighted by the wheel house observers because they moved out of the narrow range of angles being searched before the vessel approached close enough for them to be detected from the lower height.

In the development and application of line transect methods for cetaceans, concerns have been expressed for the need to explicitly account for the sighting process in analytic models (Koopman, 1982; Best, 1982; Doi, 1974, Clarke, 1982; Doi, Kasamatsu and Nakano, 1982, 1983; Hiby, 1982, 1985; Hiby and Thompson, 1985). Several aspects of the sighting process have been identified as potentially important; these can be grouped into two broad categories: (1) biological features of the target animal and (2) the detection process by human observers. The biological features which have been identified include animal movements, dive times, group size, species differences in sighting cues and changes in sighting cues with different behaviors. Features of the detection process include observer height, scanning procedures (e.g. sectors searched), fatigue, experience and the effect of environmental conditions on visibility. An additional concern is that differences may exist in the searching process at high and low densities (Figs 2 and 3).

Traditional line transect theory asserts that if methods such as the Fourier series are used to estimate f(0), then the resulting density estimates should be robust to all of these biological and detection factors except animal movements and dive times (Burnham *et al.*, 1980). Uncertainty exists about the effect of these latter two factor, particularily animal movements (Schweder, 1968; Hiby, 1982; Basson and Butterworth, 1984; Kishino, 1986, compared to Hiby, 1982). Experimental tests of the effect of animal movements and of dive times are important to ensure that the methods produce reliable estimates in practice. Harbor porpoises in the study area occur in small schools that sometimes dive synchronously for several minutes. They also move at speeds which at times approaches the speed of the vessel and appear neither attracted or replused by vessels. Thus, sighting experiments using these animals could be conducted to explore the effect of animal movement and dive time on line transect estimates of density.

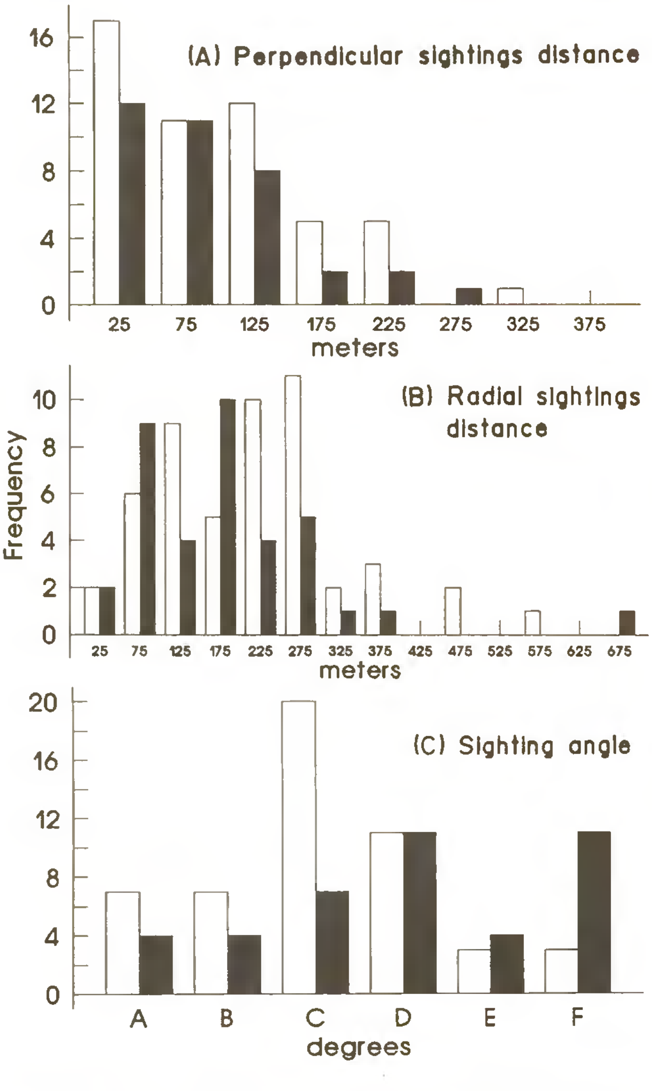


Fig. 3. Comparison of harbor porpoise sightings from two heights when the sighting rate was very high made aboard the R/V *Gloria Michelle* during transect surveyed in the Bay of Fundy: Perpendicular distances in 50 meter intervals (Frame A), radial sighting distances in 50 meter intervals (Frame B) and sighting angles (Frame C). Labels in frame A and B are the mid-points of the interval. Comparison with Fig. 2 suggests that the sighting process changed markedly with sighting rate.

The combination of study area and vessel configuration described here provides a valuable system for field testing line transect methods for cetaceans. The area is easily accessible and relatively inexpensive to survey. A large number of sightings can be made in a short time so that enough data can be collected to estimate a number of different sighting functions with large sample sizes under a variety of conditions. The vessel has three different potential sighting platforms, and up to three independent but simultaneous data sets could be collected. The advantage of having multiple dependent teams is that paired density estimates can be obtained in a situation where the true densities are known to be equal. Tests based on the differences between such pairs of estimates are statistically more powerful, less expensive and involve fewer assumptions than would corresponding tests performed using two separate vessels. Any differences that are detected can be attributed to the sighting function, eliminating the need to consider possible changes in the density and distribution of the animals during the experiment. In addition, observers can be rotated both within the observation positions within a sighting platform, and between the sighting platforms to eliminate the effect of differences among observers.

The use of multiple observer teams proposed here contrasts to previous analyses of line transect experiments using simultaneous observer teams (Holt, 1983, 1984; Barlow, 1987; Butterworth and Silberbauer, 1987). In these experiments, the second or backup team was used to estimate the fraction of animals missed on the track line. Some recent IDCR survey data for minke whales may be usable for testing certain aspects of line transect theory, as suggested by an anonymous reviewer. These data would be the sightings by the independent observer team and the topmen during passing mode surveys. Interpretation may be confounded, however, by differences in the searching patterns or the sighting ability between the topmen and the independent observers as rotation between the two sighting platforms is not done routinely.

There are a number of improvements in the procedures used in the present study which should be made in utilizing the multiple observer team method described here. Differences in observer performance should be accounted for by standardizing on experience and by randomizing team assignments. Teams and individuals should be rotated among several observation positions on a sighting platform, and teams should be rotated among sighting platforms. Awnings should be erected for the two lower sighting platforms to guarantee the independence of the three different data sets, and the crow's nest should be expanded to accommodate three observers and a data recorder.

The major limitation of this proposed testing system is the measurement of radial sighting distances and angles. This has been a problem in all shipboard sighting surveys. The fact that radial sighting distances are relatively small (i.e. less than 400m) in this field situation reduces somewhat the severity of the problem and may allow for use of simple mechanical methods that have been found unsuitable in other situations (Smith, 1982). Calibration must be done during the experiment, however.

Several specific tests of line transect theory using this field situation can be identified at this time. One is the test if estimates of density are independent of sighting platform height. If in fact the estimates of density from different heights are not equal, examination of the distribution of radial sighting distances and angles from the potentially large number of sightings may provide insights into the source of the problem. The data from the planning cruise reported here are insufficient to adequately perform this test. Too few sightings were made and it was not possible to evaluate survey procedures in the short time available.

A second test would be whether density estimates are independent of vessel speed. The data from such tests should provide an indication whether animal movement may be a serious problem in the application of line transect methods. Additionally, the potentially large number of sightings that would be generated in such tests may allow evaluation and further development of methods for estimating directly the hazard rate function (Hiby and Thompson, 1985; Hiby, 1985; 1986).

The proposed testing system would allow both of the above experiments to be conducted simultaneously in a relatively short time frame. Although necessary sample sizes can not be calculated from the available data, it would appear that sufficient numbers of sightings could be obtained for estimating the sighting functions perhaps within one week with reasonable sighting conditions. In an extended time frame, additional studies might include testing the effects of different observer instructions to control sectors searched, and testing the effects of sea state, visibility and numbers of observers. Such tests would be extremely useful in exploring the cause and possible effect of the differences in distributions of sighting distances and angles, especially those noted in the present study in high and low density areas.

Tests of line transect theory conducted in the field situation described here would be most directly applicable to the study of the harbor porpoise, but would not be limited to this species because the application of line transect theory to these animals presents problems common to many cetaceans, especially the effect of dive times and animal movement. Because of the potential for replication and large numbers of sightings the results of such tests would allow improved understanding of line transect survey methodology.

ACKNOWLEDGEMENTS

We wish to acknowledge Scott Kraus, Jim Gilbert, Andy Read and Kate Wynne, who generously volunteered their time and expertise during the planning cruise, and Gordon Waring for organizing the cruise itself. We also wish to thank the crew of the R/V *Gloria Michelle* for their patience and help during the cruise, Stephanie Sexton and Rennie Holt for their assistance in analyzing the data to estimate f(0), Janeen Cox for her aid in the preparation of the final manuscript, Dennis Heinemann and Gordon Waring for their constructive reviews, and two anonymous reviewers.

REFERENCES

Barlow, J. 1987. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: I. Ship surveys. *Fish. Bull.* 86:417–33.

Basson, M. and Butterworth, D.S. 1984. An exploratory investigation of the use of a hazard-rate model to assess the target motion correction factor in sighting estimates of minke whale abundance. *Rep. int. Whal. Commn* 34:309-14.

Best, P.B. 1982. Whales as target animals for sighting surveys. *Rep. int. Whal. Commn* 32:551–4.

Buckland, S.T. 1987. An assessment of the performance of line transect models for fitting IWC/IDCR cruise data, 1978/79 to 1984/85. *Rep. int. Whal. Commn* 37:277–9.

Burnham, K.P., Anderson, D.R. and Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Manage.* 72: 1–202.

Butterworth, D.S. and Silberbauer, M.J. 1987. A summary of initial results from the 1985/86 IWC/IDCR Antarctic minke whale assessment cruise in Area V. Paper SC/39/Mi16 presented to the IWC Scientific Committee, June 1987. (Unpublished)

Clarke, R. 1982. An index of sighting conditions for survey of whales and dolphins. *Rep. int. Whal. Commn* 32: 559–61.

Doi, T. 1974. Further development of whale sighting theory. pp. 359–68 *In:* W.E. Shevill, (ed). *The Whale Problem: a Status Report.* Harvard University Press, Cambridge, Mass.

Doi, T., Kasamatu, F. and Nakano, T. 1982. A simulation study of sighting survey of minke whale in the Antarctic. *Rep. int. Whal. Commn* 32:919–28.

Doi, T., Kasamatsu, F. and Nakano, T. 1983. Further simulation studies on sighting by introducing both concentration of sighting effort by angle and aggregations of minke whales in the Antarctic. *Rep. int. Whal. Commn* 33:403–13.

Gaskin, D.E. 1977. Harbor porpoise *Phocoena phocoena* (L.), in the Bay of Fundy 1969–1975. *Rep. int. Whal. Commn* 27: 487–92.

Gaskin, D.E. 1984. The harbor porpoise *Phocoena phocoena* (L.): Regional populations, status, and information on direct and indirect catches. *Rep. int. Whal. Commn* 34: 569–86.

Gaskin, D.E., Read, A.J., Watts, P.F. and Smith, G.J.D. 1985. Population dispersal, size and interactions of harbor porpoise in the Bay of Fundy and Gulf of Maine. *Can. Tech. Rep. of Fish. and Aquat. Sci.* 1,291.

Gilbert, J.R. and Wynne, K.M. 1985. Harbor seal populations and fisheries interactions with marine mammals in New England, 1984. Contract Rep. NA-80–FAC-00029 and NA-84-EAC-00070. Northeast Fisheries Center, Woods Hole, MA, 02543. 15pp.

Hayes, R.J. and Buckland, S.T. 1983. Radial distance models for the line transect method. *Biometrics* 39:29–42.

Hiby, A.R. 1982. The effect of random whale movement on density estimates obtained from whale sighting surveys. *Rep. int. Whal. Commn* 32:791–3.

Hiby, A.R. 1985. An approach to estimating population densities of great whales from sighting surveys. *IMA. J. of Math. Applied in Medicine and Biol.* 2:201–20.

Hiby, A.R. 1986. Results of a hazard rate model relevant to experiments on the 1984/85 IDCR minke whale assessment cruise. *Rep. int. Whal. Commn* 36:497–8.

Hiby, A.R. and Thompson, D. 1985. An analysis of sightings data from the 1983–84 IDCR minke whale assessment cruise: Estimating the hazard rate and the effective strip width. *Rep. int. Whal. Commn* 35:315–8.

Holt, R.S. 1983. Report of porpoise experiment testing detection of on-track schools (PET DOTS), March 7-April 5, 1981. U.S. Dept. of Commerce, NOAA-TM-NMFS-SWFC-27. 80pp.

Holt, R.S. 1984. Testing the validity of line transect theory to estimate density of dolphin schools. Admin. Rep. LJ-84–31, Southwest Fisheries Center, P.O. Box 271, La Jolla, CA 92038. 56pp.

Kishino, H. 1986. On parallel ship experiments and the line transect method. *Rep. int. Whal. Commn* 36:491–5.

Koopman, B.O. 1982. Comments on the appropriateness of the 'descriptive statistics' approach. *Rep. int. Whal. Commn* 32:543–4.

Kraus, S.D. and Prescott, J.H. 1984. Seasonal movements of harbor porpoise (*Phocoena phocoena*) in the Gulf of Maine. Contract Report, Northeast Fisheries Center, Woods Hole, MA 02543. 10pp.

Kraus, S.D., Gilbert, J.R. and Prescott, J.H. 1983. A comparison of aerial, shipboard, and land-based survey methodology for the harbor porpoise, *Phocoena phocoena*. *Fish. Bull.* 81(4): 910–13.

Kraus, S.D., Prescott, J. and Stone, G.S. 1983. Harbor porpoise (*Phoecoena phocoena*) in the U.S. coastal waters off the Gulf of Maine: A survey to determine seasonal distribution and abundance. Contract report, Northeast Fisheries Center, Woods Hole, MA 02543. 15pp.

Neave, D.J. and Wright, B.S. 1968. Seasonal migration of the harbor porpoise (*Phocoena phocoena*) and other Cetacea in the Bay of Fundy. *J. Mammal.* 49:259–64.

Read, A.J. and Gaskin, D.E. 1988. Incidental catch of harbor porpoises by gill nets. *J. Wildlife Manage.* 52: 517–23.

Schweder, T. 1968. Transformation of point processes: application to animal sighting and catch problems, with special emphasis on whales. Ph.D. Thesis. Univ. of California, Berkeley, CA.

Smith, T.D. 1982. Testing Methods of Estimating Range and Bearing to Cetaceans Aboard the R/V *D.S. Jordon*. NOAA Tech. Memo. NOAA-TM-NMFS-SWFC-20. 30pp.

SC/40/SM12

Monitoring Trends in Dolphin Abundance in the Eastern Tropical Pacific using Research Vessels over a Long Sampling Period: Analyses of 1987 Data

Rennie S. Holt and Stephanie N. Sexton

National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, CA, USA

ABSTRACT

During 1987, the National Marine Fisheries Service conducted the second in its series of long-term research ship surveys to determine status of dolphin stocks taken incidentally by tuna purse seiners in the eastern tropical Pacific. Line transect methodology was used by observers aboard two vessels for 120 days each. Relative abundance estimates of northern offshore spotted dolphins are approximately 1,300,000 animals with a coefficient of variation of 0.262. This estimate was larger than the 1986 estimate of 929,000 northern offshore spotted dolphins. Relative sizes of other stocks also varied. We examine reasons for these differences and discuss alternative methods of stratifying the data.

INTRODUCTION

The National Marine Fisheries Service (NMFS) is responsible for assessing the status of those dolphin stocks taken incidentally by tuna purse seiners in the eastern tropical Pacific (ETP) (Richey, 1976). The status of the spotted dolphin, *Stenella attenuata*, is of special concern because it is the major species taken by the fishery (Smith, 1979). Of the spotted dolphins, the northern offshore stock is considered to be the most affected by the fishery because it has been fished more frequently than any other stock. The spinner dolphin, *S. longirostris*, and the common dolphin, *Delphinus delphis*, are also taken. The striped dolphin, *S. coeruleoalba*, and Fraser's dolphin, *Lagenodelphis hosei*, are occasionally caught but are difficult to distinguish from the other three species at a distance (Holt and Powers, 1982). These five species are herein grouped and termed target species.

In 1986, the NMFS initiated a research program to monitor relative abundance of dolphin populations in the ETP using two research vessels for at least five years during which six surveys will be conducted. The research design for the surveys, presented by Holt, Gerrodette and Cologne (1987), indicated that a 10% annual rate of decrease in northern offshore spotted dolphins could be detected (a total 41% decrease over six surveys) with alpha and beta error levels of 10%. Analyses of the 1986 data are presented by Holt and Sexton (1988a). In 1987, the NMFS conducted a second survey using the same vessels at the same time of the year. Herein, we present relative abundance estimates for the 1987 data and compare these to the 1986 estimates. We also discuss effects of several alternate stratification methods and data treatment factors on these estimates. Because we desire to determine change in population size over several years and not estimate absolute abundance, data from several years will eventually be used to select the most consistent relative indicator of population change.

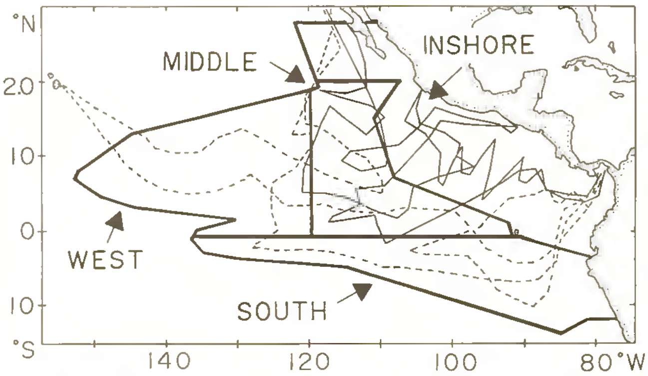


Fig. 1. Tracklines traversed by the NOAA R/V *David Starr Jordan* (solid) and *McArthur* (dash) during the 1987 survey. Tracklines generated using noontime positions.

MATERIALS AND METHODS

Study area and survey coverage

The study area and area strata were those used during the 1986 survey (Holt and Sexton, 1988a). The research vessels *McArthur* and *David Starr Jordan* traversed predetermined tracklines in the ETP from 30 July and 8 August, respectively, through 10 December (Fig. 1). Each ship was scheduled to spend approximately 120 days at sea but the *Jordan* departed 10 days late. Ship itineries, list of scientific personnel, survey equipment, data collection procedures and preliminary data summaries for each ship are presented by Holt and Sexton (1988b) and Holt and Jackson (1988). Only those factors important to this paper are presented here.

On each ship, two observers used 25X binoculars located on each side of the ship to search from directly ahead to abeam of their respective sides of the ship. A third observer served as data recorder and searched directly ahead of the ship when not recording data. Two teams of three observers each alternatively occupied the three duty stations. Each team was on duty for 2-hour shifts. During each shift, members spent approximately equal time occupying each duty station. Two of the six observers had completed several marine mammal cruises in the ETP and were experts in identifying marine mammals. These two identification specialists were assigned to separate teams such that one would always be on duty. Teams members did not change during the cruises. Observers switched ships at the mid-point of the cruises.

When possible, schools were approached and observers recorded independent 'best' estimates of school size. In some cases, an observer obtained a 'minimum' estimate but could not provide a best estimate. Independent estimates were averaged to obtain mean minimum and best estimates. When weather conditions were suitable, a *Hughes* 500D helicopter, based aboard the *Jordan* was used to photograph schools whose sizes were estimated by the observers. The photographs will be used to calibrate observer estimates of school sizes.

Abundance estimation

Relative estimates of population abundance of the target species (N_{ij}) were computed as (Holt and Sexton, 1988a):

$$N_{ij} = \sum_{k=1}^{4} (D_k S_{tk} P_{tk} P_{ik} A_k / A_{ik})(A_{ijk} + P'_{ij} A'_{ijk}), \quad (1)$$

where

D_k = estimate of density of schools of all dolphin species in area k.
S_{tk} = estimate of mean size of schools of all target species in area k,
P_{tk} = estimate of proportion of all dolphin schools which are target schools in area k,
P_{ik} = estimate of proportion of individuals of species i in target schools in area k,
P'_{ij} = estimate of proportion of individuals of stock j of species i in target schools in overlap region containing two stocks of species i (overlap region discussed in text),
A_k = total area inhabited by all target species in area k,
A_{ik} = area inhabited by species i in area k,
A_{ijk} = area inhabited by species i, stock j, in area k, and
A'_{ijk} = area inhabited by species i, stock j, in overlap region of area k.

The variance of N_{ij} was calculated using bootstrap methods. For each stratum, the number of legs of searching effort was tabulated and then effort legs equal to that number were randomly selected with replacement. This effort and the associated sightings were used to calculate school density, school size, species proportions and finally estimates of N_{ij}s. This was repeated 100 times. The variance of N_{ij} for each stock was calculated using these 100 estimates.

Formulae used to estimate school density are from Burnham, Anderson and Laake (1980), Holt (1985, 1987), and Hayes and Buckland (1983). The Fourier series (Cain *et al.*, 1979) and hazard rate (Hayes and Buckland, 1983; Buckland, 1985) models both provided adequate fits (similar point estimates and chi–square values) to the data but the hazard rate model was used because, unlike the Fourier series model, its use does not require subjective selection of the number of terms in the model and, therefore, could be used in the bootstrap procedures. Of schools containing both target and non-target species, only the proportion of individuals of the target species was used in the school size estimate. Estimates of the proportion of all dolphin schools that were target schools (P_{tk}) were calculated using formulae presented by Holt and Powers (1982). Formulae to estimate the proportions (P_{ik}) of the number of individuals for each species of all target individuals are given by Barlow and Holt (1986).

All species of dolphins encountered in the study area were included in the density analyses. Estimates were calculated using only schools containing 15 or more animals. Smaller schools were not used because we believe small schools both on and off the ships' tracklines may be difficult to detect especially during rough weather and may have been missed at a variable rate depending upon prevailing weather conditions (Holt, 1987).

Only schools detected within 3.7km (2.0 n.miles) perpendicular distance of the trackline were used to estimate school density because a 3.7-km truncation point provided the best fit of the model to this data. It was chosen because the perpendicular distance distributions of schools detected at greater distances were 'spiked' and because schools detected at greater than 3.7km have little effect on the density estimates. Schools detected at increasing distances from the trackline tend to include disproportionately more large schools because there is a direct correlation between the size of a school and the probability of it being detected (Drummer, 1985). This biases school size estimates upwards and species proportions toward species which occur in large schools. We attempted to adjust for this bias by weighting school size and species proportion estimates by the inverse of logarithm of school size (Holt and Powers, 1982). Finally, schools for which there were no 'best' estimates were not used in the school size or species proportion calculations.

Some stocks of the same species overlap geographic areas (A'_{ijk}). These overlapping stocks include (1) coastal and northern spotted, (2) eastern and whitebelly spinner and (3) Baja Neritic and northern common dolphins (Perrin *et al.*, 1984). The relative number of dolphins of each overlapping stock (P'_{ij}) was calculated for data pooled over strata. Because of small sample sizes, the pooled estimate of P'_{ij} was used in each of the bootstrapped iterations. For overlapping stocks of spotted dolphins and for spinner dolphins, the relative proportions of coastal and northern spotted and of eastern and whitebelly spinner stocks within their area of overlap were calculated as the averages of their relative abundances (percent occurrence). Few data were available to determine relative proportions of the overlapping Baja Neritic and northern common dolphins. Therefore, population estimates for Baja Neritic were combined with northern common dolphins.

The area inhabited by each target species (A_k) used to calculate the population abundance estimates were those defined by Au *et al.* (1979) and Perrin *et al.* (1984). The study area was partitioned into four strata (Holt and Sexton, 1988a). All four strata comprise the total area. The size of each stratum and the area occupied by each stock in each stratum was calculated by Holt and Sexton (1988a).

RESULTS

During the entire survey, observers aboard both vessels searched 28,611km and detected 1,249 marine mammal schools. Dolphins were present in 891 of these schools. While searching in the study area (Fig. 1), within 3.7km perpendicular distance of the trackline, and during Beaufort Sea states of 5 or less, observers on both vessels searched 26,519km and detected 352 dolphin schools (Table 1). The amount of effort and schools detected varied among strata; 42% of the total trackline searched and 53% of all schools detected were in the inshore area.

Table 1

1987 cruise data and results (see text). Data were truncated at 3.7km perpendicular distance. Schools with less than 15 animals were omitted from analyses. School sizes and species proportions were weighted by inverse of school size. Effort collecting during sea states 0 – 5 included in analyses. Data summed for both vessels. Total is for data summed over all four strata.

	Inshore	Middle	West	South	Total
Area (1,000km^2)	5,693	3,798	5,298	4,359	19,148
% Total area	30	20	28	22	100
Trackline searched (km)	11,145	7,974	3,529	3,871	26,519
% searching effort	42	30	13	15	100
Density ($\hat{D}_k$)[1]	4.74	3.15	2.16	3.58	3.75
No. schools detected[a]	187	89	27	49	352
Mean target species school size (S_{tk})	81.57	84.56	94.12	121.64	88.39
No. target schools[b]	151	77	23	38	289
Proportions:					
Target schools (P_{tk})	0.826	0.858	0.802	0.865	0.837
Spotted dolphins	0.284	0.524	0.367	0.319	0.360
Spinner dolphins	0.201	0.258	0.315	0.167	0.219
Common dolphins	0.272	0.009	0.056	0.080	0.152
Striped dolphins	0.242	0.159	0.046	0.295	0.214
Fraser's dolphins	0.000	0.050	0.217	0.139	0.055
Overlap area:					
Prop. Coastal Spotted					0.182
Prop. Offshore Spotted					0.818
No. Spotted schools					18
Prop. Eastern Spinner					0.677
Prop. Whitebelly Spinner					0.323
No. Spinner schools					83

[1] schools/1,000 km^2

[a] including unidentified dolphin schools.

[b] including schools identified as target species but for which a best estimate of school size was not made.

Table 2

Estimates of population sizes (N_{ij}) (in thousands of animals) by stock for target species in total area. Values given are weighted by stratum.

Species/stock	N_{ij}	SE(N_{ij})	CV(N_{ij})
Spotted			
Coastal	32.4	6.8	0.210
Northern Offshore	1,275.4	334.3	0.262
Southern Offshore	501.8	199.8	0.398
Total	1,809.6	540.9	0.299
Spinner			
Costa Rican	17.9	4.6	0.257
Eastern	533.2	149.8	0.281
Northern Whitebelly	334.2	96.9	0.290
Southern Whitebelly	252.2	105.1	0.417
Total	1,137.5	356.4	0.313
Common			
Northern Tropical	130.3	47.7	0.366
West Central Tropical	53.0	44.8	0.845
East Central Tropical	307.0	112.0	0.365
Southern Tropical	201.0	110.7	0.551
Total	691.3	315.2	0.456
Striped			
Northern Tropical	124.4	23.0	0.185
West Central Tropical	33.7	23.8	0.706
East Central Tropical	353.9	63.1	0.178
Southern Tropical	584.2	147.8	0.253
Total	1,096.2	257.7	0.235
Fraser's	451.0	282.5	0.626
Total	5,185.6	1,752.7	0.338

The estimate of f(0) for data in the total area was 0.577. Density estimates (D_k) in the four strata, calculated using the pooled f(0), ranged from 2.21 to 4.84 schools/1000km^2 (Table 1). Estimates of mean school size (S_{tk}) of target species ranged from 81.57 to 121.64 animals (Table 1). The proportion of identified dolphin schools that included target species (P_{tk}) ranged from 0.826 to 0.900 among strata (Table 1).

The proportions of individuals of target species that were spotted dolphins (P_{ik}) ranged from 0.284 to 0.524 among the strata (Table 1). The proportions of the other target species among strata also varied greatly. For example, the proportion of common dolphins ranged from 0.009 to 0.272 (Table 1). Only 18 spotted dolphin schools were detected in the overlap region of the coastal and offshore spotted stocks. The proportion (P'_{ij}) of these that were offshore spotted dolphins was 0.818 (Table 1). Of 83 spinner dolphin schools detected in the area of overlap of eastern and whitebelly spinner stocks, 0.677 were eastern spinner dolphin schools.

The estimate of relative abundance for each stock of the target species is presented in Table 2. Spotted dolphins were the most abundant target species. The estimate of 1,275,400 northern offshore spotted dolphins represented 70% of the estimate of all stocks of spotted dolphins. The coefficient of variation of the abundance of the northern offshore spotted stock, CV(N_{ij}), was 0.262. The abundance estimate for eastern spinner dolphins was 533,100 animals with a CV of 0.281.

DISCUSSION

Abundance estimates may be calculated using equation (1) by pooling variables across geographical strata and/or species categories. In general, the greater the degree of pooling across variables, the more precise (lower CVs) but also the more biased are estimates of abundance. For example, we calculated the density estimate (D_k) by pooling perpendicular distance distributions across strata such that

$$D_k = \sum_{k=1}^{4} n_k f(0)/2l_k.$$

where n_k is the number of dolphin schools detected in stratum k and l_k is the line length searched in stratum k.

An alternate method was examined which calculated f(0) for data in each stratum. This yielded an abundance estimate for northern offshore spotted dolphins of 1,576,600 animals compared to our estimate of 1,275,400 animals (Table 2) but the estimate of CV was 0.363 compared to 0.262 for our pooled f(0) method. The larger CV resulted because the hazard rate model was applied to small data sets in the south (27 schools) and west (49 schools) strata (Table 1).

We also investigated another alternate method by calculating abundance estimates for all variables in equation (1) pooled across all geographic strata. For the northern offshore spotted dolphins, this yielded an abundance estimate of 1,497,200 animals with a CV of 0.158. Although the estimate is very precise, it may be biased upwards because encounter rates were highest in the inshore stratum (Table 1) which received 42% of the total survey coverage but only represented 30% of the total geographic area.

We calculated school density using schools of all dolphin species; then calculated the proportion of those schools which were target species; and finally calculated the proportions of individuals of each species in the target species [equation (1)]. However, two alternate methods were investigated. They were to (1) calculate school density using only schools of target species and prorating to each species and (2) calculate abundance estimates using only data for each individual species. Method 1 does not require calculation of the proportion of all schools that are target schools, however, it utilises smaller samples than our method and a proportion of the unidentified schools must be allocated to the perpendicular distance distribution to calculate school density. We calculated the proportion of identified target schools in each perpendicular distance interval and then assigned that proportion of the unidentified schools detected in the interval to that interval.

Method 2 does not require calculation of species proportions but it utilises very small data sets. Sufficient data only exists to calculate estimates for spotted and spinner dolphins. In this method, we assumed no unidentified dolphin schools contained spotted dolphins.

Estimates of northern offshore spotted dolphins using methods 1 and 2 were 1,235,300 (CV 0.265) and 1,119,600 (CV 0.320) animals, respectively. The estimate for method 2 may have been smaller than both the method 1 estimate and our estimate of 1,275,400 animals using all dolphin schools (Table 2) because it did not include any unidentified schools. However, based on field experience the senior author believes that spotted dolphin schools rarely are not identified. CV estimates were similar for method 1 and our method (0.265 and 0.262, respectively) but both were smaller than the method 2 CV (0.320) which was based on small samples.

Abundance estimates calculated using all dolphin species and data pooled over all strata (total area in Table 1) may provide the most consistent *relative* abundance estimates during the six surveys. The method provides very precise estimates (CV for northern offshore spotted dolphins was 0.158 compared to our estimate of 0.262) because it avoids calculating estimates using small sample sizes. However, the abundance estimates may be biased upwards because proportionally more effort is expended in the high density inshore area (42%) compared to its relative size (30% of total survey area). This bias is acceptable if survey coverage among strata is relatively constant during all surveys as it was during the first two surveys. During 1986, the percents of the survey effort in the inshore, middle, west and south strata were 43, 28, 14 and 15%, respectively (Holt and Sexton, 1988a) and in 1987 they were 42, 30, 13 and 15%, respectively (Table 1).

The estimate of abundance for northern offshore spotted dolphins during 1987 was larger than the 1986 estimate. The 1986 and 1987 estimates were 929,000 (Holt and Sexton, 1988a) and 1,275,400 (Table 2) animals, respectively. These estimates were not statistically different ($p>0.01$). The larger 1987 estimate occurred because school density increased in 1987 in all strata. In addition, the proportion of spotted dolphins in the target species increased in the middle stratum. The 1986 estimates for density in the inshore, middle and west strata were 3.62, 2.56, and 1.89 schools/1000km^2, respectively (Holt and Sexton, 1988a); the corresponding 1987 estimates were 4.74, 3.15 and 2.16 schools/1000km^2, respectively (Table 1). The proportion of spotted dolphins of the target species in the middle stratum increased from 0.378 in 1986 to 0.524 in 1987. However, the proportion of all dolphins that were target species in the middle stratum slightly decreased from 0.906 in 1986 to 0.858 in 1987. In addition, school size estimates decreased slightly in the inshore and west strata and remained constant in the middle stratum. Estimates during 1986 in the inshore middle, and west strata were 89.41, 83.97 and 104.55 animals, respectively (Holt and Sexton, 1988a); in 1987 they were 81.57, 84.56 and 94.12 animals, respectively (Table 1).

The reason for the larger 1987 abundance estimate for northern offshore spotted dolphins may be attributed to sampling variability among surveys. Another factor is that dolphins in the south stratum during 1986 may have migrated into the northern strata during 1987. However, although the mean school size in the south stratum decreased from 179.04 animals (Holt and Sexton, 1988a) during the 1986 survey to 121.64 animals for 1987 survey (Table 1), the density estimate in the south stratum increased from 2.32 schools/1000km^2 in 1986 to 3.58 schools/1000km^2 in 1987. In addition, the proportion of target individuals that were spotted dolphins increased from 0.170 to 0.319. In fact, the abundance estimate for southern offshore spotted dolphins also increased (from 218,500 animals in 1986 to 501,800 animals in 1987).

Abundance estimates for the southern stocks varied greatly between 1986 and 1987. For example, the estimate for southern common dolphins was 943,200 animals during 1986 (Holt and Sexton, 1988a) but was 201,000 animals (Table 1) during 1987. This was because the proportion of common dolphins in the south stratum decreased from 0.661 during 1986 (Holt and Sexton, 1988a) to 0.080 during 1987 (Table 1). Estimates for the other species exhibited corresponding changes. This variability was because estimates in the south stratum were based upon few sightings. During 1986 and 1987, only 27 and 38 target schools, respectively, were detected in the south stratum. Species proportions in the west stratum were also based on few schools (Table 1) which may have yielded variable estimates for the western stocks.

Although estimates for some stocks varied greatly between years, the abundance estimates for all target species summed were similar. The 1986 and 1987 estimates for all target species were 4,471,200 (Holt and Sexton, 1988a) and 5,185,600 (Table 2) animals, respectively. The 1987 estimate is 16% larger than the 1986 estimate.

Selection of the best option to determine population changes will be investigated with additional years' data. We will also investigate several factors which may have contributed to differences observed between surveys. These include ship effects, observer variability, sea state effects and survey coverage variability (Holt and Cologne, 1987).

ACKNOWLEDGEMENTS

The cruises were successfully executed through the dedication of the ships' officers and crew. The data were collected by S. Beavers, S. Benson, C. Bisbee, C. Fried, W. Irwin, R. LeDuc, R. Pitman, J. Raffetto, K. Rittmaster, S. Sinclair, D. Skordal and M. Webber; they are dedicated professionals who spent many hours searching for marine mammals. P. Stangl contributed to the cruise logistics and observer training. We wish to thank J. Barlow, D. DeMaster, E. Edwards, A. Hohn, A. Jackson and M. Webber for serving as Cruise Leaders and for their exceptional dedication to collecting quality data. Finally, we thank I. Barrett, J. Carr and D. DeMaster for their support during the entire cruise preparation and execution. The data analyses were completed using a CRAY X-MP48 at the San Diego Supercomputer Center.

REFERENCES

Au, D., Perryman, W.L. and Perrin, W. 1979. Dolphin distribution and the relationship to environmental features in the eastern tropical Pacific. Southwest Fish. Cent. Adm. Rep. No. LJ-79-43. 59pp.

Barlow, J. and Holt, R.S. 1986. Proportions of species of dolphins in the eastern tropical Pacific. US Dep. Commer., NOAA-TM-NMFS-SWFC-56, 44pp.

Buckland, S.T. 1985. Perpendicular distance models for line transect sampling. *Biometrics* 41: 177–95.

Burnham, K., Anderson, D. and Laake, J. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* No. 72: 202pp.

Crain, B., Burnham, K., Anderson, D. and Laake, J. 1979. *A Fourier Series Estimator of Population Density for Line Transect Sampling.* Utah State Univ. Press, Logan. 25pp.

Drummer, T.D. 1985. Size-bias in line transect sampling. PhD Dissertation, Univ. Wyoming, Laramie, WY.

Hayes, R.J. and Buckland, S.T. 1983. Radial distance models for the line transect method. *Biometrics* 39: 29–42.

Holt, R.S. 1985. Estimates of abundance of dolphin stocks taken incidentally in the eastern tropical Pacific yellowfin tuna fishery. Southwest Fish. Cent. Adm. Rep. No. LJ-85-20. 32p.

Holt, R.S. 1987. Estimating density of dolphin schools in the eastern tropical Pacific ocean by line transect methods. *Fish. Bull., US* 85(3):419–34.

Holt, R.S. and Cologne, J.B. 1987. Factors affecting line transect estimates of dolphin school density. *J. Wildl. Manage.* 51(4):836–73.

Holt, R.S., Gerrodette, T. and Cologne, J.B. 1987. Research vessel survey design for monitoring dolphin abundance in the eastern tropical Pacific. *Fish. Bull., US* 85(3): 435–46.

Holt, R.S. and Jackson, A. 1988. Report of a marine mammal survey of the eastern tropical Pacific aboard the Research Vessel *McArthur* July 30 – December 10, 1986. US Dep. Commer., NOAA-TM-NMFS-SWFC-116. 143pp.

Holt, R.S. and Powers, J.E. 1982. Abundance estimation of dolphin stocks in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys to 1979. US Dep. Commer., NOAA-TM-NMFS-SWFC-23, 95pp.

Holt, R.S. and Sexton, S.N. 1988a. Monitoring trends in dolphin abundance in the eastern tropical Pacific using research vessels over a long sampling period: Analyses of 1986 data. In Review. (submitted to Fish. Bull.).

Holt, R.S. and Sexton, S.N. 1988b. Report of a marine mammal survey of the eastern tropical Pacific aboard the Research Vessel *David Starr Jordan* August 8 – 10 December, 1987. US Dep. Commer., NOAA-TM-NMFS-SWFC-117. 137pp.

Perrin, W.F., Scott, M.D., Walker, G.J. and Cass, V.L. 1984. Review of geographical stocks of tropical dolphins (*Stenella spp.* and *Delphinus delphis*) in the eastern Pacific. Southwest Fish. Cent. Adm. Rep. No. LJ-87-02, 68pp.

Richey, C.R. 1976. Memorandum of opinion. CA NO. 74–1465 and CA NO. 75–0227 US District Court, District of Columbia, May 11, 1976.

Smith, T.D. 1979. Report of the status of the porpoise stock workshop (August 27-31, 1979, La Jolla, CA). Southwest Fish. Cent. Adm. Rep. No. LJ-79-41, 120pp.

Other

Humpback whale in southeast Alaska, summer 1984.
Photograph courtesy of Greg Donovan (IWC).

SC/40/O 1

On the Simultaneous Estimation of Natural Mortality Rate and Population Trend from Catch-at-Age Data

William K. de la Mare

Department of Zoology, Monash University, Wellington Road, Clayton, Victoria 3168, Australia

ABSTRACT

At the 1987 meeting of the Scientific Committee there was a lack of consensus on what could be estimated in principle from a time series of catch-at-age data. This paper examines the extent to which such data can be used to calculate age-dependent natural mortality rates, time series of recruitments and trend in population size for the case where samples can be collected free of the effects of age-specific selectivity. The analyses deal with ideal circumstances, that is, the age distributions of the populations are known without error. The implications of the results for the more realistic case involving data with random error are discussed. The analyses show that it is not possible to estimate a time series of recruitment rates and age-dependent mortality rates from catch-at-age data alone and obtain a unique solution. Different mortality schedules will give different time series of recruitments and vice-versa, each capable of giving the same fit to the observations.

INTRODUCTION

At the 1987 meeting of the Scientific Committee of the IWC, the Government of Japan submitted a proposed programme of research on minke whales in the Southern Ocean. The proposed Japanese research identified as its major aim the estimation of age-dependent natural mortality rates of minke whales by an analysis of catch-at-age data. A number of papers to the Scientific Committee pointed out that it was not possible to estimate natural mortality rates without knowing the rate of change of population size (e.g. de la Mare, 1987; Goodman and Chapman, 1988; Holt, 1988; Horwood, 1987). In response, Tanaka (IWC, 1988) suggested that an iterative procedure will give the required estimates. Butterworth (IWC, 1988) tentatively suggested that this might be feasible from a catch-at-age matrix formed from the age structure of the catch over a long time scale, provided that certain parameters were time invariant. Other members of the Scientific Committee stated that the solutions to the catch-at-age matrix are not unique.

It is somewhat surprising that this debate is occurring. Beverton and Holt (1957) demonstrated that it is not possible to estimate natural mortality rate from catch-at-age data without knowing the rate of change of population size. Agger, Boetius and Lassen (1971) attempted to find a solution for the catch-at-age matrix under the assumption that there was no age-specific selection. Pope and Shepherd (1982) discussed the more general problem of ensuring that the catch-at-age matrix is consistent with a constant pattern of exploitation when estimating a time series of recruitments (via virtual population analysis [VPA]) when fishing mortality is not negligible and age-specific selectivity is estimated from the same data. They showed that a wide range of assumptions about natural mortality and population size can give equally good fits to the catch-at-age matrix, and that a unique solution requires three external parameters to be specified, namely, natural mortality, terminal fishing mortality (i.e. abundance), and a selection coefficient. Shepherd and Nicholson (1986) showed that the estimation of parameters describing a catch–at-age data matrix requires independently fixed constraints on the parameter values.

A related case has been examined in the IWC over the last few years in the form of the multi-cohort method for estimating trends in recruitment (Sakuramoto and Tanaka, 1985; 1986). It has been pointed out that the trends obtained depend on the estimates of natural mortality used in the procedure (Cooke, 1985; IWC, 1986). Horwood, Shepherd and Coleman (1985) applied a separable VPA (Pope and Shepherd, 1982) to minke whale catch-at-age data and found that discrimination between a range of population sizes and trends is poor.

The proposed Japanese catches would be taken under a sampling design which they believe will result in catch-at-age distributions which are representative of the whole population. While serious objections have been raised concerning the ability of the proposed sampling method to achieve that end (IWC, 1988), for the purposes of the analyses in this paper, it is assumed that representative samples can be obtained.

The method of analysis proposed by Tanaka (1988) is to use the multi-cohort method to estimate trends in recruitment and population size with an assumed set of natural mortality rates. Using this information, the estimates of natural mortality will be revised. The revised mortality estimates are then used in the multi-cohort method to revise the estimates of trends in recruitment and population size, the cycle being repeated until further iteration does not change the values of the estimates.

The purpose of this paper is to clarify why there is no unique solution for age-dependent mortality rates, change in population size and trend in cohort strength from catch-at-age data alone. The analyses show what additional quantities must be measured to yield a unique solution. The sensitivity of that solution to error in these quantities is also examined. The discussion of the analyses here is intended to be comprehensible to non-mathematicians. Unfortunately, there is no way to make the analyses themselves non-mathematical.

A STATEMENT OF THE PROBLEM

A sample from a population will consist of animals of different ages. The number in each age-class (cohort) within the population in a given year depends upon how many animals were born into the cohort and how many have died from all causes between birth and the year of sampling. The proposed analysis of Tanaka (1988) assumes that the age-dependent rates of natural mortality are constant, that is they do not depend on time or the size of the population. Under these assumptions, the number in age-class j in year i is given by the following expression:

$$A_{i,j}=A_{i-j+1,1}.S_1.S_2. \dots .S_{j-1} \tag{1}$$

where S_a is the survival rate from age a to a+1. If fishing mortality is negligible, then S_a represents the survival rate after natural mortality. The convention adopted here is that animals aged between 0 and 1 years belong to age-class 1. Thus $A_{i-j+1,1}$ represents the strength of the cohort at birth. However, the subsequent analyses apply *in toto* if the first age-class is not 0 year olds, so long as births are redefined as recruits to a given age-class. The total population size in year i is given by:

$$T_i=\sum_j A_{i,j} \tag{2}$$

Let $a_{i,j}$ be the number of animals aged j in a sample collected from the population in year i. Samples collected from the population give the age structure but not the population size, and so the total sample size in year i is related to the true population size by an unknown factor k_i, that is:

$$\sum_j a_{i,j}=k_i \sum_j A_{i,j} \tag{3}$$

If there is no age-specific selectivity then the same factor scales the number in each age-class in the sample to the number in each age-class in the population. Thus, the age structure of a series of samples in successive years is given by:

$$\begin{aligned}
&a_{i,1}=k_i.A_{i,1}\\
&a_{i,2}=k_i.A_{i-1,1}.S_1\\
&a_{i,3}=k_i.A_{i-2,1}.S_1.S_2\\
&a_{i,4}=k_i.A_{i-3,1}.S_1.S_2.S_3\\
&\quad\vdots\\
&\quad\vdots\\
&a_{i,n}=k_i.A_{i-n+1,1}.S_1. \dots .S_{n-1}\\
&a_{i+1,1}=k_{i+1}.A_{i+1,1}\\
&a_{i+1,2}=k_{i+1}.A_{i,1}.S_1\\
&\quad\vdots\\
&\quad\vdots\\
&a_{i+1,n}=k_{i+1}.A_{i-n+2,1}.S_1. \dots .S_{n-1}
\end{aligned} \tag{4}$$

The left hand sides of the expressions are the observed frequencies in the samples. The right hand sides are the parameters which have to be estimated. The population size in year i+1 relative to that in year i is given by:

$$T_{i+1}/T_i=(k_i/k_{i+1})(\sum_j a_{i+1,j}/\sum_j a_{i,j}) \tag{5}$$

Thus, if the total sample size is the same in each year, the relative population size is obtained from the ratio of the two k values. This restriction makes the presentation of the analyses slightly simpler, and it can be made without loss of generality.

Inspection of this set of equations show that if there were n age classes and t years of data, the number of unknown parameters (U) is given by:

$$U=2(t+n-1) \tag{6}$$

and the number of equations (E) is given by:

$$E=t.n \tag{7}$$

To obtain a unique solution for a system of simultaneous equations there must be as many independent equations as there are unknown parameters. The difference between the number of parameters and the number of equations (D) is given by:

$$D=n(t-2)-2t+2 \tag{8}$$

If there are two years of data, D is –2, and hence the number of equations that can be formed is always less than the number of unknown parameters and so no unique solution can be found from the catch-at-age data alone. It is shown in Beverton and Holt (1957) that if the relative change in population size can be specified, then the system can be solved for natural mortality rates (a simpler demonstration is given in de la Mare, 1987).

If there are three or more years of data and the number of age classes is above a minimum value, the number of equations which can be formed is greater than or equal to the number of unknown parameters U. For example, if t is 3 then D is equal to n-4, and hence D is positive if there are four or more age classes. Similarly, if t=4 then D is equal to 2n-6, and hence positive if n is 3 or more. Under these circumstances the question becomes how many of the equations are independent. This question is most easily addressed by converting the set of equations for the catch-at-age matrix to a linear system and applying standard results of linear algebra.

THE NATURE OF THE SOLUTION

The set of expressions for the age structure can be written as a simple system of linear equations by taking logarithms. Let $b_{i,j}$ be the logarithm of $a_{i,j}$, and g_i be the logarithm of k_i. Furthermore, let r_i denote the logarithm of the number of the number of animals born in year i, that is:

$$r_i = \log_e A_{i,1}$$

Provided fishing mortality is negligible, the negative of the logarithm of S_a is the natural mortality rate M_a. However, to eliminate a number of tedious minus signs, there is no algebraic difference if M is defined to be the logarithm of the survival rate, and thus in these analyses M_a is the signed value of natural mortality. Thus, the system of equations [9] has the form shown in Fig. 1.

$$\begin{array}{llllllll}
g_i & & & & + r_i & & & = b_{i,1}\\
g_i & & & + r_{i-1} & & & + M_1 & = b_{i,2}\\
g_i & & + r_{i-2} & & & & + M_1 + M_2 & = b_{i,3}\\
\quad\vdots & & & & & & & \\
\quad\vdots & & & & & & & \\
g_i & + r_{i-n+1} & & & & & + M_1 + M_2 + \dots M_{n-1} & = b_{i,n}\\
\quad g_{i+1} & & & & & + r_{i+1} & & = b_{i+1,1}\\
\quad g_{i+1} & & & & + r_i & & + M_1 & = b_{i+1,2}\\
\quad g_{i+1} & & & + r_{i-1} & & & + M_1 + M_2 & = b_{i+1,3}\\
\quad\vdots & & & & & & & \\
\quad\vdots & & & & & & & \\
\quad g_{i+1} & & + r_{i-n+2} & & & & + M_1 + M_2 + \dots M_{n-1} & = b_{i+1,n}\\
\quad\vdots & & & & & & & \\
\quad\vdots & & & & & & & \\
 & & & & & & & ..(9)
\end{array}$$

Fig. 1 (see text).

This can be expressed more conveniently in matrix form, that is:

$$\mathbf{CV = B}$$

where **B** is a column vector of length E corresponding to the right hand side (RHS) of the system of equations [9]. **V** is a column vector of length U of the unknown parameters g., r. and M., that is:

$$V = \begin{array}{l} g_i \\ g_{i+1} \\ : \\ : \\ g_{i+t-1} \\ r_{i-n+1} \\ r_{i-n+2} \\ : \\ : \\ r_{i+t} \\ M_1 \\ M_2 \\ : \\ : \\ M_{n-1} \end{array}$$

and C is a matrix of coefficients with E rows and U columns and has the form (blanks indicate 0 elements) shown in Fig. 2.

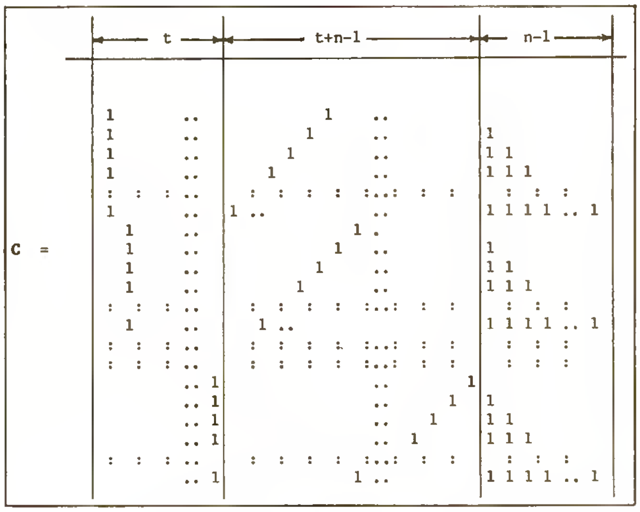


Fig. 2 (see text).

The first t columns of C consist of unit segments of length n, which are the coefficients of g_i. The next t+n-1 columns of the matrix have diagonal segments of length n, which are the coefficients of r_i. The last n-1 columns consist of triangular segments which are the coefficients of M_j.

The rank of a matrix is the number of linearly independent rows or columns, and the rank of the coefficient matrix C represents the number of independent equations in the system. If a row or column of a matrix can be converted into a row or column of zeros by elementary row or column operations then not all of the rows or columns are linearly independent. An elementary row or column operation involves the addition or subtraction of multiples of the rows or columns. Elementary row or column operations do not alter the rank of a matrix. The rank of the matrix is equal to the number of rows or columns (whichever is the less) which cannot be reduced to zeros by elementary row and column operations.

The case of interest is when C is a matrix with the number of rows (E) greater than or equal to the number of columns (U). The rank of a non-square matrix is always less than or equal to the smaller dimension. Thus, for the case in hand, the number of unknown variables is equal to the number of columns, and if not all columns are linearly independent, there are fewer independent equations than unknown variables, and hence there is no unique solution to the system of equations.

Inspection of C shows that the sum of the first t columns is a column of ones. Similarly, the sum of columns t+1 through to 2t+n-1 is also a column of ones. Thus, if columns t+1 to 2t+n-2 are added to column 2t+n-1, and the first t columns are subtracted from column 2t+n-1 then a column of zeros will result.

The rows of C can be divided into t groups of n rows. Considering any such group, e.g. the rows 1 to n, it is clear that the sum of the last n-1 columns (the coefficients of M) can be formed as the sum of multiples of the first 2t+n-1 columns. In each group of n rows, the column containing the unit elements contains only zeros in the other groups of rows (in mathematical terms, the first t column vectors are orthogonal). This means that multipliers exist which will simultaneously make the sum of the first 2t+n-1 columns equal to the sum of the last n-1 columns.

Elementary column operations can be represented by a square matrix **P** with dimension U which postmultiplies the coefficient matrix C. Elementary column operations which convert two columns of the coefficient matrix C to columns of zeros can be represented as a matrix with the form shown in Fig. 3.

$$\begin{array}{l|cccccccccccc}
\text{column number} \rightarrow & 1 & 2 & 3 & .. & & & & .. & & (2t+n-1) & .. & U \\
\hline
\text{row number} & & & & & & & & & & & & \\
1 & 1 & & & .. & & & & .. & & -1 & .. & t-1 \\
2 & & 1 & & .. & & & & .. & & -1 & .. & t-2 \\
3 & & & 1 & .. & & & & .. & & -1 & .. & t-3 \\
: & & & & .. & & & & .. & & : & .. & : \\
t & & & & .. & 1 & & & .. & & -1 & .. & t-t \\
t+1 & & & & .. & & 1 & & .. & & 1 & .. & -(t+n-2) \\
t+2 & & & & .. & & & 1 & .. & & 1 & .. & -(t+n-3) \\
: & & & & .. & & & & .. & & : & .. & : \\
2t+n-2 & & & & .. & & & & .. & 1 & 1 & .. & -1 \\
2t+n-1 & & & & .. & & & & .. & & 1 & .. & 0 \\
2t+n & & & & .. & & & & .. & & 0 & .. & 1 \\
: & & & & .. & & & & .. & & : & .. & : \\
U & & & & .. & & & & .. & & 0 & .. & 1
\end{array}$$

Fig. 3 (see text).

Post-multiplication of the coefficient matrix by **P** will always produce a matrix with two zero columns. This means that there are always two fewer independent equations than unknown variables in the system of equations. Therefore, there is *no unique solution to the system*; an infinite set of solutions satisfy the equations.

This can be made clearer with a concrete example; consider three years of age data and take the first four age-classes, i.e. t=3, n=4. The system of equations [10] can be written as shown in Fig. 4.

$$\begin{array}{llllllllllll}
g_4 & & & & & + r_4 & & & & & & = b_{4,1} \\
g_4 & & & & + r_3 & & & & + M_1 & & & = b_{4,2} \\
g_4 & & & + r_2 & & & & & + M_1 & + M_2 & & = b_{4,3} \\
g_4 & & + r_1 & & & & & & + M_1 & + M_2 & + M_3 & = b_{4,4} \\
& g_5 & & & & & + r_5 & & & & & = b_{5,1} \\
& g_5 & & & & + r_4 & & & + M_1 & & & = b_{5,2} \\
& g_5 & & & + r_3 & & & & + M_1 & + M_2 & & = b_{5,3} \\
& g_5 & & + r_2 & & & & & + M_1 & + M_2 & + M_3 & = b_{5,4} \\
& & g_6 & & & & & + r_6 & & & & = b_{6,1} \\
& & g_6 & & & & + r_5 & & + M_1 & & & = b_{6,2} \\
& & g_6 & & & + r_4 & & & + M_1 & + M_2 & & = b_{6,3} \\
& & g_6 & & + r_3 & & & & + M_1 & + M_2 & + M_3 & = b_{6,4}
\end{array} \quad ..(10)$$

Fig. 4 (see text).

The coefficient matrix (with explicit zeros rather than blanks) is shown in Fig. 5a.

a

$$\mathbf{C} = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 \end{Vmatrix}$$

b

$$\mathbf{P} = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -5 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & -4 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & -3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & -2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{Vmatrix}$$

c

$$\mathbf{CP} = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \end{Vmatrix}$$

Fig. 5 (see text).

The matrix which converts two columns to zero is shown in Fig. 5b and **CP** is shown in Fig. 5c.

Thus, the coefficient matrix has a rank of 10 which is two less than the number of unknown variables, and hence there is no unique solution to the system of equations (10) given above unless two of the unknown parameters are fixed externally (in effect adding two more independent equations to the system). However, continued examination of this example will show that specifying two g variables (i.e. the population size in two years, which is also equivalent to specifying the recruitment in the same two years) or one of the g variables and one M value will lead to a unique solution.

The solutions to a system of equations can be found by transforming the coefficient matrix into row-reduced echelon form. A matrix of rank r in row-reduced echelon form has r non-zero rows. r columns of the matrix have one unit element with the remaining elements zero, with the unit element occurring in different rows. The remaining columns correspond to 'free' variables, if there are no free variables, that is the matrix has r columns altogether, then the system of equations has a unique solution (strictly speaking, the rank of the matrix augmented by the RHS must be of the same rank as the coefficient matrix; certain forms of RHS do not lead to a solution, but they do not arise in the deterministic problem considered here). A matrix **R** can be found which transforms the coefficient matrix to row-reduced echelon form by pre-multiplication. If the row-reduced echelon form of the coefficient matrix is of rank r with r columns, then the right hand side of a system of equations, pre-multiplied by **R** is the solution vector for the system.

Returning to the example [10] above, the matrix shown in Fig. 6a reduces the coefficient matrix to row-reduced echelon form:

$$\mathbf{R} = \begin{Vmatrix} 1 & 0 & 0 & 0 & -1 & -1 & 2 & 0 & 1 & 1 & 0 & -2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ -2 & 1 & 0 & 1 & 3 & 2 & -5 & 0 & -1 & -3 & 0 & 4 \\ -2 & 1 & 1 & 0 & 3 & 2 & -5 & 0 & -1 & -3 & 0 & 4 \\ -1 & 1 & 0 & 0 & 2 & 1 & -3 & 0 & -1 & -2 & 0 & 3 \\ 0 & 0 & 0 & 0 & 1 & 1 & -2 & 0 & -1 & -1 & 0 & 2 \\ 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 & -1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 1 & 0 & -1 \\ 1 & -1 & 0 & 0 & -1 & -1 & 2 & 0 & 0 & 1 & 0 & -1 \\ 1 & 0 & -1 & 0 & -1 & -1 & 1 & 1 & 0 & 1 & 0 & -1 \\ -1 & 1 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & -1 & 1 & 0 \end{Vmatrix}$$

a

$$\mathbf{RC} = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -2 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 5 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1 & 0 & 0 & 4 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 & 3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & 2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{Vmatrix}$$

b

Fig. 6 (see text).

Premultiplying **C** by **R** gives the matrix shown in Fig. 6b.

The transformed matrix shows that the rank of the coefficient matrix is 10, as expected and that there are two free variables, in this particular case r_6 and M_3. Moving columns from the coefficient matrix to the RHS of the system of equations [10] enables the transformation of **C** to a row-reduced echelon matrix with no free variables, and hence the system can be solved in terms of the variables transferred to the RHS of the equations. For example, if g_5 and g_6 are transferred to the RHS, the system of equations (10) given earlier becomes the system of equations (11) shown in Fig. 7.

$$\begin{array}{llllllllcl} g_4 & & & & + r_4 & & & & = & b_{4,1} \\ g_4 & & & + r_3 & & & & + M_1 & = & b_{4,2} \\ g_4 & & + r_2 & & & & & + M_1 + M_2 & = & b_{4,3} \\ g_4 & + r_1 & & & & & & + M_1 + M_2 + M_3 & = & b_{4,4} \\ & & & & & r_5 & & & = & b_{5,1} - g_5 \\ & & & & r_4 & & & + M_1 & = & b_{5,2} - g_5 \\ & & & r_3 & & & & + M_1 + M_2 & = & b_{5,3} - g_5 \\ & & r_2 & & & & & + M_1 + M_2 + M_3 & = & b_{5,4} - g_5 \\ & & & & & & r_6 & & = & b_{6,1} - g_6 \\ & & & & & r_5 & & + M_1 & = & b_{6,2} - g_6 \\ & & & & r_4 & & & + M_1 + M_2 & = & b_{6,3} - g_6 \\ & & & r_3 & & & & + M_1 + M_2 + M_3 & = & b_{6,4} - g_6 \end{array} \quad ..(11)$$

Fig. 7 (see text).

The corresponding coefficient matrix is shown in Fig. 8a.

The matrix shown in Fig. 8b reduces **C** to row-reduced echelon form. The row-reduced echelon coefficient matrix is given as Fig. 8c.

$$\mathbf{C} = \begin{Vmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 \end{Vmatrix}$$

a

$$\mathbf{R} = \begin{Vmatrix} 1 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & 0 & 1 & 0 & 0 \\ -3 & 1 & 1 & 1 & 4 & 3 & -1 & -1 & 0 & -4 & 0 & 0 \\ -2 & 1 & 1 & 0 & 3 & 2 & -1 & 0 & 0 & -3 & 0 & 0 \\ -1 & 1 & 0 & 0 & 2 & 1 & 0 & 0 & 0 & -2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 & -1 & -1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & -1 & 0 & -1 & -1 & 0 & 1 & 0 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & -1 & 1 & 0 \\ -1 & 0 & 1 & 0 & 1 & 1 & -1 & -1 & 0 & -1 & 0 & 1 \end{Vmatrix}$$

b

$$\mathbf{RC} = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{Vmatrix}$$

c

Fig. 8 (see text).

$$\begin{aligned}
g_4 &= b_{4,1} - b_{5,1} - b_{5,2} + b_{6,2} + g_5 - (g_6-g_5)\\
r_1 &= -3b_{4,1} + b_{4,2} + b_{4,3} + b_{4,4} + 4b_{5,1} + 3b_{5,2} - b_{5,3} - b_{5,4} - 4b_{6,2} - g_5 + 4(g_6-g_5)\\
r_2 &= -2b_{4,1} + b_{4,2} + b_{4,3} + 3b_{5,1} + 2b_{5,2} - b_{5,3} - 3b_{6,2} - g_5 + 3(g_6-g_5)\\
r_3 &= -b_{4,1} + b_{4,2} + {} + 2b_{5,1} + b_{5,2} - 2b_{6,2} - g_5 + 2(g_6-g_5)\\
r_4 &= b_{5,1} + b_{5,2} - g_5 + (g_6-g_5)\\
r_5 &= b_{5,1} - g_5\\
r_6 &= b_{6,2} - g_6\\
M_1 &= - b_{5,1} \quad b_{6,2} - (g_6-g_5)\\
M_2 &= b_{4,1} - b_{4,2} - b_{5,1} - b_{5,2} + b_{5,3} + b_{6,2} - (g_6-g_5)\\
M_3 &= b_{4,1} - b_{4,3} - b_{5,1} - b_{5,2} + b_{5,4} + b_{6,2} - (g_6-g_5)
\end{aligned} \qquad ..(12)$$

Fig. 9 (see text).

a

$$\mathbf{C} = \left\|\begin{matrix}
1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0\\
1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0\\
1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0\\
1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0\\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0\\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1\\
0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0\\
0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0\\
0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1
\end{matrix}\right\|$$

b

$$\mathbf{R} = \left\|\begin{matrix}
1 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 1 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1\\
-2 & 1 & 0 & 1 & 0 & 2 & -4 & 0 & 0 & -3 & 0 & 3\\
-2 & 1 & 1 & 0 & 0 & 2 & -4 & 0 & 0 & -3 & 0 & 3\\
-1 & 1 & 0 & 0 & 0 & 1 & -2 & 0 & 0 & -2 & 0 & 2\\
0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & -1 & 0 & 1\\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & -1\\
1 & -1 & 0 & 0 & 0 & -1 & 2 & 0 & 0 & 1 & 0 & -1\\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
1 & 0 & -1 & 0 & 0 & -1 & 1 & 1 & 0 & 1 & 0 & -1\\
-1 & 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & -1 & 1 & 0
\end{matrix}\right\|$$

c

$$\mathbf{RC} = \left\|\begin{matrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1\\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 4\\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 3\\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 2\\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1\\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{matrix}\right\|$$

Fig. 10 (see text).

a

$$\mathbf{C} = \left\|\begin{matrix}
1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0\\
1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\
1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0\\
1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0\\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0\\
0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0\\
0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\
0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0\\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0\\
0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0\\
0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0
\end{matrix}\right\|$$

b

$$\mathbf{R} = \left\|\begin{matrix}
1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 0\\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & -1 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\
-1 & 0 & 0 & 1 & -1 & 1 & 0 & 0 & -1 & 1 & 0 & 0\\
-1 & 0 & 1 & 0 & -1 & 1 & 0 & 0 & -1 & 1 & 0 & 0\\
-1 & 1 & 0 & 0 & -1 & 1 & 0 & 0 & -1 & 1 & 0 & 0\\
0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & -1 & 1 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0\\
1 & -1 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0\\
1 & 0 & -1 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & -1 & 1 & 0\\
1 & -1 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & -1 & 0 & 1
\end{matrix}\right\|$$

c

$$\mathbf{RC} = \left\|\begin{matrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1\\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1\\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{matrix}\right\|$$

Fig. 11 (see text).

There are no free variables in the row-reduced echelon matrix. The solution of the system of equations is obtained by pre-multiplying the vector of observed constants and transferred free variables by the transformation matrix **R**. The resultant solution (equations 12) is given as Fig. 9.

Thus, if g_5 and g_6 can be specified then a unique solution is found for all of the other variables. Knowing g_5 and g_6 is in effect knowing the population size or recruitment in two years. In the equations above the term (g_6-g_5) occurs in all but two equations. Since the components of these equations are logarithms, (g_6-g_5) is the logarithm of the population size in year 6 relative to that in year 5. Thus, it is sufficient to be able to specify the relative change in population size to obtain the solutions for the coefficients of natural mortality. It is also sufficient in this deterministic case to solve for the population change and recruitment in relative terms if relative change in population is known in two years, even if the absolute population size itself is not known.

Although the number of parameters exceeds the number of independent equations by two, there are some pairs of parameters which can be moved to the RHS which still do not lead to a unique solution. For example, knowing the population size in any one year gives values for two of the unknown variables, namely g_i and r_i, however, moving two such values to the RHS of the system of equations (10) still leaves one free variable. For example, specifying g_4 and r_4 leads to the coefficient matrix given in Fig. 10a.

The matrix given in Fig. 10b reduces C to row-reduced echelon form and the row-reduced echelon form is given in Fig. 10c.

This matrix still indicates that there is one free variable. Moving all of the M values to the RHS will still leave one free variable on the left hand side (LHS), because one column of the coefficient matrix can still be set to zero. That is, even knowing the full natural mortality schedule does not lead to a unique solution, however, moving an arbitrary g value to the RHS does allow the solution for recruitment and population trend in relative terms. These points are clear from examination of the concrete example.

First, the coefficient matrix for the system with the three M values moved to the RHS of (10) is shown in Fig. 11a.

The pre-multiplier matrix given in Fig. 11b reduces C to row-reduced echelon form. The coefficient matrix in echelon form is shown in Fig. 11c.

This shows that there is one free variable even though all the M values are specified, and the system does not have a unique solution. It is easily verified that the same result is obtained even if natural mortality is independent of age; even though having only one constant M value reduces the number of unknown parameters by two. If a g variable is moved to the RHS of [10] as well then the coefficient matrix is as shown in Fig. 12a (overleaf).

The following matrix reduces the coefficient matrix to the row-reduced echelon form shown in Fig. 12b and C in row-reduced echelon form is given in Fig. 12c (overleaf).

The resultant solution to the system of equations is given by (13) shown in Fig. 13 (overleaf).

The form of the solution shows that the change in population size and pattern of recruitment can be determined in relative terms if one or more of the age dependent natural mortality rates are known.

$$C = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \end{Vmatrix}$$

a

$$R = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 1 & -1 & 0 \\ -1 & 1 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 1 & 0 & -1 \end{Vmatrix}$$

b

$$RC = \begin{Vmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{Vmatrix}$$

c

Fig. 12 (see text).

$$\begin{aligned} g_4 &= b_{4,1} - b_{5,2} + M_1 + g_5 \\ g_6 &= b_{5,1} + b_{6,2} + M_1 + g_5 \\ r_1 &= -b_{4,1} + b_{4,4} + b_{5,2} - 2M_1 - M_2 - M_3 - g_5 \\ r_2 &= -b_{4,1} + b_{4,3} + b_{5,2} - 2M_1 - M_2 - g_5 \\ r_3 &= -b_{4,1} + b_{4,2} + b_{5,2} - 2M_1 - g_5 \\ r_4 &= b_{5,2} - M_1 - g_5 \\ r_5 &= b_{5,1} - g_5 \\ r_6 &= b_{5,1} + b_{6,1} - b_{6,2} - M_1 - g_5 \end{aligned} \qquad ..(13)$$

Fig. 13 (see text).

In summary, there is no unique solution to the general system of equations which describe the catch-at-age matrix in terms of a time series of recruitments, change in population size, and age-dependent mortality rate. The relative changes in population size and time series of relative recruitments can be found, at least deterministically, if the age dependent natural mortality rates are known. Conversely, the natural mortality rates can be found if a relative change in population size is known.

SENSITIVITY ANALYSIS

The next question to consider is the extent to which the solutions alter when erroneous values are supplied for the parameters which enable the system to be solved uniquely. The definition of sensitivity used here is commonly used in control theory (for example, see Shinners, 1978, p.164). The sensitivity of function $f(x_1,\cdot\cdot x_n)$ to values of one of its parameters x_i is defined as:

$$S^f_{x_i} = \partial \log_e[f(x_1, \cdot\cdot\, x_i, \cdot\cdot\, x_n)]/\partial \log_e(x_i) \qquad (14)$$

which may be written as

$$S^f_{x_i} = \{\partial[f(x_1,\cdot\cdot x_i,\cdot\cdot x_n)]/\partial x_1\}\ \{x_i/f(x_1, \cdot\cdot\, x_i, \cdot\cdot\, x_n)\} \qquad (15)$$

Equation (15) implies that the sensitivity can be interpreted as the ratio of the fractional change in the value of f(x) to a given fractional change in x; this does not necessarily hold if the change in x is large.

For the case where two of the g values are given (equation system [12]), it is easily shown that the sensitivity of the mortality estimates to the relative change in population size is given by:

$$S^M_G = -\ (1/M) \qquad (16)$$

where the relative change in population size is

$$G_i = e^{(g_i + 1 \text{-} g_i)}$$

Taking the current estimate of M (0.086) for minke whales in the Antarctic as a numerical example, gives a sensitivity of –11.6. Thus, a 1% error in the estimate of the relative population increase leads to an error of approximately 12% in the calculated values of M.

The ratio of recruits in one year to that in the previous year (B) is given by:

$$B_i = e^{(r_{i+1}\ -\ r_i)}$$

It can be shown in general that:

$$S^B_G = -1 \qquad (17)$$

For the system of equations (13), where the M values are specified, the sensitivities of the calculated values of G are given by:

$$S^G_M = -M$$

For the Southern Hemisphere minke whale example, the sensitivity of the calculated G to the value of M is –0.086. At first appearance, this seems to be a low sensitivity, however, the examination of mortality rates and rates of population increase is most relevant to the question of the likely range of the yield from the population. That is, the parameter of interest is the fractional increase in the population size (d) since this is related to the replacement yield; d is defined by d=G-1.

Clearly, a given error in G represents a much larger error in d. For example, if G is 1.01, then d is 0.01. A 1% error in G would be to assign it the value 1.02, but this represents a 100% error in d. The sensitivity of the calculated values of d to the input values of M are of the form:

$$S^M_d = -[M(1 + d)/d]$$

The Scientific Committee has generally considered the replacement yields for Southern Hemisphere minke whales lie in the range of 1% to 4%. Supposing d to be 1% gives a sensitivity of d to M of –8.7. If d is 4% then the sensitivity is –2.2. Thus, estimates of likely replacement rates are sensitive to the value of natural mortality chosen to obtain a solution.

The sensitivity of B to the value of M has the following form:

$$S^B_M = -M$$

Thus the relative change in birth rate from one year to the next is not particularly sensitive to the value of M specified. However, effect of errors in M accumulate, such that the overall trend in birth-rate over a number of years is more dependent on the M values used.

CONCLUSION AND DISCUSSION

These analyses show that there is no unique solution in the form of age dependent mortality rates and time specific recruitments and population sizes to be found from a series of catch-at-age data collected over any number of years. The analyses here are based on perfect information, that is, that the observed age distribution does not involve any effects due to sampling variability. This ideal case is important because it gives insight into the ability to solve the problem for the more realistic case.

Any real case, where there is sampling variability, requires the system to be substantially over-determined; in effect, there are more equations than unknown parameters. Only by a rare chance would any of the equations be satisfied exactly because of the random errors. The estimates of parameters would be obtained by minimising some form of residual function between the observed and expected frequencies in each age class in each year. The deterministic analysis shows that exactly the same expected age distribution can be obtained with different mortality and recruitment schedules. This means that the value of the residual function will be the same for different parameter estimates, and hence that no unique fit can be found to the data.

To find a unique solution requires some of the unknown variables to be fixed independently. These could be the relative change in population size, the natural mortality rates or the recruitments. Some analyses of the confidence intervals that would be obtained in estimates of natural mortality, when the relative change in population size is specified using the best methods currently available, shows that the estimates would be so variable as to be useless (de la Mare, 1987).

It does not matter what technique is used to solve the equations, whether it is by direct methods as examined here or by the separate iteration proposed by Tanaka. If a set of recruitments is found by the 'multi-cohort' method with a fixed set of natural mortality rates, then using these recruitments in a further iteration to refine the estimates of mortality will return the values which were used to estimate the recruitments. But the solution obtained does not offer a unique best fit to the data. Starting with a different set of natural mortalities will give a different set of estimates of recruitments which will fit the data equally well. Similarly, if the population is assumed to be increasing or decreasing at some given rate, natural mortality estimates will be obtained that are consistent with that rate. Using those natural mortalities to estimate the rate of change in population size will return the original rate.

In practice, if a minimisation procedure is used for obtaining estimates from stochastic data then iteration may not return exactly the same estimates each time around the loop, but the estimates will all be equally consistent with the data, and no one set of estimates will have any greater validity than any other set. Examples showing this behaviour can be seen in the residual function plots given in Horwood *et al.* (1985).

Overall, as concluded by many members of the Scientific Committee at its 1987 meeting, the proposed Japanese research programme and the method of analysis outlined by Tanaka cannot give reliable estimates of natural mortality rates and rates of population increase and trends in recruitment, even in principle.

ACKNOWLEDGEMENTS

The author is grateful for comments on the initial draft of this paper by J.G. Cooke, Dept. of Biology, University of York, York, Y01 5DD, UK and S.J. Holt, Via della Fonti di Fauno 29/6, Rome, Italy. The author is also grateful to two anonymous referees for their comments and their careful checking which found some inconsistencies in the notation of the second draft.

REFERENCES

Agger, P., Boetius, I. and Lassen, H. 1971. On errors in virtual population analysis. ICES CM 1971/H:16, 10pp. (mimeo).

Beverton, R.J.H. and Holt, S.J. 1957. *On the Dynamics of Exploited Fish Populations*. Fishery Investigations Series 2, Vol. 19. HMSO, London. 533pp.

Cooke, J.G. 1985. On the estimation of trends in year class strength using cohort models. *Rep. int. Whal. Commn* 35:325–30.

de la Mare, W.K. 1987. Comments on the program for research on the Southern Hemisphere minke whale and preliminary research on the marine ecosystem in the Antarctic. Paper SC/39/O 24, presented to the IWC Scientific Committee June, 1987. (Unpublished).

Goodman, D. and Chapman, D.G. 1988. Comments on Annex R2. 'A preliminary consideration on a method for estimating age-dependent natural mortality from age-composition obtained by random sampling'. *Rep. int. Whal. Commn* 38:144–5.

Holt, S.J. 1988. Extracts from SC/39/Mi10. 'Comments on the Japanese proposal to catch Southern Hemisphere minke whales under special permit.' *Rep. int. Whal. Commn* 38:142–4

Horwood, J.W. 1988. Some comments on the Japanese research proposal. *Rep. int. Whal. Commn* 38:145–6.

Horwood, J.W., Shepherd, J.G. and Coleman, J.L. 1985. Age structure information in minke whales. *Rep. int. Whal. Commn* 35:227–30.

International Whaling Commission. 1986. Report of the sub-committee on Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 36:66–78.

International Whaling Commission. 1988. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38:32–61.

Pope, J.G. and Shepherd, J.G. 1982. A simple method for the consistent interpretation of catch-at-age data. *J. Cons. int. Explor. Mer* 40:176–84.

Sakuramoto, K. and Tanaka, S. 1985. A new multi-cohort method for estimating Southern Hemisphere minke whale populations. *Rep. int. Whal. Commn* 35:261–72.

Sakuramoto, K. and Tanaka, S. 1986. Further development of an assessment technique for Southern Hemisphere minke whale populations using a multi–cohort method. *Rep. int. Whal. Commn* 36:207–12.

Shepherd, J.G. and Nicholson, M.D. 1986. Use and abuse of multiplicative models in the analysis of fish catch-at-age data. *The Statistician* 35:221–7.

Shinners, S.M. 1978. *Modern Control System Theory and Application*. Addison Wesley, Reading, Mass. 544pp.

Tanaka, S. 1988. A preliminary consideration on a method for estimating age dependent natural mortality from age composition obtained by random sampling. *Rep. int. Whal. Commn* 38:140–2.

SC/40/O 20

Some Comments on the BIWS Catch Record Data Base

Peter B. Best[1]

Mammal Research Institute, University of Pretoria, South Africa

ABSTRACT

Practical experience with the whaling industry is used to illustrate potential problems associated with the catch data collected over 50 years by the Bureau of International Whaling Statistics and now being entered on a computer data base. Such problems include non-reporting or misidentification of catch records; stretching and shrinking of length measurements; under-reporting, inaccurate measurement and incorrect sex-determination of foetuses; and unreliable stomach content data. Users of the data base should be made aware of its potential problems.

INTRODUCTION

Since 1980 the Secretariat of the International Whaling Commission (IWC) has been engaged in a process of coding and entering on a computerised data base the individual catch records for modern whaling originally collected over 50 years and published regularly (as summaries by the Bureau of International Whaling Statistics (BIWS) in Norway). The data available represent some 2,000,000 animals (Anon., 1987).

In this note comments on certain aspects of the data are made, based on personal experience of the whaling industry. These comments are essentially an aid to interpreting the reliability of certain aspects of the data and are not intended as criticism of anyone, least of all the Bureau or the IWC Secretariat, to both of whom we owe a debt of gratitude for creating such an impressive data base.

MATERIAL AND METHODS

The periods for which I have had active contact with the whaling industry are shown in Table 1, and cover essentially two complete and one partial pelagic seasons and two complete and several partial seasons at land stations. This experience is not particularly broad or extensive, but it does include both factory ship and shore-based whaling, and operations under the flags of three nations, United Kingdom, Japan and South Africa.

In addition, in May 1971 I was appointed whaling inspector for the vessel *Run* while it operated under British jurisdiction (until November 1972) and although I never sailed in the vessel I did inspect catch records and data provided to me both in my official and private capacities.

An appreciation of the procedures used in inspecting whales and an understanding of who was responsible for collecting and recording data from the catch are essential before the reliability of the data submitted to the Bureau can be assessed.

On *Balaena* two inspectors were employed. The senior inspector was a retired naval officer who was a semi-permanent appointment. He rarely appeared on deck and mainly collated data received from platform personnel and the second inspector. The latter was a young postgraduate biologist who usually sailed for only one season, and whose main preoccupation was the collection of age and reproductive material for the UK National Institute of Oceanography (NIO). Because the ship worked a 24-hour day he was unable to examine the entire catch. Measurement of whales and the recording of associated data on sex and the incidence and size of foetuses were mainly the responsibility of the platform foreman on each shift, but the second inspector provided data on foetuses, for instance.

At Donkergat from 1958 to 1967 only one (and the same) whaling inspector was employed, a full-time Sea Fisheries inspector. He and/or the platform foreman measured virtually all whales and recorded all data on incidence of foetuses, etc., that were required by the IWC. Interaction with a biologist on the station in 1962 and 1963 greatly improved the accuracy of biological data collected.

At Durban from 1958 to 1967 only one (and the same) whaling inspector was employed, a retired individual employed part-time who (at least from 1962 onwards) simply collated all the data provided by the company. Whales were measured and associated data collected exclusively by the platform foreman and other company employees, although there was some interaction between these personnel and biologists from the NIO working on the station for various periods from 1962 to 1967, particularly as regards foetal records (R. Gambell, pers. comm.). In 1968 the South African government for the first time sent a full-time Sea Fisheries inspector from Cape Town to supervise the catch at Durban. Thereafter one or two inspectors were present each year for the whole season, their responsibility (nominally) being to measure all whales and record associated data required by the IWC,

Table 1

Periods of author's active contact with whaling industry

Name of operation	Type	Season	Area	Capacity
FF Balaena	Pelagic	1957/58	Antarctic	Lab. assistant
Donkergat Whaling Station	Land station	1958	South Africa	"
FF Balaena	Pelagic	1958/59	Antarctic	"
Donkergat Whaling Station	Land station	1962-64	South Africa	Zoologist
Durban Whaling Station	Land station	1971-75	South Africa	"
FF Nisshin Maru. No. 3	Pelagic	1978/79	Antarctic	"

---

[1] Postal address: c/o South African Museum, P.O. Box 61, Cape Town, South Africa.

as well as to supervise the collection of biological material for which the whaling company provided two Zulu part-time assistants. However in part because the station worked a 24-hour day, but mainly because there was inadequate supervision of the inspectors themselves, the data-collection arrangement was only partially effective, and (for instance) company personnel continued to measure a large proportion of the catch. Consequently the Director of Sea Fisheries decided to transfer a senior technician permanently to Durban in 1973 to supervise the inspectors' activities and to collate the data supplied by them. An international observer (from Australia) was present each season from 1972.

On the *Nisshin Maru No. 3* in 1978/79 three Japanese inspectors were present, plus an international observer from the USSR. All whales were measured and sexed by one of the two junior inspectors on each shift. The collection of other biological data and material was chiefly the responsibility of a special part-time assistant provided by the whaling company on each shift. Coverage and sampling of the catch were comprehensive and efficient. The senior Japanese inspector (and particularly the international observer) were less frequent visitors to the platform, but as the catch was entirely minke whales for which no minimum length existed, their duties could presumably be equally as effectively carried out by monitoring activities from the bridge.

COMMENTS

Species identification

Guides to species identification were rarely (if ever) supplied to whaling operatives, indeed such a move might have been considered presumptuous given the vast experience of most factory and catcher personnel. Nevertheless in my experience confusions of species identity did occur, particularly in landings of sei and Bryde's whales at Donkergat whaling station.

The situation in the early years of modern whaling in South Africa (1910–1920) has been discussed by Best and Lockyer (1977). It appears from contemporary accounts that identification of Bryde's whales was inconsistent, and that many may have been entered as sei or even fin whales in catch returns from the 'Cape Colony'. Similar difficulties persisted at the Donkergat land station in the late 1950s and early 1960s. Although the inshore form of Bryde's whale (being allopatric to the sei whale) was normally correctly identified, Bryde's whales belonging to the offshore form (Best, 1977) were often recorded as sei whales. Catcher and station personnel were unaware of the true diagnostic characters of the two species, and were misled by the extensive scarring of the offshore form into considering it as a sei whale. It was only from 1962 onwards that station personnel (and in particular the whaling inspector) became aware of the real diagnostic characters of the two species. Nevertheless, when from 1968 onwards some of the same catcher personnel became involved in the operations of the catcher/factory ship *Run* (later *Sierra*), returns sent voluntarily to BIWS recorded catches of sei, not Bryde's whales on the west coast of Africa, even though cine and still film seen by the author clearly showed that at least some were Bryde's whales. As late as 1973 it was necessary to provide a guide to species differences between sei and Bryde's whales at the Durban land station because of confusion between the two.

Apart from unintentional misidentification, there may have been some deliberate attempts to cover up illegal catches. Although I have no first–hand experience of such instances, there are indications that this may have occurred at least once elsewhere. During the 1961/62 Antarctic season, two whale marks were returned from the sector south of New Zealand that had been fired into humpback whales 2 1/2 years and six months previously on the east coast of Australia and in Cook Strait, New Zealand, respectively. At recovery they were reported as being found in a sperm whale and a fin whale.

> 'There is no likelihood that there could have been any confusion as to the species at the time that these marks were fired into the whales.....whatever the explanation of the obviously erroneous recovery data, the evidence is clear that at least two marked humpback whales were killed in Antarctic Area V during the summer of 1961–62' (Chittleborough, 1965).

Although humpback whaling was permitted for four days (January 20–23) in 1961/62, the dates of recovery of these two marks were given as 19 December 1961 and 24 February 1962, well outside the permitted season. In any case, no humpback catches at all in Area V were reported to the BIWS that year (Anon., 1963).

Numbers taken

Published volumes of BIWS statistics do contain errors in the numbers of whales taken. Thus for instance the number of minke whales reported as taken at Durban in 1971 (204) apparently includes 5 killer whales taken that year. More significantly, in 1963 the reported catches of sperm whales at Durban (1,771), and sei whales (721), Bryde's whales (50) and sperm whales (691) at Donkergat, failed to include 189 sperm whales at Durban and 5 sei, 45 Bryde's and 161 sperm whales at Donkergat, all taken under special scientific permit. Such errors and omissions are being corrected during entry into the IWC data base.

Nevertheless the data base as presently coded by the IWC only goes back as far as 1949, and an examination of reported right whale catches off South Africa in years prior to 1940 has so far revealed four errors in the figures listed by BIWS (see caption to table 6 in Best and Ross, 1986), To these should be added the fact that the 17 right whales listed as taken off Angola in 1925 are almost certainly Bryde's whales (Best, 1989). Although right whale catches may not be a fair test of the accuracy of earlier catch statistics, as they were listed somewhat parenthetically as footnotes, it seems likely that errors in the published database for the catches of other species will come to light when more attention is given to their retrieval.

Although my first-hand experience does not include any instances of whales being taken by IWC member nations without being declared to BIWS, or declared as some other species (see above), there is no doubt that such omissions did occur. The activities of the Panamanian registered *Olympic Challenger* from 1950/51 to 1955/56, resulting in very large undeclared catches of several species, are well known (Tønnessen and Johnsen, 1982).

Chittleborough (1965) has postulated that undeclared catches of humpback whales from the Area V stock (amounting to some 5,000 whales in all) must have been taken in the Antarctic seasons 1960/61 and 1961/62 to have produced the patterns of mortality and drop in catch per unit of effort (CPUE) subsequently seen at Australian land stations. Despite problems of interpretation of CPUE data (e.g. see IWC, 1988), this is at least partially supported by the recovery of the two marks from humpback whales (reported as other species) in Area V in 1961/62 (see above). From 1961 to 1966 a Soviet whaling expedition or expeditions made a minimum of three excursions to Tristan da Cunha to take right whales, but no trace of these catches can be found in the Bureau's statistics (Best, 1988). At least one right whale was taken illegally at the Donkergat whaling station (in 1953) but not declared in the landings (Best and Ross, 1986).

It is obviously very difficult to estimate how frequent and how significant such undeclared catches may have been. Rumours regarding illegal activities of other nations were rife during the period of Antarctic pelagic whaling I was involved in, but were impossible to substantiate. Clearly a combination of undeclared catches and deliberate misidentification of others could, if widespread, seriously undermine the reliability of contemporary catch statistics. It is to be hoped that such practices came to a halt at or before the implementation of the International Observer Scheme in 1972, at least in the Southern Hemisphere.

Size

In 1949 the first Schedule of the IWC (that part of the Convention that sets out detailed regulations governing whaling activities) stipulated the method of measurement:

> 'as accurately as possible by means of a steel tape measure fitted at the zero end with a spiked handle which can be stuck into the deck [or platform] planking abreast of one end of the whale. The tape measure shall be stretched in a straight line parallel with the whale's body and read abreast the other end of the whale. The ends of the whale, for measurement purposes, shall be the point of the upper jaw and the notch between the tail flukes'.

This provision remained essentially unchanged until 1974, when it was revised to read

> 'Whales must be measured ... by means of a tape-measure made of a non-stretching material. The zero end of the tape-measure shall be attached to a spike or stable device to be positioned on the deck or platform abreast of one end of the whale. Alternatively the spike may be stuck into the tail fluke abreast of the apex of the notch. The tape-measure shall be held taught in a straight line parallel to the deck and the whale's body, and other than in exceptional circumstances along the whale's back, and read abreast of the other end of the whale'.

These changes were proposed by Australia, largely as a result of the experiences of its international observers at the Durban whaling station in 1972 and 1973, where the presence of a concrete surface to most of the flensing deck prevented any spike being driven into the deck (the tape being held at chest height by one person at each end of the whale), and where whales were sometimes measured along the belly rather than the back. Both procedures could introduce errors into the measurements, especially due to sag in the tape. At Donkergat, too, no spike was used and the tape was usually held at chest height by a flenser at one end and the whaling inspector at the other, chiefly to avoid contamination of the tape with blood and other fluids on the flensing platform.

On F.F. *Balaena*, on the other hand, whales were invariably measured by the platform foreman with a stick (believed to be 2m in length) which was used to 'mark off' sections as he walked along the length of the whale (illustrated by Ash, 1962, p.45). Apart from this being essentially a measurement over the curve rather than a straight line, unless the whale's length was an exact multiple of two metres, the procedure created the problem of having to interpolate to obtain the final measurement.

The errors introduced by these various different techniques are unknown, but they have been mentioned to stress the point that, although reading the Schedule would imply that there was a standard method of measuring whales, because the original Schedule provision was impractical, many different procedures were actually used. Users of length data should therefore be careful when comparing results from different operations (see Clark, 1983).

Apart from measurement error, there was also the problem of measurement falsification, usually to meet a minimum size requirement. A good example is shown for the catch of 1,723 female sperm whales made at Durban in 1965, where only 112 (or 6.5%) were recorded as less than the minimum size limit of 35ft, despite the fact that the catch at 35ft was 14 times greater than the catch at 34ft (Fig. 1). This form of size distribution is not unique to Durban, nor to sperm whales; in the Antarctic catch of 7,796 fin whales in 1964/65, for instance, there were 101 whales taken less than 57ft in length (including only 30 at 56ft), yet the modal length of the catch was at 57ft (768 whales), which also corresponded to the minimum size limit in force (Anon., 1965).

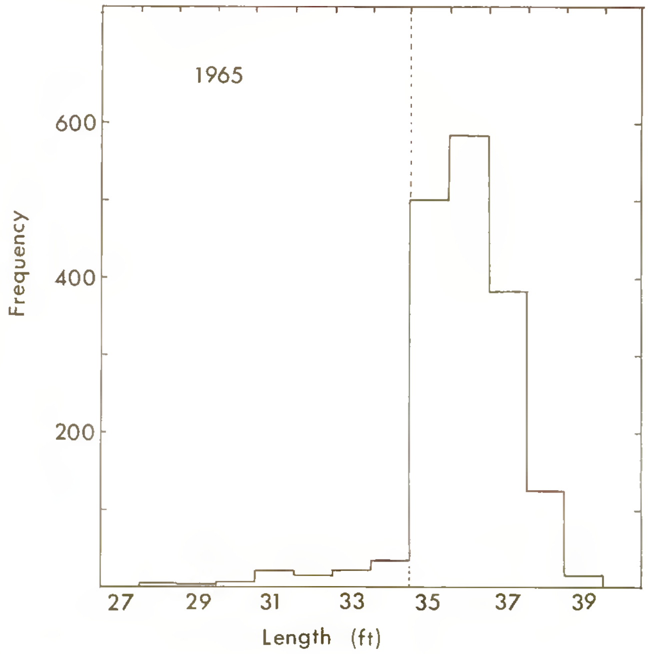


Fig. 1. Reported size composition of catch of female sperm whales, Durban, 1965 (dotted line indicates minimum size limit).

This feature of the proximity of mode and minimum legal length, if real, implies a very high degree of selectivity by the gunners. However (at least for minke whales observed by ex-whaling personnel employed on scouting boats), we know that the accuracy of length estimation at sea is extremely poor (Best, 1984), certainly not sufficient to distinguish between whales 1ft (0.3m) different in length with such consistency.

On the F.F. *Balaena*, all measurements were carried out by the platform foreman, and prior to 1968 this was normally the case at Durban too. Having the whales measured by company employees and not by national inspectors obviously increased the opportunities for falsification of records (especially if the catcher crews were paid a bonus on the length of the whale – Gaskin, 1982).

Published size compositions in which a large proportion of the lengths has been 'stretched' provide major problems for those wishing to use the data themselves or age compositions derived therefrom for modelling population

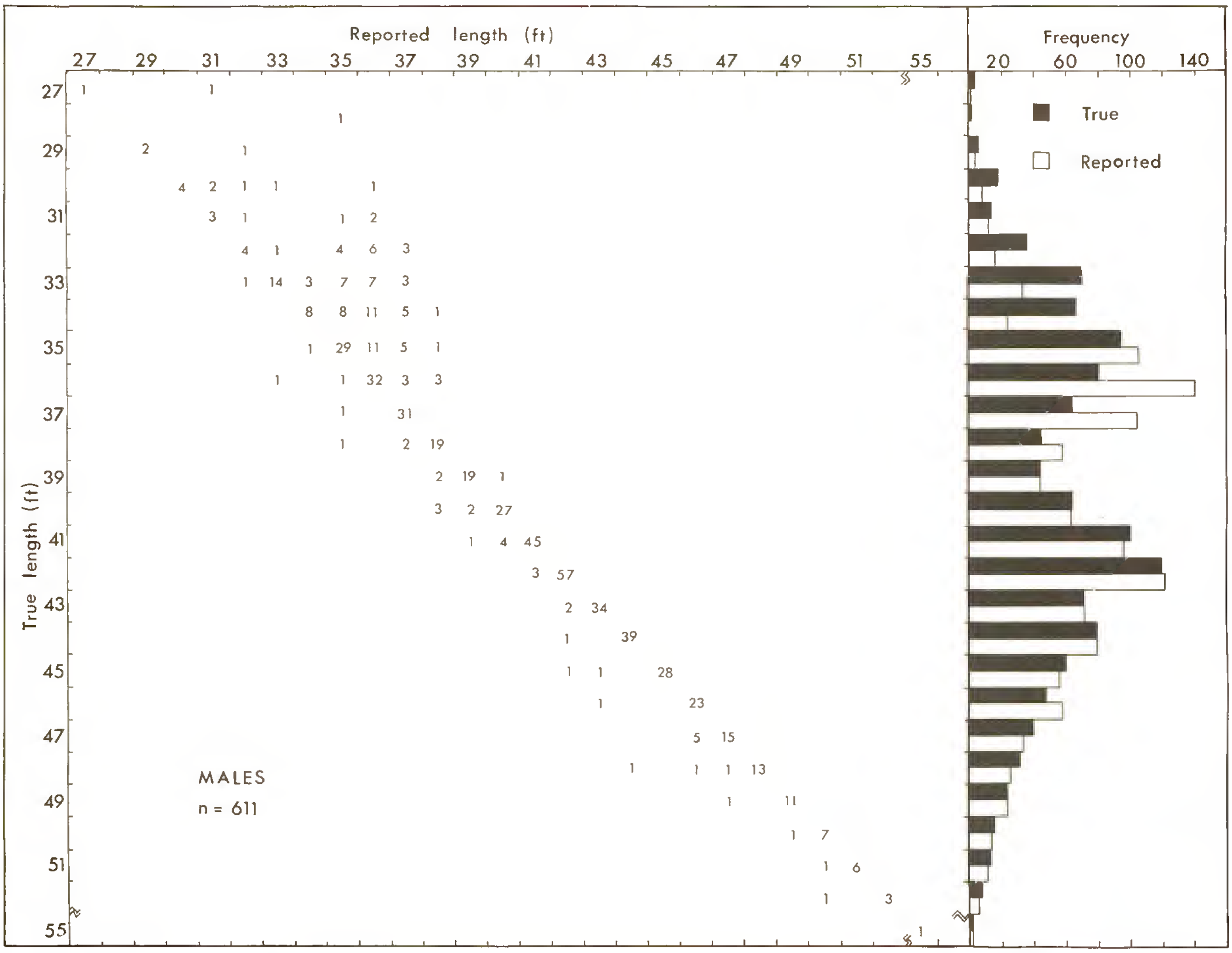


Fig. 2. Comparison of the true and reported lengths of male sperm whales at Durban, 1963–65.

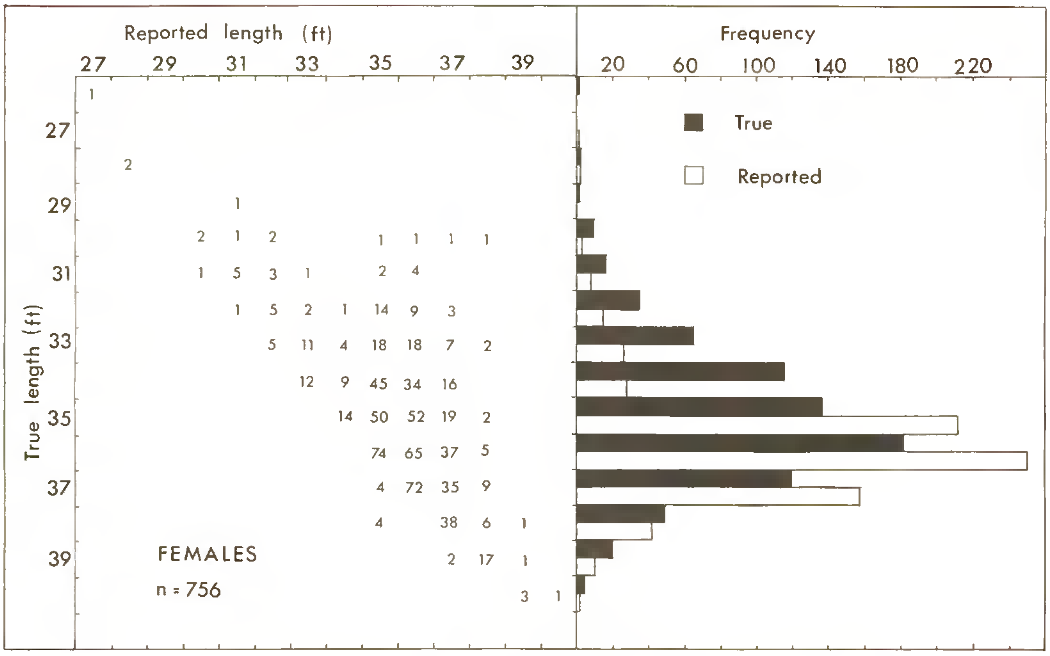


Fig. 3. Comparison of the true and reported lengths of female sperm whales at Durban, 1963–65.

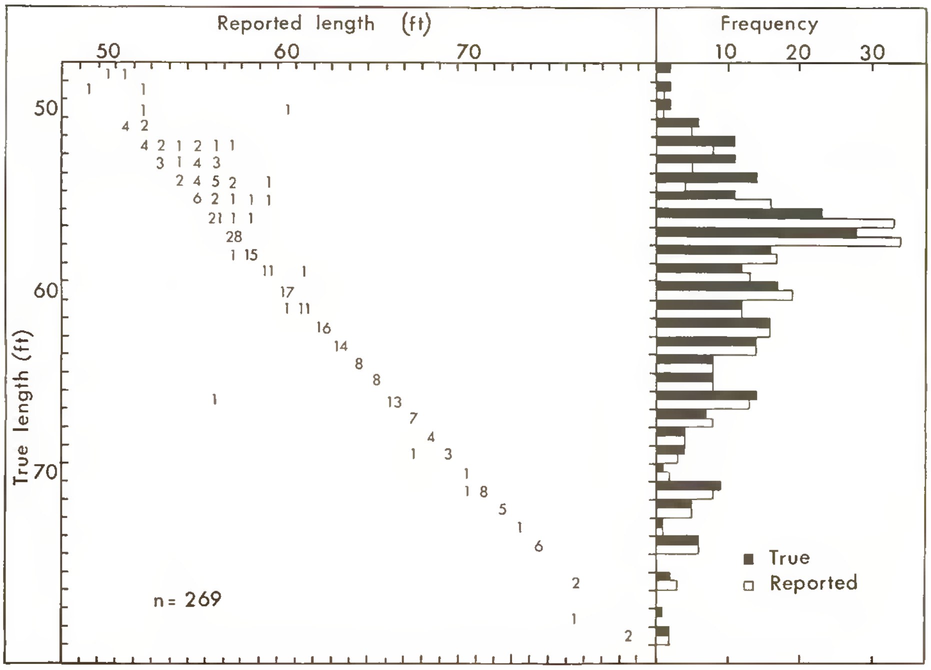


Fig. 4. Comparison of the true and reported lengths of fin whales at Durban, 1963–65.

dynamics, as (for instance) age/length keys derived from 'unstretched' data may be inapplicable to commercial length compositions.

Normally there is no evidence available from which the original, unbiassed size composition of the catch can be reconstructed. While working at the Durban whaling station from 1962 to 1965, however, scientists from NIO obtained the correct lengths of the whales they examined. These have kindly been made available to me, and a comparison of the true and reported size compositions for sperm whales from 1963 to 1965 is given by sex in Figs 2 and 3. The pattern for both sexes is similar, in that whales below the minimum size limit (35ft) are under represented and those just over the size limit are over represented in the reported statistics. However, somewhat unexpectedly, there is a tendency for the largest whales of both sexes to be under represented. The raw data indicate in fact, that not only were the smallest whales being 'stretched', but the larger ones were being 'shrunk', apparently to compensate for what would otherwise appear as an extremely low product yield, given the declared size composition. In Fig. 4 similar data are illustrated for fin whales landed at Durban over the same period. In this species also, whales below the minimum length (55ft in this instance) tend to be under represented, and those just above the minimum length to be over represented, in the reported statistics, indicating that undersize whales were frequently stretched to meet the limit. Evidence of the 'shrinking' of larger fin whales is however less apparent than for sperm whales.

Presence of foetus and its length, sex

Since the first (1949) Schedule of the IWC it has been mandatory for each nation to provide particulars with respect to each whale landed that include 'if it contains a foetus, the length and sex, if ascertainable, of the foetus'. This merely 'legitimised' something the Bureau had been collecting on a voluntary basis since 1930, and it suggested (but did not specifically state) that each and every female taken should be examined for the presence of a foetus. In practice, however, (at least in my experience) this was often interpreted as reporting of any foetus that happened to be found incidentally during flensing.

The incidence of foetuses in sei whales landed at Donkergat each season during the last phase of whaling (1957–1967) is shown in Table 2. For the first five years the numbers of foetuses reported were few, and 'pregnancy rates' varied from 0.03 to 0.14 (average 0.076). In 1962 a biological research programme was initiated, in which regular examination of all mature females was undertaken, and the whaling inspector was briefed on the significance of corpora lutea in the ovaries. From 1962 to 1967 the pregnancy rate varied from 0.59 to 0.85 (average 0.695), or almost an order of magnitude greater than in the preceding five years. A comparison of the frequency of foetal lengths reported for 1957–61 with those reported for the first full season of biological examination (1963) shows clearly that smaller foetuses were under-represented in the earlier sample, so depressing the apparent pregnancy rate (Fig. 5).

Table 2

Incidence of foetuses reported from matured sei whales landed at Donkergat whaling station

Season	No. of mature females landed	No. of foetuses reported	Proportion pregnant
1957	108	10	0.09
1958	126	8	0.06
1959	221	13	0.06
1960	215	7	0.03
1961	141	20	0.14
1962	154	106	0.69
1963	251	194	0.77
1964	211	130	0.62
1965	163	96	0.59
1966	86	56	0.65
1967	46	39	0.85

This is perhaps an extreme example that is easily detected from inspection of the data, but it serves to illustrate the nature of the problem. If the recording of the incidence of foetuses was left to company personnel (or an uninformed whaling inspector), there is a strong likelihood

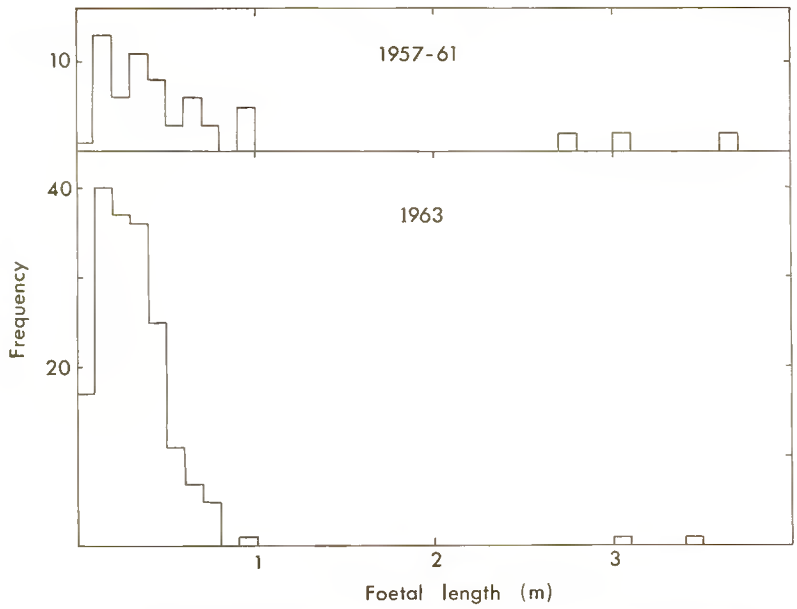


Fig. 5. Reported size compositions of sei whale foetuses at Donkergat.

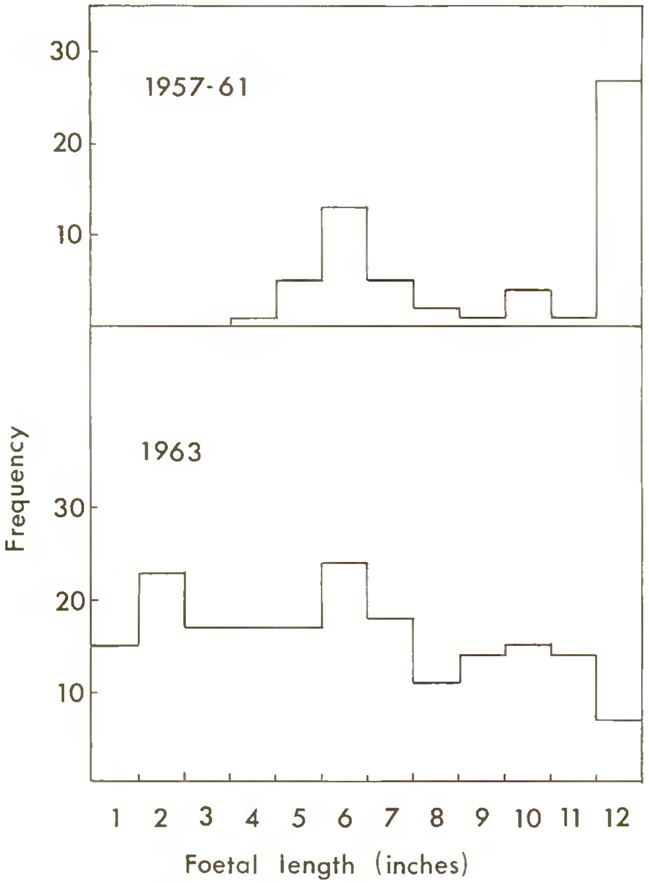


Fig. 6. Distribution of sei whale foetal lengths at Donkergat by one-inch intervals.

that some pregnant females (especially those in early pregnancy) would go undetected. The omission of small foetuses is likely to alter the slope of average foetal growth curves (Brinkmann, 1948). Gaskin (1982) also refers to the falsification of foetal records in the absence of an inspector or biologist, as a matter of convenience. The efficiency of finding and reporting foetuses could therefore be expected to vary considerably between expeditions (Sampson, 1989) or nations (Mizroch and York, 1984).

Changes in the efficiency of reporting foetuses could also produce fluctuations in the apparent pregnancy rate, which, if the Donkergat example is considered typical, could be very substantial. Interpretations of time series of pregnancy rates from commercial whaling statistics are therefore fairly meaningless without a knowledge of associated levels of reporting efficiency.

These comments apply mainly to the period before 1978, when the Schedule was revised to require all factory ships and land stations 'where possible' to collect both ovaries from each (female) whale landed. On the *Nisshin Maru No. 3* in 1978/79, the collection of ovaries and inspection for foetuses was of a very high standard indeed.

Length measurements of foetuses also tended to be imprecise when measured by company personnel. In Fig. 6 are shown the distributions of sei whale foetal lengths recorded at one inch (0.0254m) intervals for two periods at Donkergat, 1957–61 (recorded by company personnel or inspector) and 1963 (the first full season of biological observations). It is clear that in the earlier period foetal lengths tended to be recorded to the nearest foot or six inches, and intermediate lengths were rare, whereas in the 1963 sample there was a more equitable distribution of lengths between one inch intervals. Rounding-off errors such as shown by the earlier sample can be seen in other data sets in the BIWS. Laws (1959) stated that it was 'well known' that these measurements were not accurate, and he confined his analysis to data collected by biologists or specially-trained personnel.

Sex determinations of foetuses, particularly small ones, do not always appear to be reliable when carried out by company personnel or untrained inspectors. Between 1957 and 1961, 38 out of 54 (or 70.3%) of sei whale foetuses reported from the Donkergat whaling station were recorded as males, whereas in 245 foetuses examined by biologists at Donkergat in 1962 and 1963, 126 (or 51.4%) were male. It seems that the confusion may arise because of the relatively large clitoris in small female foetuses.

Stomach contents

Provision of information on the contents of the stomach has never been specified in the IWC Schedule, and the data seem to have been sent to the Bureau simply because it was included on the data sheets supplied. Perhaps partly as a consequence, and because no standardisation of collection methods was specified, company records of whale stomach contents are in my experience generally unreliable. A natural reluctance on the part of company personnel to open a whale stomach because of its (sometimes) unpleasant nature, was frequently reinforced by a directive to positively avoid doing so to prevent contamination of the flensing deck in cases where frozen meat production was important. On the *Nisshin Maru No. 3*, for instance, the Japanese biologist who wished to study complete minke whale stomach contents was restricted to examining the last whale flensed each day because of the contamination problem.

Under the circumstances it is difficult to know whether 'nil' meant that no food was present or that no attempt was made to open the stomach. Sometimes entries such as 'squid' or 'krill' are followed by a string of dittos, once again throwing doubt on whether the stomachs were actually examined. Misidentifications also occurred, such as (at Donkergat) 'octopus' for what in reality were separate brachial crowns of squids.

In my experience the only reliable stomach content data come from biological investigations. A partial exception to this would be the standard data collected on the *Nisshin Maru No 3*, where inspectors and company personnel were trained to record contents, both qualitative and quantitative, in a systematic way. However their inability to examine each stomach fully, and to identify the contents beyond a rough grouping into food-types, limits the value of even these data.

DISCUSSION

The foregoing text is not intended to create the impression that the BIWS data base is fraught with problems. My experiences (being very limited in scope) may not be typical of the data collection process in general.

Furthermore, some of the problems mentioned (stretching of lengths of undersized whales, rounding errors in foetal measurements, unreliable stomach content data) may be obvious from inspection of the data. Other problems, however, such as the non-reporting or misidentification of catch records, shrinking of larger whales, under reporting of the incidence of foetuses and systematic length measurement errors, may be less obvious.

If intelligent use is to be made of the BIWS data base, it is important that users be made aware of such potential problems. It is recommended that others familiar with the data collection process for their national industry (or that of another nation) should be approached for their comments on aspects such as those mentioned in this paper. Contemporary sources such as the logbooks of second inspectors employed on British factory ships (many of whom were graduate biologists) might also provide an insight into data-gathering practices.

ACKNOWLEDGEMENTS

I am extremely grateful to Dr R Gambell for provision of data relating to real and reported lengths for fin and sperm whales at Durban, and for reviewing an earlier draft of this paper. This work was funded by the South African Scientific Committee for Antarctic Research.

REFERENCES

Anon. 1963. *International Whaling Statistics* 50, 60pp. Oslo, Det Norske Hvalråds Statistiske Publikasjoner.

Anon. 1965. *International Whaling Statistics* 56, 47pp. Oslo, Det Norske Hvalråds Statistiske Publikasjoner.

Anon. 1987. IWC coding of individual BIWS catch records. *IWC Technical Note* No. 15, 14pp.

Ash, C. 1962. *Whaler's Eye*. New York, MacMillan Co. i-ix+ 245pp.

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. 1984. Accuracy of shipboard estimates of the length of Antarctic minke whales. *Rep. int. Whal. Commn* 34: 323–5.

Best, P.B. 1988. Right whales at Tristan da Cunha – a clue to the 'non-recovery' of depleted species? *Biol. Cons.* 46: 23–51.

Best, P.B. 1989. The 1925 catch of right whales off Angola. Paper submitted to the IWC Scientific Committee, San Diego, June 1989.

Best, P.B. and Lockyer, C.H. (1977). The biology of sei whales (*Balaenoptera borealis*) off the west coast of South Africa – a preliminary draft. Paper T21 submitted to the IWC Scientific Committee special meeting on Southern Hemisphere sei whales, Tokyo, April 1977.

Best, P.B. and Ross, G.J.B. 1986. Catches of right whales from shore-based establishments in southern Africa, 1792–1975. *Rep. int. Whal. Commn* (special issue 10): 275–89.

Brinkmann, A. 1948. Studies on female fin and blue whales. *Hvalrådets skrifter* 31: 1–38.

Chittleborough, R.G. 1965. Dynamics of two populations of the humpback whale, *Megaptera novaeangliae* (Borowski). *Austr. J. Mar. Freshwat. Res.* 16(1): 33–128.

Clark, W.G. 1983. Apparent inconsistencies among countries in measurements of fin whale lengths. *Rep. int. Whal. Commn* 33: 431–4.

Gaskin, D.E. 1982. *The Ecology of Whales and Dolphins*. Heinemann, London and Exeter, New Hampshire. i-xii + 459pp.

International Whaling Commission. 1988. Comprehensive Assessment Workshop on Catch per Unit Effort (CPUE). *Rep. int. Whal. Commn* 38: 157–62.

Laws, R.M. 1959. The foetal growth rates of whales with special reference to the fin whale, *Balaenoptera physalus* Linn. *'Discovery' Rep.* 29: 281–308.

Mizroch, S.A. and York, A.E. 1984. Have pregnancy rates of southern fin whales, *Balaenoptera physalus*, increased? *Rep. int. Whal. Commn* (special issue 6): 401–10.

Sampson, D.B. 1989. Pregnancy rate versus length in southern fin whales. Paper SC/40/Ba1 (published in this volume).

Tønnessen, J.N. and Johnsen, A.O. 1982. *The History of Modern Whaling*. C. Hurst & Co., London, i-xx + 798pp.

SC/40/O 23

On the Estimation of Age-Dependent Natural Mortality

Kazumi Sakuramoto and Syoiti Tanaka

Tokyo University of Fisheries, 4–5–7, Konan, Minato-ku, Tokyo 108, Japan

ABSTRACT

Simulations are presented which examine a method to estimate the trend of age-dependent natural mortality proposed by Tanaka (1988). The results show that this method can in principle estimate the true linear trend under the assumptions as set in the simulation. No apparent increasing trend in age-dependent natural mortality was introduced by an increase of recruitment. The important factors in the practical application of the method are the sample size and the degree of age-dependency in the true natural mortality. Further work is identified.

INTRODUCTION

Tanaka (1988) proposed a method to estimate the age-dependent natural mortality from age-composition data obtained by random sampling. However, de la Mare (1989) noted that, in principle, it was impossible to separate age-dependent natural mortality from an increase of recruitment by this method in the absence any auxiliary information. While Tanaka's method is theoretically effective for estimating the natural mortality at age in a relative manner, its applicability to actual problems is still to be demonstrated. Tanaka (1988) discussed the precision of the obtained estimates on the basis of certain assumptions and approximations.

The simulations examine whether or not a trend in age-dependent natural mortality can be estimated with the level of sample size proposed by the Government of Japan (1987) and the possible degree of dependency of natural mortality on age for the Antarctic minke whale.

The results of the present simulation study suggest that there is a good possibility of detecting dependency of the natural mortality on age if the sample size is sufficiently large and the degree of dependency is fairly large. However, further detailed examination is needed to evaluate the practical effectiveness of this method.

METHOD

Notations

$N_{a,t}$: population number of age a in year t immediately before catching
$C_{a,t}$: catch number of age a in year t
M_a : natural mortality coefficient of age a
q_a : age-specific selectivity of age a
f_t : fishing intensity in year t

A : maximum age, A=50

$N_t^{(r)}$: total number in population of age ≥ r in year t, $\sum_{a=r}^{A} N_{a,t}$

$C_t^{(r)}$: total number in catch of age ≥ r in year t, $\sum_{a=r}^{A} C_{a,t}$

$cP_{a,t}$: proportion in catch of age a among ages ≥ r in year t, $C_{a,t}/C_t^{(r)}$

$cP_t^{(r+i)}$: proportion in catch ages ≥ (r+i) in year t, $\sum_{a=r+i}^{A} cP_{a,t}$

From Tanaka (1988), if random sampling is carried out in years t and t+k and no sampling occurs between these years, and the ratio $C_{a,t}/N_{a,t}$ for age ≥ r is independent of age, then the average natural mortality coefficient of animals older than r years, $\bar{M}_k^{(r)}$, is estimated by

$$\bar{M}_k^{(r)} = -1/k \ln (C_{t+k}^{(r+k)}/C_{t+k}^{(r)}) - \ln \{N_{t+k}^{(r)}/(N_t^{(r)} - C_t^{(r)})\} \tag{1}$$

Further, the difference of M_a value from the average $\bar{M}_k^{(t)}$ is calculated by

$$\sum_{i=o}^{k-1} (M_{a+i} - \bar{M}_k^{(r)}) = \ln(cP_{a,t}) - \ln(cP_{a+k,t+k}/cP_{t+k}^{(r+k)}) \tag{2}$$

If the values of $N_{t+k}^{(r)}$ and $N_t^{(r)}$ are available from cohort analysis or sighting surveys, an absolute value for M_a can be estimated. Even without such abundance information, however, a relative value of M_a can be estimated, or $(M_{a+i} - \bar{M}_k^{(r)})$, from equation (2). In the present simulation study we only use equation (2) and only estimate the trend in age-dependent natural mortality.

ASSUMPTIONS OF SIMULATION

Recruitment

Two cases are assumed concerning recruitment in the artificial population.

Case (1). The number of recruits at age 1 is constant regardless of year. That is,

$$N_{1,t} = 9{,}000. \tag{3}$$

Case (2). The number of recruits at age 1 is increasing. That is,

$$N_{1,t} = 4{,}000 \qquad t \leq 1940$$

$$N_{1,t} = 4{,}000 * 1.05^{t-1940}\ t > 1940 \tag{4}$$

Age-dependent M

Two cases are assumed concerning the natural mortality coefficient of the artificial population.

Case (1). $M_a = 0.08 \quad a < 10$
$M_a = 0.08 + 0.008 * (a\text{-}10) \quad a \geq 10 \qquad (5)$

Case (2). $M_a = 0.12$ (Constant) $\qquad (6)$

Selectivity

The selectivity is considered to be determined by two factors dependent on age: the migration of the whales to the fishing ground and the fishing selectivity by the whalers. The selectivity in commercial whaling is quite different to that of research whaling. In the former, the catch is biased towards larger whales whereas in the latter, random sampling is practiced. However, we do not have detailed information on actual selectivities and so, for simplicity, the same selectivity is assumed for both commercial and research whaling as

$$q_a = (1/10) * a \quad a < 10$$
$$q_a = 1 \quad a \geq 10 \qquad (7)$$

Therefore, in this case, the age-composition of animals of 10 years and older ($r \geq 10$ years) can be used to estimate the age dependent natural mortality. In the case of research whaling an optional case is added, whereby whales of less than 10 years are not taken and whales of 10 years and older are randomly caught. This case is introduced to test the effects of the pattern of selectivity and increase in sample size which is used in the calculation of M_a. If the selectivity of the research take follows equation (7), the effective sample size to be used in the calculation of M_a becomes small.

Fishing intensity of commercial whaling

It is assumed that commercial whaling was carried out from 1970 to 1985. The fishing intensity is set at 0.0 or 0.04 regardless of year. The case of $f_t=0.0$ is used so that comparison of the results with $f_t=0.04$ can be made to demonstrate whether or not the earlier commercial whaling has any effect on the procedure.

Sample size and sampling schedule of research take

In the case of research whaling, two cases are assumed. One is the case where 1,650 whales are caught in year t and t+k, and no sampling is made between these years (schedule A). The other is the case where 825 whales (1,650/2) are caught in each year of t, t+1, t+k and t+k+1, with no sampling between year t+2 and t+k-1 (schedule B). Optional cases are added to test the effect of sample size, whereby the sample size is doubled for the two cases mentioned above: i.e. 3,300 whales are caught in year t and t+k, and 1,650 whales are caught in each of years t, t+1, t+k and t+k+1.

Dynamics

The dynamics of the theoretical population are represented by:

$$N_{a+1,t+1} = (N_{a,t} - C_{a,t})\exp(-M_a) \qquad (8)$$

In the case of commercial whaling, catch is calculated by

$$C_{a,t} = q_a f_t N_{a,t} \qquad (9)$$

In the case of research whaling, the catch is calculated as follows. First, the relative cumulative number of the population in the fishing ground is calculated

$$E_{a,t} = \sum_{i=1}^{a-1} (N_{i,t}q_i) / \sum_{a=1}^{A} (N_{a,t}q_a) \qquad (10)$$

In this case, the selectivity q_a is regarded as the rate of migration by age. Secondly a random number, x, is generated uniformly distributed from 0 to 1. If $E_{a,t} \leq x < E_{a+1,t}$, then the whale of age a is considered caught. This is repeated until the catch reaches 825 or 1,650 (in the optional case, 1,650 or 3,300).

Estimation of the regression coefficient of natural mortality on age

The relative M_a value is estimated on the assumption of $N_t^{(r)} - C_t^{(r)} = N_{t+k}^{(r)}$ (this assumption implies R=0), and then the linear regression coefficient of M_a on a is calculated. The sample size becomes very small for animals of over 30 years old. Therefore, in the calculation of the slope, older age groups were ignored and two different ranges of age, M_{10}-M_{25} and M_{10}-M_{30} applied. The weighting factor for calculating the regression for schedule A is

$$w=(C_{a,t}+C_{a+k,t+k})/2 \qquad (11)$$

For schedule B, the M_a value is estimated using the combined data of $C_{a,t}$ and $C_{a,t+1}$, and also $C_{a+k,t+k}$ and $C_{a+k,t+k+1}$ in place of $C_{a,t}$ and $C_{a+k,t+k}$ in schedule A. Therefore, the weighting factor is

$$w=(C_{a,t}+C_{a,t+1}+C_{a+k,t+k}+C_{a+k,t+k+1})/4 \qquad (12)$$

RESULTS

One hundred simulation runs were conducted using different series of random numbers for each of the different conditions. Means and standard deviations of the slope of age dependent mortality were calculated and the results are shown in Table 1.

Table 1 suggests that if the recruitment is constant and the slope of the age dependent natural mortality is 0.008 per age, the average slope of the age dependent natural mortality is estimated to be around the true value, 0.008. If recruitment is increasing at 5% per year and the natural mortality is constant regardless of age, the estimated average slope appears to have a small downward bias, and the standard deviations are larger than in the former case. In the case of schedule A, the estimated values are closer to zero than for schedule B. However, an increasing trend of natural mortality due to an increase of recruitment did not occur.

In the case of $f_t=0.0$, the standard deviation tends to be smaller than for $f_t=0.04$. In the case where random sampling was only carried out on whales of 10 years and older, the standard deviation is generally smaller than where whales of 1 year and older are sampled. This is because the effective sample size for whales of 10+ years increases.

It is clear that the large sample size (3,300 or 1,650+1,650) makes the standard deviation considerably smaller.

In summary, the simulations show that given the conditions above, Tanaka's (1988) method can work and an increasing trend in recruitment does not produce an apparent increasing trend of age dependent natural mortality. Practically important problems are the sample size and the degree of dependency of natural mortality on age.

Table 1

Average trend of age-dependent natural mortality and their standard deviation of 100 simulations under the various conditions

				10–25		10–30	
Case	q_a	f_t	Sampling	Mean	(SD)	Mean	(SD)
Recruitment: constant; M_a: increases by 0.008/age							
1	$1 \leqslant a$	0.04	1,650	0.0086	(0.0044)	0.0077	(0.0038)
			825 825	0.0080	(0.0048)	0.0075	(0.0037)
2	$1 \leqslant a$	0.0	1,650	0.0080	(0.0038)	0.0075	(0.0032)
			825 825	0.0081	(0.0036)	0.0083	(0.0031)
3	$10 \leqslant a$	0.04	1,650	0.0089	(0.0028)	0.0087	(0.0026)
			825 825	0.0081	(0.0026)	0.0081	(0.0023)
4	$10 \leqslant a$	0.0	1,650	0.0088	(0.0024)	0.0090	(0.0022)
			825 825	0.0083	(0.0025)	0.0085	(0.0022)
5	$1 \leqslant a$	0.04	3,300	0.0080	(0.0030)	0.0080	(0.0029)
			1,650 1,650	0.0083	(0.0035)	0.0083	(0.0030)
6	$1 \leqslant a$	0.0	3,300	0.0078	(0.0024)	0.0081	(0.0021)
			1,650 1,650	0.0083	(0.0031)	0.0086	(0.0026)
7	$10 \leqslant a$	0.0	3,300	0.0080	(0.0019)	0.0082	(0.0018)
			1,650 1,650	0.0080	(0.0021)	0.0082	(0.0018)
8	$10 \leqslant a$	0.04	3,300	0.0080	(0.0022)	0.0083	(0.0020)
			1,650 1,650	0.0080	(0.0025)	0.0083	(0.0021)
Recruitment: 0.05/year; M_a: constant							
9	$1 \leqslant a$	0.04	1,650	–0.0011	(0.0056)	–0.0025	(0.0050)
			825 825	–0.0048	(0.0076)	–0.0062	(0.0059)
10	$1 \leqslant a$	0.0	1,650	–0.0005	(0.0046)	–0.0007	(0.0039)
			825 825	–0.0032	(0.0056)	–0.0031	(0.0045)
11	$10 \leqslant a$	0.04	1,650	0.0006	(0.0031)	0.0005	(0.0025)
			825 825	–0.0011	(0.0030)	–0.0009	(0.0027)
12	$10 \leqslant a$	0.0	1,650	0.0003	(0.0026)	0.0004	(0.0022)
			825 825	–0.0006	(0.0026)	–0.0006	(0.0023)
13	$1 \leqslant a$	0.04	3,300	–0.0003	(0.0043)	–0.0006	(0.0038)
			1,650 1,650	–0.0018	(0.0048)	–0.0018	(0.0040)
14	$1 \leqslant a$	0.0	3,300	–0.0006	(0.0030)	–0.0004	(0.0026)
			1,650 1,650	–0.0007	(0.0036)	–0.0006	(0.0031)
15	$10 \leqslant a$	0.0	3,300	–0.0001	(0.0020)	–0.0001	(0.0017)
			1,650 1,650	–0.0006	(0.0023)	–0.0003	(0.0020)
Recruitment: constant; M_a: constant							
16	$1 \leqslant a$	0.04	1,650	–0.0005	(0.0047)	–0.0004	(0.0036)
			825 825	–0.0024	(0.0048)	–0.0020	(0.0040)
17	$10 \leqslant a$	0.04	1,650	0.0002	(0.0026)	0.0003	(0.0020)
			825 825	–0.0009	(0.0026)	–0.0005	(0.0020)
18	$1 \leqslant a$	0.0	1,650	–0.0003	(0.0041)	0.0000	(0.0032)
			825 825	–0.0017	(0.0040)	–0.0010	(0.0028)
19	$10 \leqslant a$	0.0	1,650	0.0001	(0.0027)	0.0002	(0.0019)
			825 825	–0.0005	(0.0027)	–0.0005	(0.0020)

DISCUSSION

Tanaka's (1988) method firstly considers the age-composition of animals of r years and older in the population. The age-composition at year t may be influenced by an increasing or decreasing trend in recruitment, age-dependent natural mortality and age-specific fishing selectivity. However, the difference in the shape between the age-compositions of r years and older animals at year t and animals of $r+k$ years and older at year $t+k$ will be due only to natural mortality, as it is assumed that no sampling is carried out between years $t+1$ and $t+k-1$.

Therefore, if the natural mortality is constant, irrespective of both age and year, the shape of the age-composition of animals of r years and older at year t will be identical to that of $r+k$ year-old animals in year $t+k$. Thus, the ratio of the whales of age a $(a \geq r)$ to whales of r years and older at year t is the same as the ratio of whales of age $a+k$ to the whales of $r+k$ years and older at year $t+k$. [In this case, the right hand side of equation (2) below will be zero.]

If age-dependent natural mortality exists the above ratio will change. This will be detected from two age compositions, that of animals of r years and older at year t, and that of $r+k$ years old and older animals at year $t+k$.

When $k=1$, this difference can be estimated for each age. If the age dependent natural mortality is linear, as has been assumed for the purposes of this paper the estimated value of age-dependent natural mortality from equation (2) below will show the results in Fig. 1. If, however, the age dependent natural mortality is curvilinear, Fig. 2 might, for example, result. Therefore, it could be said that this method might theoretically estimate the relative age dependent natural mortality regardless of whether the relationship be linear or curvilinear. This, however, requires more detailed consideration.

The above ratio could be estimated by data from animals of r+ years, randomly sampled. The aim of the present simulation was to examine the variability in the estimated value, assuming random sampling is achieved.

In this simulation study, two cases of sampling schedule, A and B, were tried. For the case where recruitment is increasing and natural mortality is constant regardless of age, schedule A seemed to perform better than schedule B. However, in this study, the method of calculating the trend simply followed the manner in schedule A as an approximation. If we calculate the trend using the full information from the catch data of t and $t+1$, $t+1$ and $t+k$, and $t+k$ and $t+k+1$, and then calculate the average of those three estimated values, the precision of the estimate may be higher. This paper shows that the age-dependency of natural mortality may be detected, assuming a linear relationship between natural mortality and age. Further evaluation of the effect of curvilinear models need to be considered. Further simulations are also needed to examine the precision of this kind of estimation under a variety of realistic practical situations.

REFERENCES

De la Mare, W.K. 1989. On the simultaneous estimation of natural mortality rate and population trend from catch at age data. Paper SC/40/O 1 (published in this volume).

Government of Japan, 1987. The program for research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic. Paper SC/39/O 4 presented to the IWC Scientific Committee, June 1987. 28pp.

Tanaka, S. 1988. A preliminary consideration on a method for estimating age-dependent natural mortality from age-composition obtained by random sampling. *Rep. int. Whal. Commn* 38:140–2.

SC/40/O 25

A Bayesian Cohort Model for Catch-At-Age Data Obtained from Research Takes of Whales

Takashi Nakamura

The Institute of Statistical Mathematics, 4–6–7, Minami-Azabu, Minato-ku, Tokyo 106, Japan

and

Shuhei Ohnishi and Yoshiharu Matsumiya

Ocean Research Institute, University of Tokyo, 1–15–1, Minamidai, Nakano-ku, Tokyo 164, Japan

ABSTRACT

A Bayesian cohort model is proposed to separate age, period and cohort effects in the analysis of catch-at-age data obtained from research takes of whales. It is assumed that the population sizes are sufficiently large compared with the corresponding catch sizes and that the age-specific selectivity is constant. The proposed model includes the prior information that the period effect can be roughly controlled and that both the age and the cohort effects should change gradually. The optimal model is selected based on Akaike's Bayesian information criterion, ABIC. Numerical examples show that the trend in recruitment and the absolute values of the age-dependent natural mortality coefficients can be successfully estimated.

INTRODUCTION

The primary aim of the cohort analysis of catch-at-age data is to separate fishing intensities, age-dependent natural mortality rates and trend in recruitment. It is known that there is no unique solution for these three effects from catch-at-age data alone (de la Mare, 1987). The same problem, called the identification problem, arises in cohort analysis in the field of the social sciences (Mason, Mason, Winsborough and Poole, 1973; Pullum, 1978; Fienberg and Mason, 1978).

Butterworth (1987) noted that the impossibility of the separation of three effects in cohort analysis is an obvious truism, but further noted that, given certain assumptions, it becomes incorrect. In general, the age, period and cohort effects cannot be separated. The use of appropriate prior information, however, makes it possible to estimate these three effects.

Nakamura (1987) proposed a Bayesian cohort model for catch-at-age data, extending the basic idea of general Bayesian modeling for linear problems developed by Akaike (1980). Nakamura (1982; 1986) also applied Bayesian cohort models to archival data in the social sciences, and overcame the identification problem in cohort analysis successfully.

Butterworth (1988) commented on the Bayesian cohort model for catch-at-age data given in Nakamura (1987). One question was whether or not a simulation case with the trend in recruitment increasing at 3% per annum and an age-dependent natural mortality coefficient, M, equal to 0.1, could be distinguished from a case where the trend in recruitment remains constant with M = 0.13. In fact, Akaike's Bayesian information criterion, ABIC, gives the same values for both cases, and consequently our model fails to separate the three effects in the cohort analysis of catch-at-age data. This is chiefly because the catch-at-age data do not contain any information about the trend in recruitment when the total sample size in each year is determined and the concept of the rate of operation is not introduced.

This paper presents a Bayesian cohort model for catch-at-age data obtained from research takes of whales where fishing intensities can be roughly controlled. The model still assumes that the population sizes are sufficiently large compared with the corresponding catch sizes and that the age-specific selectivity is constant.

The present simulation study reveals the following points: (1) the absolute values of the age-dependent natural mortality coefficients can be estimated; and (2) the trend in recruitment can be estimated.

Further investigations and experiments are needed for the proposed model to be applicable to catch-at-age data in more realistic situations. Further studies should also evaluate variances of estimated parameters.

COHORT MODEL FOR CATCH-AT-AGE DATA

The following notation is used:

a : age ($a=1,\ldots,A$);
A : number of age classes;

t : year ($t=1,\ldots,T$);
T : number of survey years;
y : cohort ($y=t-a+A$, $y=1,\ldots,Y$);
Y : number of cohorts ($Y=A+T-1$);

N_{at} : population size at age a at the beginning of year t;
C'_{at} : expected catch at age a in year t;
C_{at} : observed catch at age a in year t;

M_a : natural mortality coefficient at age a;
q_{at} : age-specific selectivity at age a in year t;
f_t : fishing effort in year t;
p_t : rate of operation in year t;

ε_{at} : error term at age a in year t.

Consider the following three equations:

the catch equation,

$$C'_{at} = q_{at}f_tN_{at} \tag{1}$$

the population dynamics equation,

$$N_{a+1,t+1} = (N_{at} - C_{at})\exp\{-M_a\} \qquad (2)$$

and the observation equation,

$$\log C_{at} = \log p_t C'_{at} + \varepsilon_{at}, \qquad (3)$$

with ε_{at} assumed to be independently distributed according to normal with zero mean and variance $\{\sigma^2/(p_t C'_{at})\}$. Here log stands for the natural logarithm.

The assumed distribution of the error term ε_{at} is approximated and may not be reasonable if either C_{at} or N_{at} is small. For this paper, however, we use the above assumption for convenience, as its main purpose is to show how to overcome the identification problem in cohort analysis of catch-at-age data. Further investigation of the assumed distribution of the error term is needed when the model is applied to real data.

Considering the case of research takes of whales, we make the following assumptions:

(A1) the population sizes are sufficiently large compared with the corresponding catch sizes, i.e., $N_{at} >> C_{at}$;
(A2) the age-specific selectivity is constant, i.e. $q_{at}=1$.

In the case of research takes of whales, we can take a representative sample of the population, and so it is acceptable to make assumption (A2). On the other hand, in analysing the historical catch-at-age data, we would need to relax this assumption.

Under assumption (A1), the population dynamics equation (2) can be approximated as

$$N_{a+1,t+1} \approx N_{at}\exp\{-M_a\}.$$

Applying this equation recursively, we obtain

$$\begin{aligned} N_{at} &\approx N_{a-1,t-1}\exp\{-M_{a-1}\} \\ &\approx N_{a-2,t-2}\exp\{-M_{a-1}-M_{a-2}\} \\ &\approx \dots \\ &\approx N_{1,t-a+1}\exp\{-M_{a-1}-M_{a-2}-\dots-M_1\} \\ &\approx R_y\exp\{-M_{a-1}-M_{a-2}-\dots-M_1\}, \qquad (4) \end{aligned}$$

where $R_y(=N_{1,t-a+A})$ denotes the size of population recruited.

Under assumption (A2), we can regard the catch equation (1) as

$$C'_{at} = f_t N_{at}. \qquad (5)$$

Using the results (4) and (5), the observation equation (3) is expressed as

$$\begin{aligned} \log C_{at}/p_t &= \log f_t N_{at} + \varepsilon_{at} \\ &= \log f_t + \log R_y + \sum_{i=1}^{a-1} (-M_i) + \varepsilon_{at} \\ &= \mu + \mu_t^P + \mu_y^C + \sum_{i=1}^{a-1} \mu_i^A + \varepsilon_{at}, \end{aligned} \qquad (6)$$

where μ denotes the grand mean effect; μ_t^P $(=\log f_t - \Sigma_{t=1}^T \log f_t/T)$, μ_y^C $(=\log R_y - \Sigma_{y=1}^Y \log R_y/Y)$, and μ_i^A $(=-M_i)$ are the period, the cohort and the age effect, respectively. The μ's are subject to the following zero sum constraints:

$$\sum_{t=1}^{T} \mu_t^P = \sum_{y=1}^{Y} \mu_y^C = 0. \qquad (7)$$

We can rewrite model (6) with the constraints (7) in vector and matrix representation as

$$\mathbf{c} = \mathbf{D}\boldsymbol{\mu} + \boldsymbol{\varepsilon},$$

where

$$\mathbf{c} = (\log C_{11}/p_1, \log C_{21}/p_2, \dots, \log C_{AT}/p_T)',$$

$$\boldsymbol{\mu} = (\mu, \boldsymbol{\mu}_*')',$$

$$\boldsymbol{\mu}_* = (\mu_1^A, \dots, \mu_{A-1}^A, \mu_1^P, \dots, \mu_{T-1}^P, \mu_1^C, \dots, \mu_{Y-1}^C)',$$

$$\boldsymbol{\varepsilon} = (\varepsilon_{11}, \varepsilon_{21}, \dots, \varepsilon_{AT})',$$

$$\mathbf{D} = [\mathbf{1}\ \mathbf{D}_*],$$

$$\mathbf{I} = (1, \dots, 1)',$$

and $\mathbf{D}_*$ is an appropriate AT×(A+T+Y-3) design matrix describing the relation among three factors. (The prime (′) denotes transposition.) For example, in the case where A = 5 and T = 3, the design matrix is given as follows:

$$\mathbf{D}_* = \left[\begin{array}{cccccccccccc} \multicolumn{4}{c}{\leftarrow A-1 \rightarrow} & \multicolumn{3}{c}{\leftarrow T-1 \rightarrow} & \multicolumn{5}{c}{\longleftarrow Y-1 \longrightarrow} \\ 0&0&0&0&1&0&0&0&0&0&1&0 \\ 1&0&0&0&1&0&0&0&0&1&0&0 \\ 1&1&0&0&1&0&0&0&1&0&0&0 \\ 1&1&1&0&1&0&0&1&0&0&0&0 \\ 1&1&1&0&1&0&0&1&0&0&0&0 \\ \\ 0&0&0&0&0&1&0&0&0&0&0&1 \\ 1&0&0&0&0&1&0&0&0&0&1&0 \\ 1&1&0&0&0&1&0&0&0&1&0&0 \\ 1&1&1&0&0&1&0&0&1&0&0&0 \\ 1&1&1&1&0&1&0&1&0&0&0&0 \\ \\ 0&0&0&0&-1&-1&-1&-1&-1&-1&-1&-1 \\ 1&0&0&0&-1&-1&0&0&0&0&0&1 \\ 1&1&0&0&-1&-1&0&0&0&0&1&0 \\ 1&1&1&0&-1&-1&0&0&0&1&0&0 \\ 1&1&1&1&-1&-1&0&0&1&0&0&0 \end{array}\right] \begin{array}{c} \\ \uparrow \\ \\ A \\ \\ \downarrow \\ \\ \uparrow \\ \\ A \\ \\ \downarrow \\ \\ \uparrow \\ \\ A \\ \\ \downarrow \end{array}$$

LIKELIHOOD AND THE BAYESIAN MODEL

Likelihood

Under the assumption that ε_{at} is normally and independently distributed with zero mean and variance $\{(\sigma^2/p_t C'_{at})\}$, the likelihood of the model is given by

$$f(\mathbf{c}|\boldsymbol{\mu},\sigma^2) = (2\pi\sigma^2)^{-AT/2}|W|^{-1/2}\exp \{(-1/2\sigma^2)\ (\mathbf{c}-\mathbf{D}\boldsymbol{\mu})'W^{-1}(\mathbf{c}-\mathbf{D}\boldsymbol{\mu})\},$$

where W is an AT×AT positive definite diagonal matrix whose $\{a+(t-1)\ A\}$th diagonal element is $\{1/(p_t C'_{at})\}$. Usually we use the maximum likelihood procedure to estimate the unknown parameter $\boldsymbol{\mu}$. Unfortunately, in the cohort model, the estimate of $\boldsymbol{\mu}$ cannot be uniquely determined, since the column vectors of the design matrix $\mathbf{D}_*$ are linearly dependent. Further information on the parameters is needed to specify the cohort model completely.

Fishing effort

Fishing effort should be essentially independent of age-dependent natural mortality rates and a trend in recruitment. Nakamura (1987), however, constructed a cohort model in which fishing effort is assumed to be affected by the trend in recruitment. For example, fishing effort tends to decrease as the trend in recruitment increases. This was why the model failed to separate the three effects.

In spite of the difficulty in evaluating the magnitudes of fishing effort, we can assume fishing effort to be roughly controlled, at least in the case of research takes of whales. For example, if twice as many research fleets are used, the fishing effort is considered to roughly double.

As far as a research take is concerned, it is reasonable to expect that the parameters of the period effect are not exactly but approximately equal to certain predetermined values, i.e., in general,

$$\mu_t^P \approx z_t^P, \text{ for } t = 1,\ldots,T;$$

where z_t^P is known and satisfies the constraint:

$$\sum_{t=1}^{T} z_t^P = 0.$$

In the simplest case where we continue to carry out research takes on the same schedule, we can expect $z_t^P=0$, that is $\mu_t^P \approx 0$, for $t=1,\ldots,T$.

Rate of operation and sample size

The model considered here is

$$\log C_{at} = \log p_t C'_{at} + \varepsilon_{at},$$

where C'_{at} is the expected catch determined by the population size N_{at} and the fishing effort f_t through the catch equation (1), p_t is the rate of operation affected by, for example, weather condition and ε_{at} is an error term mainly due to sampling.

The observed catch changes in proportion to the 'rate of operation' even though the fishing effort is kept constant. For example, let the population size N_{at} be 100,000 and the fishing effort f_t be 0.0005. This results in an expected catch C'_{at} of 50. Suppose the research period is restricted to 100 days. If the research take operation can occur for 80 days, p_t is equal to 0.8 and the observed catch C_{at} is expected to be 40, although $C'_{at}=50$. Similarly if the operation can only last for 40 days, $p_t=0.4$ and C_{at} is expected to be 20.

Furthermore, the rate of operation is influenced not only by weather conditions but also by catch limits for research takes. For example, consider the situation where the catch limit is 800 and the research period is 100 days. In this case, we cannot raise p more than 0.5. If the total expected catch is 1,600, we are able to reach a catch limit of 800 during a 50-day operation with p=0.5. If the expected catch is 400, we can get only 200 samples by the 50-day operation where p=0.5 or 320 samples by the 80-day operation with p=0.8.

The introduction of rates of operation enables catch-at-age data to contain information on the trend in the population.

Age-dependent natural mortality rate and trend in recruitment

As the age-dependent natural mortality rates and the trend in recruitment are considered to have the ordinal property, one would expect that the successive parameters of each effect are not very different, or change gradually. In other words, the first order differences of the successive parameters are close to zero:

$$\mu_i^A - \mu_{i+1}^A \approx 0, \text{ for } i = 0,\ldots,A-2;$$

$$\mu_y^C - \mu_{y+1}^C \approx 0, \text{ for } y = 1,\ldots,Y-1;$$

where μ_0^A $(=-M_0)$ is used as an anchor parameter.

Bayesian model

To overcome the difficulty of the identification problem arising in cohort analysis we use a Bayesian approach as discussed by Akaike (1980). To meet these requirements we attempt to minimise the weighted sum of squares

$$(1/\sigma_A^2) \sum_{i=0}^{A-2} (\mu_i^A - \mu_{i+1}^A)^2 + (1/\sigma_P^2) \sum_{t=1}^{T} (\mu_t^P - z_t^P)^2 + (1/\sigma_C^2) \sum_{y=1}^{Y-1} (\mu_y^C - \mu_{y+1}^C)^2$$

for μ_0^A and the weights $1/\sigma_A^2, 1/\sigma_P^2$ and $1/\sigma_C^2$.

In order to realise the expectation stated above, we assume that the parameter vector $\boldsymbol{\mu}_*$ has the prior distribution given by

$$\pi(\boldsymbol{\mu}_* | \sigma^2, \sigma_A^2, \sigma_P^2, \sigma_C^2, \mu_0^A)$$

$$\propto (2\pi\sigma^2)^{-L/2} |D_s' S^{-1} D_s|^{-1/2} \exp\{(-1/2\sigma^2)$$

$$(\mathbf{z} - D_s \boldsymbol{\mu}_*)' S^{-1} (\mathbf{z} - D_s \boldsymbol{\mu}_*)\},$$

where D_s is an L×L matrix expressing the first order differences of the parameters, $\mathbf{z}=(\mu_0^A, 0,\ldots,0, z_1^P,\ldots,z_T^P, 0,\ldots,0)'$, $S=\text{diag}\{\sigma_A^2,\ldots,\sigma_A^2, \sigma_P^2,\ldots,\sigma_P^2, \sigma_C^2,\ldots,\sigma_C^2\}$, and $L=(T-1)+(Y-1)+(A-1)$. In the case where $A=5$ and $T=3$, the difference matrix D_s is given as follows:

$$D_s = \left(\begin{array}{cccccccccccc|c}
\multicolumn{4}{c}{\leftarrow A-1 \rightarrow} & \multicolumn{3}{c}{\leftarrow T-1 \rightarrow} & \multicolumn{5}{c}{\longleftarrow Y-1 \longrightarrow} & \\
-1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \uparrow \\
1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & A-1 \\
0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \\
0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \downarrow \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \uparrow \; T-1 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & \downarrow \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & \uparrow \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & -1 & 0 & 0 & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & Y-1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 2 & \downarrow
\end{array}\right.$$

,If we can specify the values of σ_A^2, σ_P^2, σ_C^2 and μ_0^A, it is reasonable to estimate $\boldsymbol{\mu}$ by the mode of the posterior distribution, i.e.

$$f(c|\boldsymbol{\mu}, \sigma^2).\pi(\boldsymbol{\mu}_*|\sigma^2, \sigma_A^2, \sigma_P^2, \sigma_C^2, \mu_0^A) \rightarrow \max.$$

We now denote this estimate by $\hat{\boldsymbol{\mu}}$, which can be easily computed by the weighted least squares method.

ABIC

The problem is now how to determine the values of hyper-parameters, σ^2, σ_A^2, σ_P^2, σ_C^2 and μ_0^A. For this problem, we use ABIC (Akaike's Bayesian Information Criterion) proposed by Akaike (1980), and select the above values so as to minimise ABIC. ABIC is defined by

$$\mathrm{ABIC} = -2\log(\textit{marginal likelihood}) + 2\times(\textit{number of hyper-parameters})$$

$$= -2\log \int f(\mathbf{c}\,|\boldsymbol{\mu}, \sigma^2).\pi\,(\boldsymbol{\mu}_*|\sigma^2, \sigma^2_A, \sigma^2_P, \sigma^2_C, \mu^A_0)\, d\boldsymbol{\mu}_* + 2h,$$

where h is the number of hyper-parameters, which can be ignored in this paper. Closely related works on this subject are the type II maximum likelihood method by Good (1965) and the maximum penalised likelihood method of Good and Jaskins (1980). As it is natural to call $\int f.\pi\, d\boldsymbol{\mu}_*$ the likelihood of the Bayesian model, ABIC can be regarded as a kind of AIC (Akaike's Information Criterion) introduced by Akaike (1973). AIC is defined by

$$\mathrm{AIC} = -2\log(\textit{maximum likelihood}) + 2\times(\textit{number of adjusted parameters}).$$

In our Bayesian cohort model for catch-at-age data, the value of ABIC is evaluated by

$$\mathrm{ABIC} = (AT)\log \hat{\sigma}^2 - \log|D_s'S^{-1}D_s| + \log|D_w'W^{-1}D_w + D_s'S^{-1}D_s|,$$

where

$$\hat{\sigma}^2 = [(\mathbf{c}-D\hat{\boldsymbol{\mu}})'W^{-1}(\mathbf{c}-D\hat{\boldsymbol{\mu}}) + (\mathbf{z}-D_s\hat{\boldsymbol{\mu}})'S^{-1}(\mathbf{z}-D_s\,\hat{\boldsymbol{\mu}}_*)]/(AT),$$

and

$$D_w = D_* - (\mathbf{1}'W^{-1}\mathbf{1})^{-1}\mathbf{1}\mathbf{1}'W^{-1}D_*$$

Since ABIC is a non-linear function of hyper-parameters, we use the grid search technique to obtain the smallest ABIC. In practice, for a series of values of μ^A_0, we compare the values of ABIC for every $(\sigma^2_A, \sigma^2_P, \sigma^2_C)$, where σ^2_A/σ^2, σ^2_P/σ^2 and σ^2_C/σ^2 take the values over the set, for example, {0.0625, 0.25, 1, 4, 16}.

NUMERICAL EXAMPLES

To examine the Bayesian cohort model proposed in the last section, we generate some sets of artifical data, using the catch equation (1), the population dynamics equation (2) and the observation equation (3).

In an experiment, the values of M_a, R_y, f_t and q_{at} have to be determined beforehand for a=1,..., A; y=1,..., Y; and t=1,..., T. We call these true values. We recall that assumption (A2) gives $q_{at}=1$ for all a and all t. Further we put $p_t=1$ for all t (for simplicity), and $\sigma^2=0$ (i.e., no error case). To compare the estimates of the parameters with the corresponding true values, we standardise R_y to $\mu^C_y(=\log R_y - \Sigma^Y_{y=1}\log R_y/Y)$ and f_t to $\mu^P_t(=\log f_t - \Sigma^T_{t=1}\log f_t/T)$.

The procedure for generating a set of catch-at-age data is described below.

(1) Suppose that we have obtained an initial set of N_{at} for year $t=-A+1$.

(2) Obtain the expected catch, C'_{at}:

$$C'_{at}=q_{at}f_tN_{at}, \text{ for } a=1,\ldots,A.$$

(3) Calculate the population of the succeeding year, $N_{a+1,t+1}$:

$$N_{1,t+1}=R_y, \text{ for } y=t-a+A;$$
$$N_{a+1,t+1}=(N_{at}-C'_{at})\exp\{-M_a\}, \text{ for } a=1,\ldots,A;$$

where R_y and M_a are given.

(4) Generate the observed catch C_{at} by adding the error term ε_{at}:

$$C_{at}=\exp\{\log p_tC'_{at}+\varepsilon_{at}\}, \text{ for } a=1,\ldots,A;$$

where $\varepsilon_{at} \sim N(0, \sigma^2/(p_tC'_{at}))$.

(5) Increment t, and go to step (2) while $t\leq T$.

Here we analyse the four sets of artificial catch-at-age data using the proposed Bayesian cohort model. All sets are generated under the following fixed values for some parameters:

the number of age classes, A=15;
the number of survey years, T=10;
the number of cohorts, Y=24;
and the rate of operation, $p_t=1$, for t=1,...,T.

Case 1

The first artifical data set is a very simple one. We put $M_a=0.08$ for all a; $f_t = 88/100000$ for all t; and $R_y = 100{,}000$ for all y.

In this case, $\{M_a\}$, $\{f_t\}$ and $\{R_y\}$ are flat.

Tables 1a and 1b present the generated population sizes of Case 1 and the corresponding catch-at-age data, respectively. The model selection process is as follows:

μ^A_0	σ^2_A	σ^2_P	σ^2_C	ABIC
0.06	16.0000	0.0625	4.0000	−2169.0905
0.07	16.0000	0.0625	16.0000	−2335.3811
0.08	16.0000	0.0625	16.0000	−2696.8567*
0.09	16.0000	0.0625	16.0000	−2383.0735
0.10	16.0000	0.0625	4.0000	−2192.9123

The actual estimated values of σ^2_A, σ^2_P and σ^2_C are on the boundary of the parameter space, because the numerical examples treated here have no observation errors.

Fig. 1 compares the estimates of the parameters with the true values. The block labeled as <PERIOD> in the figure contains the estimates $\hat{\mu}^P_t$ in the left-hand side (*) with the true values of $\hat{\mu}^P_t$ in the right-hand side (○). The comparison for the $\hat{\mu}^C_y$ and μ^C_y are shown in the <COHORT>. Note that the <AGE> block does not contain the estimates and the true values of μ^A_i, but those of $M_i(=-\mu^A_i)$.

Table 1a

Population sizes, $\{N_{at}\}$, of Case 1
AC = Age class

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
2	92312	92230	92230	92230	92230	92230	92230	92230	92230	92230
3	85214	85139	85064	85064	85064	85064	85064	85064	85064	85064
4	78663	78594	78524	78455	78455	78455	78455	78455	78455	78455
5	72615	72551	72487	72423	72360	72360	72360	72360	72360	72360
6	67032	66973	66914	66855	66796	66738	66738	66738	66738	66738
7	61878	61824	61769	61715	61661	61607	61552	61552	61552	61552
8	57121	57071	57020	56970	56920	56870	56820	56770	56770	56770
9	52729	52683	52636	52590	52544	52498	52451	52405	52359	52359
10	48675	48632	48590	48547	48504	48461	48419	48376	48334	48291
11	44933	44893	44854	44814	44775	44736	44696	44657	44618	44578
12	41478	41442	41405	41369	41332	41296	41260	41223	41187	41151
13	38289	38256	38222	38188	38155	38121	38088	38054	38021	37987
14	35345	35314	35283	35252	35221	35190	35159	35128	35097	35067
15	32628	32599	32571	32542	32513	32485	32456	32428	32399	32370

Table 1b

Catch-at-age data, $\{C_{at}\}$, of Case 1
AC = Age class, T = Total

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00
2	81.23	81.16	81.16	81.16	81.16	81.16	81.16	81.16	81.16	81.16
3	74.99	74.92	74.86	74.86	74.86	74.86	74.86	74.86	74.86	74.86
4	69.22	69.16	69.10	69.04	69.04	69.04	69.04	69.04	69.04	69.04
5	63.90	63.84	63.79	63.73	63.68	63.68	63.68	63.68	63.68	63.68
6	58.99	58.94	58.88	58.83	58.78	58.73	58.73	58.73	58.73	58.73
7	54.45	54.41	54.36	54.31	54.26	54.21	54.17	54.17	54.17	54.17
8	50.27	50.22	50.18	50.13	50.09	50.05	50.00	49.96	49.96	49.96
9	46.40	46.36	46.32	46.28	46.24	46.20	46.16	46.12	46.08	46.08
10	42.83	42.80	42.76	42.72	42.68	42.65	42.61	42.57	42.53	42.50
11	39.54	39.51	39.47	39.44	39.40	39.37	39.33	39.30	39.26	39.23
12	36.50	36.47	36.44	36.40	36.37	36.34	36.31	36.28	36.24	36.21
13	33.69	33.66	33.64	33.61	33.58	33.55	33.52	33.49	33.46	33.43
14	31.10	31.08	31.05	31.02	30.99	30.97	30.94	30.91	30.89	30.86
15	28.71	28.69	28.66	28.64	28.61	28.59	28.56	28.54	28.51	28.49
T	799.84	799.22	798.66	798.17	797.75	797.38	797.06	796.79	796.56	796.38

We can see that the optimal model selected by ABIC reproduces almost the same values as we specify. This implies that the natural mortality coefficients can be estimated in their absolute values.

Case 2

The second data set contains only the age effect. We assume that

$$\{M_a\} = 0.01\times\{11,10,9,8,7,6,7,8,9,10,11,12,13,14,15\};$$
$$f_t = 88/100000 \text{ for all } t;$$
and R_y = 100,000 for all y.

Tables 2a and 2b give the generated population sizes of Case 2 and the corresponding catch-at-age data, respectively. A summary of the model selection process is given as follows:

μ_0^A	σ_A^2	σ_P^2	σ_C^2	ABIC
0.09	16.0000	0.0625	1.0000	−1989.0927
0.10	16.0000	0.0625	1.0000	−2016.5061
0.11	16.0000	0.0625	1.0000	−2027.9741*
0.12	16.0000	0.0625	1.0000	−2019.5809
0.13	16.0000	0.0625	1.0000	−1994.2507

The optimum model is selected as the one corresponding to the smallest value of ABIC. The table suggests to select the model with μ_0^A=0.11, σ_A^2=16, σ_P^2=1/16 and σ_C^2=1. Fig. 2 shows that the estimates are almost the same as the true values.

Table 2a

Population sizes, $\{N_{at}\}$, of Case 2
AC = Age class

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
2	89583	89505	89505	89505	89505	89505	89505	89505	89505	89505
3	81058	80987	80916	80916	80916	80916	80916	80916	80916	80916
4	74082	74017	73951	73886	73886	73886	73886	73886	73886	73886
5	68386	68326	68266	68206	68146	68146	68146	68146	68146	68146
6	63763	63707	63651	63595	63539	63483	63483	63483	63483	63483
7	60050	59997	59944	59891	59838	59786	59733	59733	59733	59733
8	55990	55941	55891	55842	55793	55744	55695	55646	55646	55646
9	51685	51640	51594	51549	51503	51458	51413	51368	51322	51322
10	47237	47195	47154	47112	47071	47029	46988	46946	46905	46864
11	42741	42704	42666	42629	42591	42554	42516	42479	42442	42404
12	38289	38256	38222	38188	38155	38121	38088	38054	38021	37987
13	33960	33930	33900	33870	33840	33810	33781	33751	33721	33692
14	29820	29793	29767	29741	29715	29689	29663	29637	29610	29584
15	25924	25901	25878	25856	25833	25810	25787	25765	25742	25719

Table 2b

Catch-at-age data, $\{C_{at}\}$, of Case 2
AC = Age class, T = Total

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00
2	78.83	78.76	78.76	78.76	78.76	78.76	78.76	78.76	78.76	78.76
3	71.33	71.27	71.21	71.21	71.21	71.21	71.21	71.21	71.21	71.21
4	65.19	65.13	65.08	65.02	65.02	65.02	65.02	65.02	65.02	65.02
5	60.18	60.13	60.07	60.02	59.97	59.97	59.97	59.97	59.97	59.97
6	56.11	56.06	56.01	55.96	55.91	55.86	55.86	55.86	55.86	55.86
7	52.84	52.80	52.75	52.70	52.66	52.61	52.57	52.57	52.57	52.57
8	49.27	49.23	49.18	49.14	49.10	49.05	49.01	48.97	48.97	48.97
9	45.48	45.44	45.40	45.36	45.32	45.28	45.24	45.20	45.16	45.16
10	41.57	41.53	41.50	41.46	41.42	41.39	41.35	41.31	41.28	41.24
11	37.61	37.58	37.55	37.51	37.48	37.45	37.41	37.38	37.35	37.32
12	33.69	33.66	33.64	33.61	33.58	33.55	33.52	33.49	33.46	33.43
13	29.88	29.86	29.83	29.81	29.78	29.75	29.73	29.70	29.67	29.65
14	26.24	26.22	26.20	26.17	26.15	26.13	26.10	26.08	26.06	26.03
15	22.81	22.79	22.77	22.75	22.73	22.71	22.69	22.67	22.65	22.63
T	759.06	758.47	757.95	757.49	757.09	756.74	756.45	756.20	755.99	755.82

Case 3

The third data set is generated by setting

$$\{M_a\} = 0.01\times\{11,10,9,8,7,6,7,8,9,10,11,12,13,14,15\};$$
$$f_t = 88/100000 \text{ for all } t;$$
$$R_{15} = 100{,}000;$$

$$\text{and } R_{y+1}/R_y = \begin{cases} 1.00 \text{ for } y=1 \text{ to } 4, \text{ and } 20 \text{ to } 23; \\ 1.03 \text{ for otherwise.} \end{cases}$$

In this case, the natural mortality coefficients are the same as in Case 2 and the trend in recruitment increases 3% per annum in the middle of the cohorts.

Tables 3a and 3b are the population sizes and the corresponding catch sizes of Case 3, respectively. The model selection process is summarised as follows:

μ_0^A	σ_A^2	σ_P^2	σ_C^2	ABIC
0.09	16.0000	0.0625	16.0000	−1637.7161
0.10	16.0000	0.0625	16.0000	−1641.2807
0.11	16.0000	0.0625	16.0000	−1642.6168*
0.12	16.0000	0.0625	16.0000	−1641.6643
0.13	16.0000	0.0625	16.0000	−1638.4662

The best model that gives the smallest ABIC can be found in Fig. 3, where the estimates and the true values are nearly the same.

Table 3a

Population sizes, $\{N_{at}\}$, of Case 3
AC = Age class

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	100000	103000	106090	109273	112551	112551	112551	112551	112551	112551
2	86974	89505	92190	94955	97804	100738	100738	100738	100738	100738
3	76405	78628	80916	83343	85844	88419	91071	91071	91071	91071
4	67795	69768	71798	73886	76103	78386	80738	83160	83160	83160
5	60760	62528	64347	66219	68146	70190	72296	74465	76699	76699
6	55002	56603	58249	59944	61688	63483	65387	67349	69369	71450
7	50291	51754	53259	54809	56403	58044	59733	61525	63371	65272
8	45525	46849	48212	49615	51059	52544	54073	55646	57315	59035
9	40801	41988	43209	44466	45760	47091	48462	49871	51322	52862
10	36203	37256	38340	39456	40604	41785	43000	44252	45539	46864
11	31804	32729	33681	34661	35669	36707	37775	38874	40005	41169
12	28491	28466	29294	30146	31023	31926	32855	33811	34794	35806
13	25269	25247	25225	25959	26714	27491	28291	29114	29961	30833
14	22189	22169	22150	22130	22774	23437	24118	24820	25542	26285
15	19290	19273	19256	19239	19222	19781	20357	20949	21559	22186

Table 3b

Catch-at-age data, $\{C_{at}\}$, of Case 3
AC = Age class, T = Total

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	88.00	90.64	93.36	96.16	99.04	99.04	99.04	99.04	99.04	99.04
2	76.54	78.76	81.13	83.56	86.07	88.65	88.65	88.65	88.65	88.65
3	67.24	69.19	71.21	73.34	75.54	77.81	80.14	80.14	80.14	80.14
4	59.66	61.40	63.18	65.02	66.97	68.98	71.05	73.18	73.18	73.18
5	53.47	55.02	56.63	58.27	59.97	61.77	63.62	65.53	67.49	67.49
6	48.40	49.81	51.26	52.75	54.29	55.86	57.54	59.27	61.04	62.88
7	44.26	45.54	46.87	48.23	49.64	51.08	52.57	54.14	55.77	57.44
8	40.06	41.23	42.43	43.66	44.93	46.24	47.58	48.97	50.44	51.95
9	35.90	36.95	38.02	39.13	40.27	41.44	42.65	43.89	45.16	46.52
10	31.86	32.79	33.74	34.72	35.73	36.77	37.84	38.94	40.07	41.24
11	27.99	28.80	29.64	30.50	31.39	32.30	33.24	34.21	35.20	36.23
12	25.07	25.05	25.78	26.53	27.30	28.09	28.91	29.75	30.62	31.51
13	22.24	22.22	22.20	22.84	23.51	24.19	24.90	25.62	26.37	27.13
14	19.53	19.51	19.49	19.47	20.04	20.62	21.22	21.84	22.48	23.13
15	16.98	16.96	16.95	16.93	16.92	17.41	17.91	18.44	18.97	19.52
T	657.18	673.87	691.87	711.13	731.60	750.26	766.87	781.61	794.64	806.06

Case 4

The last data set is substantially that suggested by Butterworth (1988). We put

$$M_a = 0.06 \text{ for all a;}$$
$$f_t = 88/100000 \text{ for all t;}$$
$$R_{15} = 100{,}000$$

and $R_{y+1}/R_y = 1.02$ for y = 1 to 23.

Tables 4a and 4b present the generated population sizes and catch sizes of Case 4. If the fishing intensities are affected by the trend in recruitment and the rate of operation is not taken into account, we cannot distinguish the catch-at-age data of Case 4 from that of Case 1 (Table 1a). However, both tables of the population sizes of Case 4 and of Case 1 are quite different.

In Table 4b, we can see the catch sizes reflect the trend in recruitment because the fishing intensities are free from the catch limits.

μ_0^A	σ_A^2	σ_P^2	σ_C^2	ABIC
0.04	16.0000	16.0000	16.0000	−1690.9977
0.05	4.0000	16.0000	16.0000	−1704.2447
0.06	0.0625	0.0625	16.0000	−1757.9894*
0.07	0.2500	16.0000	16.0000	−1732.2492
0.08	4.0000	16.0000	16.0000	−1704.7963

Fig. 4 shows the optimal model suggested by the above table. The estimates of the parameters are almost the same as the true values.

Table 4a

Population sizes, $\{N_{at}\}$, of Case 4
AC = Age class

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	100000	102000	104040	106121	108243	110408	112612	114869	117166	119509
2	92330	94094	95975	97895	99853	101850	103887	105965	108084	110246
3	85248	86876	88536	90307	92113	93955	95834	97751	99706	101700
4	78709	80213	81745	83307	84973	86672	88406	90174	91977	193817
5	72672	74060	75475	76917	78386	79954	81553	83184	84848	86545
6	67098	68380	69686	71017	72374	73756	75232	76736	78271	79836
7	61952	63135	64341	65570	66823	68099	69400	70788	72204	73648
8	57200	58293	59406	60541	61697	62876	64077	65301	66607	67939
9	52813	53821	54850	55897	56965	58053	59162	60292	61444	62673
10	48762	49693	50642	51610	52596	53600	54624	55668	56731	57815
11	45022	45882	46758	47651	48562	49489	50435	51398	52380	53380
12	41568	42362	43172	43996	44837	45693	46566	47456	48362	49286
13	38380	39113	39860	40622	41398	42189	42994	43816	44653	45506
14	35436	36113	36803	37506	38223	38953	39697	40455	41228	42015
15	32718	33343	33980	34629	35291	35965	36652	37352	38066	38793

Table 4b

Catch-at-age data, $\{C_{at}\}$, of Case 4
AC = Age class, T = Total

	Survey period									
AC	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
1	88.00	89.76	91.56	93.39	95.25	97.16	99.10	101.08	103.11	105.17
2	81.25	82.80	84.46	86.15	87.87	89.63	91.42	93.25	95.11	97.02
3	75.02	76.45	77.91	79.47	81.06	82.68	84.33	86.02	87.74	89.50
4	69.26	70.59	71.94	73.31	74.78	76.27	77.80	79.35	80.94	82.56
5	63.95	65.17	66.42	67.69	68.98	70.36	71.77	73.20	74.67	76.16
6	59.05	60.17	61.32	62.50	63.69	64.91	66.20	67.53	68.88	70.26
7	54.52	55.56	56.62	57.70	58.80	59.93	61.07	62.29	63.54	64.81
8	50.34	51.30	52.28	53.28	54.29	55.33	56.39	57.46	58.61	59.79
9	46.48	47.36	48.27	49.19	50.13	51.09	52.06	53.06	54.07	55.15
10	42.91	43.73	44.57	45.42	46.28	47.17	48.07	48.99	49.92	50.88
11	39.62	40.38	41.15	41.93	42.73	43.55	44.38	45.23	46.09	46.97
12	36.58	37.28	37.99	38.72	39.46	40.21	40.98	41.76	42.56	43.37
13	33.77	34.42	35.08	35.75	36.43	37.13	37.84	38.56	39.29	40.05
14	31.18	31.78	32.39	33.01	33.64	34.28	34.93	35.60	36.28	36.97
15	28.79	29.34	29.90	30.47	31.06	31.65	32.25	32.87	33.50	34.14
T	800.72	816.09	831.84	847.96	864.45	881.33	898.60	916.26	934.32	952.78

DISCUSSION

It is true that the age, period and cohort effects in cohort analysis cannot be separated without some prior information. Whether or not we succeed in overcoming the difficulty in cohort analysis depends on what assumptions we make on parameters of the three effects and on how we select the optimal model according to a criterion such as ABIC.

A Bayesian cohort model for catch-at-age data obtained from research takes is presented in this paper. The model is constructed on the basis of the fact that fishing intensities can be roughly controlled at least in the circumstances of research takes. We may use sightings data together with catch-at-age data. We can estimate the natural mortality rates and the trend in recruitment from catch-at-age data obtained from research takes. Once we get the age-dependent natural mortality rates, we have a possibility of analysing catch-at-age data from commercial takes.

We need to develop the model to the extent that age-specific selectivity is not constant and that the influence of catches on population is considered. Further investigations should be made for a Bayesian cohort model to be applicable to catch-at-age data in more general and realistic situations.

ACKNOWLEDGEMENT

The authors are grateful to Dr A. Raftery for his helpful comments on this manuscript.

REFERENCES

Akaike, H. 1973. Information theory and an extention of the maximum likelihood principle, *2nd Inter. Symp. on Information Theory. In:* B.N. Petrov and F. Csaki (eds), Akademiai Kiado, Budapest.

Akaike, H. 1980. Likelihood and the Bayes procedure. *In:* J.M. Bernardo, M.H. DeGroot, D.V. Lindley and A.F.M. Smith (eds), University Press, Valencia.

Butterworth, D.S. 1987. Comments on: The Research Plan for the Feasibility Study on 'The Program for Research on the Southern Hemisphere Minke Whale and for Preliminary Research on the Marine Ecosystem in the Antarctic', Paper SC/D87/34 presented to the Special Meeting of the IWC Scientific Committee to consider the Japanese Research Permit (Feasibility Study), December 1987 (unpublished).

Butterworth, D.S. 1988. Terms of reference for analysis of catch curve data. Appendix 4 of SC/40/O 5, Report of the Working Group on Catch-at-age data, presented to the IWC Scientific Committee, May 1988.

de la Mare, W.K. 1985. On the estimation of mortality rates from whale age data, with particular reference to minke whales (*Balaenoptera acutorostrata*) in the Southern Hemisphere, *Rep. int. Whal. Commn* 35: 239–50.

de la Mare, W.K. 1987. On the simultaneous estimation of natural mortality rate and population trends from catch-at-age data. Paper SC/D87/39 presented to the Special Meeting of the IWC Scientific Committee to consider the Japanese Research Permit (Feasibility Study), December 1987 (unpublished).

Fienberg, S.E. and Mason, W.M. 1979. Identification and estimation of age-period-cohort models in the analysis of discrete archival data. K.F. Schuessler (Ed.), *Sociological Methodology 1979*, Jossey-Bass, London.

Good, I.J. 1965. *The Estimation of Probabilities: An essay on modern Bayesian methods*. MIT Press, Cambridge.

Good, I.J. and Gaskins, R.A. 1980. Density estimation and bump-hunting by the penalised likelihood method exemplified by scattering and meteorite data. *JASA*, 75(369): 42–73.

Mason, W.M. and Fienberg, S.E. (Eds). 1985. *Cohort Analysis in Social Research*, New York, Springer-Verlag.

Mason, K.O., Mason, W.M., Winsborough, H.H. and Poole, W.K. 1973. Some methodological issues in cohort analysis of archival data, *Am. Sociolog. Rev*. 38: 242–58.

Nakamura, T. 1982. A Bayesian cohort model for standard cohort table analysis. *Proc. Inst. Statist. Math*. 29: 77–97. (In Japanese).

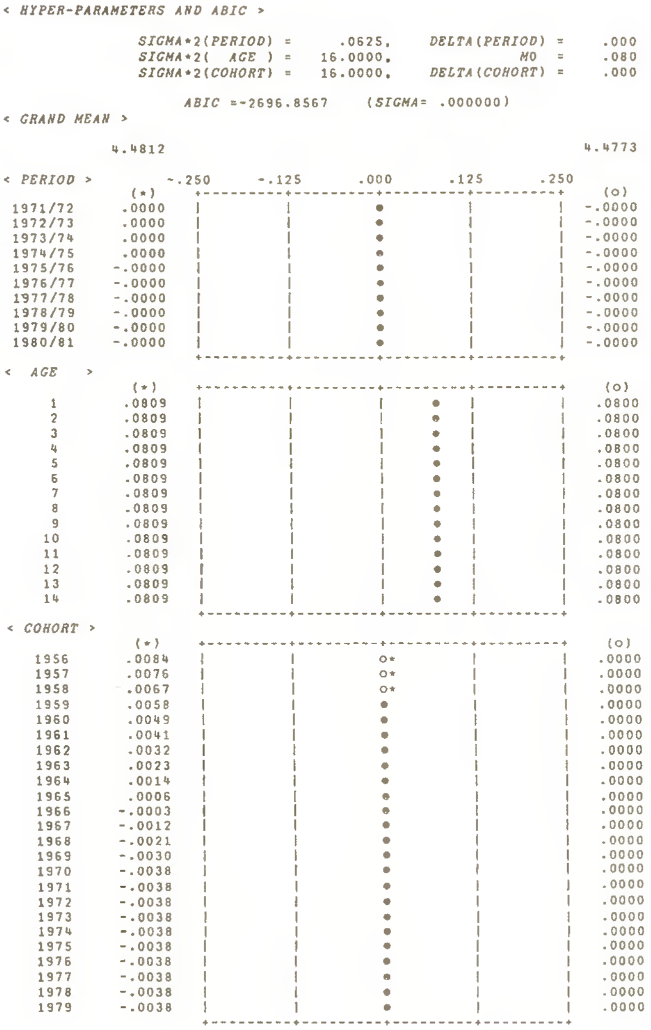
Nakamura, T. 1986. Bayesian cohort models for general cohort table analyses. *Ann. Inst. Statist. Math*. B 38: 353–70.

Nakamura, T. 1987. A Bayesian cohort model for catch-at-age data. Paper SC/D87/36 presented to the Special Meeting of the IWC Scientific Committee to consider the Japanese Research Permit (Feasibility Study), December 1987 (unpublished).

Pullum, T.W. 1978. Parameterizing age, period, and cohort effects: an application to U.S. delinquency rates, 1964–1973. *In:* K.F. Schuessler (Ed.), *Sociological Methodology 1978*. Jossey-Bass, San Francisco.

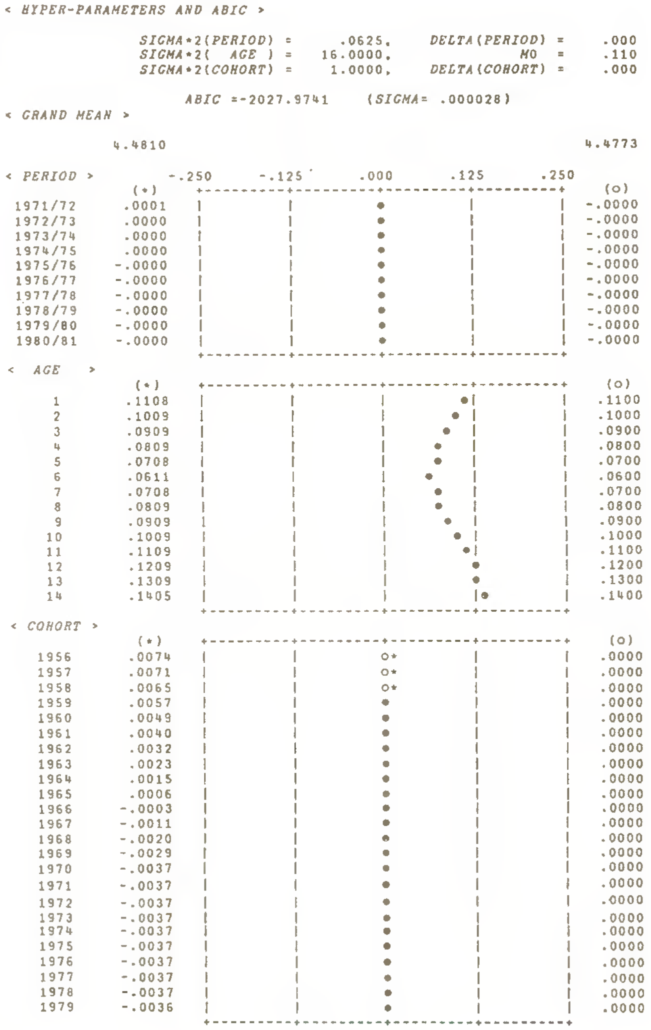
Sakuramoto, K. and Tanaka, S. 1985. A new multi-cohort method for estimating Southern Hemisphere minke whale populations. *Rep. int. Whal. Commn* 35: 261–71.

Sakuramoto, K. and Tanaka, S. 1986. Further development of an assessment technique for Southern Hemisphere minke whale populations using a multi-cohort method. *Rep. int. Whal. Commn* 36: 207–12.



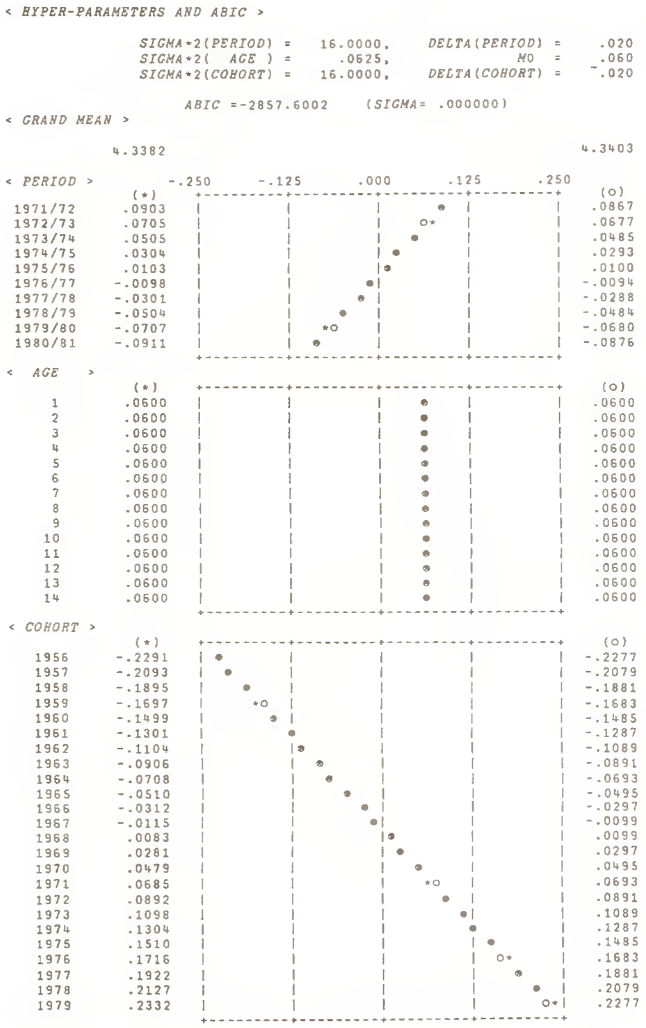
```
< HYPER-PARAMETERS AND ABIC >

                SIGMA*2(PERIOD) =      .0625,    DELTA(PERIOD) =     .000
                SIGMA*2(  AGE  ) =   16.0000,               MO   =     .080
                SIGMA*2(COHORT) =    16.0000,    DELTA(COHORT) =     .000

                    ABIC =-2696.8567    (SIGMA= .000000)
< GRAND MEAN >

            4.4812                                                  4.4773

< PERIOD >       -.250      -.125      .000       .125       .250
             (*)   +----------+----------+----------+----------+    (o)
 1971/72     .0000 |          |          ●          |          |  -.0000
 1972/73     .0000 |          |          ●          |          |  -.0000
 1973/74     .0000 |          |          ●          |          |  -.0000
 1974/75     .0000 |          |          ●          |          |  -.0000
 1975/76    -.0000 |          |          ●          |          |  -.0000
 1976/77    -.0000 |          |          ●          |          |  -.0000
 1977/78    -.0000 |          |          ●          |          |  -.0000
 1978/79    -.0000 |          |          ●          |          |  -.0000
 1979/80    -.0000 |          |          ●          |          |  -.0000
 1980/81    -.0000 |          |          ●          |          |  -.0000
                   +----------+----------+----------+----------+
<  AGE    >
             (*)   +----------+----------+----------+----------+    (o)
     1       .0809 |          |          |      ●   |          |   .0800
     2       .0809 |          |          |      ●   |          |   .0800
     3       .0809 |          |          |      ●   |          |   .0800
     4       .0809 |          |          |      ●   |          |   .0800
     5       .0809 |          |          |      ●   |          |   .0800
     6       .0809 |          |          |      ●   |          |   .0800
     7       .0809 |          |          |      ●   |          |   .0800
     8       .0809 |          |          |      ●   |          |   .0800
     9       .0809 |          |          |      ●   |          |   .0800
    10       .0809 |          |          |      ●   |          |   .0800
    11       .0809 |          |          |      ●   |          |   .0800
    12       .0809 |          |          |      ●   |          |   .0800
    13       .0809 |          |          |      ●   |          |   .0800
    14       .0809 |          |          |      ●   |          |   .0800
                   +----------+----------+----------+----------+
< COHORT >
             (*)   +----------+----------+----------+----------+    (o)
   1956      .0084 |          |          o*         |          |   .0000
   1957      .0076 |          |          o*         |          |   .0000
   1958      .0067 |          |          o*         |          |   .0000
   1959      .0058 |          |          ●          |          |   .0000
   1960      .0049 |          |          ●          |          |   .0000
   1961      .0041 |          |          ●          |          |   .0000
   1962      .0032 |          |          ●          |          |   .0000
   1963      .0023 |          |          ●          |          |   .0000
   1964      .0014 |          |          ●          |          |   .0000
   1965      .0006 |          |          ●          |          |   .0000
   1966     -.0003 |          |          ●          |          |   .0000
   1967     -.0012 |          |          ●          |          |   .0000
   1968     -.0021 |          |          ●          |          |   .0000
   1969     -.0030 |          |          ●          |          |   .0000
   1970     -.0038 |          |          ●          |          |   .0000
   1971     -.0038 |          |          ●          |          |   .0000
   1972     -.0038 |          |          ●          |          |   .0000
   1973     -.0038 |          |          ●          |          |   .0000
   1974     -.0038 |          |          ●          |          |   .0000
   1975     -.0038 |          |          ●          |          |   .0000
   1976     -.0038 |          |          ●          |          |   .0000
   1977     -.0038 |          |          ●          |          |   .0000
   1978     -.0038 |          |          ●          |          |   .0000
   1979     -.0038 |          |          ●          |          |   .0000
                   +----------+----------+----------+----------+
```

Fig. 1. True values of Case 1 data and their estimates based on the Bayesian cohort model.



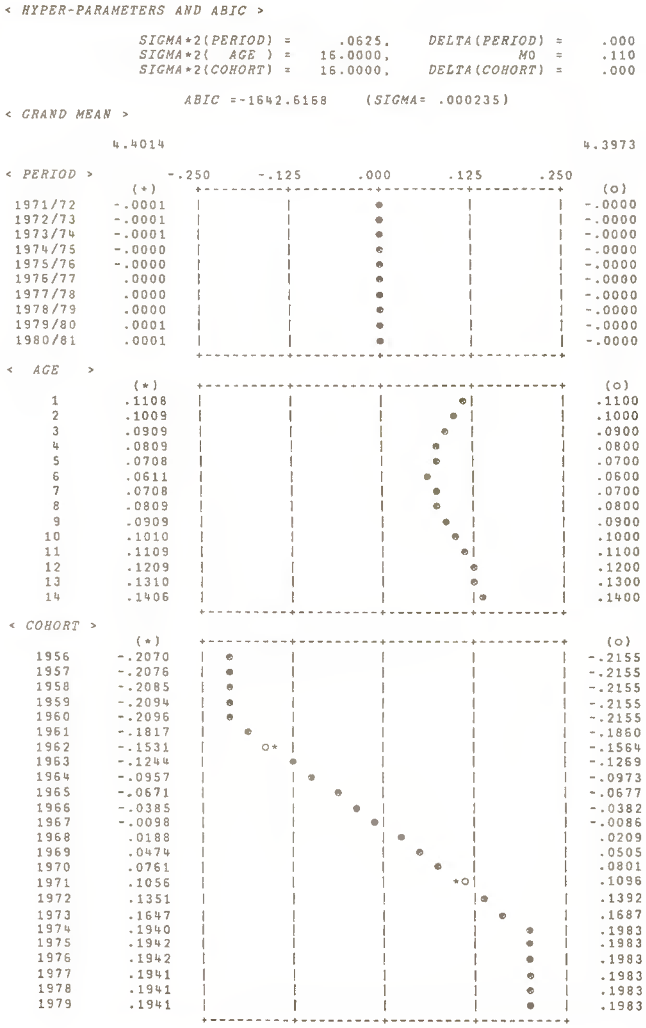
```
< HYPER-PARAMETERS AND ABIC >

                SIGMA*2(PERIOD) =      .0625,    DELTA(PERIOD) =     .000
                SIGMA*2(  AGE  ) =   16.0000,               MO   =     .110
                SIGMA*2(COHORT) =     1.0000,    DELTA(COHORT) =     .000

                    ABIC =-2027.9741    (SIGMA= .000028)
< GRAND MEAN >

            4.4810                                                  4.4773

< PERIOD >       -.250      -.125      .000       .125       .250
             (*)   +----------+----------+----------+----------+    (o)
 1971/72     .0001 |          |          ●          |          |  -.0000
 1972/73     .0000 |          |          ●          |          |  -.0000
 1973/74     .0000 |          |          ●          |          |  -.0000
 1974/75     .0000 |          |          ●          |          |  -.0000
 1975/76    -.0000 |          |          ●          |          |  -.0000
 1976/77    -.0000 |          |          ●          |          |  -.0000
 1977/78    -.0000 |          |          ●          |          |  -.0000
 1978/79    -.0000 |          |          ●          |          |  -.0000
 1979/80    -.0000 |          |          ●          |          |  -.0000
 1980/81    -.0000 |          |          ●          |          |  -.0000
                   +----------+----------+----------+----------+
<  AGE    >
             (*)   +----------+----------+----------+----------+    (o)
     1       .1108 |          |          |         ●|          |   .1100
     2       .1009 |          |          |        ● |          |   .1000
     3       .0909 |          |          |       ●  |          |   .0900
     4       .0809 |          |          |      ●   |          |   .0800
     5       .0708 |          |          |      ●   |          |   .0700
     6       .0611 |          |          |     ●    |          |   .0600
     7       .0708 |          |          |      ●   |          |   .0700
     8       .0809 |          |          |      ●   |          |   .0800
     9       .0909 |          |          |       ●  |          |   .0900
    10       .1009 |          |          |        ● |          |   .1000
    11       .1109 |          |          |         ●|          |   .1100
    12       .1209 |          |          |          ●          |   .1200
    13       .1309 |          |          |          ●          |   .1300
    14       .1405 |          |          |          |●         |   .1400
                   +----------+----------+----------+----------+
< COHORT >
             (*)   +----------+----------+----------+----------+    (o)
   1956      .0074 |          |          o*         |          |   .0000
   1957      .0071 |          |          o*         |          |   .0000
   1958      .0065 |          |          o*         |          |   .0000
   1959      .0057 |          |          ●          |          |   .0000
   1960      .0049 |          |          ●          |          |   .0000
   1961      .0040 |          |          ●          |          |   .0000
   1962      .0032 |          |          ●          |          |   .0000
   1963      .0023 |          |          ●          |          |   .0000
   1964      .0015 |          |          ●          |          |   .0000
   1965      .0006 |          |          ●          |          |   .0000
   1966     -.0003 |          |          ●          |          |   .0000
   1967     -.0011 |          |          ●          |          |   .0000
   1968     -.0020 |          |          ●          |          |   .0000
   1969     -.0029 |          |          ●          |          |   .0000
   1970     -.0037 |          |          ●          |          |   .0000
   1971     -.0037 |          |          ●          |          |   .0000
   1972     -.0037 |          |          ●          |          |   .0000
   1973     -.0037 |          |          ●          |          |   .0000
   1974     -.0037 |          |          ●          |          |   .0000
   1975     -.0037 |          |          ●          |          |   .0000
   1976     -.0037 |          |          ●          |          |   .0000
   1977     -.0037 |          |          ●          |          |   .0000
   1978     -.0037 |          |          ●          |          |   .0000
   1979     -.0036 |          |          ●          |          |   .0000
                   +----------+----------+----------+----------+
```

Fig. 2. True values of Case 2 data and their estimates based on the Bayesian cohort model.



```
< HYPER-PARAMETERS AND ABIC >

        SIGMA*2(PERIOD) =   16.0000,    DELTA(PERIOD) =    .020
        SIGMA*2(  AGE ) =     .0625,               MO =    .060
        SIGMA*2(COHORT) =   16.0000,    DELTA(COHORT) =   ¯.020

             ABIC =-2857.6002    (SIGMA= .000000)
< GRAND MEAN >

           4.3382                                           4.3403

< PERIOD >          -.250     -.125      .000      .125      .250
             (*)                                                   (o)
 1971/72    .0903                                                 .0867
 1972/73    .0705                                                 .0677
 1973/74    .0505                                                 .0485
 1974/75    .0304                                                 .0293
 1975/76    .0103                                                 .0100
 1976/77   -.0098                                                -.0094
 1977/78   -.0301                                                -.0288
 1978/79   -.0504                                                -.0484
 1979/80   -.0707                                                -.0680
 1980/81   -.0911                                                -.0876
<  AGE   >
             (*)                                                   (o)
     1      .0600                                                 .0600
     2      .0600                                                 .0600
     3      .0600                                                 .0600
     4      .0600                                                 .0600
     5      .0600                                                 .0600
     6      .0600                                                 .0600
     7      .0600                                                 .0600
     8      .0600                                                 .0600
     9      .0600                                                 .0600
    10      .0600                                                 .0600
    11      .0600                                                 .0600
    12      .0600                                                 .0600
    13      .0600                                                 .0600
    14      .0600                                                 .0600
< COHORT >
             (*)                                                   (o)
   1956    -.2291                                                -.2277
   1957    -.2093                                                -.2079
   1958    -.1895                                                -.1881
   1959    -.1697                                                -.1683
   1960    -.1499                                                -.1485
   1961    -.1301                                                -.1287
   1962    -.1104                                                -.1089
   1963    -.0906                                                -.0891
   1964    -.0708                                                -.0693
   1965    -.0510                                                -.0495
   1966    -.0312                                                -.0297
   1967    -.0115                                                -.0099
   1968     .0083                                                 .0099
   1969     .0281                                                 .0297
   1970     .0479                                                 .0495
   1971     .0685                                                 .0693
   1972     .0892                                                 .0891
   1973     .1098                                                 .1089
   1974     .1304                                                 .1287
   1975     .1510                                                 .1485
   1976     .1716                                                 .1683
   1977     .1922                                                 .1881
   1978     .2127                                                 .2079
   1979     .2332                                                 .2277
```

Fig. 3. True values of Case 3 data and their estimates based on the Bayesian cohort model.



```
< HYPER-PARAMETERS AND ABIC >

        SIGMA*2(PERIOD) =     .0625,    DELTA(PERIOD) =    .000
        SIGMA*2(  AGE ) =   16.0000,               MO =    .110
        SIGMA*2(COHORT) =   16.0000,    DELTA(COHORT) =    .000

             ABIC =-1642.6168    (SIGMA= .000235)
< GRAND MEAN >

           4.4014                                           4.3973

< PERIOD >          -.250     -.125      .000      .125      .250
             (*)                                                   (o)
 1971/72   -.0001                                                -.0000
 1972/73   -.0001                                                -.0000
 1973/74   -.0001                                                -.0000
 1974/75   -.0000                                                -.0000
 1975/76   -.0000                                                -.0000
 1976/77    .0000                                                -.0000
 1977/78    .0000                                                -.0000
 1978/79    .0000                                                -.0000
 1979/80    .0001                                                -.0000
 1980/81    .0001                                                -.0000
<  AGE   >
             (*)                                                   (o)
     1      .1108                                                 .1100
     2      .1009                                                 .1000
     3      .0909                                                 .0900
     4      .0809                                                 .0800
     5      .0708                                                 .0700
     6      .0611                                                 .0600
     7      .0708                                                 .0700
     8      .0809                                                 .0800
     9      .0909                                                 .0900
    10      .1010                                                 .1000
    11      .1109                                                 .1100
    12      .1209                                                 .1200
    13      .1310                                                 .1300
    14      .1406                                                 .1400
< COHORT >
             (*)                                                   (o)
   1956    -.2070                                                -.2155
   1957    -.2076                                                -.2155
   1958    -.2085                                                -.2155
   1959    -.2094                                                -.2155
   1960    -.2096                                                -.2155
   1961    -.1817                                                -.1860
   1962    -.1531                                                -.1564
   1963    -.1244                                                -.1269
   1964    -.0957                                                -.0973
   1965    -.0671                                                -.0677
   1966    -.0385                                                -.0382
   1967    -.0098                                                -.0086
   1968     .0188                                                 .0209
   1969     .0474                                                 .0505
   1970     .0761                                                 .0801
   1971     .1056                                                 .1096
   1972     .1351                                                 .1392
   1973     .1647                                                 .1687
   1974     .1940                                                 .1983
   1975     .1942                                                 .1983
   1976     .1942                                                 .1983
   1977     .1941                                                 .1983
   1978     .1941                                                 .1983
   1979     .1941                                                 .1983
```

Fig. 4. True values of Case 4 data and their estimates based on the Bayesian cohort model.

SC/40/O 35

Analysis of North Atlantic Fin Whale Marking Data From 1979–1988 with Special Reference to Iceland

Thorvaldur Gunnlaugsson and Jóhann Sigurjónsson

Marine Research Institute, Programme for Whale Research, P.O. Box 1390, Skulagata 4, 121 Reykjavík, Iceland.

ABSTRACT

The lack of mark returns in catches from East Greenland/Iceland fin whales has been found significant in earlier analyses which included recoveries up to 1983. The present paper includes mark/recapture data from the most recent years. The lack of mark returns from East Greenland and the east coast of Iceland is increasingly significant with continued returns from the grounds. Within the grounds, there is some affinity to locality of between-season returns. The time-lag to recovery, the age distribution of marked and recovered animals and double-mark returns are also found to favour the slow mixing hypothesis and are discussed with respect to possible mark shedding.

INTRODUCTION

Sigurjónsson and Gunnlaugsson (1985) reviewed and analysed available information on Discovery marks recoveries up to and including 1983, for the East-Greenland/Iceland population of fin whales (*Balaenoptera physalus*). This comprised 35 recoveries from 250 marks placed in animals during the years 1965–73 and 1979–83 off East Greenland (59 marks), on the traditional whaling grounds west and southwest of Iceland (189 marks) and off northeast Iceland (2 marks). That analysis was primarily aimed at estimating the stock size and examining segregation and the rate of mixing of animals occurring on the traditional whaling grounds west of Iceland, with fin whales elsewhere, particularly off East Greenland. A significant decrease in mark returns with time was found, which caused the calculated stock estimates to increase with time. Although mark loss could not be precluded, the authors suggested that the most likely explanation was a decreased availibility of whales with age, probably due to segregation within the population (Rørvik, Jonsson, Mathisen and Jonsgård, 1976) and a slow mixing of the local population with the remaining part of the stock, which resides mainly outside the whaling grounds. The paper also examined short-term recoveries of whale marks and within-season movements of fin whales on the grounds.

This paper partially updates the earlier fin whale mark/recapture analysis. Further, it examines, in more detail, localities of markings and recoveries with respect to the recorded verdicts when the marks were placed and takes note of equivalent data available for marked sei whales. Attention is given to the discussions that have taken place recently in the Scientific Committee on the possibility of significant shedding of whale marks (de la Mare, 1985; Buckland and Duff, 1989).

MATERIAL

Successful markings ('hits') and recoveries

The paper is mainly based on the recent markings (1979–84) and recoveries up to the end of the 1988 season. The data are summarised in Table 1. Data up to 1983 are given in tables 2 and 3 of Sigurjónsson and Gunnlaugsson (1985). Marking conducted in the 1984 season (39 marks placed in fin whales) and the recoveries made from the 1984 to 1987 seasons are given in Anon. (1986, 1987 and 1988). No marks were recovered in the 1987 season but four marks (from three whales) were recovered in 1988. Use is also made of data for multiple markings and recoveries in sei whales (*Balaenoptera borealis*) placed and recovered in the period 1979–1985 (Sigurjónsson, 1983; Anon., 1984, 1985, 1986, 1987), totalling 61 sei whales marked and 8 recoveries.

Table 1

Recent Icelandic fin whale markings and recoveries.
* = Marks placed on Greenland side of mid-line.

		Year of marking					
		1979	1980	1981	1982	1983	1984
E. Iceland				2		7	
Coastal E. Greenland				26		5	13
Greenland side of mid-line				3		2	19
W. Iceland (Whaling grounds)		35	11	64	52	8	
Total		35	14	64	52	10	19
Year of recovery:	1979	1					
	1980	3	1				
	1981	1	0	4			
	1982	1	1	5	3		
	1983	1	0	3	1	0	
	1984	0	1	4	4	0	0
	1985	0	0	3	1	0	0
	1986	0	0	0	1	0	1*
	1987	0	0	0	0	0	0
	1988	0	0	0	0	1*	2*
	Total	7	3	19	10	1	3
	Remaining marks	28	11	45	42	9	16

Fin whales have been marked in other stock areas in the North Atlantic (Brown, 1977, 1979 and 1984; Aguilar, Grau, Sanpera, Jover and Donovan, 1983; Sanpera, Aguilar, Grau and Jover, 1984; Christensen, 1980; Anon., 1981, 1982 and 1983; Bloch and Joensen, 1984). The UK marked 9 whales in 1950; Spain marked four in 1981, two in 1982 and 27 in 1983; 12 were marked off the Faroe Islands in 1982; Norway marked two whales in 1971, 5 in 1973 and 24 in 1978, and an additional 54 were marked off Spitzbergen during an IDCR cruise in 1982; 15 whales were marked off West Greenland from 1979–1981; Canada marked 287 whales (Canadian coast to the south of Greenland) from 1960–73 and 27 whales off Funk Island, Newfoundland in 1979, with one recovery in the Icelandic catch in 1988.

Recoveries of marks not classified as 'hits'

When a mark is fired, the observers record their verdict of its fate: hit, possible hit, protruding, ricochet, miss, no verdict. No between-season recoveries of marks recorded as 'protruding' have occurred but two fin whales and one sei whale were recovered within the same season with two marks reported when found as 'protruding' and one as 'embedded in the blubber'. One mark recorded as a 'miss' and one as a 'possible hit' have been recovered from fin whales within the same season. As within-season recoveries are not used here, these are not considered further. Two marks recorded as 'possible hits' in addition to a 'hit' have been recovered and are mentioned later. All the extra recoveries are from markings conducted on the whaling grounds.

AGE AT RECOVERY AND MARKING

Table 2 gives the available age-frequency distribution of marked fin whales in the Icelandic catch and the corresponding age at marking. The ages were obtained by earplug growth layer counts (data on files at the Marine Research Institute, Reykjavík). In addition, there are four animals from pre-1979 markings aged at 20, 18, 14 and 25 (Lockyer and Brown, 1979), that had consequently been marked at the ages of 13, 18, 4 and 24 years, respectively. The last two were Norwegian marks placed off the east coast of Greenland. One animal marked off Newfoundland in 1979 (M.C. Mercer, pers. comm.) was recovered at the age of 20+ in the Icelandic catch in 1988. The distribution of age at recovery appears somewhat lower than that of the total catch. The median age at recovery is between 8 and 9 years and the median age of the catch by years is as follows:

1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
9	10	8–9	8–9	9–10	9–10	11–12	12–13	11–12	11

If only recoveries from same season and first year after marking are considered (all placed prior to 1985), the median age is 8 years. The difference is not significant, but might be factual as these markings were conducted on the whaling grounds where the average age is expected to be lower than for the animals outside the main whaling grounds (Sigurjónsson and Gunnlaugsson, 1985; Rørvik *et al.*, 1976). The distribution of the age at marking is lower by the time-lag to recovery. The peak is at very young ages and it thus appears that the population is equally markable from the age of two or three years. There are too few data to detect any change in markability with higher ages.

MULTIPLE MARK RECOVERIES

Double markings

A total of 5 fin and 5 sei whales have been recorded as 'double-hits' and 1 sei whale was recorded as a 'triple-hit'. In addition, 4 fin and 8 sei whales have been successfully marked with a 'hit' and a second mark recorded as a 'possible hit'.

There is only one incidence of a 'double-hit' fin whale being recovered (the following season) and one of a 'double-hit' sei whale being recovered (three seasons after marking). Of whales recorded with one 'hit' and one 'possible hit', there have been reported recoveries of both marks in a fin and a sei whale, first and second season after marking, respectively. Hence there are 6 mark survival observations for marks recorded as 'hits' over a total of 11 mark-years.

Table 2

Available age-frequency distribution in fin whales marked and recovered off Iceland.

	Frequency			Frequency			Frequency	
Age	No. marked	No. recovered	Age	No. marked	No. recovered	Age	No. marked	No. recovered
2	5	1	10	4	2	18		1
3	2	2	11	3	1	19	1	1
4	1	2	12	2	1	20		1
5	4	1	13	1	3	21	1	1
6	3	2	14	1	1	22	1	1
7	4	6	15		1	23		1
8	2	6	16	2	2	:		
9	1	1	17	1	1	28	1	1

Lost marks

One 'possibly hit' mark, second to a recovered 'hit', was absent from a fin whale caught the same season. This mark was thus most likely a 'miss'. Protruding marks, second to a recovered 'hit', were not recovered from a sei and a fin whale caught the first and second season after marking, respectively. This is to be expected of marks recorded as protruding. In the post-1979 marking, there has been no case of a double-marked animal found with one mark in place and another mark recorded as a 'hit' missing.

One Norwegian mark placed in a fin whale at East Greenland in 1973 was recovered in 1983. This fin whale was recorded as a 'double hit' (S.G. Brown, pers. comm.). However the verdicts given to these marks may not be as reliable as in the more recent Icelandic marking experiments, which applied specially designed visible streamer marks (Sigurjónsson, 1983).

GEOGRAPHICAL DISTRIBUTION OF FIN WHALE MARKINGS

Icelandic markings by area

Figs 1 and 2 show the positions of marks placed in fin whales off West Iceland and known positions of between season recoveries. In the following discussion we only consider marks placed as 'hits' and between-season recoveries.

The whaling grounds are limited to the west by the Iceland/Greenland mid-line (fisheries limits) and in the north by the ice edge. The whalers rarely go beyond 66°N. The range is approximately to 62°30′N to the south and as far east as the Westmann Islands (Fig. 1) where sei whales have been caught in the autumn but fin whales only occasionally (see Fig. 3). Sei whales are not found in large numbers in the northern part of the whaling grounds.

Prior to 1983, while sperm whale (*Physeter macrocephalus*) catches were permitted, the whalers tended to go farther north where this species was normally to be found in significant concentrations, although the fin whale was still the target species. With the protection of sperm whales and a stronger emphasis on meat quality in recent years, the whalers go less frequently as far north as in earlier years (Sigurjónsson, 1988). However, only a minor fraction of the fin whale catches during the recent marking period were taken east of the Reykjanes ridge (i.e. south of Reykjanes), and then only during primary sei whale hunting in the autumn. In the 1987 and 1988 seasons, however, a larger part of the fin whale catches came from south of Reykjanes, even early in the season, a shorter distance from the station than the more traditional fin whale grounds (Fig. 3).

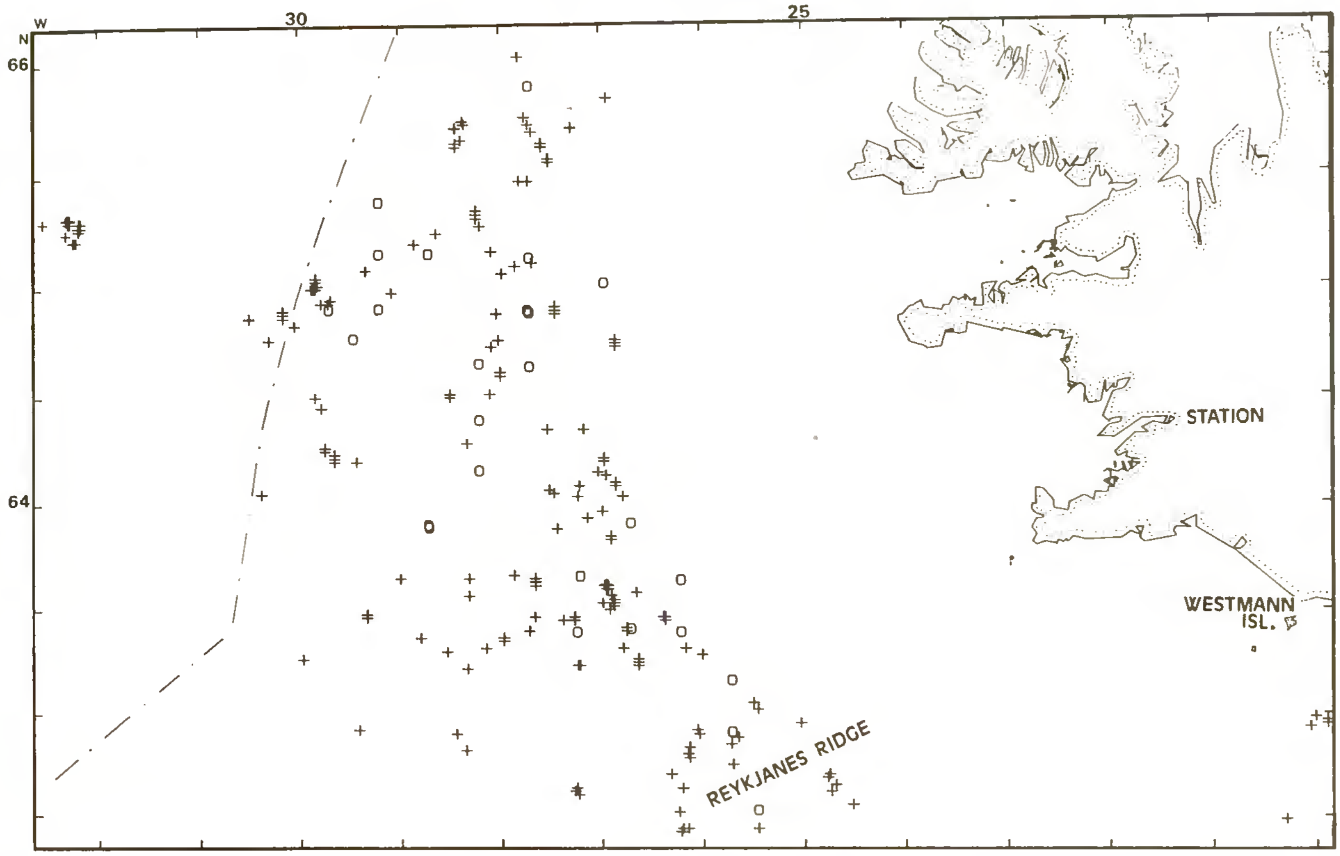


Fig. 1. Recent marking (+) and recovery positions (□). Only between season recoveries are shown. East Greenland coastal and East Iceland markings are outside the range of the figure. The dotted line is the Iceland–Greenland mid-line.

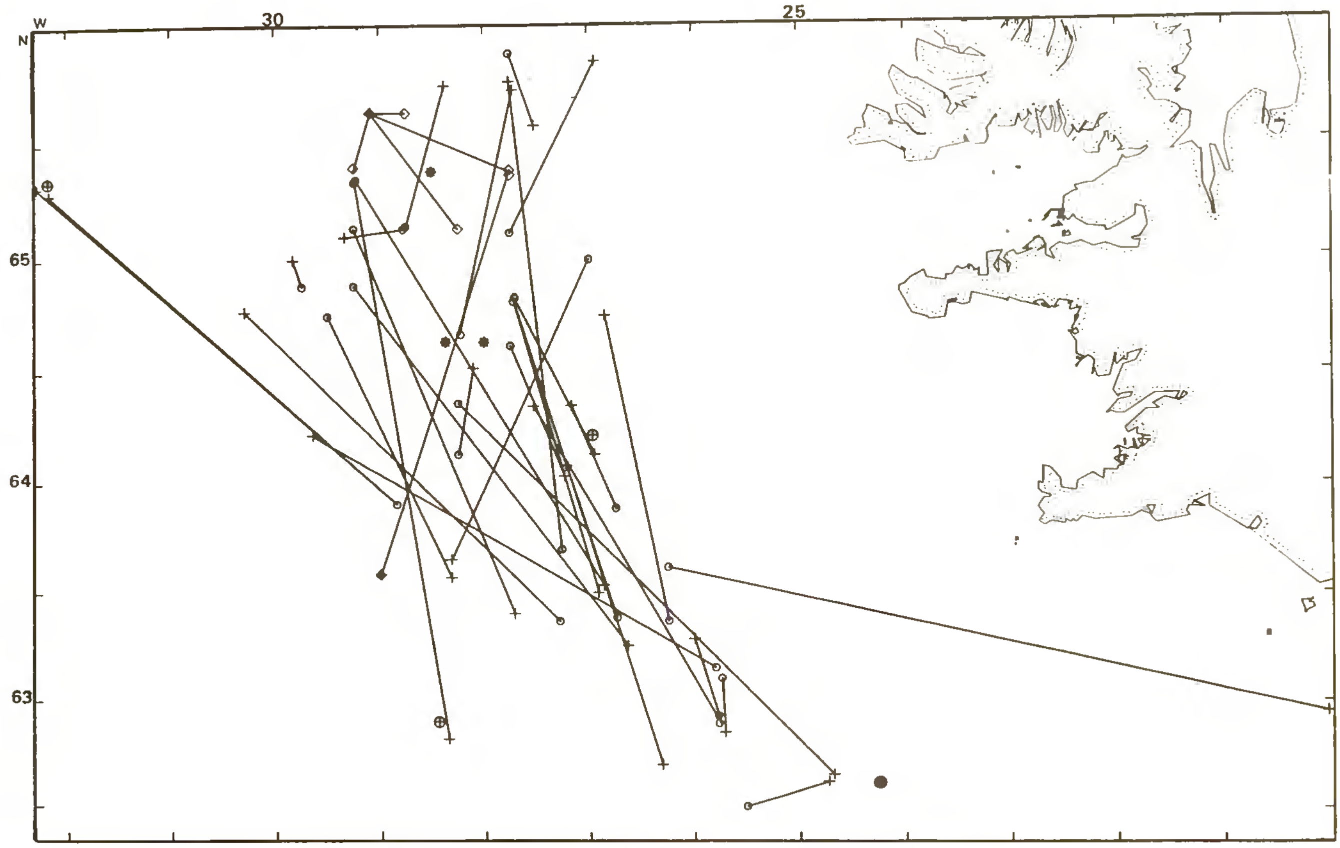


Fig. 2. Between season recoveries. Positions (○) found and marking positions (+). Some recovery positions are unknown (⊕). Early markings markings (◆) and recoveries (◇) are also shown as are recovery positions from earlier markings on the east coast of Greenland (*) and the recovery from Newfoundland (●).

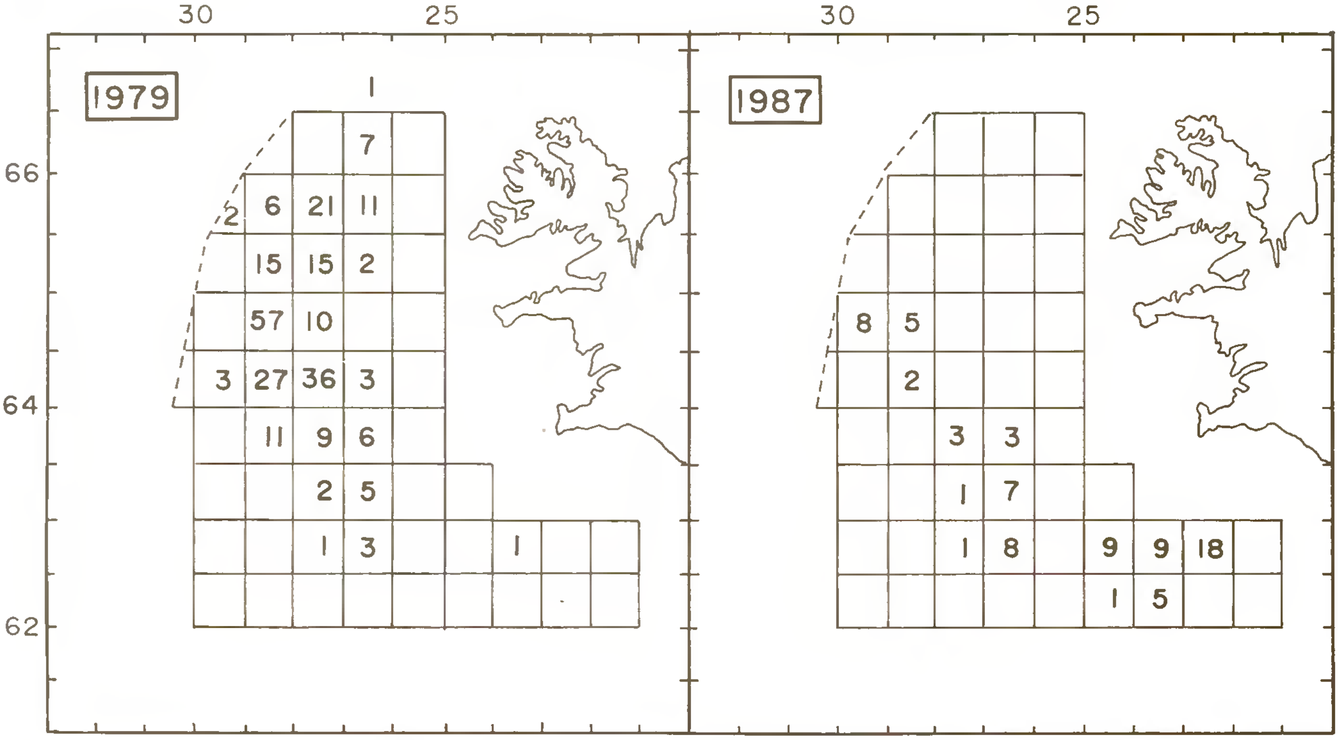


Fig. 3. Catch positions in the Icelandic fishery in 1979 and 1987.

The number of marks placed in fin whales on the whaling grounds west and southwest of Iceland by year is given in Table 1. Some of these marks were placed close to the Iceland-Greenland mid-line (Fig. 1) and in addition a number of marks have been placed on the Greenland side, west of the mid-line but east of 32°40′W.

Further to the west, in the area between 32°30′W and 35°30′W, no marks have been placed, but marking has been conducted by Iceland in recent years at the rise of the East Greenland shelf, west of 35°30′W, and further southwest at the East Greenland coast (Table 1). These marks are not shown on Fig. 1 nor are the nine marks that have been placed off the northeast coast of Iceland.

Recoveries from markings on the whaling grounds

Only five marks have been placed south of the Westmann Islands (3 in 1980 and 2 in 1981) with one of the marks from 1981 returned in the 1982 season (Fig. 2). Six marks were placed further to the west, on the east side of the Reykjanes ridge in 1979, with one recovery in each of the next two seasons. The recoveries were still further to the west. All marks were placed in late June or early July and recovered in late June. These few observations do not suggest that groups south of Iceland or east of the Reykjanes ridge are separate from the animals on the main grounds.

The recoveries frequently appear to occur close to the position of marking on the grounds, even years later (Fig. 2). The distances from position of marking on the grounds to the position of recovery have been calculated. Excluding the five marks placed south of the Westmann Islands, the mean distance is 74.4 n.miles (SE 9.5 n.miles). To test whether there is any indication of site fidelity, this has been compared to the mean distance from the place of mark recapture to the positions of marking of any other recovered marks (89.1 n.miles) and the mean distance from the position of recovery to positions of any other markings placed in the same year as the recovered mark (84.1 n.miles). As expected, the distance from the position of marking of the same recovered mark is shorter but the difference is not statistically significant. The impression of Fig. 2. is that the lines run primarily north–south; in fact if only the east/west component is looked at the difference is close to 90% significance.

Of the marks placed just outside the Iceland-Greenland mid-line there was one recovery from 1984 in the 1986 season and in 1988 there was one recovery of a mark placed in 1983 and two in 1984 (found in the same animal – this was not recorded as double marking; the marks had been placed at an interval of one hour). All these recoveries were made west of the Reykjanes ridge, north of 63°15′N. If these marks and the ones placed south of the Westmann Islands are included in the calculations, the mean distance from marking to the recovery of the same mark becomes statistically significantly shorter than the other distances. However, then the definition of the area in question is not clear and the results are very sensitive to these few additional marks.

It is worth mentioning that the recoveries from just outside the Iceland Greenland mid-line are rather late or 2, 4, 4 and 5 years after marking. But the proportion of returns in 1988 is just as high as that of markings on the whaling grounds. These marks have thus been pooled along with the marks placed on the grounds. The recoveries, the catch multiplied by non-recovered marks and the recovery rate of marks by year after marking are given in Table 3. Fishing mortality is accounted for by excluding recovered marks. A natural mortality (or replacement) rate of 7% is assumed in the last column. (If a high proportion of marks was lost, interaction with mortality becomes non-trivial, but this is ignored here; see discussion below).

The rate of returns is relatively constant for the first years but then falls off quite abruptly (Table 3). Extrapolating from the first four years after marking and even assuming a high natural mortality rate of 7%, over 13

Table 3

Fin whale marks west of Iceland – rates of recovery by year after marking.

Year after marking	Hit marks	Catch times marks	Recovery		
			Number	Rate	(M=7%)
0	-	-	9	-	-
1	186	33,984	9	1/3,776	1/3,512
2	177	28,273	10	1/2,873	1/2,485
3	167	25,156	6	1/4,192	1/3,372
4	162	18,798	8	1/2,349	1/1,757
5	137	13,908	1	1/13,908	1/9,676
6	127	11,857	0	-	0/7,671
7	84	6,040	0	-	0/3,634
8	39	2,988	0	-	0/1,672
9	28	1,904	0	-	0/991
Total	195		43		

marks should have been recovered in the fifth and later seasons after marking; only one was observed. This is statistically significant. As the average age of animals at marking was lower than that of the catch (see above), it takes some years for marked animals to be fully recruited into the exploitable population. This could, to some extent, explain the constant return rate for the first few years. The abrupt decline in the return rate after the fourth year could be a function of mixing and/or segregation by age (Rørvik *et al.*, 1976; Sigurjónsson and Gunnlaugsson, 1985), but also it could be attributed to the change in operation patterns discussed above. Since mark shedding would be expected to take place predominantly in the first few years after marking, an assumption of a significant shedding rate is not in conformity with what is observed in the present material.

Recoveries from other parts of the East Greenland-Iceland stock area

Along the coast of East Greenland (west of 35°W), 44 marks have been placed since 1981 while to the east of Iceland 9 marks have been placed since 1983; no marks have been recovered to date.

The last recovery from East Greenland was a mark placed in 1973 and recovered in 1983 from a whale recorded as double-marked (see above). The four returned marks placed by Norway off Greenland were all found in whales caught north of 64°30′N.

Extrapolating the rate of recovery of marks on the whaling grounds and just outside the mid-line (excluding within-season recoveries) to marks placed at East Greenland and the northeast of Iceland, the expected number of recoveries is 8.2 for East Greenland and 1.1 for eastern Iceland. Compared to the earlier marking experiments in the 1960s and early 1970s, to date three marks would be expected from Greenland. This lack of recoveries from Greenland in the more recent years might to some degree be explained by the smaller fraction of catches taken to the far northwest of the grounds as explained above.

Recoveries from other stock areas

In 1988 there was one recovery in the Icelandic scientific take of a mark placed by Canada at Funk Island, Newfoundland, in 1979, this is the only recovery at Iceland found east of the Reykjanes ridge (62°30′N 24°15′W; see Fig. 2). It is also the only mark recovery crossing fin whale stock boundaries as defined by the IWC. Of interest with respect to mark shedding and mixing is the nine year time-lag. During the period 1950 to 1983 a total of 440 marks were placed in fin whales in other stock areas in the North Atlantic as detailed above.

DISCUSSION

Incorrect verdict of marking success, initial mark loss and initial mark mortality cannot possibly be separated by analysis of mark returns. Furthermore, if these factors are large and the returns add to a substantial fraction of marks placed, they would later affect the rate of returns in the same way as if subsequent mark shedding had taken place. As an example, suppose that of 100 whales assumed to be marked, only 70 whales were actually marked. After 40 marks are returned there will be 70–40 or 30 'hits' left when 100–40 or 60 would be expected left. The rate of recovery is subsequently only half the rate expected, which could be confused with mark shedding. In the case of failure to find or report returned marks, the effects would be the same.

It is worth examining the information concerning double marked whales further, to see if it can provide some idea of mark loss. Let us denote by p the probability of a mark not having been lost from a live whale over one year. If p is close to the survival rate s, as observed in the catch, or lower, the animals will soon have lost one of their marks. Assuming constant effort and summing over the years (i), the probability of finding both marks in place is

$$\sum_{i=1}^{\infty} (sp^2)^i = sp^2/(1-sp^2)$$

and the probability of finding only one mark in place is

$$\sum_{i=1} s^i p^i (1-p^i) = 2sp(1-p)/[(1-sp)(1-sp^2)]$$

so the ratio of animals caught with only one of two marks in place over the number of animals with both marks in place tends to the limit

$$2(1-p)/[p(1-sp)]$$

which is for $p<s$, greater than one.

All the double marks were placed on the Icelandic whaling grounds or just west of the Iceland-Greenland mid-line, so they would be expected to return relatively soon. Thus, given the observations with both marks in place (11 mark-survival-years) if mark shedding is high or of the same order of magnitude as the mortality (p is low or close to s), at least three observations of only one mark in place would be expected for Icelandic fin and sei whale catches; no such observations have been made. The expected returns from now on are very low and only about a tenth of the marks are double-marks, so any additional recovery of a double marked animal (with both marks or one missing) is unlikely.

If we include in the calculations the mark loss of one of the two Norwegian marks, placed in the same fin whale 10 years earlier, and take s as 0.9 (10% mortality), the expected p is 0.97, an annual mark shedding of 3%. In fact, mark shedding of only 4% a year is sufficient to make recovery of only one of the double-marks more likely than recovery of both marks ten years later. In fact the limited number of double-mark observations cannot support tests of statistical significance. However, we believe the implications of this, when considered along with the other indications as to the affinity to same localities of mark/recaptures, the time-lag to recovery from other areas and the observed age distribution, provide additional support to the slow mixing hypothesis of Sigurjónsson and Gunnlaugsson (1985).

ACKNOWLEDGEMENTS

The authors would like to thank Joseph Horwood, Fisheries Laboratory, Lowestoft, UK and Philip S. Hammond, SMRU, Cambridge, UK for commenting on our earlier draft and Carl-Jakob Rørvik, Sandnes, Norway and an anonymous reviewer for useful comments and suggestions for the manuscript.

REFERENCES

Aguilar, A., Grau, E., Sanpera, C., Jover, L. and Donovan, G.P. 1983. Report of the 'Ballena 1' whale marking and sighting cruise in the waters off Spain. *Rep. int. Whal. Commn* 33: 649–55.

Anon. 1981. Norway progress report on cetacean research June 1979-May 1980. *Rep. int. Whal. Commn* 31: 209–10.

Anon. 1982. Denmark (Greenland) progress report on whale research June 1980–May 1981. *Rep. int. Whal. Commn* 32: 173–4.

Anon. 1983. Denmark (Greenland) progress report on cetacean research June 1981-May 1982. *Rep. int. Whal. Commn* 33: 203–8.

Anon. 1984. Iceland progress report on cetacean research June 1982 to May 1983. *Rep. int. Whal. Commn* 34: 199–201.

Anon. 1985. Iceland. Progress report on cetacean research, June 1983 to May 1984. *Rep. int. Whal. Commn* 35: 166–68.

Anon. 1986. Iceland progress report on cetacean research, June 1984 to May 1985. *Rep. int. Whal. Commn* 36: 156–57.

Anon. 1987. Iceland. Progress report on cetacean research, June 1985 to May 1986. *Rep. int. Whal. Commn* 37: 169–71.

Anon. 1988. Iceland. Progress report on cetacean research, June 1986 to May 1987. *Rep. int. Whal. Commn* 38: in press.

Bloch, D. and Joensen, J.S. 1984. Appendix 1. Denmark (Faroe Islands). Progress report on cetacean research 1982. *Rep. int. Whal. Commn* 34: 194–5.

Brown, S.G. 1977. Whale marking in the North Atlantic. *Rep. int. Whal. Commn* 27: 451–5.

Brown, S.G. 1979. Whale marking in the North Atlantic 1950–78. Paper submitted to ICES Marine Mammals Committee, CM/1979/N:11, 6 pp.

Brown, S.G. 1984. Whale marking in the North Atlantic Ocean 1979–82. Paper submitted to ICES Marine Mammals Committee, CM/1984/N:2, 6 pp.

Buckland, S.T. and Duff, E.I. 1989. Analysis of Southern Hemisphere minke whale mark-recovery data. *Rep. int. Whal. Commn* (special issue 11).

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.

de la Mare, W. 1985. Some evidence for mark shedding with Discovery whale marks. *Rep. int. Whal. Commn* 35: 477–86.

International Whaling Commission. 1985. Report of the Scientific Committee – Annex G. *Rep. int. Whal. Commn* 35: 100–18.

Lockyer, C and Brown, S.G. 1979. Notes on age data for fin whales taken off Iceland. *Rep. int. Whal. Commn* 29: 185–9.

Rørvik, C.J., Jónsson, J., Mathiesen, O. A. and Jonsgård, Å. 1976. Fin whales, *Balaenoptera physalus* (L), off the west coast of Iceland –Distribution, segregation by length and exploitation. *Rit Fiskideildar 5* (5): 1–30.

Sanpera, C., Aguilar, A., Grau, E. and Jover, L. 1984. Report of the 'Ballena 2' whale marking and sighting cruise in the Atlantic waters off Spain. *Rep. int. Whal. Commn* 34: 653–66.

Sigurjónsson, J. 1983. The cruise of the *Ljósfari* in the Denmark Strait (June-July 1981) and recent marking and sightings off Iceland. *Rep. int. Whal. Commn* 33: 667–82.

Sigurjónsson, J. 1988. Operational factors in the Icelandic coastal-based large whale fishery. *Rep. int. Whal. Commn* 38: 327–33.

Sigurjónsson, J. and Gunnlaugsson, Th. 1985. Further mark-recapture analysis of fin whales caught off Iceland with a note on stock identity and movements of the East-Greenland/Iceland population. *Rep. int. Whal. Commn* 35: 357–62.

SC/40/O 42

Satellite-Monitored Radio Tracking as a Method for Studying Cetacean Movements and Behaviour

Bruce Mate

School of Oceanography, Hatfield Marine Science Center, Oregon State University, Newport, Oregon 97365, USA

ABSTRACT

In summer 1987, a pilot whale tagged with an Argos satellite-monitored radio tag was tracked for 95 days in the western North Atlantic. The whale was located 479 times by satellite during movements of at least 7,588km and sighted from an aircraft several times in the company of other pilot whales. Duration of dive data were collected on 187,866 dives. Transmitter temperature information was also sent and indicated that virtually all deep dives occurred at night, when the whale was likely feeding on squid. Surface resting occurred most often immediately after sunrise on a four– to seven-day cycle. Future movement and dive information in conjunction with oceanographic data will be important in identifying the critical habitats of whales and understanding their behaviour. Satellites offer an important new cost–effective tool for studying whales.

INTRODUCTION

Siginificant advances in understanding whale movements have been made using natural marks, Discovery tags and conventional radio telemetry. However, remarkably little is known of the normal movements, behaviour and dive patterns of most whale species because they are difficult to identify as individuals and follow over long periods of time. The habits of individual whales are important because, collectively, they describe what the population does. The development of the Argos (satellite-monitored) Location and Data Collection System now makes it possible to track transmitter-equipped whales anywhere in the world without extensive follow-up labor and logistics. The system can also monitor data from transmitters to interpret the whale's health and activities. This feasibility was demonstrated during a 1987 experiment tracking a pilot whale released off Cape Cod in the western North Atlantic.

The Argos system

Argos is the only satellite-based location system presently available to civilians which can locate specialised transmitters anywhere in the world. The system is composed of three basic units: transmitters, satellite-based receivers and ground processing services.

Argos transmitters, termed 'platform transmitter terminals' (PTTs) transmit a 1-watt signal on an ultra-high frequency (UHF) of 401.650MHz. PTTs must maintain an extremely stable frequency because locations are determined from calculations of the Doppler shift (change in received frequency) associated with the satellite moving past the transmitter. Thus, any frequency instability results in location errors. Each PTT transmits a discrete identification code and 32 to 256 bits of encoded data during a signal lasting from 320 to 980msec. Transmissions are spaced at least 40s apart to avoid receiver system saturation. As PTTs cannot transmit through seawater, cetacean PTTs conserve power by incorporating a saltwater switch to initiate transmissions only when the transmitter is at the surface. The PTT used in this experiment was also programmed to transmit only during times when satellites were expected within reception range.

Four Argos receivers are carried on each of the NOAA TIROS-N series weather satellites, which are in sun-synchronous, polar orbits at elevations of 830 to 870km with an orbital duration of 101 mins. Two satellites are kept active; they have orbital planes 75° from one another to assure coverage at different times of the day (Fig. 1). Coverage of a specific geographic area is accomplished at the same local solar time daily. From a fixed point on earth, satellites go from horizon to horizon in 8 to 15 min. The satellites cross over both poles on every orbit and change their equator crossing by 25°W (approximately 2,800km) on each successive orbit. The receivers pick up PPT messages within a range of 2,500km of the satellite's ground path. Thus, the full width of a satellite's coverage is 5,000km (note the circles along the ground path in Fig. 1). There is approximately a 40% overlap in reception range of orbits even at the equator, with much greater overlap at higher latitudes and complete coverage of areas above 75° latitude on every orbit.

PTT information received by the satellites is returned to earth two ways: (1) data are stored and transmitted when the satellite passes over one of three ground telemetry

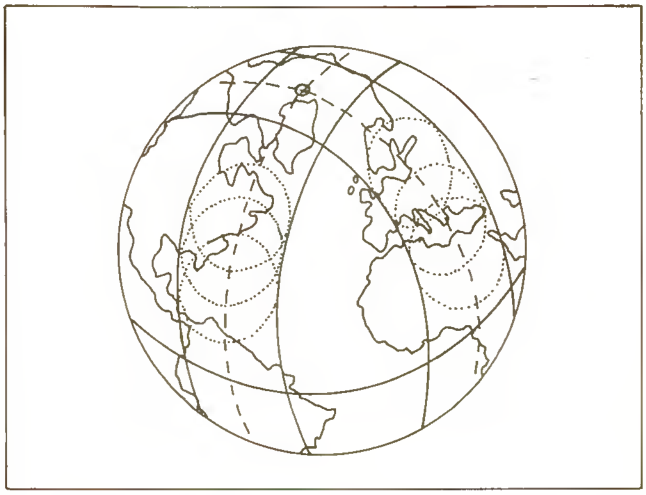


Fig. 1. A map of the earth showing the separation of 75° between orbital planes (dashed lines) of two NOAA TIROS-N satellites. Overlapping circles show the satellite reception range for ARGOS PTT's at 5′ intervals.

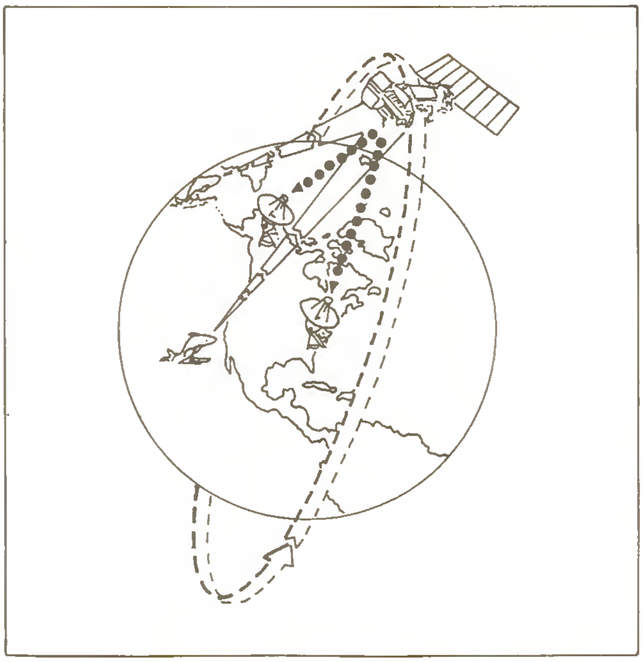


Fig. 2. Representation of a NOAA TIROS-N satellite in polar orbit receiving transmissions from two different whale PTT's and relaying the information to ground stations at Wallops Island, Virginia and Gilmore Creek, Alaska.

stations [Lannion, France; Wallops Island, Virginia, USA; or Gilmore Creek, Alaska, USA (Fig. 2)]; and (2) the satellite immediately re-transmits received data, reception time, Doppler data and signal strength data which can be monitored by a local user terminal (LUT). An LUT is a specialised receiver for Argos down-link data which can be located virtually anywhere and is capable of calculating locations from three or more PTT messages during a single orbit.

The information received by the ground stations is processed by the Argos Data Processing Centers in Suitland, Maryland, USA and Toulouse, France. Locations are calculated by Service Argos as a standard product when three or more messages are received during a single orbit. Location accuracy increases with the number of messages received. Locations and encoded sensor data are made available to investigators within three to six hours by Service Argos via computer modem links or telex. The delay is due to down-link, transmission and processing times. Magnetic tapes (or floppy disks) and print-outs can be obtained monthly or bimonthly by mail. Satellite-monitored Argos radio tags can potentially track large numbers of tagged whales anywhere simultaneously.

Cetacean tracking

The first successful tracking of a large whale by satellite occurred in 1983, when a humpback whale off Newfoundland was tracked 700km between 10 locations during six days (Mate *et al.*, submitted manuscript). The whale moved from the nearshore at an average speed of 5.9km/h to an area offshore when the cold Labrador current converged with the warm Gulf Stream. Such areas characteristically attract large concentrations of fish. This area was a productive area for capelin fishermen and was often frequented by humpback whales (H. Whitehead and J. Lien, pers. comm.). Compared to PTTs today, the humpback PTT was large and not very energy effeicient. It also did not attach well, which resulted in a short operational life.

Further miniaturization, design of energy-efficient circuits and improved attachments made it possible to track a free-ranging pilot whale for 95 days in the North Atlantic during the summer of 1987 (Mate *et al.*, submitted manuscript). An immature pilot whale stranded in December, 1986 was rehabilitated by the New England Aquarium and released on 29 June, 1987 off Cape Cod. An Argos PTT manufactured by Telonics (Mesa, Arizona) was attached to a heat-molded plastic saddle, which was pinned to the dorsal fin with six Delrin rods. The whale was tracked over at least 7,588km between 479 preliminary locations. Daily movements of up to 234km were observed ($\bar{x}$=80km/day). Every dive >6s was counted ($\bar{x}$=2,020/day) and its duration measured ($\bar{x}$=40s). The average number of dives in a 12hr period varied from 636 to 1,433, reflecting changes in the animal's activity patterns. Swimming speeds averaged 3.3km/h over the entire 95 day period. Speeds >16km/h were observed for periods exceeding three hours.

Important correlations of the animal's movements and dive patterns were noted with sea-surface temperatures, which ranged from 14° to 30°C. Transmitter temperatures down to 6°C were encountered during deep dives, which occurred primarily at night and just before sunset. Deep diving coincided with the nocturnal rise of the deep-scattering layer and the pilot whale's primary prey, squid. Few deep dives were recorded during daylight. If daytime feeding occurred, the whale used a completely different strategy, such as feeding on surface-schooling fish. The highest swimming speeds were also observed at night and just before sunset, suggesting either the fast chasing of prey or the need to search widely to locate prey patches. Argos experiments tracking *Tursiops truncatus* for up to 35 days in the western North Pacific found similar correlations with sea surface temperatures and diurnal speed changes (Tanaka, 1987).

Surface resting activity (no submergence) exceeded the duration of some of the longest satellite passes (15 min.) and was most common during the first three hours after sunrise, on a four– to seven-day cycle. These are the first data on the long-term surface resting patterns of a free-ranging whale.

DISCUSSION

The number of daily dives, maximum durations and swimming speeds were reasonably consistent throughout this study, suggesting that the whale was still healthy when the PTT finally lost battery power. The repeated sightings of the tagged whale within a pod of pilot whales also suggests that its movements may be typical of untagged pilot whales as well. The whale's movements during the last two months mirrored the likely movements, from offshore to nearshore, of squid for spawning. The final locations, in early October, at the tip of the Cape Cod peninsula, coincided with the usual time for pilot whales to start entering Cape Cod Bay. The whale's health did not appear compromised by the tag. This is important under humane considerations and is critical to using the data for interpretations of 'normal' behaviour.

The feasibiility of tracking whales for relatively long periods has now been demonstrated and its future utility looks promising. Attachments, packaging and deployment are likely to be the biggest problems for future large whale efforts and deserve further attention. With suitable attachments and energy–efficient transmitters, satellite-monitoring can be cost effective. PTTs cost from $3,000 to $5,000 each and if programmed on a conservative transmission schedule will last for much longer periods. Presently, PTTs are monitored by Service Argos for $12/day.

Data analyses for some management issues may be relatively simple, e.g. how do 'stocks' mix, do pods break up and re-group and how do the surfacing patterns of whales in different regions or seasons influence aerial and ship sightings? However, the major contribution of this new technique may be much more complex. In addition to the items examined here (locations, speed, diving behaviour, diurnal rhythms and limited oceanographic data), future studies will likely examine foraging strategies, energetics, acoustics and additional oceanographic factors in sufficient detail to describe the critical habitats of whales geographically and functionally. Ultimately, the identification and protection of critical habitats may be much more important to the long-term survival of many whale species than present harvest issues.

ACKNOWLEDGEMENTS

I am grateful to: John Prescottt, Joseph Geraci, the New England Aquarium staff and the crew of the NOAA vessel *Albatross IV* for their assistance and the opportunity to tag the pilot whale in 1987; to Minerals Management Service and the Oregon State University Sea Grant program for partial funding; to the Office of Naval Research for earlier developmental funding; and to William Perrin (National Marine Fisheries Service, SWFC, PO Box 271, La Jolla, CA 92037, USA) and Tim Smith (Chief, Population Dynamics Branch, National Marine Fisheries Service, Woods Hole Laboratory, Woods Hole, Massachusetts 02543, USA) for reviewing this manuscript.

REFERENCES

Tanaka, S. 1987. Satellite radio tracking of bottlenosed dolphins, *Tursiops truncatus*. *Nippon Suisan Gakkaishi* 53(8): 1327–38.

North Atlantic Sightings Survey 1987

Lief Petersen checking the fuel level of OY-CAG, one of the aircraft used in both Iceland and Greenland during the 1987 North Atlantic Sightings Survey.

SC/40/O 29

NASS-87: Shipboard Sightings Surveys in Icelandic and Adjacent Waters June-July 1987

Johann Sigurjónsson and Thorvaldur Gunnlaugsson

Marine Research Institute, Programme for Whale Research, P.O. Box 1390,
Skulagata 4, 121 Reykjavík, Iceland

Michael Payne

Manomet Bird Observatory, P.O.Box 936, Manomet, MA 02345, USA

ABSTRACT

The present paper gives an account of Icelandic shipboard surveys conducted during June-July 1987 onboard three vessels allocated by Iceland to the joint 1987 North Atlantic Sightings Survey (NASS-87). The study area covered the seas between East Greenland, Iceland, Jan Mayen, Faroe Islands, and deep waters off the coasts of the British Isles and Ireland. A total of 11,786 n.miles of effective searching area was covered, resulting in over 1,300 sightings of approximately 5,800 whales. The species encountered were blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*), humpback (*Megaptera novaeangliae*), sperm (*Physeter macrocephalus*), minke (*B. acutorostrata*), killer (*Orcinus orca*), Northern bottlenose (*Hyperoodon ampullatus*) and pilot (*Globicephala melas*) whales, in addition to a number of small odontocete species. A single right whale (*Eubalaena glacialis*) was observed in deep waters west of Iceland, which represents one of the few records of this species in the area during the 20th century. Also briefly reported are results of sightings of large whales made onboard the Faroese sightings vessel, *M/V Hvítaklettur*, participating in the survey in the area around the Faroe Islands and west of the British Isles; these will be reported and analysed more completely elsewhere.

INTRODUCTION

Systematic sightings surveys of cetaceans in Icelandic and adjacent waters have in recent years been conducted during a number of expeditions at sea (Sigurjónsson, 1983, 1985; Martin, Hembree, Waters and Sigurjónsson, 1984; Anon., 1986). However, earlier shipboard surveys have either had whale marking or fisheries investigations as their main objective and have thus not been conducted specifically to yield estimates of stock sizes or determination of densities of different whale species over anything but limited areas.

After experimental aerial surveys in coastal and deep Icelandic waters in 1982 (Hiby, Martin and Fairfield, 1984) and in 1985 (Anon., 1987a), the first successfully completed aerial survey in shallow waters around Iceland was conducted in June-July 1986 (Gunnlaugsson, Sigurjónsson and Donovan, 1988), giving useful information on the distribution and abundance of coastal (i.e. within 600m depth contour) cetacean species, mainly the minke whale (*Balaenoptera acutorostrata*).

In 1986 the Marine Research Institute (MRI) initiated a four year programme of intensified research into the whale stocks off Iceland. As a part of this programme, a large scale sightings survey onboard vessels and aircraft was scheduled in the summer of 1987. The Scientific Committee of the International Whaling Commission (IWC) had earlier made proposals for marking and sightings cruises (IWC, 1976; 1981) in the North Atlantic. Recognising the need for extensive sightings surveys throughout the North Atlantic Ocean and the plans presented by Iceland, the Committee again recommended in 1986 that efforts be made to coordinate simultaneous surveys in other areas of the North Atlantic (IWC, 1987). Subsequently, several interested national laboratories met in early 1987 to organise a joint North Atlantic Sightings Survey (NASS-87) to be implemented in June-August 1987 in the area from Spitzbergen and Barents Sea in the north and the Spanish coast in the south, and between West Greenland in the west and the Norwegian coast in the east (Anon., 1987b; 1987c).

The aim of the joint survey was to obtain simultaneous information on the distribution and abundance of all cetacean species in this vast ocean area, with emphasis on different species from one area to another. In the present study the main target species were East Greenland-Iceland stock of fin whales (*B. physalus*) and other large cetacean species, including the Central stock of minke whales, with emphasis on offshore areas. The Icelandic coastal grounds, where the main concentrations of minke whales occur, were simultaneously covered by aircraft (Donovan and Gunnlaugsson, 1989).

The present paper gives an account of the surveys conducted from 24 June – 28 July 1987 onboard three sightings vessels allocated by Iceland to the joint effort. The area covered by this study spans the seas between East Greenland, Iceland, Jan Mayen, Faroe Islands, and deep waters off the coasts of the British Isles and Ireland. In addition, a brief discussion of the sightings of large cetaceans made during June-August onboard the Faroese sightings vessel, *Hvítaklettur* is given; these results will be reported in more detail elsewhere. Results on the distribution and relative abundance of large and medium sized cetaceans (dolphins and porpoises will be dealt with in a separate paper) observed during the cruises are presented, along with a brief discussion of secondary tasks conducted. A separate analysis of pilot whale (*Globicephala melas*) sightings based on data from the Icelandic and Faroese vessels is given by Bloch, Gunnlaugsson, Hoydal and Sigurjónsson (1989). Reports of boat surveys by other national laboratories are given elsewhere (Lens, Quiroga and Gil de Sola, 1989; Øritsland, Øien, Calambokidis, Christensen, Cubbage, Hartvedt, Jensen, Joyce, Tellnes and Troutman, 1989) and that of the 1987 aerial survey around Iceland, including assessment of minke whales in the area, by Donovan and

Gunnlaugsson (1989) and Hiby, Ward and Lovell (1989). Estimates of abundance, based on the combined shipboard surveys of blue (*B. musculus*), fin, sei (*B. borealis*), humpback (*Megaptera novaeangliae*), Northern bottlenose (*Hyperoodon ampullatus*) and killer whales (*Orcinus orca*) are reported by Gunnlaugsson and Sigurjónsson (In Press) and IWC (1989).

METHODS

Planning and cruise design

During the survey planning meetings (Anon., 1987b; 1987c) it was agreed that the cruise track design should be the saw-tooth pattern described by Cooke (1987) and Cooke and Hiby (1987), for which it is not necessary that the coverage within each area be uniform, but rather that it be objectively determinable. The method allows different coverage in different areas to be surveyed; an advantage that was made use of in areas of known high abundance, where tracklines were more densely spaced than elsewhere. The method allows for tracklines to be altered during the survey, if adjustments are needed due to ice, weather or time constraints.

The survey area was divided between the three participating vessels (Figs 1 and 2, see also Narrative below): the East Greenland coast and Irminger Sea south to 58°N and the West Icelandic coast north towards the ice edge; north, northeast (towards Jan Mayen) and east (to 7°W) of Iceland; and the area south (to 60°N) and southeast of Iceland with the eastern boundary located approximately from 63°N, 7°W and 55°N, 15°W, the deep waters west of Ireland (Rockall area). The survey area was adjacent to the area surveyed by the Faroese sightings vessel, *Hvítaklettur*, in the east (blocks 11–14 in Fig. 1), the Norwegian sightings vessels in the northeast (see Øritsland *et al.*, 1989) and the Spanish vessel in the south (Lens *et al.*, 1989). The vessels cruised in opposite alternate directions during approximately the first and second part of the cruise, respectively, in order to even out possible migration effects during the survey period.

Vessels

The three participating vessels were: R/V *'Arni Fridriksson* RE 100, M/V *Skírnir* AK 16 and M/V *Keflvíkingur* KE 100.

R/V *'Arni Fridriksson* (hereafter called '*AF*') is 40.4m, 449Btn Icelandic fisheries research vessel, owned by the MRI. She is a stern trawler of 996 (2x498) HP and an effective maximum speed of 10 knots. Fuel and provisions for crew and vessel were optimally for less than 15–18 days. Navigation is by Loran-C, under normal conditions giving accuracy of between 0.2 and 1.0 n.miles in the survey area. Prior to the cruise, several modifications were made including: installation of: a whaling vessel-type observation platform (windshield etc.) on the roof (upper bridge), 7.3m above sea level; an observation barrel or crow's nest just behind the upper bridge, 12m above sea level; a Loran-C repeater in the upper bridge for direct reading of positions; an inter-communication system between the lower and upper bridges, and the upper bridge and barrel; specially designed (by the Sea Mammal Research Unit, UK) angle-boards in the upper bridge and barrel; and a magnetic compass and gyro-compass repeater in the upper bridge. The main mast of *AF*, with antennae and radar auxiliaries, was located behind the upper bridge and did therefore not interfere with forward or side-views.

M/V *Skírnir* ('*Sk*') is a chartered 37.8m, 233Btn, 660HP Icelandic fishing vessel (combined trawler and purse-seiner). *Sk* was equipped with equivalent navigational aids to those on *AF*, apart from the magnetic compass. As anticipated, as on *AF*, some problems were encountered with position fixing near the latitude of the Loran C transmitter station in Snaefellsnes peninsula, West Iceland. This and some malfunctions in the Loran repeater in the upper bridge during part of the survey may have caused inconsistencies in effort and sightings logs. During the first part of the cruise, some distortions caused by iron in the barrel were revealed, which caused errors in estimating the true angles and course of direction, although the ship's course was usually set out with the aid of the Loran navigation system and the auto-pilot instruments. Similar modifications were made to those on *AF*, including installation of an upper bridge (7.5m above sea level) and a barrel positioned immediately behind the bridge (12m above sea level). *Sk*'s normal cruising speed was 9.5–10.5 knots. The forward mast hindered somewhat the forward view from the upper bridge at the immediate track-line, but this did not disturb the view from the barrel.

M/V *Keflvíkingur* ('*Ke*') is also a chartered Icelandic combined trawler/purse seiner. She measures 210 Btn, is 33.9m in length and has a 750HP engine. *Ke* was equipped with a Loran C navigational system and a magnetic compass. Prior to the cruise she had been through similar modifications to the other vessels, including the installation of an upper bridge (7m above sea level) and a barrel mounted in the forward mast, 12m above sea level. The forward mast did, although to an unknown degree, disturb the forward view from the upper bridge. *Ke* had a cruising speed of 9–10 knots under normal searching conditions. Both *Sk* and *Ke* were equipped with extra fuel and water tanks to give them similar endurance to that of *AF*.

M/V *Hvítaklettur* of the Faroes is a combined whaling/fishing vessel, 34.7m in length, measuring 276Btn and has a cruising speed of 10 knots. She had no observation barrel and the observers' eye level was just over 6m (Bloch and Lockyer, 1988).

Crew

Each vessel had a standard crew consisting of the captain, one or two officers, two machinists, one cook and four observers, as well as a scientific crew consisting of a cruise leader and two additional scientists. The captain onboard *Sk* had extensive experience in whale spotting as a former gunner and captain on a commercial whaling vessel. Most observers had also some experience in spotting whales, mainly from earlier whaling activities, although this varied considerably.

The scientific crew (see Appendix 1) had experience in whale research, some with several years of training in whale sighting. The scientific crew consisted of MRI staff, three scientists sponsored by the US government, one from the Institute of Cetacean Research, Japan, and one from the IWC. Prior to the start of the survey a special meeting was held at MRI for all participants to explain and discuss the project in general, and specifically to go carefully through essential parts of the observation procedures. A post-cruise meeting with participating scientists was held at MRI at the end of the survey to discuss preliminary results and to discuss practical problems identified during the conduct of the survey, which need to be taken into account in future surveys.

Observation procedures

Under normal searching conditions the vessels cruised at 8.5–10.5 knots. The predetermined cruise track was followed with some changes (see below) when necessary (new way–points and zig-zag lines set out in accordance with the adopted procedure; see Anon., 1987b; 1987c). Weather permitting (cloud cover and wind speed/sea state) and depending on latitude, searching generally began around 0400–0600hrs and continued until 2200–2400hrs when darkness prevented effective searching. However, in the northernmost areas (North Iceland-Jan Mayen area) onboard *AF*, watch was maintained on a 24-hour basis under ideal conditions (there were fourteen 24-hour searching days out of about twenty effective days on the grounds). Searching was usually abandoned in poor sightability, and crews were instructed to stop searching in Beaufort 4–5 or more or when dense fog prevented searching beyond 1 n.mile from the vessel. However, due to time constraints and a tendency to underestimate the wind speed, searching was often continued when the wind was somewhat in excess of ideal conditions, which may have influenced the probability of detecting both small and large whales.

Onboard *AF* the whole crew worked on fixed six hour shifts starting at midnight; the shifts were not rotated. Onboard *Sk* and *Ke* the crew worked on five rotating shifts, which went from 02, 08, 12, 16 and 20 hrs. Normally, two observers and one scientist were present on each shift; the observers were alternatively on watch (one hour at a time) in the barrel and the bridge. Hence, there was one observer and one scientist in the upper bridge most of the time and one observer in the barrel (sometimes two onboard *Sk*). The officer onboard *Ke*, a trained whale spotter, acted also as 2nd observer on one of the shifts. The cruise leaders on all vessels stayed on watch in the upper bridge on a more opportunistic basis on both shifts (during part of the survey, the scientists onboard *AF* acted also as cruise leaders). Onboard *AF* and *Ke* the captains and officers on duty were located in the lower bridge and made occasional observations. When the captain onboard *Sk* was on duty in the lower bridge (mainly during the day), the officer on duty was on watch as an additional observer in the upper bridge. Due to extensive experience in whale spotting, the captain and officers onboard *Sk* made a significant contribution in terms of number of sightings, although located in the lower bridge, while this was generally not the case on the two other vessels. Some of the sightings thus made were quite close to the vessel and were therefore of great significance to estimates of effective track-width (see Gunnlaugsson and Sigurjónsson, In Press).

The general practise was to search for animals with the naked eye, but binoculars were frequently used, although at somewhat irregular intervals, to scan the more distant areas towards the horizon. The more experienced observers (e.g. ex-whalers) were the more efficient in using binoculars, made the largest number of sightings and some at least appeared to cover a greater effective sighting distance. Observations of all cetaceans were recorded by the scientists on shift during the entire cruise, while logs on weather conditions and effort (including the ship's course) were recorded on an hourly basis by the person in-charge in the lower bridge. All records were kept on specially designed forms approved at the planning meetings (Anon., 1987c).

On first making a sighting, the time of observation, the ship's position (Loran C) and bearing to the sighting (as reported by the person making the sighting, based on the angle board measurement) were noted. The estimated (mainly by eye) distance to the whale was recorded; onboard *AF* and *Ke* the distance sticks were not used, except during the very first days of the cruise, as the scale markings on the sticks were misinterpreted – this appears to have caused some bias in later distance estimations. Onboard *Sk*, distance estimation sticks were frequently used. Information on resightings (i.e. a second observation of the same sighting) was generally recorded onboard *Sk* and *AF* with the position determined to one tenth of a minute (less precision recorded onboard *Ke*). This was generally in good agreement with the estimated distances. When possible, the resighting observations were used to correct the initial distance estimates. The position and initials of the observer initially making the sighting was recorded (the latter information is missing for the *Ke*). Routinely noted for each sighting were species, school size and behaviour.

Ideally, the vessel did not divert from course for confirming sightings, but if necessary due to doubts about number of animals in a school or species identification, the vessel left the track 'off-effort'. After confirming the sighting, the vessel returned back towards the track 'on-effort' under a convenient angle or by an adjusted heading to the next way-point. A combination of passing and closing mode was thus applied. *Sk* generally used delayed closure on large baleen whales if sightability was good and there was little risk that the sighting would be lost. Minke whales were generally passed. *Ke* used direct closing on all large whales, except for the first few days. *AF* used both modes, mainly depending on areas, usually only allowing closure in areas of relatively low large whale density.

Other studies

As a secondary task of the expedition, when not interfering with sightings activities, the crews were instructed to spend some limited effort on obtaining photographs of killer whale dorsal views and the ventral side of humpback whale flukes for individual photo-identification studies.

Whenever possible, killer whales were carefully approached by the vessel and initial efforts were made to determine the number of animals and the pod composition. Weather permitting an inflatable skiff was launched and the whales were approached, counted and photographed (the same methods as described in Sigurjónsson, Lyrholm, Leatherwood, Jónsson and Víkingsson (1988). Photographs are being processed, catalogued and the results will be published in a separate report.

Similarly, when humpback whales were observed and the risk of interfering with sightings activities was judged to be minimal, efforts were made to obtain identifiable photographs of the ventral side of their flukes from the vessels with the same photographic equipment as described above. On several occasions this was attempted, resulting in photos of readily distinguishable flukes. These will be catalogued for comparison with other photographs obtained off Iceland and elsewhere in the North Atlantic.

Scientists were instructed to spend some effort to obtain series of measurements of dive-time information for minke whales, both in shallow and deep waters. The methodology and results are given in Gunnlaugsson (1989).

Onboard *AF* several attempts were made to record acoustically (using floating sonobuoys with VHF transmitter) sounds from both killer whales and Northern bottlenose whales, but with no success.

NARRATIVE

All vessels departed Reykjavík on 24 June 1987. The tracklines for each vessel are shown in Figs 2–8. The names of locations mentioned in the text and the location of the ice-edge during the survey period off East Greenland and North Iceland are shown in Fig. 1.

The *'Arni Fridriksson* surveyed the grounds northwest (Denmark Strait), north and northeast of Iceland twice. She had brief stops in port in Isafjördur (30 June) and Seydisfjördur (14 July) for changing crews. In both cases this did not interfere much with the survey, since the track was close to harbour and weather did not permit searching. On 10 July the vessel came to port in Seydisfjördur for bunkering, refuelling and for resting the crew.

The searching conditions were generally good or adequate, and the planned cruisetrack was by and large completed. Ice-coverage in the northwestern and northern grounds was somewhat less than anticipated in the original plans, requiring subsequent adjustments of the cruisetrack. At the time of the survey, the exact location of the ice-edge was not known. The northerly legs towards the ice-edge were thus extended until the ice was located and the way–points were then adjusted accordingly.

After spending several hours on dive-time experiments in Breidafjördur and Faxaflói (SW Iceland), *AF* returned to Reykjavík on 28 July.

The *Skírnir* covered the area west of Iceland (the traditional large whaling grounds), the Irminger Sea and the East Greenland coast twice. She came once (July 9–12) into port in Reykjavík for bunkering, refuelling and a change of crew. As densities were unexpectedly low in the southernmost area off East Greenland in the first half of the cruise, *Sk* did not survey that part of the deep waters east of Greenland in the latter half of the survey as originally planned. Instead an attempt was made to increase the total coverage at the Greenland coast.

Generally, the searching conditions were favourable during the first half of the survey, except for a few hours. During the second half, fog and rain prevented searching for parts of days and during 24–25 July searching was abandoned due to strong winds. *Sk* returned to Reykjavík on 28 July.

The *Keflvíkingur* came twice (7 and 18 July) to port due to shortage of water and for refuelling, in both cases to Höfn, southeast Iceland. The vessel completed most of its scheduled track south and southeast of Iceland. Unfortunately, time constraints did not allow the high density areas west of Iceland to be covered, thus no overlapping with the area covered by the other vessels occurred.

The searching conditions were least favourable in the *Ke* survey area, especially during the first half of the cruise (25 June to 4 July), when the vessel repeatedly stopped surveying for prolonged periods due to both strong winds and poor visibility. The vessel returned to Keflavík on 27 July after completing a series of dive-time experiments earlier the same day off the Reykjanes peninsula and in Faxaflói, southwest Iceland.

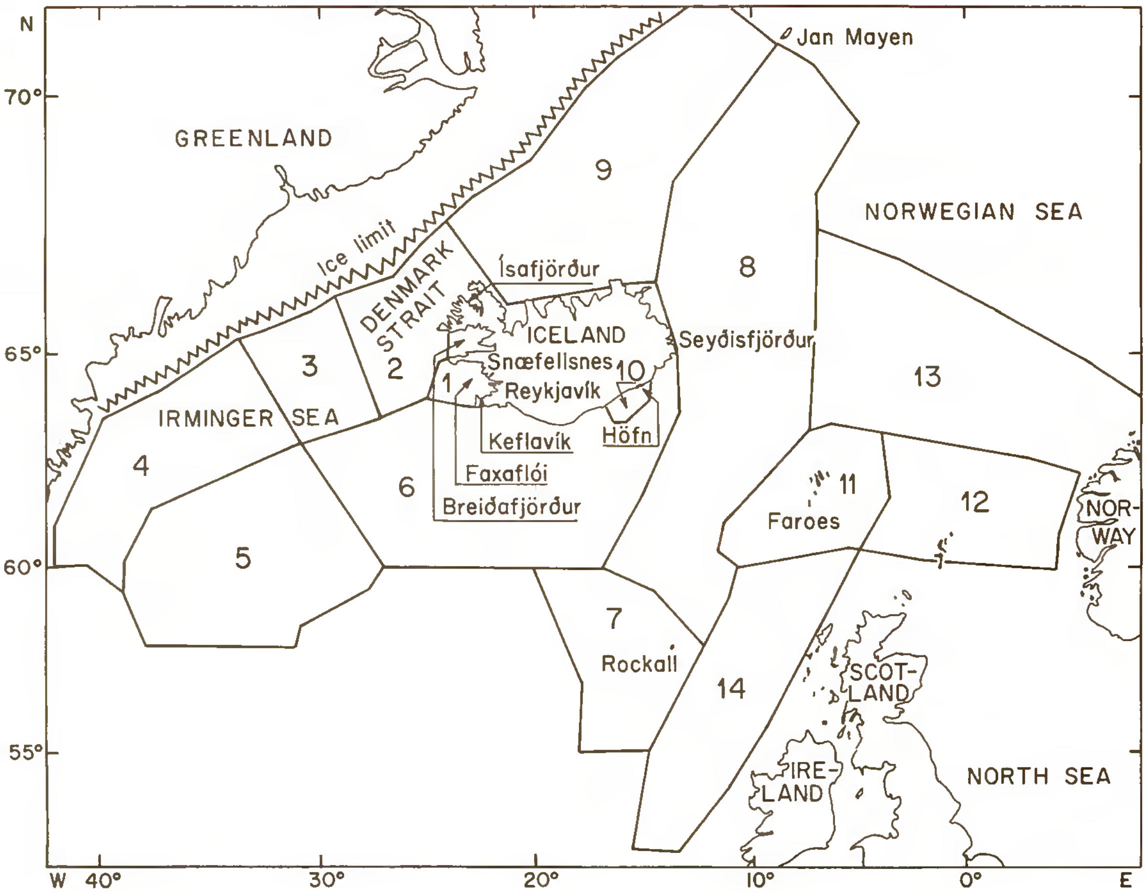


Fig. 1. Division of survey areas into geographical blocks covered by the three Icelandic sightings vessels during 24 June through 28 July 1987 and one Faroese vessel during June-August 1987, with location names mentioned in text.

RESULTS

Survey area

The *AF*, *Sk* and *Ke* completed 3,991, 3,612 and 4,183 n.miles of effective searching, respectively, giving a total of 11,786 n.miles. Table 1 gives the distance cruised in each of the 14 geographical blocks surveyed by the three Icelandic vessels and the Faroese one. The blocks were defined afterwards into strata of approximately even coverage (see Gunnlaugsson and Sigurjónsson, In Press). The geographical blocks surveyed by the Icelandic vessels covered approximately the following areas:

Block 1: Faxaflói, SW Iceland; covered by all vessels.
Block 2: E Denmark Strait, NW Iceland; covered by *AF* and *Sk*.
Block 3: NW Denmark Strait towards the ice edge; covered by *Sk* and *AF*.
Block 4: E Greenland coast; covered by *Sk*.
Block 5: Irminger Sea; covered by *Sk*.
Block 6: Deep SW and S Icelandic waters; covered by *Ke* and partly *Sk*.
Block 7: Waters west of the British Isles and Ireland (Rockall area); covered by *Ke*.
Block 8: Deep SE to NE Icelandic waters to Jan Mayen, Iceland-Faroe Islands Ridge to the ice edge; covered by *Ke* and *AF*.
Block 9: N Icelandic waters; covered by *AF*.
Block 10: Coastal SE Icelandic waters; covered by *Ke*.

Table 1

Block areas (B), track lengths and average inter-track distances (area/track) for all survey vessels (see also text and Fig. 1). T = Total, Hv = *Hvitaklettur*

B	Sq. miles	Sk	AF	Ke	Density	B	Sq. miles	Hv	Density
Icelandic vessels						**Faroese vessel**			
1	3,870	164.2	116.4	88.5	10.5	11	29,609	2,274.3	13.01
2	21,622	148.6	910.0	-	20.4	12	40,400	796.7	50.70
3	18,030	420.9	375.3	-	22.6	13	69,381	1,232.7	56.28
4	34,854	1,228.4	-	-	28.4	14	73,465	1,303.8	56.35
5	75,697	1,009.2	-	-	75.0	T	212,855	5,607.5	
6	87,267	640.7	-	1,634.0	38.4				
7	45,378	-	-	917.1	49.5				
8	105,206	-	1,540.9	1,225.9	37.6				
9	51,236	-	1,056.5	-	48.5				
10	1,611	-	-	78.2	20.6				
11	7,591	-	-	209.0	36.3				
T	452,362	3,612.0	3,991.1	4,182.7					

Average group size

Table 3 gives the average group sizes (of primary sightings) for each of the large and medium sized species. The coefficient of variation (CV) was obtained by fitting a scaled Poisson model to G-1. The coefficient of variation for group size was then calculated by multiplying with (G-1)/G. This model fitted well and gives substantially smaller CVs in all cases where G is small. However, for killer whales this model gave a very poor fit and the CV given in the table is calculated from the direct or equally the logarithmic average.

Geographical distribution of sightings

Table 2 gives the total number of primary and secondary sightings by species and vessel. Tables 4–11 and Figs 2–8 give the geographical distribution of primary sightings of the large whale species and Northern bottlenose, minke and killer whales. (Pilot whales are dealt with by Bloch *et al.*, 1989; other smaller odontocete species will be dealt with in separate papers).

Table 2

Total sightings and animals of all cetacean species observed during Icelandic/Faroese vessel surveys June–August 1987. For each species, first line gives primary sightings, second line secondary sightings. AF = R/V *Arni Fridriksson*; Sk = M/V *Skirnir*; Ke = M/V *Keflvikingur*; Hv = *Hvitaklettur*; s = number of sightings; a = number of animals

	Vessels									
Species	AF-s	AF-a	Sk-s	Sk-a	Ke-s	Ke-a	Hh-s	Hv-a	Sightings	Animals
Fin	64	110	156	250	27	42	18	28	265	430
	11	14	16	29	1	1	1	2	29	46
Sei	4	8	20	39					24	47
	1	1	8	12					9	13
Blue	5	9	7	11	4	6			16	26
	2	4	7	10	1	1			10	15
Humpback	51	86	18	30	5	8			74	124
	9	15	6	8					15	23
Right			1	1					1	1
Sperm	27	36	28	31	24	25	12	20	91	112
	6	8	2	2	2	6	1	1	11	17
Unid. large whales	1	1	20	22	1	1	2	2	24	26
	1	1	6	8					7	9
Northern bottlenose	47	107	20	61	19	53	6	16	92	237
	2	4	4	12	1	2	2	3	9	21
Killer	11	109	3	16	7	32	4	42	25	199
	2	16			1	4	1	2	4	22
Minke	73	76	43	50	53	58	28	31	197	215
	8	10	6	6			1	1	15	17
Beaked			2	10	2	4	2	7	6	21
Pilot	5	45	36	1,275	30	422	21	2,457	92	4,199
	6	60	2	12	3	20	2	146	13	238
Unid. med. sized whales	5	5	1	1			5	5	11	11
Dolphin spp.	49	286	15	105	147	750	34	550	246	1,691
	11	64	5	26	1	10	5	88	21	188
Unid. dolphins	19	84	91	924	14	91	27	143	151	1,242
	4	17	3	39			3	12	10	68
Harbour porpoise	19	32	8	20	20	34	30	52	77	138

Table 3

Average group size of primary sightings. Coefficient of variation by Poisson model, except for killer whales (c.f. text)

Species	Group size	CV	Species	Group size	CV
Blue	1.625	0.110	Humpback	1.676	0.051
Fin	1.623	0.033	Sperm	1.165	0.030
Sei	1.958	0.112	N. bottlenose	2.570	0.055
Minke	1.089	0.014	Killer	7.913	0.170

Table 4

Fin whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a	Block	Hv-s	Hv-a
1							0	0	11	4	4
2					1	1	1	1	12	2	2
3	20	38			85	131	105	169	13	5	8
4					47	73	47	73	14	7	14
5					5	7	5	7	Total	18	28
6			20	27	18	38	38	65			
7			3	9			3	9			
8	43	71	4	6			47	77			
9	1	1					1	1			
10							0	0			
11							0	0			
Total	64	110	27	42	156	250	247	402			

Table 5

Sei whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a
1							0	0
2	3	5					3	5
3					1	1	1	1
4					6	10	6	10
5					11	25	11	25
6					2	3	2	3
7						0	0	
8	1	3					1	3
9							0	0
10							0	0
11							0	0
Total	4	8	0	0	20	39	24	47

Table 6

Blue whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a
1	1	1					1	1
2					1	1	1	1
3	1	1			2	3	3	4
4							0	0
5					1	2	1	2
6			4	6	3	5	7	11
7							0	0
8	3	7					3	7
9							0	0
10							0	0
11							0	0
Total	5	9	4	6	7	11	16	26

Table 7

Humpback whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a
1					1	1	1	1
2	24	38			6	10	30	48
3	3	4			8	15	11	19
4							0	0
5							0	0
6			1	2	3	4	4	6
7							0	0
8	19	34	1	1			20	35
9	5	10					5	10
10			3	5			3	5
11							0	0
Total	51	86	5	8	18	30	74	124

Table 8

Minke whale primary sightins (and total animals(by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a	Block	Hv-s	Hv-a
1	22	22	33	35	23	27	78	84	11	12	14
2	22	22			1	1	23	23	12	5	5
3	9	10			8	10	17	20	13	7	8
4					8	9	8	9	14	4	4
5							0	0	Total	28	31
6			8	9	3	3	11	12			
7							0	0			
8	11	13					11	13			
9	8	8					8	8			
10			12	14			12	14			
11							0	0			
Total	73	76	53	58	43	50	169	184			

Table 9

Sperm whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a	Block	Hv-s	Hv-a
1							0	0	11	7	11
2	16	24			1	1	17	25	12	1	3
3	5	6			2	2	7	8	13	1	1
4					15	17	15	17	14	3	5
5					9	10	9	10	Total	12	20
6			9	9	1	1	10	10			
7			4	4			4	4			
8	1	1	11	12			12	13			
9	5	5					5	5			
10							0	0			
11							0	0			
Total	27	36	24	25	28	31	79	92			

Table 10

Northern bottlenose whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a	Block	Hv-s	Hv-a
1							0	0	11	1	5
2							0	0	12	1	2
3	2	6			7	19	9	25	13	4	9
4					4	10	4	10	14		
5					1	3	1	3	Total	6	16
6			4	11	8	29	12	40			
7			1	2			1	2			
8	43	98	14	40			57	138			
9	2	3					2	3			
10							0	0			
11							0	0			
Total	47	107	19	53	20	61	86	221			

Table 11

Killer whale primary sightings (and total animals) by geographical blocks (see Fig. 1) and vessels, and Icelandic vessels combined (Icl). Same abbreviations as in Table 2

Block	AF-s	AF-a	Ke-s	Ke-a	Sk-s	Sk-a	Icl-s	Icl-a	Block	Hv-s	Hv-a
1							0	0	11	3	27
2	1	4					1	4	12	1	15
3	1	5					1	5	13		
4							0	0	14		
5					1	4	1	4	Total	4	42
6			2	4	2	12	4	16			
7							0	0			
8	6	71	5	28			11	99			
9	3	29					3	29			
10							0	0			
11							0	0			
Total	11	109	7	32	3	16	21	157			

In all 1,340 sightings (of which 1,203 were primary sightings) were made onboard the three Icelandic vessels, of an estimated 5,788 whales (5,366 primary). Including the Faroese sightings, the total was 1,545 sightings (1,392 primary) of 9,396 whales (8,719 primary). Onboard the Icelandic vessels 166 of the sightings (152 primary) or 1,194 whales (1,129 primary) were of unidentified species; adding the Faroese sightings the numbers are 203 sightings and 1,356 animals. Thirty-one sightings (35 animals) were of unidentified large whales, mainly recorded onboard the *Sk* in the high density areas between Iceland and Greenland. Eleven sightings of the same number of animals were recorded as unidentified medium sized whales, while far the greatest number of sightings (161) and animals (1,310) in this category were unidentified dolphins. This was particularly so in the areas of high density of large whales, where the vessels operated in

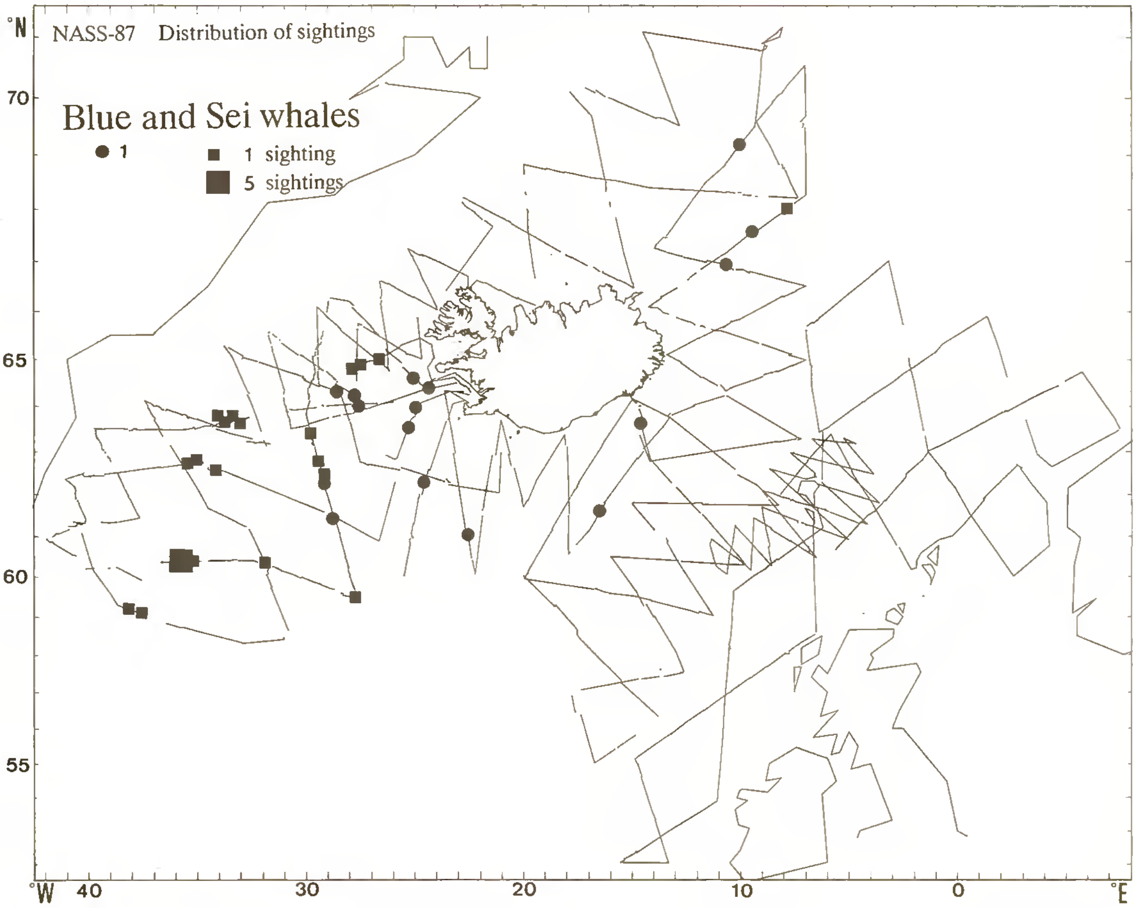


Fig. 2. Distribution of blue (circles) and sei (boxes) whale sightings during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

passing/delayed-closure mode and the species identity could thus not always be confirmed. In the following account of species, the numbers given refer to primary sightings, unless otherwise stated. The reader is referred to Table 2 with respect to the total number of sightings (primary and secondary) for each species. The distribution of sighting distances for each species is given in Gunnlaugsson and Sigurjónsson (In Press).

Right whale sighting

A single right whale (*Eubalaena glacialis*) was encountered onboard *Sk* on 5 July west off Iceland at 63°15′N, 32°30′W (Fig. 4). The whale appeared to be feeding. Although the animal showed no strong reaction to the vessel, it was difficult to confirm its identification because of severe weather conditions. Fortunately, photographs of the animal were obtained and confirm the species identity.

Blue whales

A total of 16 sightings of 26 blue whales was recorded during the survey (Fig. 3). All were seen onboard the Icelandic vessels, north of 61°N, mainly in shallow and deep waters west and southwest of Iceland. Whales accompanied by calves were observed on 25 June at 62°17′N, 24°32′W and on 25 July at 62°52′N, 39°09′W (secondary sighting). Of all sightings made (including secondary sightings), only two were of groups of more than two whales, the remainder being equally divided between solitary animals and pairs. The average group size was 1.6.

Fin whales

The fin whale was the most widely distributed and abundant large whale species recorded in the survey. A total of 247 primary sightings (402 animals) was made onboard the Icelandic vessels, of which 105 were recorded in Block 3 west of Iceland, with substantial numbers also found in Blocks 4, 6 and 8, i.e. southwest of Iceland, off Greenland and northeast of Iceland (Fig. 3). In addition 18 sightings (28 animals) were observed from *Hvítaklettur* around the Faroes and in the northern North Sea, and off the coasts of the British Isles and Ireland.

Thirteen fin whale calves were recorded (all as primary sightings) either as mother/calf pairs (8) or calves accompanied by two adult animals (5). The calves were observed off East Greenland (2), in the Denmark Strait or in the southern Irminger Sea (5), around Jan Mayen (2), deep south and southeast of Iceland (3) and deep west of Scotland (1). The average school size of all sightings (secondary included) was 1.6 with 59% recorded as singles, 27% as pairs, 9% as groups of three and 5% as groups of four or more. The largest recorded group size was seven.

Sei whales

A total of 24 sei whale sightings of 47 animals was recorded during the survey, all from the *Sk*. The sei whale was the baleen whale species least often encountered apart from the blue and right whales. It had a very restricted distribution in the Irminger Sea with two additional sightings northeast of Iceland (Fig. 2). Five sei whale

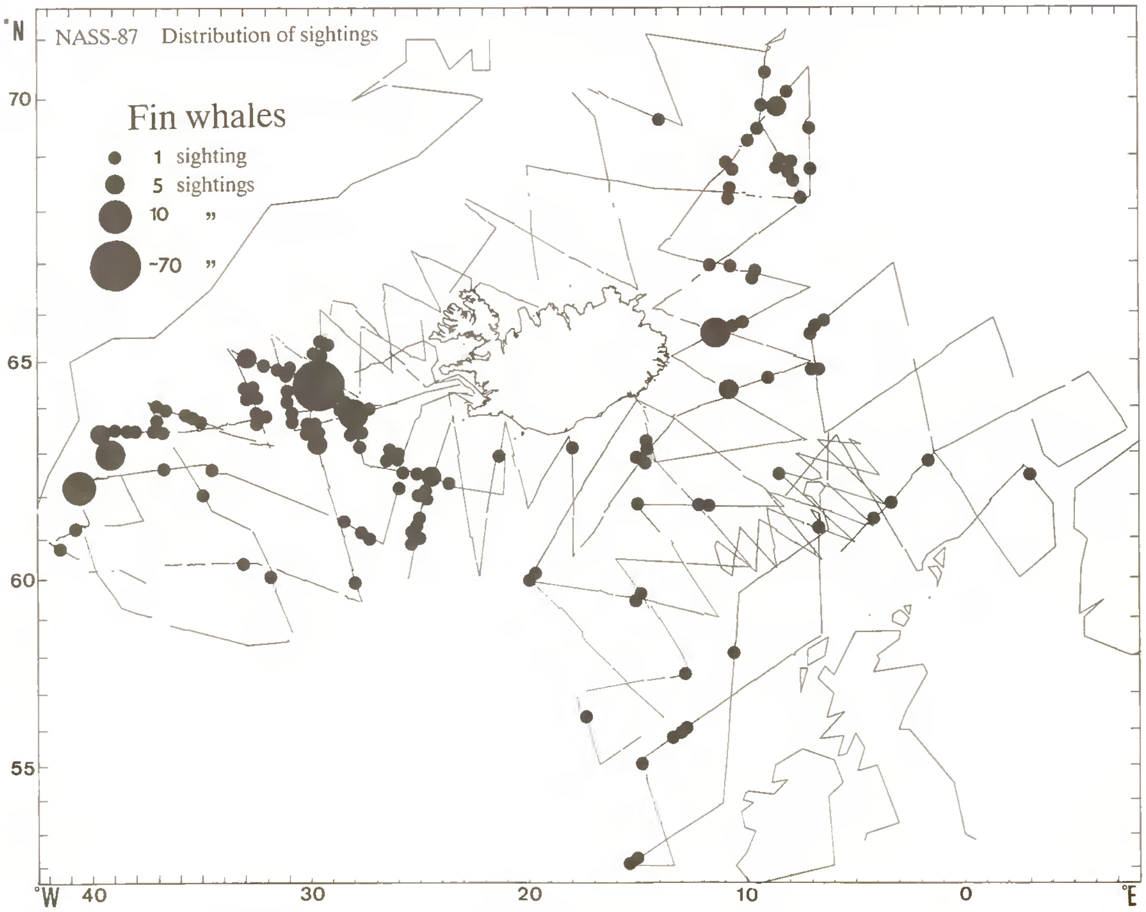


Fig. 3. Distribution of fin whale sightings during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

females (including 1 secondary sighting) accompanied by a calf were observed. Of all sightings, 14 were of single animals, 12 of pairs, 6 of three animals in a group and 1 of four animals, the average being 2.0.

Humpback whales
The humpback whale was the second most common large whale species (Fig. 4) with a total of 74 sightings made of 124 animals. All except one were encountered in the Denmark Strait and all around Iceland, except off the southern coast. A solitary animal was seen deep west of Scotland. Humpbacks occurred usually as singles (48%), as pairs (40%) or in groups of three (10%); only one group of four or more was recorded. The average group size was 1.7. Six of the pairs were of a mother and a calf and an additional calf was observed in a group of three. Three of the calves were observed west of Iceland, three at the continental edge east of Iceland and one was seen towards the ice edge deep to the north of Iceland.

Minke whales
A total of 184 animals (169 sightings) was seen from the Icelandic vessels; 31 were seen from the Faroese vessel. The sightings were mainly made on the banks relatively close to the shore (Fig. 5), especially in Faxaflói, western Iceland (Block 1). The species was also found in significant numbers deeper offshore in the Denmark Strait, off Jan Mayen, around the Faroes and into the southern Norwegian Sea. Only a few animals were encountered in other areas surveyed.

Minke whales were mostly encountered as single animals (92% of all sightings), 7% as pairs of animals and only one sighting of three or more animals. The average school size was 1.1 animals. The only calf recorded was seen in a group of three whales in shallow waters northeast of Iceland.

Sperm whales
Sperm whales (Fig. 6) were widely and evenly distributed in offshore areas and seen onboard all vessels. A total of 112 whales was seen in 91 sightings, mostly as solitary animals (80%) or pairs (17%). The largest group contained five whales. The average group size was 1.2 animals.

Northern bottlenose whales
Significant numbers (92 sightings; 237 whales) of this species were recorded onboard all vessels (Fig. 7). They usually (82% of all sightings) occurred in small groups (average 2.6 animals) of 2–5 animals; single animals represented 16% of total sightings. The largest group recorded contained ten whales. Most sightings were made at and off the shelf edge east and west of Iceland and around the Faroes, with fewer animals seen west of Scotland. All sightings were made north of 60°N.

Killer whales
Killer whales (Fig. 8) were seen from all survey vessels and a total of 25 sightings (199 whales) was made. They were found in both deep and shallow waters north of 60°N. The average group size was 7.9 (range 1–20). Calves were observed in six of the encounters, totalling 9 animals.

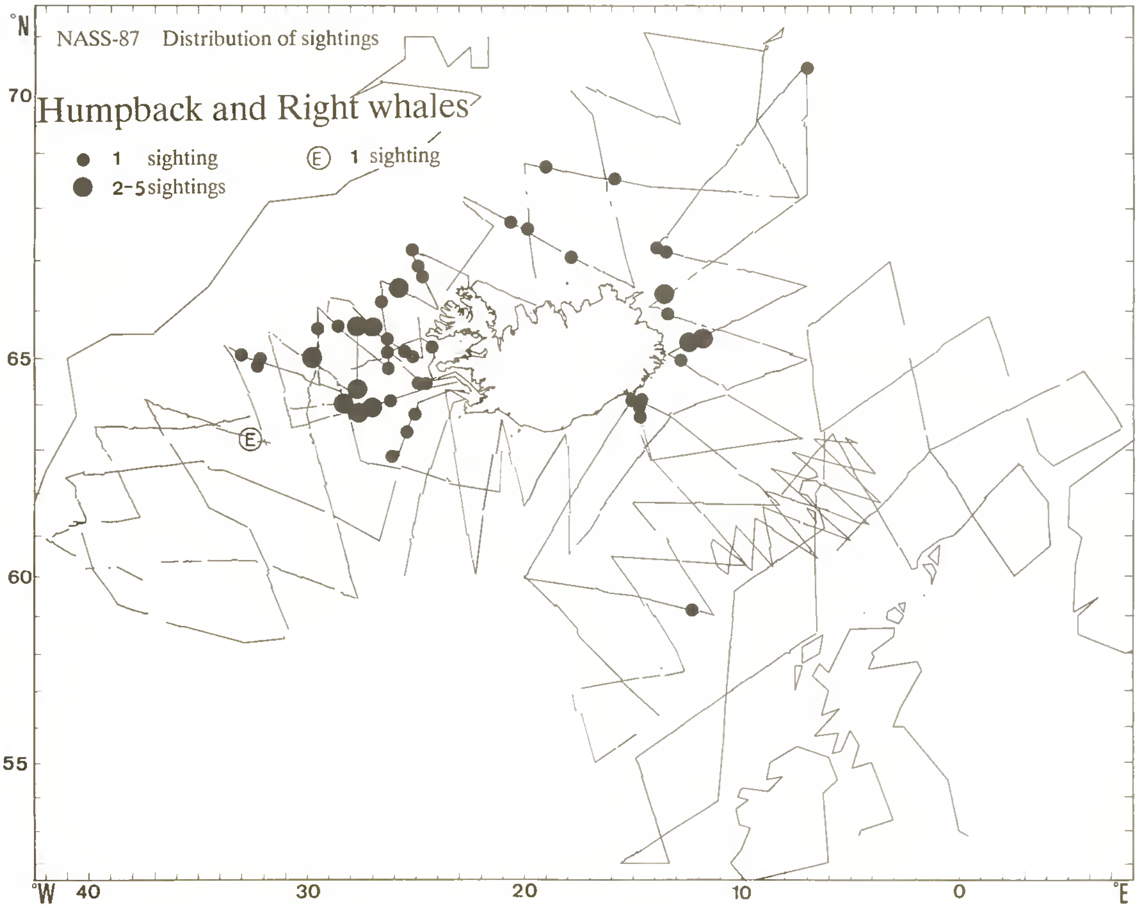


Fig. 4. Distribution of humpback whale sightings (circles) and the position of a single Biscayan right whale (E) sighting during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

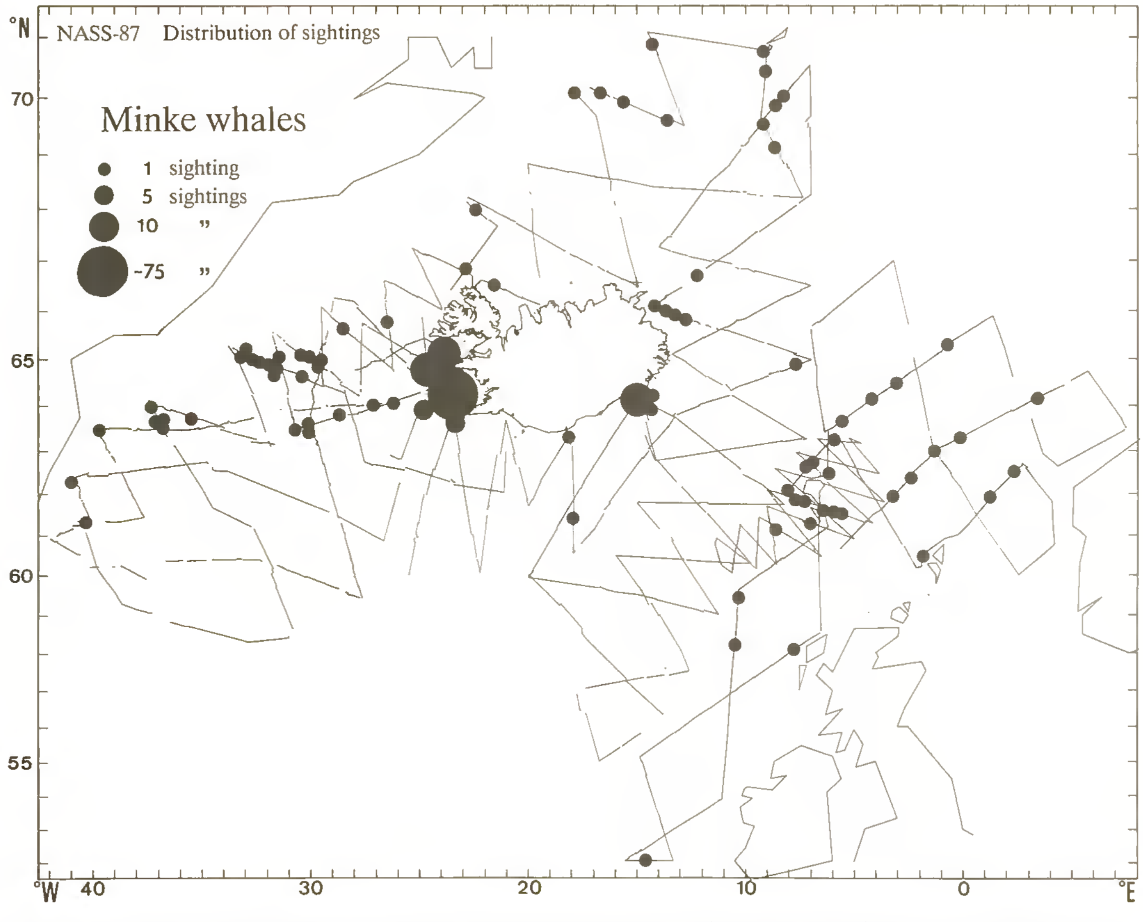


Fig. 5. Distribution of minke whale sightings during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

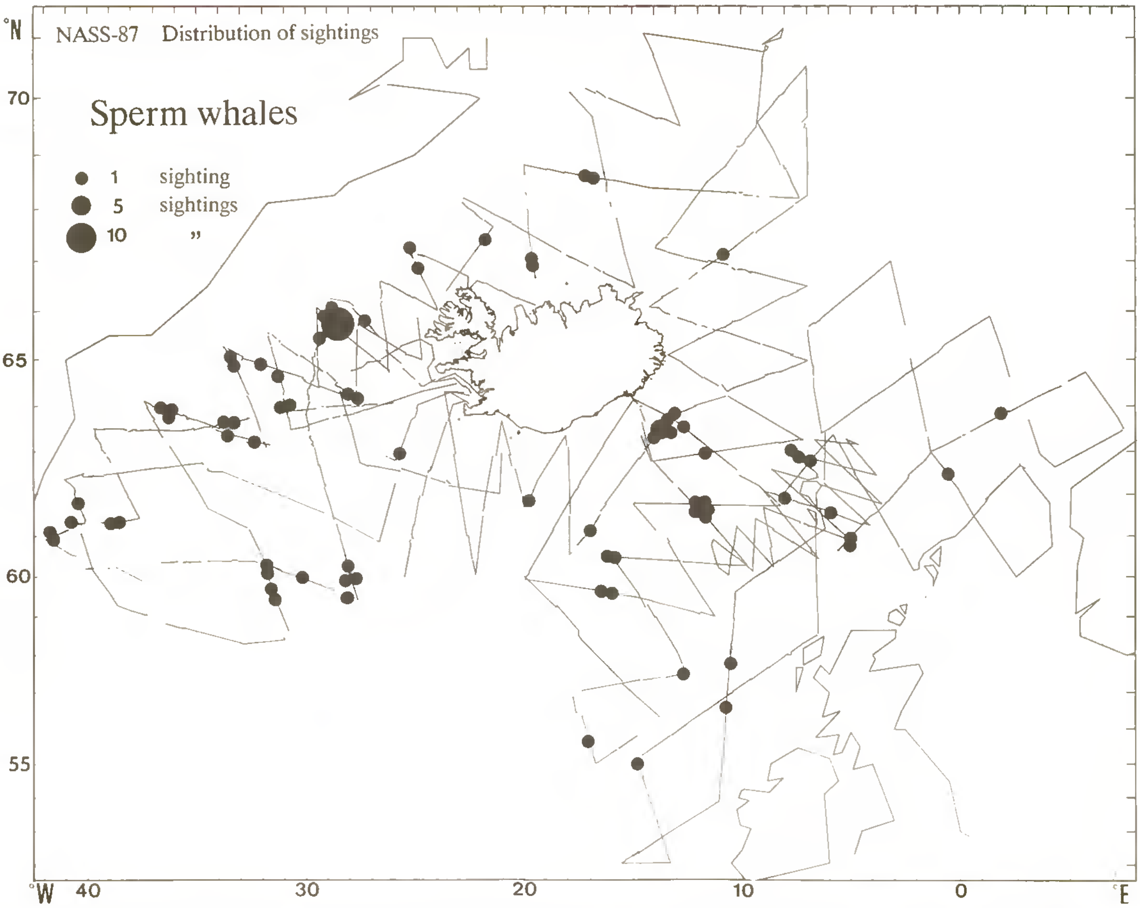


Fig. 6. Distribution of sperm whale sightings during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

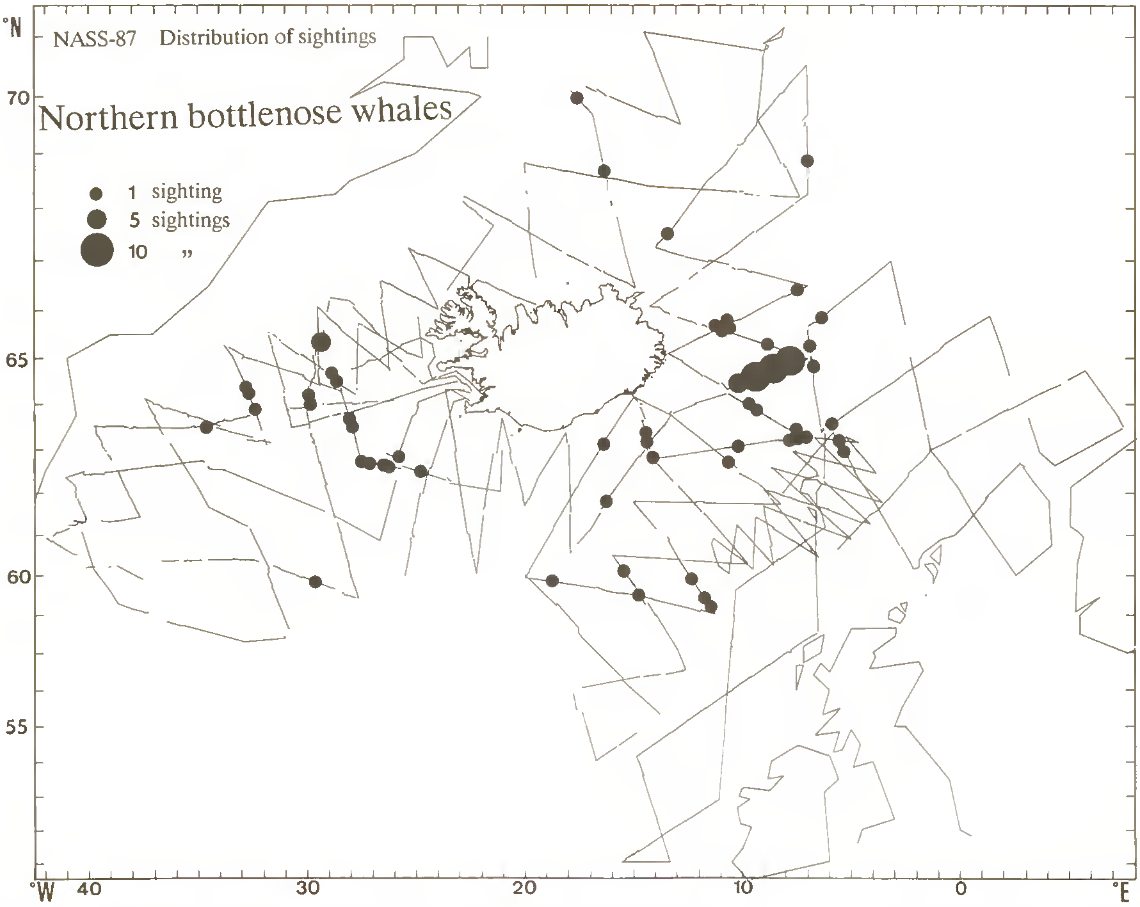


Fig. 7. Distribution of Northern bottlenose sightings during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

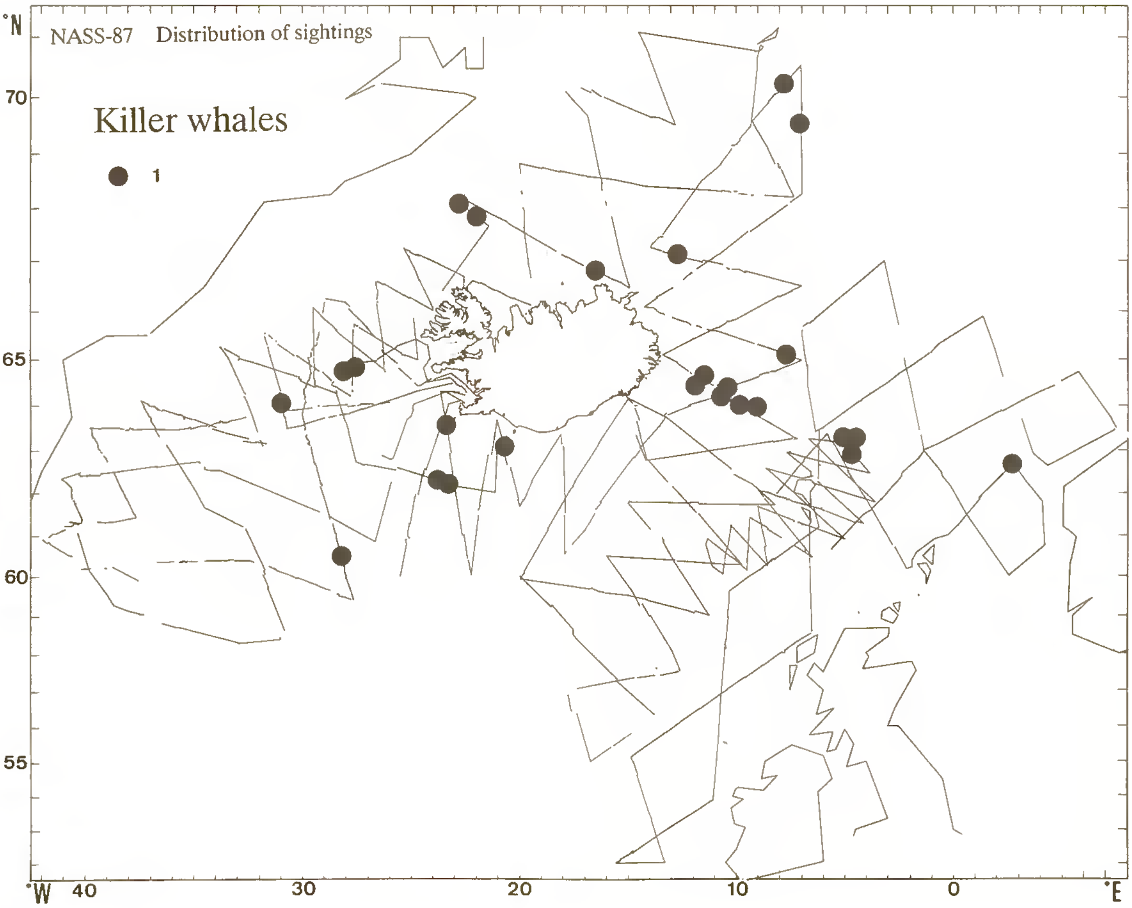


Fig. 8. Distribution of killer whale sightings during vessel surveys June-July (Icelandic vessels) and June-August (Faroese vessel) 1987.

Other small odontocetes
Other odontocete species that were encountered during the survey onboard the Icelandic vessels were pilot whales (72 primary sightings of approximately 1,742 animals), Sowerby's beaked whales (*Mesoplodon bidens*), white-beaked dolphins (*Lagenorhyncus albirostris*), Atlantic white-sided dolphins (*L. acutus*), bottlenosed dolphins (*Tursiops truncatus*) and harbour porpoises (*Phocoena phocoena*). Dolphins were far the most numerous group of animals observed comprising 336 sightings of approximately 2,240 animals. The most abundant species were Atlantic white-sided and white-beaked dolphins, which along with other dolphin species showed marked geographical distribution. However, a large proportion of the sightings were not positively identified as noted earlier. These and other observations made on small odontocete whales will be reported in a separate report.

DISCUSSION

Methodology

There are a number of practical aspects of the conduct of a large scale sightings survey that should be considered in the future planning of similar surveys. These have been addressed by the NASS-87 joint planning and post cruise meetings (Anon., 1987b; 1987c; 1988) and include: the importance of a convenient platform for making observations, at least 10–12m above sea level; the importance of simple but precise measuring tools for estimating distances and angles to whales when first seen; and data sheets that are easily understood by the many individuals of different nationalities that participate in the survey.

However, having well trained observers and scientists onboard participating vessels is perhaps the single most important factor in the successful completion of any survey. Even with well trained observers, though, priorities in work must be identified. For example in the present study, most observers were experienced whalers. As such they may have had search strategies that do not entirely conform with the basic assumptions of line-transect theory. We noted for example that when the sun was at a low angle and there was a place at the horizon where blows were likely to be seen at great distances, the typical whaler tended to concentrate at an angle of about 60° towards the glow; in fact, an experienced whaler would tend to sail in that direction to maximize the probability of detecting any animal under these otherwise difficult sightings conditions. While the blow visibility could be good at a distances of 1–6 n.miles following this strategy, it could be limited to within only a narrow band in other directions. If the importance of concentrating searching on the trackline is not emphasised, the above searching strategy would lead to a very wide and incorrect estimate of the effective track width.

In the survey area west of Iceland, where a choice existed it was preferred to head east in the morning and west in the evening. This could sometimes be accomplished by using the night hours for transit. In general, more flexibility in choosing a heading should be considered in the conduct of surveys and one should not hesitate to change the course of the vessel if there are good possibilities of avoiding fog or rain patches. Nevertheless, surveying during 'night' hours should probably not occur unless the track happens to be in the optimal sightability direction.

Distribution and abundance

The relative abundance of minke whales in the coastal waters of Iceland in 1987 (see also Donovan and Gunnlaugsson, 1989) seems similar to that found in the 1986 aerial survey (Gunnlaugsson *et al.*, 1988). The distribution of minke whale sightings in both aerial and vessel surveys show high densities in the Faxaflói region and in nearshore waters southeast of Iceland as would be anticipated from earlier surveys. As shown by Sigurjónsson (1982), the main catches by Icelandic small-type whalers have, however, occurred mainly in northwest and northern Icelandic coastal waters. The sightings in the Denmark Strait, off East Greenland and around Jan Mayen indicate significant numbers of animals there, although far less than in the nearshore areas mentioned above. No animals were observed in the deep waters of the Irminger Sea, and only one sighting was recorded off the south coast of Iceland. The lack of sightings in the Iceland/Faroe ridge area, i.e. at the stock boundary of the Central and Northeastern Atlantic minke whale stocks is also noteworthy.

Earlier shipboard surveys (although primarily aimed at whale marking), concentrating on the traditional whaling grounds west off Iceland, i.e. at the continental edge to the 2,000m depth contour, and the East Greenland coast north to and inclusive of the Denmark Strait (Christensen, 1977; Sigurjónsson, 1983; Martin *et al.*, 1984), have shown significant numbers of fin whales, as was the case in 1987. However, these surveys have not covered sufficiently shallow waters around Iceland, or other deep Icelandic waters. The present material demonstrates significant numbers of this species northeast of Iceland, around Jan Mayen and outside the continental shelf east of Iceland. This is of special interest with regard to earlier exploitation of fin whales at the turn of the century, when a substantial fishery took place in these areas in the early season (Sigurjónsson, in prep.; Gunnlaugsson, Magnússon and Sigurjónsson, 1989). The sightings made onboard Norwegian survey vessels in 1987 (Øritsland *et al.*, 1989) show a somewhat continuous distribution of fin whales in the area east of Jan Mayen. The present July observations west of Ireland and Scotland add to Evans' (1980) August-October sightings in the same areas.

The present material also shows the wide distribution of humpback whales in both coastal and deep Icelandic waters. The number of sightings made and the resulting abundance estimate (Gunnlaugsson and Sigurjónsson, 1988) suggest an apparently healthy stock in the survey area as indicated by earlier surveys (Sigurjónsson, 1983; Martin *et al.*, 1984). No humpback whales were observed off East Greenland, although Christensen (1977; 1980) noted a few animals in this area in his review of whale observations from Norwegian platforms in the 1970s and Sigurjónsson (1985) reported a single sighting in August 1983. The single sighting deep northwest off Scotland and absence of sightings in shallower British waters, confirm Evans' (1980) conclusion of the scarcity of this species in British waters.

While blue whales were encountered over a relatively wide area, their numbers are considerably lower than for humpback whales. This casts some doubt on their apparently more frequent occurrence on and *en route* to the whaling grounds west of Iceland shown by records kept regularly onboard the whaling vessels (Sigurjónsson, 1983). An alternative explanation may be, as also suggested by observations made in 1981, that the onset of the blue whale migration into the survey area is somewhat later in the season. A more thorough analysis of the whaling vessel sightings records may elucidate this question to some extent. Christensen reports only one sighting of blue whale east of Greenland during 1971 to 1978 (Christensen, 1977; 1980). Our single July primary sighting reconfirms the low density of this species in these waters. Evans (1980) noted that no blue whales have stranded on the coasts of the British Isles since 1923, and that no definite sightings have been recorded in recent years, both of which concur with the absence of blue whales in that area in the summer of 1987.

It is evident that the survey period chosen (mainly with respect to fin and minke whales) did not capture the peak abundance of sei whales in the Denmark Strait (Rørvik, Jónsson, Mathisen and Jonsgård, 1976; Martin, 1983). Therefore, the present survey did not cover the entire summer range of the Iceland/Denmark Strait stock of sei whales, although the stock size may be considerably lower than that of the fin whale stock in the area. However, it is interesting to note that most of the sightings in the Irminger Sea and west of Iceland were made in the latter part of July, i.e. during the second zig-zag of the vessels through the area, while only a few sightings were made in the first sweep at the southern boundary of the survey area. This indicates that the animals were starting to move into the area and supports Sigurjónsson's (1983; 1985) suggestion that the species migrates along the deep waters from the southwest, when approaching the whaling grounds, typically in late July and August. This, and the fact that the only sei whales encountered east of 27°W, were those sighted south of Jan Mayen, shows that future planning of surveys for this species needs either to be expanded far more to the south or take place later in the season, or both.

The sightings of sperm, Northern bottlenose and killer whales can give rise to a first approximation of stock sizes of these species in the area (Gunnlaugsson and Sigurjónsson, In Press). However, due to the well known deep diving behaviour of both sperm and bottlenosed whales, the numbers observed give only an indication of actual numbers. The Northern bottlenose sightings were especially numerous off the continental edge east of Iceland, at the southern border of one of the main catch grounds of the Norwegian operation earlier this century (Jonsgård and Øynes, 1952; Benjaminsen and Christensen, 1979). Although a number of sightings were made deep south and southeast of Iceland, no animals were seen south of 59°N. Most sightings and strandings of this species off Britain occur in August-September, which Evans (1980) relates to the southward migration that begins in July according to Risting (1922).

For the killer whale, the survey reveals a widely distributed summer population, as one would have assumed from Norwegian catches in the 1960s (Jonsgård and Lyshoel, 1970; Øien, 1988), with an apparent absence of the strong coastal affinity found in recent years in East Icelandic waters while herring (*Clupea harengus*) aggregates in the area in autumn and winter. The winter aggregations in that area have been estimated to number in the low hundreds (Sigurjónsson, 1984; Sigurjónsson *et al.*, 1988). This would seem, based on the present data, to be only a fraction of a much larger stock. The occurrence of killer whales is also well known for East Greenland waters (Øien, 1988; Heide-Jørgensen, 1988) to the south of Cape Farvell (Reeves and Mitchell, 1988), around the Faroes (Bloch and Lockyer, 1988) and in British and Irish waters (Evans, 1980; 1988; Hammond and Lockyer, 1988) and also south of 60°N and east of 30°W, where no observations were made in the present survey.

The exceptional record for the Irminger Sea (and even the entire northeast Atlantic) of a Biscayan right whale (see review by Brown, 1986), demonstrates quite well the general scientific value of a large synoptic survey such as the NASS-87. The last reliable record of this species off Iceland was of a single animal sighted near the coast in North Iceland in early 1971, at approximately 66°05′N, 17°30′W (Sigurjónsson, unpubl. data). Two earlier, but perhaps less reliable, records of sightings of the species after the end of the large whale operations off Iceland in 1915, were north and northwest of Iceland in the mid 1930s and late 1950s, respectively. The animal seen during the survey seems therefore to be one of a very few individuals inhabiting these waters, or it may be a straggler from the more numerous population in the western North Atlantic.

Proportions of calves

Although calves were recorded when seen, it must be kept in mind that not all sightings were closed on. Since calves are often far less detectable at the surface than adults, some may have been missed, particularly of the smaller species. This may have also been the case for minke whales, although the single minke whale calf recorded may also suggest that only exceptionally can one expect to find mother/calf pairs at this time of the year in these latitudes. Most minke whales may simply have weaned at this point of their reproduction cycle or, alternatively, the mother may not enter the higher latitudinal waters until the calf is weaned. Jonsgard's (1951) suggestion of 4–5 months period of suckling after a peak frequency of births in January, would result in most calves being weaned in late June-July, i.e. at the time of the 1987 survey.

For the larger baleen whales, the risk of not seeing calves is probably less of a problem and the observations made on the calf/total animals ratio are worth considering. The 13 fin whale calves recorded during primary effort are a significantly higher proportion (3%) of the total than that of the minke whales; this compares well with Sigurjónsson's (1983) figure of 3.1% in June-July 1981 in the grounds off west Iceland. For humpback whales, the proportion is 4.8% (6 calves); 8.5% of sei whales classed as primary sightings were calves. Although the sei whale sample obviously is small, the relatively high proportion for that species may be attributed to its more southerly distribution and possible segregation by reproductive class.

Group size

An inherent problem in estimating group sizes of many of the whale species in the present study is the question of defining what a school is. The problem is often more difficult in the case of baleen whales, which typically occur in loose aggregations in contrast to some of the small odontocete species. In judging what a school was, we tried to determine which animals were actually swimming together and these were taken as a separate school.

The estimates given in Table 3 are based on averages of all primary sightings. The results seem to be quite similar to earlier surveys in these waters, although the present estimate for fin whales (1.6) is somewhat lower than the 2.5 in 1981 (Sigurjónsson, 1983) and 3.1 in the 1982 survey (Martin *et al.*, 1984). In both earlier surveys the main objective was marking, which may have influenced the results. The group sizes reported for Northern bottlenose whales off east and northeast Iceland in April and May 1967 (Benjaminsen and Christensen, 1979) seem also somewhat different from the present results with respect to relative frequency of school sizes. While only two schools (2%) in the present survey were greater than five animals (largest 10 animals), the equivalent figure for the 1967 sample was 14 (16.7%) out of 84 groups (8 groups of ten or more animals). No geographical differences in group size were found in the present survey for any of the large whale species or minke whales, nor could differences be detected between shallow waters and coastal sightings of minke whales.

CONCLUSION

The information on distribution and abundance of cetaceans obtained during the NASS-87 international shipboard sightings surveys reported herein and elsewhere (see Donovan and Gunnlaugsson, 1989; Gunnlaugsson and Sigurjónsson, In Press; Lens *et al.*, 1989; Sanpera and Jover, 1989; Øien, 1989; Øritsland *et al.*, 1989) casts an entirely new light on this aspect of the biology of whales inhabiting the northeast Atlantic waters. Such a synoptic view of this vast ocean area has not been available before.

The present material has for the first time made possible calculations of stock sizes of two species that have recently been commercially exploited by Iceland, i.e. the Central North Atlantic stock of minke whales and the East Greenland/Iceland stock of fin whales (see Gunnlaugsson and Sigurjónsson, 1988; IWC, 1989). First approximations of abundance for other important species in the area have also been obtained. In addition, many survey areas reported herein, such as the areas clockwise north to south of Iceland have never before been covered systematically under acceptable sightings conditions. All this reveals how much can be accomplished by extensive international cooperation in terms of useful scientific knowledge, which will serve as an important basis for the future management and conservation of the stocks. Continued cooperation in the conduct of future sightings surveys in the northeastern Atlantic is still needed to add important information for other species of whales. For the area around Iceland, sei whales are an example, where a different timing and area coverage than in 1987 is needed to yield reliable estimates of abundance.

ACKNOWLEDGEMENTS

The authors are indebted to Drs D. Bloch (Museum of Natural History, Torshavn, Faroe Islands) and K. Hoydal (Director of Fisheries, Faroe Islands) for access to material collected onboard M/V *Hvitaklettur* and to the observers and scientists onboard the vessel. Our thanks to captains Thórdur Eythórsson, Ingi Lárusson, Gudmundur Bjarnason and Einar Gudmundsson as well as the efficient crews and observers for their great interest in the successful completion of the project and good humour and hard work during the survey. Special thanks go to 'Arni Sigurbjörnsson, Halldór Ólesen, Haraldur Sturlaugsson, Gudbjartur Gunnarsson and Vignir Thoroddsen, for their valuable help during preparations of the survey. Finally we are greatly indebted to our colleagues Atli Konrádsson, Fujio Kasamatsu, David Borchers, Thomas C. Potthoff, Sigurdur Gunnarsson, Albert Stefánsson, Michael Newcomer and Jon Francine, who all put so much energy and efforts into collecting the necessary information during the entire survey. M. Newcomer and J. Francine are especially thanked for staying in charge during part of the cruise onboard *AF*, due to the unexpected absence of the cruise leader. Arni Alfredsson helped in compiling and analysing the data. The US and Japanese governments as well as the IWC Secretariat are thanked for sponsoring participation of scientists in the survey. Greg Donovan, International Whaling Commission, The Red House, Station Road, Histon, Cambridge, CB4 4NP, UK and Phil Hammond, Sea Mammal Research Unit, c/o British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK made useful comments on an earlier draft of this manuscript.

REFERENCES

Anon. 1986. Iceland progress report on cetacean research June 1984 to May 1985. *Rep. int. Whal. Commn* 36: 156–7.

Anon. 1987a. Iceland. Progress report on cetacean research, June 1985 to May 1986. *Rep. int. Whal. Commn* 37: 169–71.

Anon. 1987b. Report of the North Atlantic Sighting Survey planning meetings, February 18–19 and March 21–22 1987. Paper SC/39/O 14 presented to the IWC Scientific Committee, May 1987. (Unpublished). 18 pp.

Anon. 1987c. Report of the third planning meeting of 1987 North Atlantic Sightings Survey. Paper prepared by NASS-87 Planning group, Bournemouth, June 1987 (Mimeo.), 5 pp.

Anon. 1988. North Atlantic Sightings Survey 1987. Joint post-cruise meeting, 18 Dec. 1987. Paper SC/40/O 28 presented to the IWC Scientific Committee, May 1988. (Unpublished), 8 pp.

Benjaminsen, T. and Christensen, I. 1979. The natural history of the bottlenose whale, *Hyperoodon ampullatus* (Forster). pp. 143–64. *In:* H.E. Winn and B.L. Olla (eds) *Behavior of Marine Animals–Current perspectives in research. Volume 3: Cetaceans.* Plenum Press, N.Y. 438 pp.

Bloch, D. and Lockyer, C. 1988. Killer whales (*Orcinus orca*) in Faroese waters. *Rit Fisk.* 11: 55–64.

Bloch, D., Gunnlaugsson, Th., Hoydal, K. and Sigurjónsson, J. 1989. Distribution and abundance of pilot whale (*Globicephala melas*) in the northeast Atlantic in June–August 1987, based on shipboard sightings survey. Paper SC/41/SM10 presented to the IWC Scientific Committee, May 1989.

Brown, S.G. 1986. Twentieth-century records of right whales (*Eubalaena glacialis*) in the Northeast Atlantic Ocean. *Rep. int. Whal. Commn* (special issue 10): 121–7.

Christensen, I. 1977. Observation of whales in the North Atlantic. *Rep. int. Whal. Commn 27*: 388–99.

Christensen, I. 1980. Observation 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.

Cooke, J.G. 1987. Estimation of the population of minke whales in Antarctic Area IVW in 1984/85. *Rep. int. Whal. Commn* 37: 273–6.

Cooke, J.G. and Hiby, L. 1987. Some suggestions for survey design for the North Atlantic Sightings Survey summer 1987. Paper prepared for the 3rd Planning meeting for the 1987 North Atlantic Sightings Survey, Bournemouth, June 1987, 4 pp.

Donovan, G.P. and Gunnlaugsson, Th. 1989. North Atlantic sightings survey 1987: Report of the aerial survey off Iceland. Paper SC/40/O 10. (Published in this volume).

Evans, P.G.H. 1980. Cetaceans in British waters. *Mammal Review* 10(1):1–52.

Evans, P.G.H. 1988. Killer whales (*Orcinus orca*) in British and Irish waters. *Rit Fisk.* 11:42–54.

Gunnlaugsson, Th. 1989. Report on Icelandic minke whale surfacing experiments in 1987. *Rep. int. Whal. Commn* 39:

Gunnlaugsson, Th. and J. Sigurjónsson. In Press. NASS-87: Estimation of abundance of large cetaceans from observations made on board Icelandic and Faroese survey vessels. Paper SC/40/O 30 revised. *Rep. int. Whal. Commn* 40.

Gunnlaugsson, Th., Sigurjónsson, J. and Donovan, G.P. 1988. Aerial survey of cetaceans in the coastal waters off Iceland, June-July 1986. *Rep. int. Whal. Commn* 38: 489–500.

Gunnlaugsson, Th., Magnusson, K. and Sigurjónsson, K. 1989. Stock trajectories for the East-Greenland Iceland fin whale stock based on revised catch statistics, 1883–1987. Paper SC/40/Ba4. (Published in this volume).

Hammond, P.S. and Lockyer, C. 1988. Distribution of killer whales in the eastern North Atlantic. *Rit Fisk.* 11: 24–41.

Heide-Jørgensen, M.-P. 1988. Occurrence and hunting of killer whales in Greenland. *Rit Fisk.* 11: 115–35.

Hiby, A.R., Martin, A.R. and Fairfield, F. 1984. IDCR cruise/aerial survey in the North Atlantic 1982: Aerial survey report. *Rep. int. Whal. Commn* 34: 633–44.

Hiby, L., Ward, A. and Lovell, P. 1989. Analysis of the 1987 North Atlantic Sightings Survey: Aerial survey results. Paper SC/40/O 12 (Published in this volume).

International Whaling Commission. 1976. Scientific Committee International Decade of Cetacean Research; Research proposals for the North Atlantic. *Rep. int. Whal. Commn* 26: 142–79.

International Whaling Commission. 1981. Report of the Scientific Committee, Annex N: Report of working group on proposals for North Atlantic IDCR vessel cruise. *Rep. int. Whal. Commn* 31: 162–5.

International Whaling Commission. 1987. Report of the Scientific Committee. *Rep. int. Whal. Commn* 37: 28–145.

International Whaling Commission. 1989. Report of the Scientific Committee. (Published in this volume).

Jonsgård, Å. 1951. Studies on the little piked whale or minke whale (*Balaenoptera acuto-rostrata* Lacepede). *Norsk Hvalfangsttid.* 40(5): 209–32.

Jonsgård, Å. and Øynes, P. 1952. Om bottlenosen (*Hyperoodon rostratus*) og spekkhoggeren (*Orcinus orca*). *Fauna, Oslo* 5(1): 1–18.

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.

Lens, S., Quiroga, H. and Gil de Sola, L. 1989. Spanish cruise of the North Atlantic survey 1987. Paper SC/40/O 15. (Published in this volume).

Martin, A.R. 1983. The sei whale off western Iceland. I. Size, distribution and abundance. *Rep. int. Whal. Commn* 33: 457–63.

Martin, A.R., Hembree, D., Waters, T.D., and Sigurjónsson, J. 1984. IDCR cruise/aerial survey in the North Eastern Atlantic 1982: Cruise report. *Rep. int. Whal. Commn* 34: 645–53.

Øien, N. 1988. The distribution of killer whales (*Orcinus orca*) in the North Atlantic based on Norwegian catches, 1938–1981, and incidental sightings, 1967–1987. *Rit Fisk.* 11: 65–78.

Øien, N. 1989. Sightings estimates of northeast Atlantic minke whale abundance from Norwegian shipboard surveys in 1987. Paper SC/40/Mi9 (Published in this volume).

Øritsland, T., Øien, N., Calambokidis, J., Christensen, I., Cubbage, J.C., Hartvedt, S., Jensen, P.M., Joyce, G.G., Tellnes, K. and Troutman, B.L. 1989. Norwegian whale sightings surveys in the North Atlantic, 1987. Paper SC/40/O 9. (Published in this volume).

Reeves, R.R. and Mitchell, E. 1988. Killer whale sightings and takes by by American pelagic whalers in the North Atlantic. *Rit Fisk.* 11: 7–23.

Risting, S. 1922. *Av Hvalfangstens Historie*. J. Petlitz, Kristiania. 631 pp.

Rørvik, C.J., Jónsson, J., Mathisen, O.A. and Jonsgård, Å. 1976. Fin whales, *Balaenoptera physalus* (L), off the west coast of Iceland. Distribution, segregation by length and exploitation. *Rit Fisk.* 5(5): 1–30.

Sanpera, C. and Jover, L. 1989. Density estimate of fin whales in the North Atlantic from NASS-87 Spanish cruise data. Paper SC/40/Ba13. (Published in this volume).

Sigurjónsson, J. 1982. Icelandic minke whaling 1914–1980. *Rep. int. Whal. Commn* 32: 287–95.

Sigurjónsson, J. 1983. The cruise of the *Ljósfari* in the Denmark Strait (June–July 1981) and recent markings and sightings off Iceland. *Rep. int. Whal. Commn* 33: 667–82.

Sigurjónsson, J. 1984. Killer whales census off Iceland during October 1982. *Rep. int. Whal. Commn* 34: 609–12.

Sigurjónsson, J. 1985. Sightings survey in the Irminger Sea and off Iceland in 1983. *Rep. int. Whal. Commn* 35: 499–503.

Sigurjónsson, J., Lyrholm, T., Leatherwood, S., Jónsson, E. and Víkingsson, G. 1988. Photoidentification of killer whales, *Orcinus orca*, off Iceland, 1981 through 1986. *Rit. Fisk.* 11:99–114.

Appendix 1

LIST OF PARTICIPATING SCIENTISTS IN THE SURVEY

R/V Arni Fridriksson

Cruise leader: Johann Sigurjónsson, MRI, Iceland
Scientist: Michael Newcomer, Monterey Research Laboratory, USA
Scientist: Jon Francine, MRI, Iceland, Hubbs Marine Research Institute, USA.

M/V Skírnir

Cruise leader: Thorvaldur Gunnlaugsson, MRI, Iceland
Scientist (first half): Sigurdur Gunnarsson, MRI, Iceland
Scientist (first half): Albert Stefansson, MRI, Iceland
Scientist (second half): David Borchers, International Whaling Commission
Scientist (second half): Fujio Kasamatsu, Institute of Cetacean Research, Japan

M/V Keflvíkingur

Cruise leader: P. Michael Payne, Manomet Bird Observatory, USA
Scientist: Atli Konradsson, MRI, Iceland
Scientist: Thomas C. Potthoff, Natl. Marine Fisheries Service, USA

SC/40/O 9

Norwegian Whale Sightings Surveys in the North Atlantic, 1987

T. Øritsland[1], N. Øien[1], J. Calambokidis[2], I. Christensen[1], J.C. Cubbage[2], S. Hartvedt[1], P.M. Jensen[3], G.G. Joyce[4], K. Tellnes[1], B.L. Troutman[5].

ABSTRACT

The present paper gives an account of the Norwegian shipboard and aerial surveys conducted as part of the joint 1987 North Atlantic Sightings Survey. The areas covered were the Barents, Greenland and Norwegian Seas. A total of 3,493 n.miles were searched under primary effort during the ship survey and 50 hours were flown by aircraft. The greatest species diversity was seen in the Norwegian Sea, which also proved to support an even but low density of minke whales which has not been reflected in historic catch statistics. The total species list includes minke, fin, sei, sperm, Northern bottlenose, killer, blue, humpback and white whales, white-beaked dolphins and harbour porpoises. Surfacing rate experiments were also performed during the shipboard survey.

INTRODUCTION

Encouraged by the IWC Scientific Committee's endorsement of plans submitted in 1987 (Anon., 1987a), Denmark, the Faroes, Iceland, Norway and Spain combined their resources in a joint programme using a total of eight ships and three aircraft in coordinated surveys of whales in the North Atlantic during the summer of 1987. This programme, which has been the most extensive effort ever to survey whales in the North Atlantic, was supported by the participation of scientists from Britain, Japan and the USA, and by partial funding from the Nordic Council of Ministers.

The agreed objectives of the programme were firstly to chart simultaneously the distribution of whales in the North Atlantic and, secondly, to provide data for abundance estimates of species of primary interest to each participating nation.

In order to achieve temporal coordination it was agreed to concentrate efforts to July 1987. Recognising national priorities, areas were selected and effort allocated on the basis of available information on whale distribution. Final plans, including principles for transect design, were agreed in June (Anon., 1987b) and national activities and the practical experiences gained during this joint venture were reviewed in December 1987 (Anon., 1988).

Norway contributed to the programme by employing three ships and one aircraft in transect surveys of whales and dolphins in the Greenland, Norwegian and Barents Seas. Minke whale (*Balaenoptera acutorostrata*) abundances have been calculated from the shipboard survey (Øien, 1989) and from the aerial survey (Hiby, Ward and Lovell, 1989), and dive time experiments performed during the survey have been analysed by Joyce, Calambokidis, Cubbage and Øien (1989). The activities of ships and aircraft and the sightings recorded during the Norwegian surveys are reviewed in this report.

SHIPBOARD SURVEYS

Requirements added to the original plans during the process of international coordination (Anon., 1987a and b), after submission of the national budget, limited the shiptime available for Norwegian surveys to three ships for three weeks. Design and stratification was made with regard to the time available and previous knowledge of minke whale distribution (Øien, Jørgensen and Øritsland, 1987).

Transect tracks were designed using guidelines developed for the North Atlantic surveys by J.G. Cooke and L. Hiby (Anon., 1987b), which are similar to methods developed and used for the IWC/IDCR Southern Hemisphere assessment cruises. Data forms and procedures were also adapted from the Southern Hemisphere designs, with only minor changes mostly of a simplifying character.

Each ship carried a scientific staff of three and six experienced whalers hired as whale spotters in addition to the minimum crew needed to run the ship around the clock. Crews and spotters were organised in two watches, working regular 6-hour shifts. The scientific staff worked overlapping shifts, with one or two on duty at any time. With few exceptions the transects were run with two spotters (topmen) in the mast-head barrel, reporting by intercom to the bridge where researchers recorded the data and checked the observations as far as practicable.

The ships and crews all met in Tromsø, the port of departure, and scientific staff, whale spotters and navigators were briefed in a pre-cruise meeting the day before the scheduled sailing date 5 July.

The areas and transect tracks covered by the ships are shown in Fig. 1. Transects were planned on the assumption that weather would permit 30% of the total available time to be utilised in effective surveys. Search effort alternated between passing (ship continues along the predetermined course upon sighting a whale) and closing (ship diverts from course upon sighting a whale) modes. With only a few exceptions, the sightings were not approached in passing mode. In closing mode most sightings of large whales were approached immediately after the sighting was made if there was any question of species identity or school size.

The survey was conducted by the three vessels *Asbjørn Selsbane*, *Veslekari* and *Arnt Angel*. The planned transect tracks comprised a total of 4,392 n.miles for all areas. A

---

[1] Institute of Marine Research, PO Box 1870, N-5024 Bergen, Norway
[2] Cascadia Research, 218 1/2 W. Fourth Ave. Olympia, WA 98501, USA
[3] Biodata, Kjelsasveien 152C, N-0491 Oslo 4, Norway
[4] 826 NE 80th, Seattle, WA 98115, USA
[5] Washington Dept. Wildlife, Marine Mammal Investigations Mail Stop EX-12, Olympia, WA 98504, USA

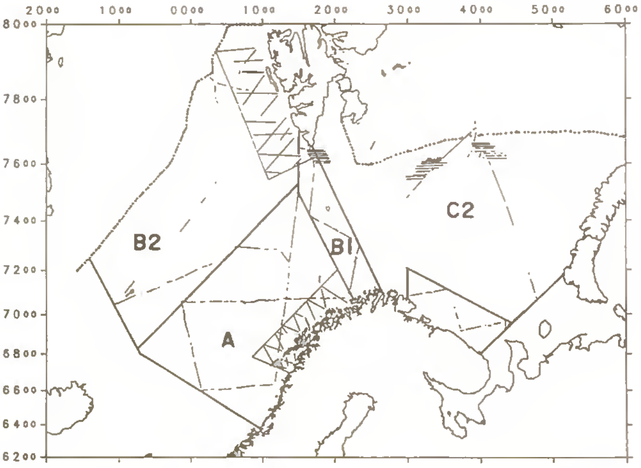


Fig. 1. Areas and transects surveyed by ship and aircraft in July 1987 as part of the Norwegian contribution to the North Atlantic Sightings Survey 1987. Punctuated lines indicate ice edges anticipated from prior satellite mapping. Hatching indicate areas found to be covered by open drifting ice during the survey.

total of 3,493 n.miles or 79% of the planned tracks had been completed in primary search effort by the end of the cruises. Staff, spotters and navigators were debriefed in a postcruise meeting in Tromsø on 24 July. Experiences from the ship surveys were shared between the scientific personnel at a meeting in Bergen on 27 July.

Asbjørn Selsbane

Area A of the Norwegian Sea (Fig. 1), comprising waters between 68°N07′W, 65°N05′E, 75°N15′E and 71°N22′E, was surveyed by the small-type whaling vessel *Asbjørn Selsbane*. She is a 42m combined fishing and whaling vessel of 310 GRT with an open barrel, 6m above the deck.

Weather conditions were good compared to those expected for the region, allowing a greater part of the time to be spent conducting surveys than anticipated. Surveys were successfully conducted along 1,671 n.miles of track. A total of 148 sightings of 444 cetaceans was made along these survey tracks and during off-effort transits. Minke whales were seen on 13 out of 17 days on effort. They were seen near shore as well as up to 200 n.miles offshore. Sperm whales (*Physeter macrocephalus*) were the next most widely encountered cetacean and were seen on 10 days. Fin whales (*Balaenoptera physalus*) and killer whales (*Orcinus orca*) were seen on 6 days. The largest numbers of killer whales were found far offshore (Table 1).

Blow rate experiments were conducted on four minke whales (Joyce *et al.*, 1989) of which three experiments were conducted for the prescribed 30 minutes. Weather conditions in all cases were excellent with virtually no waves so that few surfacings could be missed.

On two days killer whales were photographed for individual identification. The *Asbjørn Selsbane* approached these whales to within 100–200m, and at least 20 individuals were photographed.

Veslekari

Areas B1 and B2, a narrow strip between Finnmark and Spitsbergen, and a wide area between the ice edge in the northwest and Area A in the southeast, from Spitsbergen towards the areas covered by Icelandic surveys (Fig. 1), were surveyed by the *Veslekari*, a 42m, 329 GRT sealing vessel with a covered 23m high barrel in the mast.

Storm reports delayed the departure of the *Veslekari* until 6 July when she left for Area B1. Excellent weather and sea conditions, and 24-hour daylight permitted rapid advancement along the cruise track. Conditions slightly deteriorated from excellent to good on the second day of research, but by the end of the second day Area B1 was completed. Ice encountered along the cruise track just south of Spitsbergen caused a minor deviation in the track but no serious problems resulted.

The single-side-band radio aboard the *Veslekari* failed on the second day of research and required parts. Arrangements were made to have these parts flown to Longyearbyen, Spitsbergen, but required at least one day's delay in the research. While waiting for the parts, a survey grid was conducted to the west of Spitsbergen to locate whales for experiments. The grid was designed in a very biased manner, using the topographic features of the ocean floor plus traditional whaling knowledge to locate as many whales as possible, and therefore cannot be used for any population estimation. The survey did result in at least 13 minke whale sightings, and permitted nine blow rate experiments to be conducted, all on one day (Joyce *et al.*,

Table 1

Sightings of whales recorded during Norwegian transect surveys in 1987 by species and area (Fig. 1). Each sighting may include more than one whale

	Asbjorn Selsbane	Veslekari			Arnt Angel		Aircraft		
	Area A Northern Norwegian Sea	Area B1 Finnmark-Svalbard	Experiment Svalbard	Area B2 Svalbard-Jan Mayen	Area C1 Finnmark-Kola	Area C2 Northeast Barents Sea	Svalbard	North Norway	Sum
Minke	35	29	13	12	22	2	44	14	171
Fin	34	–	–	20	–	–	3	1	58
Sei	1	–	–	–	–	–	–	–	1
Sperm	25	–	–	–	–	–	1	3	29
Bottlenose	–	–	–	1	–	–	–	–	1
Killer	14	–	–	–	–	–	–	5	19
Blue	–	–	–	1	–	–	–	–	1
Humpback	–	–	–	2	1	–	1	–	4
White whale	–	–	–	–	–	–	2	–	2
White-beaked dolphin	10	–	–	–	4	–	4	3	21
Harbour porpoise	6	1	–	–	2	–	–	–	9
Unidentified large whales	5	–	–	–	–	–	1	3	9
Unidentified small whales	17	9	2	1	8	–	–	–	37
Unclassified	1	–	–	–	1	–	–	–	2
Total	148	39	15	37	38	2	56	29	364

1989). Five of the trials were completed, but in two of the trials the whales appeared affected by the presence of the drifting ship.

The following day was spent with radio repairs in Longyearbyen and then Area 2 was started. Poor weather conditions were soon encountered and continued for most of the time in this area. The first leg was designed to end at the ice edge. An additional transit of 25 n.miles was needed to reach the ice. Transit along the second leg was halted by strong winds and fog and only 115 n.miles of search effort was accomplished in 6 days. Because of the large area remaining to be sampled and the short time left to survey, a major change in strategy was made.

During a period of poor weather conditions a straight-line transit was initiated to the final waypoint. The planned cruise track was then resumed, heading from the last planned waypoint toward the second-to-last planned waypoint. In this manner, transit to the west could be carried out in bad weather, and the return to the east towards the home port of Tromsø would be along the planned cruise track, and, if conditions were acceptable, in survey mode. This plan provided an extra 1.5 days of survey while decreasing the return transit to Tromsø by a like amount.

Area B1 was effectively searched with 387 n.miles surveyed of the planned 427 n.miles trackline. Numerous minke whale and dolphin sightings were made during the survey (Table 1).

Area B2 was concluded with only 428 n.miles surveyed of the planned 746 n.miles trackline. Including the transit to the final way point, there were 1,029 n.miles of track line, of which 509 n.miles were surveyed. Few minke whales (10 sightings) were seen in the area, but numerous fin whales (17 sightings) were seen near Jan Mayen. A single blue whale (*Balaenoptera musculus*) was observed west of Spitsbergen, the first record in the area in many years (Jonsgard, 1966). A single humpback (*Megaptera novaeangliae*) was also observed just west of Spitsbergen (Table 1).

Arnt Angel

Areas C1 and C2 were assigned to the *Arnt Angel*, a 29.3m, 178 GRT sealing vessel with a covered barrel 16.5m up the forward masthead. *Arnt Angel* departed Tromsø on 5 July with the other vessels, after waiting for improved weather conditions in their research areas. In transit via inshore passages to the starting waypoint in Area C1, the time was used to conduct briefings for the ship's officers, observers and researchers. Upon reaching the open sea northeast of Nordkapp, several hours of search effort were conducted in passing mode prior to arriving at the research area.

The *Arnt Angel* commenced its survey in Area C1 at 70°50′N 30°00′E on 6 July. Good weather prevailed throughout most of the first two days, allowing a major portion of the area to be surveyed with only minor periods of drifting or steaming with topmen down. A prolonged period of poor weather was encountered in the southeast corner of the area beginning late on 7 July, forcing the vessel to drift offshore of the Kola Peninsula. The *Arnt Angel* resumed survey on 10 July and completed her survey of Area C1 later that same day at 69°30′N 44°00′E, although segments of the last few legs had been steamed with topmen down due to frequent local fog patches.

The survey of Area C2 began on 10 July, the initial waypoint being identical with the last waypoint of Area C1. Poor weather prevailed throughout the early part of the survey in C1 with nearly 139hrs of available survey time being lost by midday of 17 July when search effort resumed. Ice, in the form of a large tongue of consolidated first-year ice, was encountered on 18 July at 76°09′N 41°03′E about 30 n.miles south of the limit of very close pack-ice shown by the 29 June satellite analysis and nearly 60 n.miles south of the anticipated ice edge. Approximately 1.5 days were spent in circumnavigating the western periphery of the large, irregularly-shaped ice tongue. The *Arnt Angel* was finally able to rejoin her original trackline late on 19 July, shortly before reaching her northernmost waypoint at the anticipated ice edge. No ice was encountered at the northernmost waypoint and an additional trackline segment intended to intersect the ice edge was constructed. This new course was steamed for 15 n.miles before dense, area-wide fog was met. Safety considerations prevented further steaming to locate the ice edge and time constraints prohibited drifting to await better visibility. The *Arnt Angel* was thus forced to turn back toward the original ice edge waypoint without having located the ice edge. Unanticipated ice was also encountered on the southward track at 76°42′N 37°13′E. Only minor course deviations were required to circumvent the loose floes and narrow strips on the edge of the more heavily packed ice which lay just west of the trackline.

By the 21 July a point was reached where little extra time remained to wait out periods of poor weather and *Arnt Angel* was forced to steam an entire leg (89 n.miles) with topmen down in an attempt to reach an area of better weather. Severe weather with gale force winds and heavy seas continued throughout 22 July and it became obvious that the remaining leg of the planned trackline would have to be abandoned due to the very limited amount of extra time remaining. A decision was made to leave the planned trackline and to steam to the southeast to attempt an alternate survey leg in the area to the northeast of Nordkapp. The last few hours of extra time were spent waiting at the new waypoint at 72°00′N 30°00′E. Weather conditions did not improve sufficiently to permit survey and the *Arnt Angel* began her transit back to Tromsø via the inshore passage, arriving in Tromsø on 24 July.

The *Arnt Angel* completed 88% (350 n.miles) of the survey in Area C1 under acceptable sighting conditions with nearly equal amounts of search effort in passing and closing modes. The survey of Area C2 was less successful. Extensive periods of poor weather required that significant portions of the trackline be steamed in transit in an attempt to complete the survey coverage of this stratum. Only 65% (575 n.miles) of the originally planned trackline were successfully surveyed, with 74% of transit steaming occurring on closing mode legs. No survey was possible along the alternate survey leg established near the end of the cruise.

Virtually all of the *Arnt Angel*'s cetacean sightings occurred in Area C1, the designated high density stratum (Table 1). Here, minke whales (22 groups and 24 whales) were the predominant species observed, followed by dolphins of the genus *Lagenorhynchus* (some of which were positively identified as white-beaked dolphins, *L. albirostris*), harbour porpoises (*Phocoena phocoena*) and a single humpback whale. No additional cetaceans were observed throughout the remainder of the cruise. The greatest concentration of minke whales observed (nine groups, 10 animals) was in the centre of the area.

Only two identified cetacean sightings occurred during the entire survey period within Area C2. Both of these were minke whales sighted while steaming in transit in heavy seas.

Non-cetacean marine mammal sightings consisted primarily of numerous groups of harp seals observed both in the open sea and along the ice tongue. In addition, two separate polar bears were sighted, both at the extreme southern edge of the ice.

No blow rate experiments were carried out aboard the *Arnt Angel*. All minke sightings occurred during the very early stages of the cruise while observers and researchers alike were adjusting to normal survey procedures. Thereafter, no minke whales were sighted under conditions acceptable for conducting blow rate experiments. No opportunities for recording natural markings of whales by photography arose during the survey.

AERIAL SURVEYS

Supplementing the Norwegian shipboard surveys, transects were also flown by aircraft off the west coast of Spitsbergen and along the coasts of Nordland, Troms and Finnmark counties on the Norwegian mainland (Fig. 1) from 7 July to 17 August 1987.

A twin-engined, high-winged *Partenavia Observer* (G-OBSV), fitted with blister windows on the sides for whale observations was used in these surveys. In addition to the whale surveys, the aircraft was also chartered for tracking and surveys of polar bears at Svalbard by the Norwegian Polar Institute. A two week delay in delivery of the aircraft complicated the execution of the combined surveys. However, a total of 24hrs were flown in whale surveys at Spitsbergen, and 26hrs in surveys off northern Norway.

The aircraft was fitted with radar-altimeter, magnetic and gyro compasses, automatic direction finder (ADF) and a DME-distancemeter. Individual tape recorders for data-logging were connected to a portable computer providing automatic timing to the data-logs. Vertical angles to sightings were measured by inclinometer.

During whale surveys the aircraft had only one pilot, carried one researcher in the co-pilot seat who assisted in navigation, and two whalers acting as spotters, one on each side in the cabin. Transects were flown at 750ft (230m) and 100 knots (indicated airspeed). Because of inadequate navigational instrumentation, positions had to be corrected by visual sightings at each landfall. However, deviations were small, since transects were flown only in favourable weather with little sidewind.

The Spitsbergen surveys (Fig. 1) were flown from 7 July to 2 August to cover a block of approximately 23,000 n.miles^2. Difficult weather and the lack of weather reports and forecasts slowed down the operations and prevented full coverage of the planned transects. However, successful flights were completed on the 9, 26 and 29 July, with a total of 61 minke, 6 fin, 12 humpback, 3 sperm whales and some smaller odontocetes recorded on these three days. In addition, some 30 minke, 3 fin and 4 humpback whales were sighted on 26 July, but these were not recorded because of malfunction in the data-logging system.

Because of the delay and other complications, surveys on the Norwegian coast (Fig. 1) 2–17 August, comprising about 20,000 n.miles^2 plus 3,400 n.miles^2 in Vestjorden, were flown with a crew reduction of one whale spotter after 7 August. In spite of the problems, a large area off Lofoten and Vesteralen (67°20′N – 70°10′N) was covered on 9 August, with a total of 73 sightings recorded on that particular flight. Only 9 sightings were made in Vestfjorden the next day, and one single sperm whale was sighted in four transects flown further north on 15 August.

An attempt to survey the Finnmark coast on 16 August failed because of difficult weather, and faced with unfavourable forecasts, further aerial surveys were abandoned on 17 August.

RESULTS AND DISTRIBUTION OF SPECIES

All sightings recorded in the Norwegian surveys in 1987 are listed by species and area in Table 1. The list includes the sightings recorded off searching effort which cannot be used for estimates of abundance. Distributions of minke, fin and sperm whales are shown in Fig. 2.

The Norwegian surveys were planned primarily to elucidate the distribution and abundance of minke whales, and the minke whale also dominates the list of sightings.

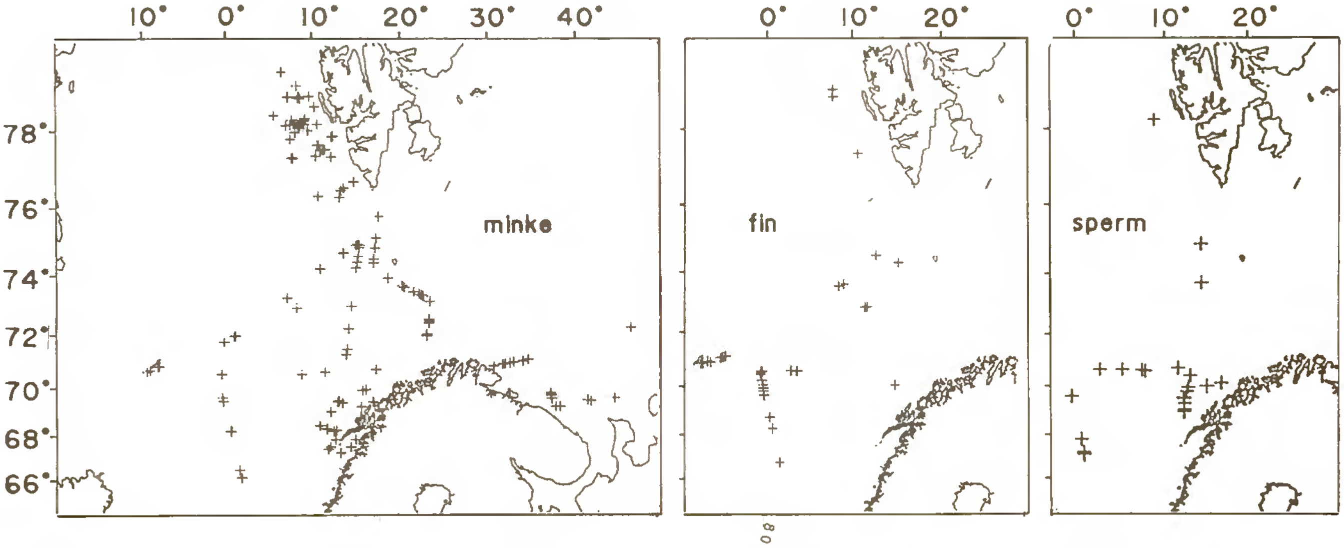


Fig. 2. Distribution of minke (171 recorded sightings), fin (58 sightings) and sperm whales (29 sightings) seen during the Norwegian shipboard and and aerial surveys, June–August 1987.

Except for the northern Barents Sea (Area C2) and the northern part of the Norwegian Sea (Area B2), the species appeared to be fairly well distributed in the areas covered by the surveys. Of particular interest are the sightings in the Norwegian Sea south of the Jan Mayen ridge towards Svalbard (Fig. 2) which suggest an even low density distribution of minke whales between the feeding areas at Iceland-Jan Mayen and in the Barents Sea. A combined analysis of these data with sightings from the Icelandic and Faeroese surveys (Sigurjónsson, Gunnlaugsson and Payne, 1989) may throw further light on the question of separation between minke whales in the Central North Atlantic and the Northeast Atlantic stock unit areas.

Fin whales were recorded northwards to about 79°N west of Spitsbergen, but the largest numbers were sighted to the west in the Norwegian Sea. These data may supplement Icelandic, Faroese and Spanish sightings of fin whales in 1987 (Sigurjónsson *et al.*, 1989; Lens, Quiroga and de Sola, 1989).

Practical experiences with consequences for the planning of further surveys were reviewed at the joint postcruise meeting in December 1987 (Anon., 1988).

ACKNOWLEDGEMENTS

The sightings survey was funded by the Norwegian Government through 'Fondet for fiskeleiting og forsøk' with an additional contribution from the Nordic Council of Ministers. The participation of US scientists was made possible by funding from National Marine Fisheries Service, NOAA, Washington, D.C. We would also like to thank the captains and crews on the vessels and aircraft; their cooperation was crucial to the successful conduction of this survey. Thanks are due to Philip Hammond, Sea Mammal Research Unit, Cambridge and Johann Sigurjónsson, Marine Research Institute, Reykjavík, for reviewing the manuscript.

REFERENCES

Anon. 1987a. Report of the North Atlantic sighting survey planning meetings February 18–19 and March 21–22. Paper SC/39/O 14 presented to the IWC Scientific Committee, June 1987 (unpublished). 18pp.

Anon. 1987b. 3rd planning meeting of the 1987 North Atlantic sightings survey. MS 15 June 1987, 5pp. (Mimeo.)

Anon. 1988. North Atlantic sightings survey 1987. Joint post-cruise meeting 18 Dec. 1987. Paper SC/40/O 28 presented to the IWC Scientific Committee, June 1987 (unpublished). 8pp.

Hiby, A., Ward, A. and Lovell, P. 1989. Analysis of the 1987 North Atlantic Sightings Survey: Aerial survey results. Paper SC/40/O 12 (published in this volume).

Jonsgård, Å. 1966. The distribution of Balaenopteridae in the North Atlantic Ocean. pp. 114–24. *In*: K.S. Norris (ed.) *Whales, Dolphins and Porpoises*. University of California Press, Berkeley and Los Angeles. 789pp.

Joyce, G.G., Calambokidis, J., Cubbage, J.C. and Øien, N. 1989. Surfacing rates of minke whales in Norwegian waters. Paper SC/40/Mi15 (published in this volume).

Lens, S., Quiroga, H. and Gil de Sola, L. 1989. The Spanish cruise of The North Atlantic Sightings Survey. 1987. Paper SC/40/O 15 (published in this volume).

Øien, N. 1989. Provisional sightings estimates of Northeast Atlantic minke whale abundance from Norwegian shipboard surveys in 1987. Paper SC/40/Mi9 (published in this volume).

Øien, N., Jørgensen, T. and Øritsland, T. 1987. A stock assessment for Northeast Atlantic minke whales. *Rep. int. Whal. Commn* 37: 225–36.

Sigurjónsson, J., Gunnlaugsson, T. and Payne, M. 1989. NASS-87: Shipboard sightings surveys in Icelandic and adjacent waters, June-July 1987. Paper SC/40/O 29 (published in this volume).

SC/40/Mi9

Sighting Estimates of Northeast Atlantic Minke Whale Abundance from the Norwegian Shipboard Survey in July 1987

Nils Øien

Institute of Marine Research, P.O. Box 1870, Nordnes, N-5024 Bergen, Norway

ABSTRACT

Estimates of minke whale abundance in the area covered by Norwegian ships as part of the July 1987 North Atlantic Sightings Survey (NASS-87) are presented. The survey area, covering the Norwegian, Greenland and Barents Seas, was divided into five blocks of varying expected minke whale density. No confirmed primary sightings were made in the block comprising the northeastern part of the Barents Sea, but coverage in that area and also in the Greenland Sea block was very low. Effective search half-widths have been calculated by fitting a hazard-rate model to the perpendicular distance data. The survey alternated between closing and passing modes, and the total abundance estimates based on pooling perpendicular distances over blocks for the area surveyed are 17,382 (CV 0.304) and 22,774 (CV 0.235) minke whales, respectively. Pooling the perpendicular distances also over modes prior to fitting the hazard-rate model, results in a combined minke whale abundance estimate of 17,918 (CV 0.228). The data from the area surveyed by Norwegian vessels have been stratified with respect to the present IWC minke whale stock boundaries in the North Atlantic to relate the abundance to these. The estimated contribution to the Central stock is 4,461 (CV 0.273) animals, and to the northeastern stock 12,459 (CV 0.293) minke whales. None of the estimates presented here have been corrected for possible deviations from the assumption g(0)=1 (i.e. all animals on trackline detected) since relevant information is not available at present.

INTRODUCTION

The two main objectives of the 1987 North Atlantic Sightings Survey (NASS-87) were to map the simultaneous distribution of whale species and to estimate their abundance (Anon., 1987). Compared to earlier surveys (Øien and Christensen, 1985), the area covered by Norway was greatly extended by including the Barents Sea to the northern ice edge, the Greenland Sea to the western ice edge and the northern Norwegian Sea. The southern and western parts of the Norwegian Sea were covered by Faroese and Icelandic vessels (Sigurjónsson, Gunnlaugsson and Payne, 1989).

Øritsland *et al.* (1989) reports on the sightings surveys conducted by Norway as part of NASS-87, including information on distribution of sightings by species. This paper deals with estimation of abundance of minke whales from the Norwegian shipboard survey.

ESTIMATION OF ABUNDANCE

Survey block boundaries

The total area surveyed by the Norwegian vessels was divided into five blocks (A, B1, B2, C1 and C2) as shown in Fig. 1. The blocks were covered by three vessels: *Asbjørn Selsbane* (block A), *Veslekari* (blocks B1 and B2) and *Arnt Angel* (blocks C1 and C2). Block areas have been calculated using outer coastlines and ice edges, as evaluated from the July 1987 monthly mean sea ice chart from the Norwegian Meteorological Institute, as borderlines where appropriate. Supplementary aerial surveys were intended at blocks west of Svalbard and in coastal waters of northern Norway (Øritsland *et al.*, 1989; Hiby, Ward and Lovell, 1989). These blocks, believed to be high density areas, received little effort from the shipboard surveys and then only as parts of the larger blocks B2 and A, respectively.

Search effort

The primary sighting platform was a barrel mounted in the foremost masthead on each vessel. The transects were run with two experienced whalers as topmen when in primary searching mode.

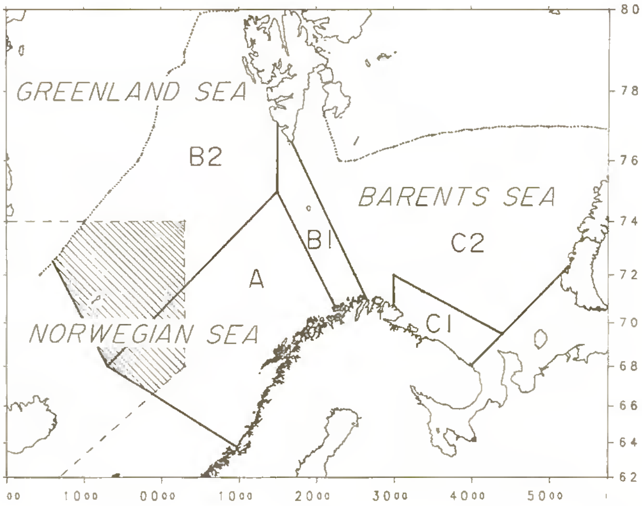


Fig. 1. Boundaries between the five blocks A, B1, B2, C1 and C2 of the total area surveyed by Norwegian ships in July 1987. Dotted lines indicate ice edges. The hatched area represents the parts of blocks A and B2 belonging to the Central stock of minke whales, as defined by IWC, while the remaining areas are considered as parts of the northeastern minke whale stock area.

The search effort was alternated between closing mode (ship diverts from trackline when sighting a whale) and passing mode (ship continues on the predetermined trackline upon sighting a whale), ideally on an equal share basis. This was accomplished by alternating modes between legs, or dividing longer legs into sections. The transect runs in each mode are shown in Figs 2 (closing mode) and 3 (passing mode). An additional transect was run at the continental shelf west of Spitsbergen to find whales for blow-rate experiments. The data from this transect have been dealt with separately.

During closing mode, sightings where species identification and/or school size were uncertain, were approached immediately.

Sighting rate

Only primary sightings recorded as confirmed with respect to species identification have been used for estimation of sighting rates. The main sighting cue was the body, which

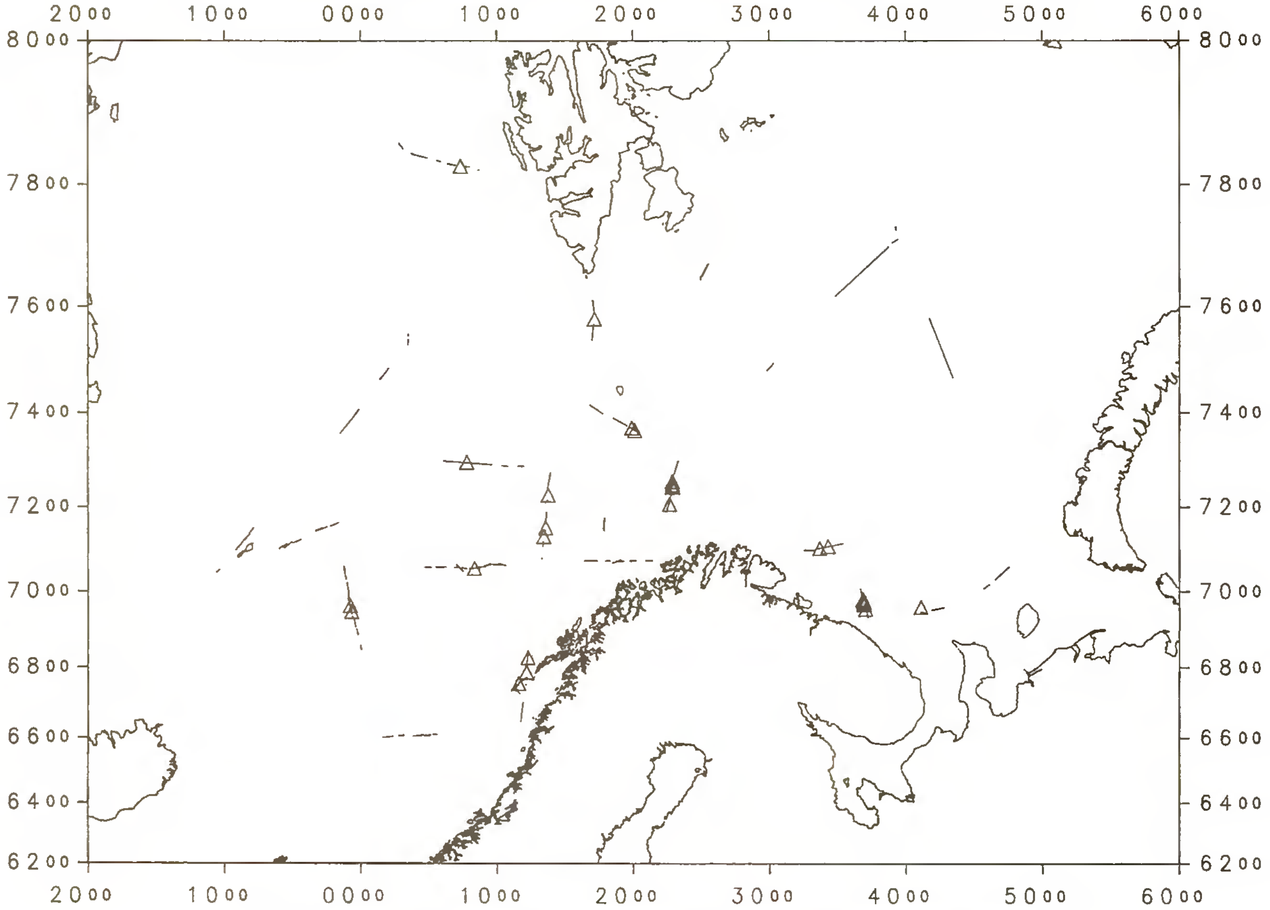


Fig. 2. Surveyed closing mode transects. Primary sightings are indicated by triangles.

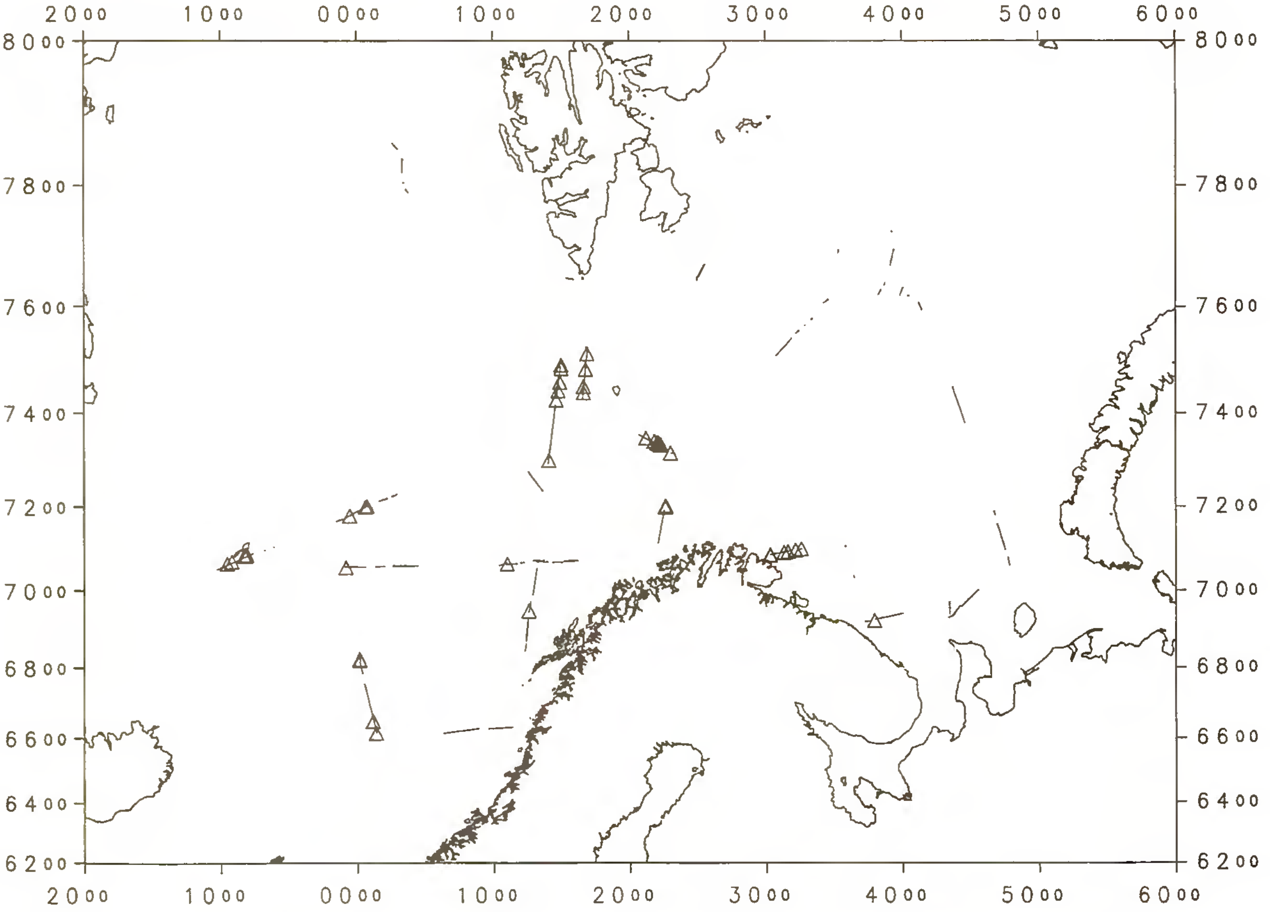


Fig. 3. Surveyed passing mode transects. Primary sightings are indicated by triangles.

Table 1

Data used to estimate abundance of minke whales in the area surveyed by Norwegian vessels in July 1987 by blocks. No primary sightings were made in block C2. Effective search half-widths have been calculated separately, but pooled over blocks for closing and passing modes. Results from the searching for minke whales for blow-rate experiments at Svalbard are given separately. Figures in brackets are coefficients of variation

Block	A - Northern Norwegian Sea		B1 - Bear Island		B2 - Greenland Sea		C1 - Kola coast		Exp. at Svalbard
Survey mode	Closing	Passing	Closing	Passing	Closing	Passing	Closing	Passing	Closing
Primary effort, L, n.miles	820.1	797.0	185.3	202.0	273.3	235.5	165.1	184.8	123.8
No. of schools, n	7	13	8	18	1	8	8	7	10
Sighting rate n/L	0.0085 (0.363)	0.0163 (0.391)	0.0432 (0.552)	0.0891 (0.385)	0.0037 (0.724)	0.0340 (0.330)	0.0485 (0.399)	0.0379 (0.812)	0.0808 (0.429)
Effective search half-width, w, n.miles	0.1671 (0.231)	0.3041 (0.103)	0.1671 (0.231)	0.3041 (0.103)	0.1671 (0.231)	0.3041 (0.103)	0.1671 (0.231)	0.3041 (0.103)	0.2233 (0.385)
Density of schools, Ds = (n/L) . (1/2w)	0.0255 (0.430)	0.0268 (0.404)	0.1293 (0.598)	0.1465 (0.399)	0.0111 (0.760)	0.0559 (0.346)	0.1450 (0.461)	0.0623 (0.819)	0.1809 (0.576)
Mean school size, s	1.00 (0)		1.86 (0.320)		1.00 (0)		1.18 (0.103)		1.18 (0.103)
Density of whales, Dw = Ds . s	0.0255 (0.430)	0.0268 (0.404)	0.2404 (0.679)	0.2725 (0.511)	0.0111 (0.760)	0.0559 (0.346)	0.1711 (0.472)	0.0735 (0.825)	0.2135 (0.586)
Area, (n.miles)^2	185,699		25,113		158,696		28,315		-
Uncorrected estimate of abundance	4,743 (0.430)	4,977 (0.404)	6,038 (0.679)	6,843 (0.511)	1,757 (0.760)	8,872 (0.346)	4,844 (0.472)	2,082 (0.825)	
Uncorrected total estimate	Closing: 17,382 (0.304)				Passing: 22,774 (0.235)				

accounted for 91% of passing mode and 96% of closing mode primary sightings. Primary sightings were made by the topmen in the barrel (76% of total in passing mode and 82% in closing mode, respectively), by observers located on the wheelhouse roof (11%/7%) and by observers located in the wheelhouse (11%/11%). All these have been used in the fitting procedures, but a few sightings were left out after truncation of data.

No confirmed primary sightings of minke whales were made during the survey of block C2, although 245.7 n.miles and 329.7 n.miles were run with primary effort in closing mode and passing mode, respectively. In this block one minke whale approached the ship while drifting and one 'like-minke' was observed in passing mode. It follows from this that no abundance estimate is available for that block from the 1987 survey.

Coefficients of variation for the sighting rates have been calculated from truncated data using daily variation, with the exception of the result from the transect surveyed in connection with the blow-rate experiments at Spitsbergen (Table 1), which is based on variation between legs of the transect. The sighting rates compared between modes are not significantly different.

Mean school size

Mean school sizes (s) were calculated from all sightings made in closing mode where school sizes were recorded as confirmed. For blocks A and B2, all minke whale sightings with confirmed school sizes were of single animals, although a few observations of schools of two whales were recorded as unconfirmed in those areas. The mean school size estimated from data pooled over blocks is 1.27 (CV 0.119).

Effective search half-width

As decided at the joint post-cruise meeting (Anon., 1988), effective search half-widths have been estimated by fitting a hazard-rate model (Hayes and Buckland, 1983) with a detection function of the form $g(y)=1\text{-EXP}(-(y/a)^{1-b})$ to estimated perpendicular sightings distance data y. Generally, the numbers of primary sightings in each surveyed block are too few to allow a proper analysis with respect to the two-parameter hazard-rate model. The data were therefore pooled over all strata by mode (Fig. 4), truncated at 0.5 n.miles and effective search half-widths calculated for each mode separately. These estimates are the basis of calculations given in Table 1.

The closing mode and passing mode perpendicular sighting distance distributions shown in Fig. 4 were tested by the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf, 1981) and not found to be significantly different at the 1% level, for either the untruncated data ($D=0.174 < D_{0.01}=0.390$) or the data truncated at 0.5 n.miles ($D=0.257 < D_{0.01}=0.410$). The data truncated at 0.5 n.miles were therefore also pooled over mode and fitted to the hazard-rate model, resulting in an effective search half-width of w=0.2701 (CV 0.088). Recalculations based on the pooled data are presented in Table 2.

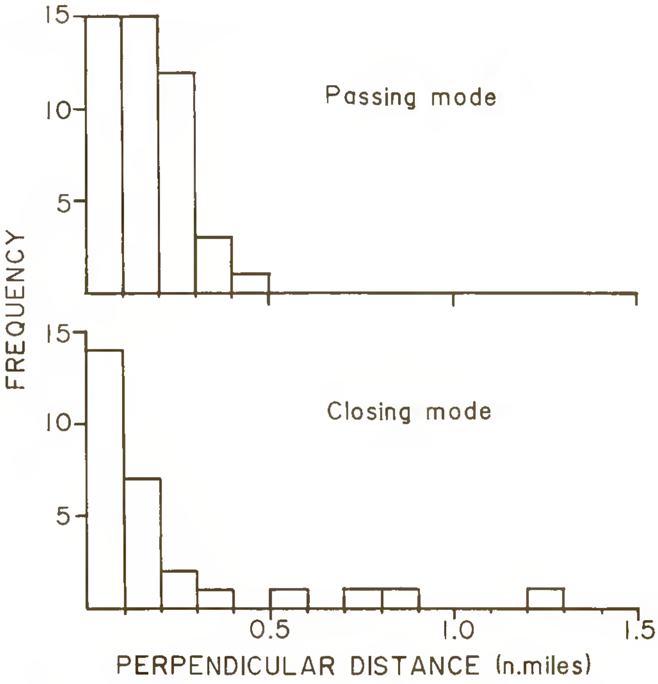


Fig. 4. Frequency distributions of passing mode and closing mode perpendicular distances for primary sightings pooled over all surveyed blocks.

Table 2

Uncorrected abundance estimates of minke whales in each of the survey blocks from data pooled over modes and truncated at 0.5 n. miles. Effective search half-width has been calculated from fitting the hazard-rate model to perpendicular distance data pooled over modes and blocks. Figures in brackets are coefficients of variation

Block	A	B1	B2	C1
Primary effort, L, n.miles	1,671.1	387.3	508.8	349.9
No. of schools, n	20	26	9	15
Sighting rate n/L	0.0124 (0.327)	0.0671 (0.431)	0.0177 (0.327)	0.0429 (0.442)
Effective search half-width, w, n.miles	0.2701 (0.088)			
Mean school size, s	1.00 (0)	1.86 (0.320)	1.00 (0)	1.18 (0.103)
Density of whales, Dw = (n/L) . (1/2w) . s	0.0230 (0.339)	0.2310 (0.544)	0.0328 (0.339)	0.0937 (0.462)
Area, (n.miles)^2	185,699	25,113	158,696	28,315
Uncorrected estimate of abundance by block	4,263 (0.339)	5,802 (0.544)	5,200 (0.339)	2,653 (0.462)
Uncorrected total estimate of abundance in survey area	17,918 (0.228)			

The approximate coverages as calculated from the latter effective search half–width are for block A: 0.5%; block B1: 0.8%; block B2: 0.2%; block C1: 0.7% and block C2: 0.2%.

IWC stock boundaries

The blocks were not defined to fit the present IWC classification of minke whale stock boundaries in the North Atlantic (IWC, 1977). However, a compilation of abundance estimates referring to these boundaries, outlined in Fig. 1, has been made by rearranging the basic data from the two blocks concerned, i.e. blocks A and B2, into a Central stock component and a Northeastern stock component. The results are summarised in Table 3.

Table 3

Restratification of data collected from blocks A and B2 to fit the IWC minke whale stock boundaries. Uncorrected total contributions to the stocks from the survey area have been given by including B1 and C1 from Table 2 in the Northeastern estimate. Effective search half-width has been calculated as in Table 2 and sightings outside the truncation distance of 0.5 n. miles have been excluded. Coefficients of variation are given in brackets

	Central		Northeastern	
Block	A	B2	A	B2
Primary effort, L, n.miles	259.4	323.9	1,357.7	184.9
No. of schools, n	5	8	15	1
Sighting rate n/L	0.0193 (0.348)	0.0247 (0.334)	0.0110 (0.403)	0.0054 (0.447)
Effective search half-width, w, n.miles	0.2701 (0.088)			
Mean school size, s	1.0 (0)			
Density of whales, Dw = (n/L) . (1/2w) . s	0.0357 (0.359)	0.0457 (0.345)	0.0205 (0.412)	0.0100 (0.456)
Area, (n.miles)^2	31,790	72,757	153,909	85,939
Uncorrected estimate of abundance	1,134 (0.359)	3,327 (0.345)	3,148 (0.412)	856 (0.456)
Uncorrected total contribution to stocks from survey area	4,461 (0.273)		12,459 (0.293)	

DISCUSSION

During sightings surveys in 1984 and 1985 (Øien and Christensen, 1985), the areas along the Kola and Finnmark coasts, and from Finnmark through Bear Island area to and including the west coast of Spitsbergen, were covered. These areas were thought to be the most important areas of minke whale distribution, based on previous knowledge from incidental sightings and catch distributions. However, the present expanded study has revealed a significant contribution to the abundance estimates from the northern Norwegian Sea area.

The survey in block B2, the Greenland Sea, was less successful with regard to abundance estimation as only one primary sighting was recorded in closing mode and eight in passing mode. However, coverage was very low in this block. The parts of the planned transect surveyed in closing mode were evenly distributed over the block as shown in Fig. 2, in contrast to the parts surveyed in passing mode (Fig. 3), mainly in the Jan Mayen area (76%). In the latter area all primary sightings were made in passing mode. It therefore seems unlikely that the density of minke whales from passing mode data as calculated in Table 1 is representative of the entire block B2.

In the northeastern Barents Sea (block C2) no primary sightings of minke whales were made. This area received some coverage in 1984 (Øien and Christensen, 1985) with no primary sightings made. Catch distributions, at least in the 1980s (Øien, Jørgensen and Øritsland, 1987), seem to confirm a present low abundance of minke whales in this area for parts of the year where information is available.

Passing mode was alternated with closing mode to ensure reliability both to species identification and school size estimations. It has been realized that the sighting rates in these areas are too low to allow such a data collection procedure with the present effort put into the surveys. The experience from this survey is that species identification is a minor problem in most of the areas covered. The exception is primarily the Norwegian Sea area which has the greater species diversity (Øritsland *et al.*, 1989) with species that are prone to erroneous identification. Regarding school sizes, the minke whales were mostly seen in these waters as single individuals with a pooled average of 1.27 (CV 0.119) as compared to 1.20 (CV 0.111) in the 1984 survey and 1.42 (CV 0.224) in 1985 (Øien and Christensen, 1985). For minke whale abundance estimation, a passing mode survey with delayed closure (diverting from course at approximately 90° to the sighting) when needed for confirming species identification or school size is therefore preferable.

None of the abundance estimates obtained by pooling perpendicular distance data over blocks prior to fitting the hazard-rate model are significantly different by mode. They are very similar for A and B1 but rather different for block B2. This may be a result of the unequal distribution of effort in the two modes but it should be noted that no primary sightings of minke whales were made in closing mode in the Jan Mayen area, although passing mode sightings were made there.

The perpendicular distance frequency distributions from the two modes appear to be very different: the passing mode distribution exhibits a shoulder whereas the closing mode distribution is approximately exponential. Although this has to be investigated further, these two distributions are not statistically different and were thus pooled to give a single estimate of the effective search half-width. The sighting rates were also pooled over modes, resulting in a single combined estimate for each of the blocks (Table 2). For all blocks this pooling procedure made the abundance estimates lower than any weighted or unweighted mean of corresponding estimates in Table 1. The reason for this is that the separate pooling gives an estimate of closing mode half–width that is approximately half the passing mode half-width, while the pooled-over-mode half-width is similar to that based on passing mode data. This is not unexpected since 46 passing mode observations are included compared to 24 observations made in closing mode.

A transect was planned at the west coast of Svalbard to find whales for blow–rate experiments. Although the planned transect was intentional and thus invalid for unbiased abundance estimation, it is interesting to note that the density of minke whales calculated from these data (0.2135 whales n.miles^2) is well in accordance with the density (0.248) found during the survey of that area in 1985 (Øien and Christensen, 1985). A separate block was designed for this area to be covered by aircraft during the 1987 survey (Øritsland *et al.*, 1989). Results from that survey (Hiby *et al.*, 1989) indicate a lower density than from shipboard surveys by a factor of about five. Whatever the reason for this discrepancy, the result seems to be contradictory to the reputation of the Svalbard coastal area as a high-density area in which considerable catches have been taken, especially during the last decade.

To obtain an estimate of the total contribution from this survey to the two IWC stock areas concerned, the data from blocks A and B2 were restratified, primarily to cope with the bias that might arise from the uneven distribution of sightings in block B2. This procedure lowered the total estimate for block B2 by approximately 1,000 minke whales (Table 3 compared to Table 2) while the estimate for block A remained the same. This illustrates the difficulties in calculating a valid estimate for block B2 and suggests that alternative procedures should be investigated, for example using the variable coverage probability method described by Cooke (1987).

The contribution to the Central stock of minke whales has been calculated to be 4,461 whales and to the northeastern stock 12,459 whales. Areas to the south of the southern boundary (approximately 66°N) of areas surveyed by the Norwegian vessels in 1987 also contribute to the northeastern minke whale stock abundance. These areas were surveyed by a Faroese vessel and abundance estimates from this and the Icelandic vessels are given in Gunnlaugsson and Sigurjónsson (1988).

No correction factors have been applied to the abundance estimates presented in this paper, although particularly a correction for deviations from the assumption $g(0)=1$, i.e. that no schools are missed on the trackline, seems appropriate. However, since correction factors calculated for other surveys are inconclusive and not necessarily applicable to the present survey, the question of g(0) corrections remains unsolved until relevant experimental data have been collected.

ACKNOWLEDGEMENTS

The assistance of Siri Hartvedt in entering and validation of data is highly appreciated. Torger Øritsland and Øyvind Ulltang, IMR Bergen, commented on early drafts. Thanks are also due to Philip Hammond, Sea Mammal Research Unit, Cambridge and Johann Sigurjónsson, Marine Research Institute, Reykjavík, for reviewing the manuscript, and to Thorvaldur Gunnlaugsson and an anonymous reviewer for their comments on the paper.

REFERENCES

Anon. 1987. Report of the North Atlantic sighting survey planning meetings February 18–19 and March 21–22. Paper SC/39/O 14 presented to the IWC Scientific Committee, June 1987. (Unpublished). 18pp.

Anon. 1988. North Atlantic sightings survey 1987. Joint post-cruise meeting 18 Dec. 1987. Paper SC/40/O 28 presented to the IWC Scientific Committee, May 1988. (Unpublished). 8pp.

Cooke, J.G. 1987. Estimation of the population of minke whales in Antarctic Area IVW in 1984/85. *Rep. int. Whal. Commn* 37:273–6.

Gunnlaugsson, T. and Sigurjónsson, J. 1988. NASS-87: Estimation of abundance of large cetaceans from observations made onboard Icelandic and Faroese survey vessels. Paper SC/40/O 30 presented to the IWC Scientific Committee, May 1988. (Unpublished). 26pp.

Hayes, R.J. and Buckland, S.T. 1983. Radial-distance models for the line-transect method. *Biometrics* 39:29–42.

Hiby, A., Ward, A. and Lovell, P. 1989. Preliminary analysis of the 1987 North Atlantic Sightings Survey: Aerial survey results. (Published in this volume).

International Whaling Commission. 1977. Report of the Scientific Committee. *Rep. int. Whal. Commn* 27:36–70.

Øien, N. and Christensen, I. 1985. A sighting survey for minke whales in the Barents Sea in 1984 (with a preliminary report of the 1985 survey). Paper SC/37/Mi3 presented to the IWC Scientific Committee, June 1985. (Unpublished). 18pp.

Øien, N., Jørgensen, T. and Øritsland, T. 1987. A stock assessment for Northeast Atlantic minke whales. *Rep. int. Whal. Commn* 37:225–236.

Øritsland, T., Øien, N., Calambokidis, J., Christensen, I., Cubbage, J.C., Hartvedt, S., Jensen, P.M., Joyce, G.G., Tellnes, K. and Troutman, B.L. 1989. Norwegian whale sightings surveys in the North Atlantic, 1987. Paper SC/40/O 9 (published in this volume).

Sigurjónsson, J., Gunnlaugsson, T. and Payne, M. 1988. NASS-87: Shipboard sightings surveys in Icelandic and adjacent waters June-July 1987. (Published in this volume).

Sokal, R.R. and Rohlf, F.J. 1981. *Biometry* (2nd Edn). W.H. Freeman and Company. San Francisco. 859pp.

SC/40/O 15

Report of the Cruise Undertaken by Spain as Part of the North Atlantic Sightings Survey, 1987

S. Lens
Instituto Español de Oceanografia, Centro Oceanografico de Vigo, Aptdo. 1552, 36280 Vigo (Pontevedra) Spain
H. Quiroga
Delegacion Provincial del M.A.P.A., Edif. Servicios Multiples, 3a p. Monelos, 15080 La Coruna, Spain
and
L. Gil de Sola
Instituto Español de Oceanografia, Centro Oceanografico de Fuengirola, Aptdo. 255, 29640 Fuengirola (Malaga), Spain

ABSTRACT

Results from a cruise undertaken by Spain as part of a general North Atlantic Sightings Survey are presented.

Between 6 July and 3 August 1987 a total of 2,323 n.miles were steamed on searching effort in three areas between southwest Ireland and northwest Spain. A total of 151 sightings was made, 91 of fin whales, 5 of sperm whales, 11 of pilot whales and 44 of other cetacean species. Some comments are made about the fin whale distribution found in the cruise.

INTRODUCTION

In the summer of 1987, a large-scale co-ordinated sightings survey of the northern North Atlantic was undertaken using a total of eight ships and three aircraft from Denmark, the Faroes, Iceland, Norway and Spain.

An international working group had been established to co-ordinate and design the Survey (hereafter called NASS-87). The aim of NASS-87 was to collect information on the distribution and abundance of the minke, fin and pilot whale. The methodological and practical aspects of the planning of NASS-87 are given in the working group's report (Anon., 1987).

The population of fin whales close to the Iberian Peninsula, belonging to the 'British Isles-Portugal-Spain' IWC management stock, has been studied using sightings surveys since 1981 in an attempt to define its distribution, stock identity and abundance (Aguilar, Grau, Sanpera, Jover and Donovan, 1983; Mizroch and Sanpera, 1984; Sanpera and Jover, 1985; Sanpera and Jover, 1986). A major problem of these surveys was the difficulty of covering the entire distribution of the 'stock'. NASS-87 presented an opportunity to investigate the distribution of the fin whale for a larger area than previously surveyed while also helping to provide information on the distribution and perhaps relative abundance of other species in the same area.

This paper provides a general description of the cruise and its results together with some comments on the patterns of distribution of the sightings. An estimate of fin whale abundance based on these data is presented in Sanpera and Jover (1989).

MATERIAL AND METHODS

The 'Spanish' sightings box was designed to cover the area from the west of Ireland down the north and west of the Iberian coasts, connecting with a 'northern' box to the west of the British Isles. Plans were made to use one vessel for a month, with an intermediate stop due to logistic reasons, trying to reach the northern boundary by mid-July.

The survey design and cruise track followed the method described by Cooke (1987). A modified version of data collection forms used on the IWC/IDCR Southern Hemisphere minke whale cruises (Anon., 1986) was used.

The cruise was carried out on board the *Opermar Uno*, a former tuna boat transformed into an off-shore supplier (30.26m length and 600HP) that had been used on previous cruises: 'Ballena 3' (Sanpera, Grau, Jover, Recasens, Aguilar, Olmos, Collet and Donovan, 1985), and 'Ballena 4' (Sanpera and Jover, 1986). The ship was equipped with a satellite navigation system.

Two sighting positions were established, one on the bridge (4.2m above sea level) and another in the barrel (11m above sea level). Sightings were made with the naked eye by three professional whalers who worked in turns in both places, one at a time, during daylight hours (from 0800 – 2200hrs). Although angle-boards and distance gauges were available, they were not used, largely because the observers found them difficult to use without prior training; angles and distances were thus directly estimated by the observers. At least four scientists were present on each leg of the cruise. They were responsible for completing the weather, effort and sighting forms.

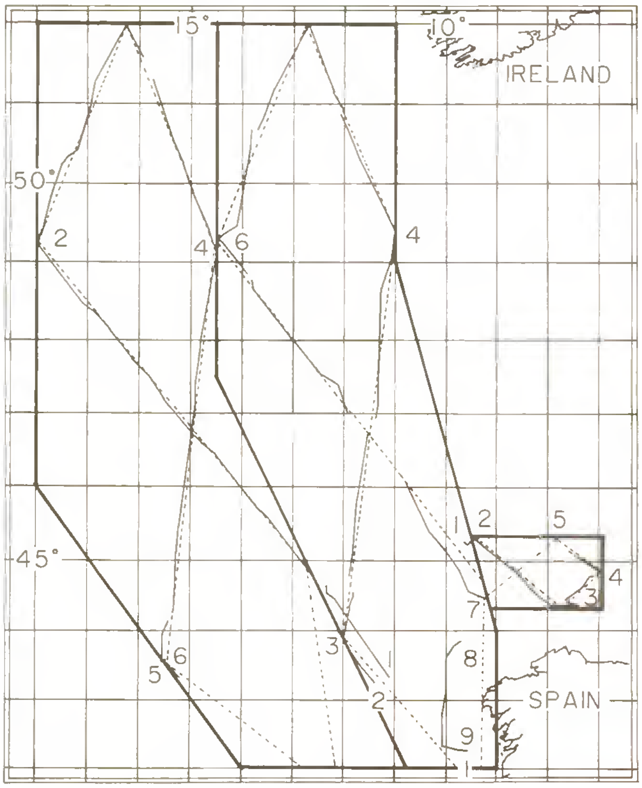


Fig.1. Area covered by the Spanish cruise NASS-87. Planned track, dotted line and actual track, solid line.

RESULTS

The cruise started on 6 July and ended on 3 August with a total of 20 effective searching days. The area covered was slightly different from that first planned because of vessel time constraints (Fig. 1). The area (52°N-42°N and 9°W-18°W) was divided into three sub-areas: eastern; western; and a smaller area in the Bay of Biscay. The cruise track was drawn separately for each Area.

A total of 3,457 n.miles was navigated of which 2,323 n.miles were on sighting effort. The rest were spent travelling from the cruise track to the ports or between transects (see Fig. 1).

The actual track followed off the Galician coast was somewhat further to the west (points 8 to 9) than the planned track. In addition, there were minor deviations due to the navigation system and some parts of some lines were not covered due to bad weather. In total, 85% of the planned cruise track was surveyed. The average searching speed was 9 knots. Most of the searching effort was spent in 'passing' mode (i.e. no deviation from the trackline to investigate a sighting), sightings only being closed on a few occasions to confirm identification of the species.

The numbers of sightings and animals seen are given in Table 1. A total of 151 sightings of at least eight species were made. The fin whale was the most frequently encountered species. No other species of baleen whales were identified, although 13 sightings of 'unidentified' baleen whales were made. Of the fin whale sightings, 69 were of lone animals, 14 were of two and 8 were of groups of three or more animals. The mean group size for the 91 sightings (123 animals) was thus 1.35.

Five sperm whale sightings were made (an estimated 27 animals); group size ranged from 2–9 animals. Forty sightings of small cetaceans were also made, but identification was only possible in some cases. Of those identified, the pilot whale was the most common, with 11 sightings and 123 animals (group size 4–35 animals). Other species identified were the killer whale, the common dolphin and the bottlenose dolphin.

Table 1

Sightings made during the NASS-87 cruise (Spain). Numbers in parentheses refer to animals sighted in mixed schools as secondary species

Species	Number of sightings	Number of whales
Fin (*Balaenoptera physalus*)	91	123
Sperm (*Physeter macrocephalus*)	5	27
Killer (*Orcinus orca*)	1	1
Beaked/Bottlenosed (Ziphiidae)	2	4
Pilot (*Globicephala melas*)	11	123
Common dolphin (*Delphinus delphis*)	4	32
Stenella sp.	4	60
Bottlenose dolphin (*Tursiops truncatus*)	–	(6)
Unidentified baleen whale	13	17
Unidentified dolphins	18	244 (72)
Unidentified cetaceans	2	2

Fig. 2 shows the distribution of the large whale sightings. Fin whales were regularly sighted in the survey area except in the northeastern zone.

No pilot whales were sighted near the Spanish coasts (Fig. 3). Its distribution in the rest of the survey area was similar to that of the fin whale, and on several occasions they were seen close to fin whale sightings. Pilot whales were also found in mixed schools with dolphins. Dolphins were seen throughout the survey, especially in the northeastern part where no other cetacean species were sighted. The number of sightings of other dolphin species is too few to allow comments on their distribution (Fig. 3).

DISCUSSION

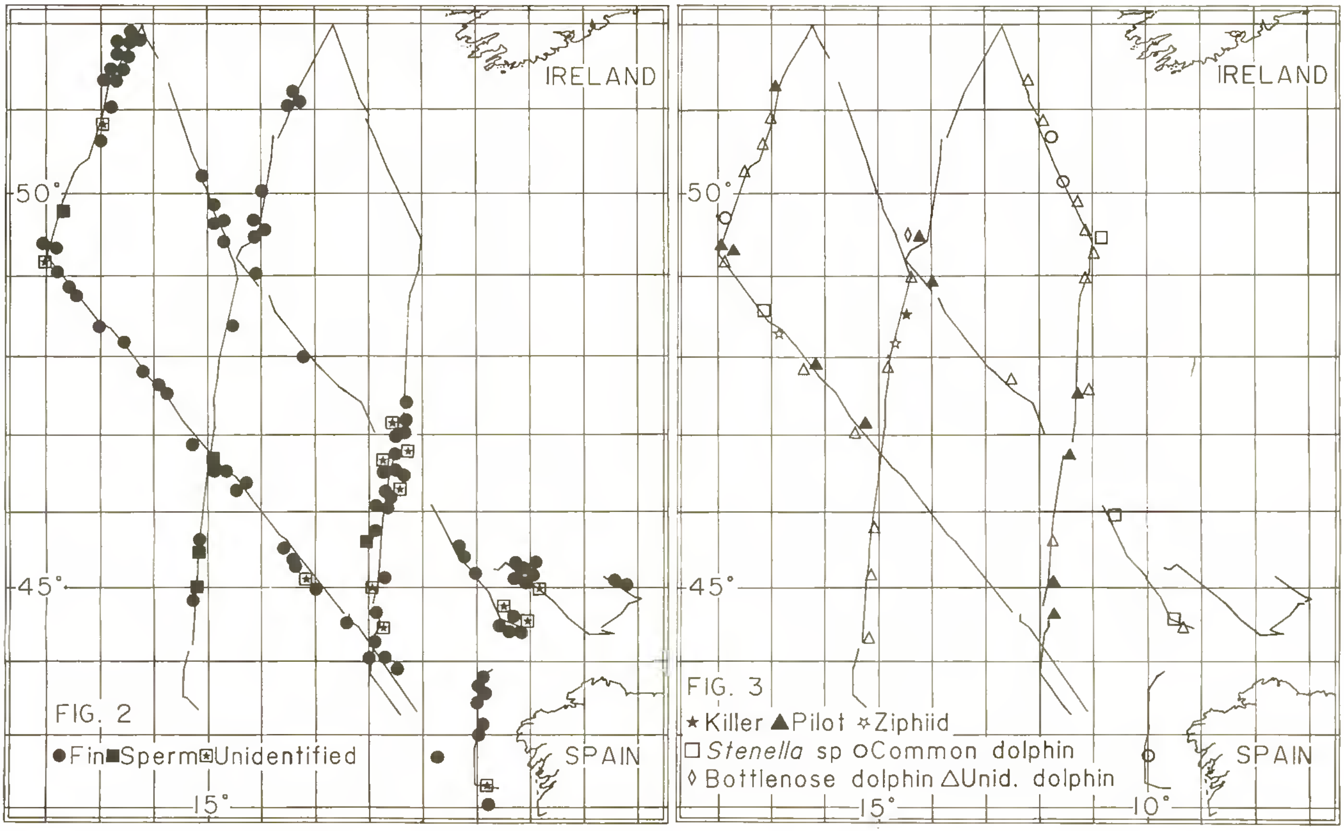
In addition to being seen inside the operational limits of the traditional whaling grounds (Aguilar and Lens, 1981), many fin whales were seen to the north and west over a wider area, in what seems to be a continuous distribution. A similar distribution was found in earlier surveys (Sanpera, Aguilar, Grau, Jover and Mizroch, 1984; Sanpera *et al.*, 1985; Sanpera and Jover, 1986).

The lack of fin whale sightings in the northeastern area coincides with the continental shelf of the Celtic Sea. However, a considerable number of sightings in the northwestern track were made just outside the continental shelf. This shows a similar pattern of distribution with respect to bathymetry to that found on the Galician coast, in this and previous cruises (Aguilar *et al.*, 1983). In general it can be said that fin whales were found in waters more than 2,000m depth, with some local concentrations outside the continental shelf.

ACKNOWLEDGEMENTS

We are indebted to P. Hammond of SMRU (Cambridge) for the design of the cruise track line. Thanks are given to the crew, whale spotters and members of the scientific team who participated in the cruise. O. Cendrero (Instituto Español de Oceanografia, Promontoiro de S. Martin, Santander) and A. Gonzalez Garces (Instituto Español de Oceanografia, Vigo) reviewed the paper.

Funds were provided by the Fisheries Secretariat of the Ministry of Agriculture, Fisheries and Food of Spain.



Figs. 2 and 3. Distribution of large whale sightings and small cetacean sightings made during the cruise.

REFERENCES

Aguilar, A., Grau, E., Sanpera, C., Jover, L. and Donovan, G. 1983. Report of the 'Ballena 1' whale marking and sighting cruise in the waters off western Spain. *Rep. int. Whal. Commn* 33:649–55.

Aguilar, A. and Lens, S. 1981. Preliminary report on Spanish whaling activities. *Rep. int. Whal. Commn* 31:639–43.

Anonymous. 1986. Planning meeting of IWC/IDCR southern minke whale assessment cruise in 1986/87. Tokyo 6–8 October 1986. (Unpublished).

Cooke, J.G. 1987. Estimation of the population of minke whales in Antarctic Area IV W in 1984/85. *Rep. int. Whal. Commn* 37:273–6.

Mizroch, S.A. and Sanpera, C. 1984. A preliminary estimate of abundance of fin whales in the Atlantic waters near Spain. *Rep. int. Whal. Commn* 34:395–7.

Sanpera, C., Aguilar, A., Grau, E., Jover, L. and Mizroch, S.A. 1984. Report of the 'Ballena 2' whale marking and sighting cruise in the Atlantic waters off Spain. *Rep. int. Whal. Commn* 34:663–6.

Sanpera, C., Grau, E., Jover, L., Recasens, E., Aguilar, A., Olmos, M., Collet, A. and Donovan, G.P. 1985. Report of the 'Ballena 3' fin whale marking and sightings cruises off Spain, 1983. *Rep. int. Whal. Commn* 35:495–7.

Sanpera, C. and Jover, L. 1985. Population estimates of fin whales inhabiting Atlantic waters near Spain. *Rep. int. Whal. Commn* 35:353–5.

Sanpera, C. and Jover, L. 1986. Results of the 'Ballena 4' fin whale sighting cruise. *Rep. int. Whal. Commn* 36:253–5.

Sanpera, C. and Jover, L. 1989. Density estimate of fin whales in the North Atlantic from NASS-87 Spanish cruise data. Paper SC/40/Ba13 (published in this volume).

SC/40/Ba13

Density Estimate of Fin Whales in the North Atlantic from NASS-87 Spanish Cruise Data

Carolina Sanpera and Lluis Jover

Department de Biologia Animal (Vertebrats), Facultat de Biologia, Universitat de Barcelona, Avda. Diagonal 645, Barcelona 08028, Spain

ABSTRACT

As part of the 1987 North Atlantic Sightings Survey, Spain conducted a summer shipboard survey in the temperate waters of the North Atlantic. A total of 84 primary sightings of fin whales was made and a survey area of 193,947n.miles^2 was covered by 2,323n.miles on effort. The density of fin whale groups is estimated at 0.0177 groups/n.miles^2 (SE(D)=0.0014) using a Fourier series estimator (one-term) on ungrouped smeared perpendicular distance data truncated at 1.8n.miles. This corresponds to an exploitable population size of 4,109 fin whales in the survey area, using a mean school size of 1.301 and a takeable proportion of 0.92.

INTRODUCTION

Estimating current abundance using techniques involving line transect methodology constitutes an essential part of the Comprehensive Assessment being carried out by the Scientific Committee (IWC, 1987a). In recent years several aerial and shipboard surveys have been carried out in the eastern North Atlantic with the aim of estimating distribution and abundance of certain whale stocks (e.g. Kapel and Larsen, 1983; Sigurjónsson, 1983; Kapel, 1984; Hiby, Martin and Fairfield, 1984; Martin, Hembree, Waters and Sigurjónsson, 1984; Mizroch and Sanpera, 1984; Sigurjónsson, 1985; Sanpera and Jover, 1985; Sanpera and Jover, 1986). However, practical problems in covering the entire distributional range of any species, have meant that only point estimates for the areas surveyed could be computed.

In recent years, the Scientific Committee of the IWC has expressed interest in a large scale sighting survey in the North Atlantic, and in 1986 recommended that efforts be made to coordinate simultaneous surveys between research groups in the North Atlantic (IWC, 1987b).

Plans for such a North Atlantic Sighting Survey in 1987 (NASS-87) were initiated in June 1986 and the aim was to conduct simultaneous surveys in order to collect distributional data and calculate estimates of abundance for cetacean species. Minke, fin and pilot whales were the major target species. (Anon, 1987a).

This paper presents a density estimate for fin whales in the area covered by the Spanish cruise.

MATERIALS AND METHODS

The survey took place from 7 July to 3 August 1987 in North Atlantic temperate waters from the northwest coast of Spain to the southwest coast of Ireland, extending westwards to 18°00′W (for a detailed description see Lens, Quiroga and Gil de Sola, 1988).

The area surveyed incorporated and was larger than those areas covered by the earlier 'Ballena-2' and 'Ballena-3' cruises (Mizroch and Sanpera, 1984; Sanpera and Jover, 1985) but was roughly similar to that of the 'Ballena-4' cruise (Sanpera and Jover, 1986) (see Fig. 1). All cruises were carried out at approximately the same period of the year.

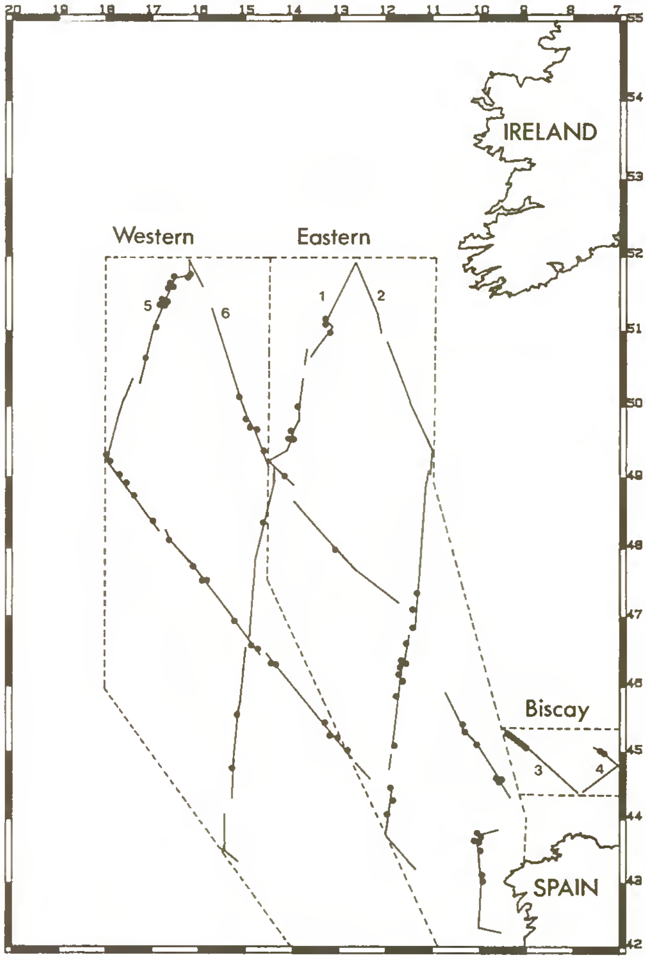


Fig. 1. Area surveyed, cruise tracks and fin whale sightings in each block.

The intended survey area was divided into three blocks (Eastern, Western and Bay of Biscay) because of the vessel's limited range (Fig. 1). For each block, the tracks were placed with a saw-tooth design following the method of Cooke and Hiby (1987). Data were collected as recommended in Anon. (1987b). Each block was surveyed by a total track comprising two transects (one running North and one running South). Table 1 lists separately for each transect the number of fin whale primary sightings, miles on effort and area covered.

Table 1

Number of fin whale primary sightings (s = schools, a = animals), nautical miles surveyed and areas given by transects and blocks

	Transect number	Primary sightings s	Primary sightings a	Miles surveyed	Block areas
Eastern block	1	15	24	565	101,125
	2	21	30	634	
Biscay block	3	7	9	95	6,077
	4	2	2	38	
Western block	5	31	39	526	86,745
	6	8	9	465	
Totals		84	113	2,323	193,947

All transects were surveyed in passing mode except for a short fraction at the beginning of the cruise, which was surveyed in closing mode. The original data were smeared prior to analysis using the technique described by Hammond (1984), applying smearing factors of ± 7.5° for sighting angles and ± 0.05n.miles (when $r \leq (0.5$n.miles) or ±0.25n.miles (when $r > 0.5$n.miles) for radial distances. Density estimates were computed by means of the transect program, using a Fourier Series estimator (Laake, Burnham and Anderson, 1979).

RESULTS AND DISCUSSION

Fig. 2 shows a plot of the original sighting distances (r) and angles (θ) relative to the position of the sighting platform. Rounding of data to the nearest convenient value (0.5 n.miles) clearly occurred for the estimated radial distances. Most of the sightings were made at angles less than 45° (55 of 84). This may have been due to the non-uniform distribution of observer effort over the entire angle range and to the fact that most of the unidentified primary sightings were made at greater angles.

The distribution of perpendicular distances (y) based on the original data is given in Fig. 3A. Because rounding errors probably also occurred during distance estimation, the smearing procedure described above was applied. The resulting distribution of perpendicular distances is given in Fig. 3B.

In order to estimate f(0), a Fourier series model was fitted to the pooled ungrouped smeared perpendicular distances truncated at 1.8n.miles. The truncation point was chosen after consideration of Fig. 3B. The number of terms was selected using the stopping rule (Burnham, Anderson and Laake, 1980) provided by the Transect program. The estimated f(0) was 1.051 and SE(f(0))=0.081.

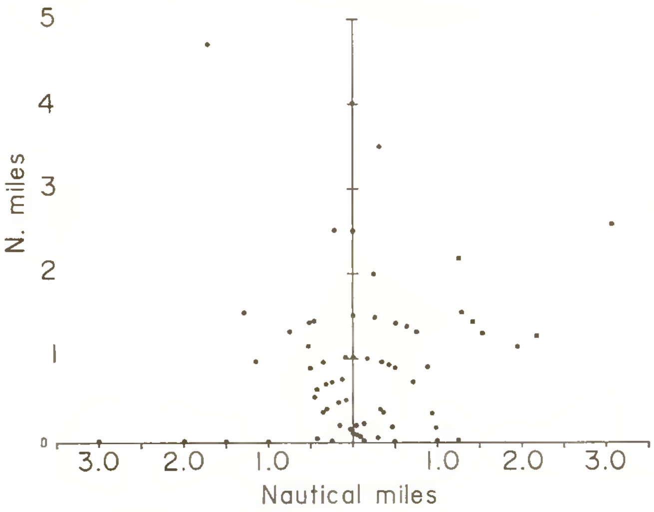


Fig. 2. Distribution of the position of fin whales primary sightings in relation to the sighting platform.

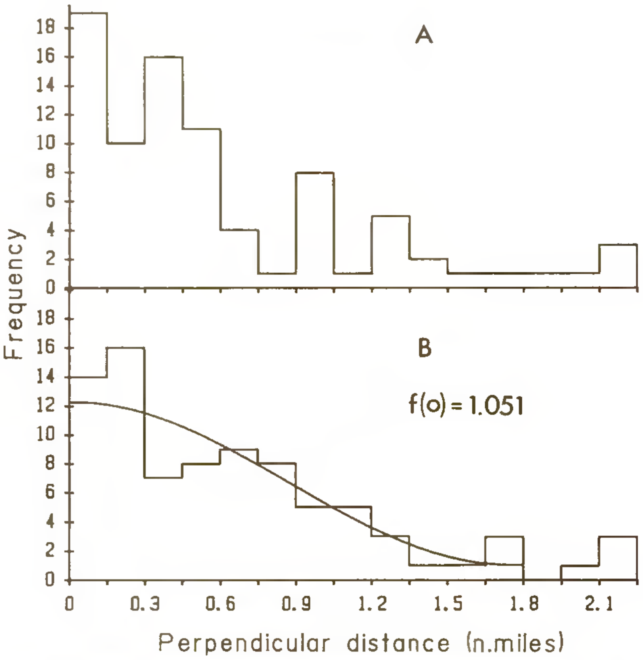


Fig. 3. Distribution of perpendicular distances at cut points 0.15 nm. A: original data, B: smeared data. Also shown in B is the one-term Fourier series fitted to the ungrouped pooled smeared data truncated at 1.8 n.miles.

A jackknife procedure was used to obtain an estimate of var(D). In order to do this, smeared data were divided into four sets (set 1: transects 1+3, set 2: transects 2+4, set 3: transect 5 and set 4: transect 6). Transects 3 and 4 were pooled with 1 and 2 respectively because of the low effort in the Bay of Biscay block. In the analysis carried out to obtain the jacknife estimate, all the selected sets of perpendicular distances were fitted by a model with one term (shown in Fig. 3b for all data, cut points 0.15n.miles, $\chi^2_{10}=6.99$, p=0.64), although the stopping rule selected two terms when data set 4 was excluded.

The resulting estimates are for the pooled data, D=0.0181 and SE(D)=0.0045; and for the jacknife procedure; $D_j=0.0177$ and $SE(D_j)=0.0014$.

The estimates are similar. If D_j is chosen as the estimate having the lower variance, the number of schools (N) for the area surveyed is (AD_j) 3,433 schools with SE(N)=267.7. The 95% confidence interval (Burnham *et al.*, 1980) is Area x $[D_j, \pm t_{.05,3}\, SE(D_j,)]$ = 2,569 to 4,297 schools.

As the survey was carried out in passing mode, it was difficult to estimate the lengths of individual animals. Using the value for the takeable proportion (T=0.92, SE(T)=0.0432) estimated by Sanpera and Jover (1986), with the values for mean school size (s=1.301, SE(s)=0.619) from this cruise's primary sightings (Table 2) gives an exploitable population size of (P=N s T) 4,109 animals with SE(P)=1,992.6.

As shown in Table 3, the present density estimate is larger than those of Sanpera and Jover (1985 and 1986) although not that of Mizroch and Sanpera (1984). Several factors may account for this: the changes in the areas covered; the weather conditions; the distribution of fin whales. The annual variations in the sightings per unit effort (Table 3) are extremely difficult to evaluate.

Table 2

Observed school size distribution from 84 fin whale primary sightings (mean school size is 1,345 and se(s) = 0.736, excluding one school of five animals (s = 1.301, se(s) = 0.619))

Group size	Frequency	Percentage	Group size	Frequency	Percentage
1	65	77.4	3	7	8.3
2	11	13.1	5	1	1.2

Table 3

Density estimates (D), median perpendicular distance, unsmeared, to sightings (y schools) and to individuals (y indiv. = y schools weighted by school size), and sightings per unit effort (n/100 n.miles) of all fin whale primary sightings for recent cruises (see references in the text)

Cruise:	Ballena-2	Ballena-3	Ballena-4	NASS-87
D	0.01888	0.00572	0.00647	0.0177
se(D)	0.00485	0.00146	0.00169	0.0014
y schools	0.684	1.200	0.707	0.425
y^1 schools	-	1.305	0.737	0.464
y indiv.	-	-	0.860	0.464
y^1 indiv.	-	-	0.860	0.470
SPUE	2.82	1.20	0.97	3.62
SPUE[1]	-	1.42	1.11	4.09

[1] Primary fin whales plus primary unidentified balaenopterids have been pooled.

Regarding the estimates of f(0), the 1987 survey was conducted entirely in passing mode, thus eliminating the problems of secondary sightings and so–called 'stop/start' effects associated with closing mode surveys (Kishino and Kasamatsu, 1987; Hiby and Hammond, 1989). Median y values from a passing mode survey are expected to be smaller than from an equivalent closing mode survey because the probability of a sighting being unidentified increases with perpendicular distance. This is balanced, however, by the smaller number of identified sightings included in estimation of density.

The distribution of perpendicular distance data seems to fulfill the 'shape criterion' proposed by some authors (Burnham *et al.*, 1980; Buckland, 1985; Hiby and Hammond, 1989), since a 'shoulder' is present near f(0). However, inaccuracies in recording sighting angles and radial distances have required the application of a smearing correction. The Fourier Series estimator is usually considered to be model robust, although it does not appear to be very stable on some data sets (e.g. some IDCR minke whale data) in which the hazard-rate model performs better (Hiby and Hammond, 1989). The small difference observed when fitting the one term (f(0)=1.051) or two term (f(0)=1.103) Fourier series models to our smeared data, suggest that the estimate of f(0) presented here is quite reliable.

ACKNOWLEDGEMENTS

Thanks are due to Phil Hammond from the SMRU (Cambridge) for his assistance in the design of the cruise tracks, valuable suggestions and for the revision of the manuscript. Thanks are also given to Sally A. Mizroch for her cooperation in the fieldwork, as well as to the other members of the cruise crew, especially the observers. We also acknowledge the comments from two anonymous referees.

Funding for this work was provided by the Fishery Secretariate, Ministry of Agriculture, Fisheries and Food of Spain.

REFERENCES

Anonymous. 1987a. Report of the North Atlantic Sighting Survey. Planning Meeting. February 1987. (Unpublished).

Anonymous, 1987b. Report of the 3rd Planning Meeting of the 1987 North Atlantic Sightings Survey. (Unpublished).

Buckland, S.T. 1985. Perpendicular distance models for line transect sampling. *Biometrics* 41: 177–95.

Burnham, K.P., Anderson, D.R. and Laake, J.R. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monog.* 72: 1–102.

Cooke, J.G. and Hiby, L. 1987. Some suggestions for survey design for the North Atlantic Sightings Survey Summer, 1987. 3rd Planning Meeting of the 1987 North Atlantic Sightings Survey. Appendix 1. (Unpublished).

Hammond, P.S. 1984. An investigation into the effects of different techniques of smearing the IWC/IDCR minke whale sightings data and of the use of different models to estimate density of schools. *Rep. int. Whal. Commn* 34: 301–7.

Hiby, A.R., Martin, A.R. and Fairfield, F. 1984. IDCR Cruise/Aerial Survey in the North Atlantic 1982: Aerial survey report. *Rep. int. Whal. Commn* 34: 633–44.

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. *Rep. int. Whal. Commn* (special issue 11).

International Whaling Commission. 1987a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 37:33.

International Whaling Commission. 1987b. Report of the Scientific Committee. *Rep. int. Whal. Commn* 37:44.

Kapel, F.O. and Larsen, F. 1983. Whale sightings off West Greenland in June–September 1981. *Rep. int. Whal. Commn* 33:657–66.

Kapel, F.O. 1984. Whale observations off West Greenland in June-September 1982. *Rep. int. Whal. Commn* 34:621–7.

Kishino, H. and Kasamatsu, F. 1987. Comparison of closing and passing mode. *Rep. int. Whal. Commn* 37:253–8.

Laake, J.L., Burnham, K.P. and Anderson, D.R. 1979. User's manual for program Transect. Utah State University Press, Logan, Utah. 26pp.

Lens, S., Quiroga, H. and Gil de Sola, L. 1988. Spanish cruise of the North Atlantic survey 1987. Paper SC/40/O 15 published in this volume.

Martin, A.R., Hembree, D., Waters, T.D. and Sigurjónsson, J. 1984. IDCR Cruise/Aerial Survey in the North Eastern Atlantic 1982: Cruise Report. *Rep. int. Whal. Commn* 34: 645–53.

Mizroch, S.A. and Sanpera, C. 1984. A preliminary estimate of abundance of fin whales in the Atlantic waters near Spain. *Rep. int. Whal. Commn* 34: 395–8.

Sanpera, C. and Jover, L. 1985. Density estimates of fin whales inhabiting Atlantic waters near Spain. *Rep. int. Whal. Commn* 35: 353–5.

Sanpera, C. and Jover, L. 1986. Results of the 'Ballena 4' fin whale sighting cruise. *Rep. int. Whal. Commn* 36: 253–6.

Sigurjónsson, J. 1983. The cruise of the *Ljosfari* in the Denmark Strait (June-July 1981) and recent marking and sightings off Iceland. *Rep. int. Whal. Commn* 33:667–80.

Sigurjónsson, J. 1985. Sightings survey in the Irminger Sea and off Iceland in 1983. *Rep. int. Whal. Commn* 35: 499–503.

SC/40/Mi15

Surfacing Rates of Minke Whales in Norwegian Waters

Gerald G. Joyce
826 N.E. 80th Street, Seattle, WA 98115, USA
Nils Øien
Institute of Marine Research, P.O. Box 1870, N-5011 Nordnes-Bergen, Norway
John Calambokidis and James C. Cubbage
Cascadia Research, 218 1/2 W. Fourth Avenue, Olympia, WA 98501, USA

ABSTRACT

Surfacing rates of minke whales in Norwegian waters were sampled during the 1987 North Atlantic Sightings Survey, using techniques similar to those used on the Southern Hemisphere minke whale assessment cruises. A total of 13 trials was attempted with 8 trials successfully completed. The mean surfacing rate was 52.4 surfacings per hour (SE=9.4, n=4) using only the four completed trials in which no obvious reaction by the whales to the ship was recorded. The mean duration a whale was at the surface was 3.2 secs (SE=0.53, n=77). Additional studies are needed to determine if the surfacing rates of minke whales in Norwegian waters are significantly different from the surfacing rates of minke whales in other areas.

INTRODUCTION

For surveys based on traditional line transect theory, information on whale surfacing rates can provide an initial indication of the probability of detecting a whale on the trackline and can possibly be used to correct sightings survey data where the probability is not equal to 1 (e.g. see Miyashita, 1986). It is essential information for surveys utilising the cue counting approach (see the review by Hiby and Hammond, 1989).

Although surfacing rate information has been collected for Southern Hemisphere minke whales (e.g. see Ward, 1988), Gunnlaugsson, Sigurjónsson and Donovan (1988) found that little systematic information has been collected for North Atlantic minke whales. They concluded that the available data were insufficient to allow them to correct the aerial survey data they had collected in 1986. In the light of that survey they also concluded that future aerial surveys should use the cue counting technique for which, as we have noted, surfacing rate information is essential. For the above reasons, the International Whaling Commission's Scientific Committee (IWC, 1988) recommended that such studies should be undertaken during the 1987 North Atlantic Sightings Survey (NASS-87; Anon., 1987). This paper describes the experiments undertaken by Norwegian vessels as part of their contribution to NASS-87.

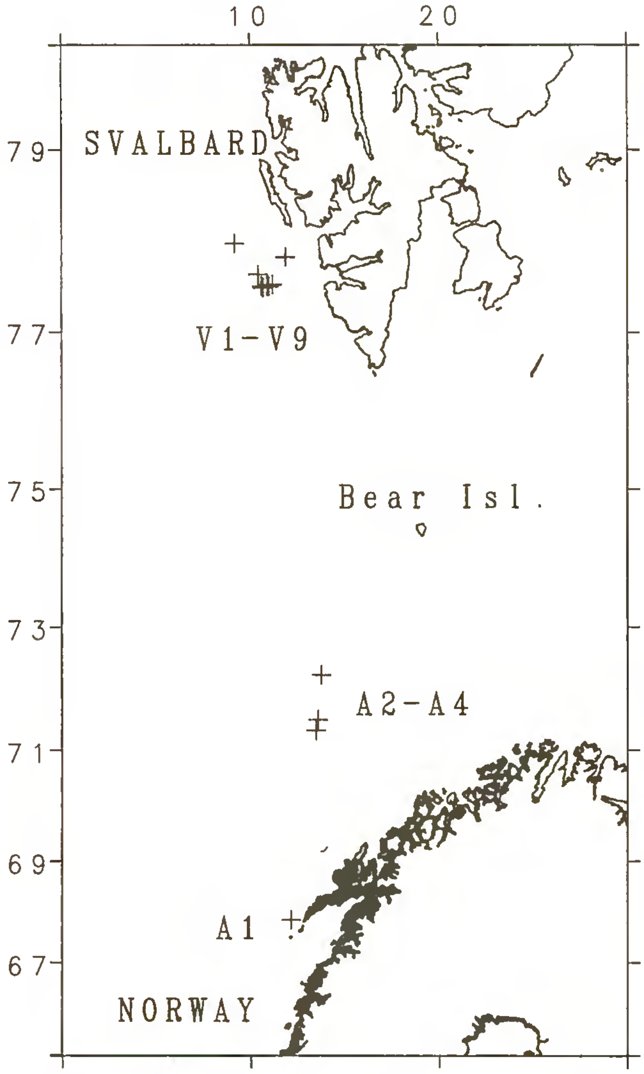


Fig. 1. Location of each experimental trial conducted.

MATERIALS AND METHODS

The study was conducted between 5–24 July 1987 from the chartered ships *'Asbjorn Selsbane* and *Veslekari*. Further details of the vessels and cruise are given in Calambokidis, Christensen, Cubbage, Hartvedt, Jensen, Joyce, Øien, Øritsland, Tellnes and Troutman (1989). The procedures and data forms used were the same as those used during the

Table 1

Experimental trials conducted during the Norwegian North Atlantic Sightings Survey, 1987. Start time is local time; Duration is length of trial in minutes; Surface dur. is the number of surfacings in which the time at the surface was measured

Trial	Date	Start time	Duration	No. whales	No. surface	Surface dur.	Comments
Svalbard							
V1*	870709	0243	35	1	23	14	
V2	870709	0357	–	2	11	4	Aborted
V3*	870709	0424	30	1	26	13	Milling
V4	870709	0502	–	1	5	0	Aborted
V5*	870709	0539	30	1	27	27	Ship seeking
V6*	870709	0625	30	1	21	11	Ship seeking
V7*	870709	0829	30	1	33	5	Slow swimming
V8	870709	1144	30	1	8	2	Surfacings missed
V9	870709	1617	–	1	5	1	Aborted
Norwegian Sea							
A1*	870714	2109	35	1	19	–	Ship seeking
A2*	870718	0254	30	1	26	–	Milling
A3	870718	0439	30	1	0	–	Aborted
A4*	870718	0933	30	1	7	–	Avoidance?

* = 'successful' trial—see text.

Southern Hemisphere minke whale assessment cruises (Hiby and Ward, 1986). Surfacings of the animal were determined by the observation of the whale's body at the surface and not by blows as in the Antarctic, since blows are rarely visible in North Atlantic waters.

Once a whale was sighted, the vessel stopped and the whale was observed for a period of 30–35 mins. The time of each surfacing was recorded to the nearest second and summarised at five minute intervals; the duration the animal was visible at the surface was recorded on an opportunistic basis. After completion of the experiment, the group was approached to confirm the number of whales present.

Table 2

Surfacing rates and surfacing duration of minke whales off Norway

Trial	Surfacing rate (Surfacing/whale/hour)	Surfacing Duration		
		N	Mean	SE
Svalbard				
V1*	39.5	14	3.12	0.44
V2	–	4	3.11	0.40
V3*	52.0	13	2.75	0.34
V4	–	0	–	–
V5*	54.0	27	3.52	0.51
V6*	42.0	11	3.03	0.49
V7*	66.0	5	3.57	0.24
V8	16.0	2	3.13	0.40
V9	–	1	2.99	–
Norwegian Sea				
A1*	32.6	–	–	–
A2*	52.0	–	–	–
A3	–	–	–	–
A4*	14.0	–	–	–

* = 'successful' trial—see text.

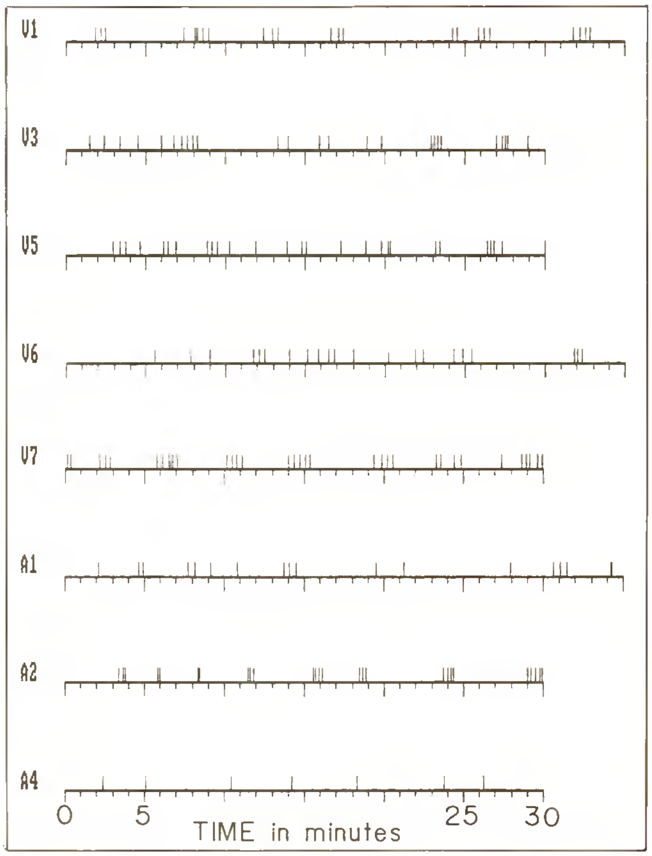


Fig. 2. Surfacing pattern of minke whales observed during the 1987 NASS study. Time is indicated in minute intervals. Each vertical line indicates the surfacing of a whale. Duration of each surfacing is not incorporated into the figure.

RESULTS

Experimental trials from the *'Asbjorn Selsbane* were conducted in the Norwegian Sea while those from the *Veslekari* were made on the banks within 50 n.miles of the west coast of Svalbard (Fig. 1).

A total of 13 trials was conducted. Four trials were halted when the group was either lost (n=3) or confused with another group in the area (n=1). A further trial, although completed, was excluded from the analysis as some surfacings were likely missed. Of the remaining eight 'successful' trials, in three the whales directly approached the ship in apparent ship-seeking behavior, while in one the whale may have been actively avoiding the ship after the ship approached to within 50m of the whale. All trials are summarised in Table 1. The surfacing profiles for the 'successful' trials are shown in Fig. 2.

Pooling the observations from the 'successful' trials yields a mean surfacing rate of 44.0 surfacings per hour (SE=14.9). If trial A4, which has a markedly different profile and was conducted with a whale apparently avoiding the ship, is omitted, the mean surfacing rate is 48.3 surfacings per hour (SE=10.26). If the three trials in which the whales were apparently attracted to the ship (V5, V6 and A1) are also omitted, the mean surfacing rate is 52.4 (n=4, SE=9.4). The mean duration a whale is at the surface, based on the 77 observations from the data pooled from all trials, is 3.2s (SE=0.53).

The mean surfacing rate (surfacings per whale per hour), and the mean duration that the whale was at the surface, by experimental trial, are shown in Table 2.

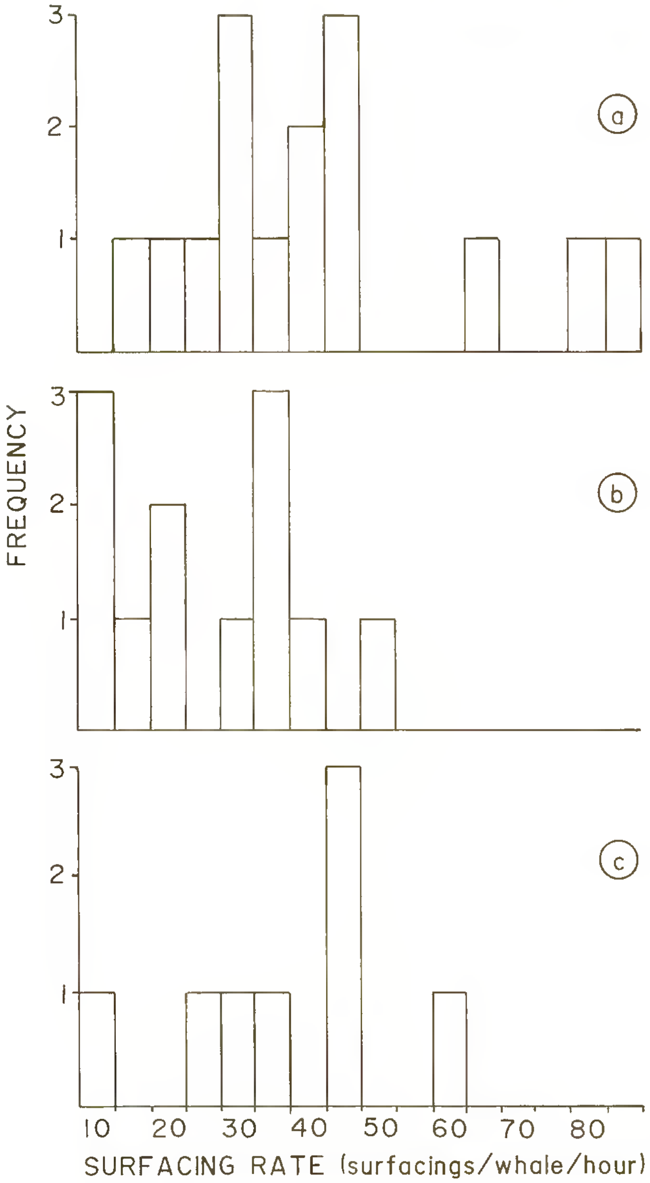


Fig. 3. Surfacing rates of minke from different studies.
a: Antarctic minke whales during the 1980–81 cruise (Source: Joyce, 1982);
b: Antarctic minke whales during the 1984–85 cruise (Source: Hiby and Ward, 1986);
c: North Atlantic minke whales during 1987 NASS.

DISCUSSION AND CONCLUSIONS

Analysis of the experimental results is limited by the small sample size obtained in the study. Much of this was due to the behaviour of the whales, particularly their tendency to react to the vessels; in only four of the attempted 13 trials could the whales be observed for the entire 30 minutes with no apparent reaction to the vessel being noted. These four trials produced a mean surfacing rate of 52.4 but a larger sample size is required to determine if this is significantly different from the mean surfacing rate of 33–37 reported from the Southern Hemisphere data (Hiby and Hammond, 1989).

Minke whales are apparently unaware of the need for statistical precision when they are swimming and surfacing, and depend more on their own choice and level of activity to determine when they surface. This inter-whale variability in surfacing rates is demonstrated in Fig. 3 which includes results from both the Antarctic and this study. In the Antarctic, mean surfacing rates have ranged from 14.4 to 88.1 blows per hour (Joyce, 1982; Hiby and Ward, 1986; Ward and Hiby, 1987), while in this study the rate ranges from 16.0 to 66.0 surfacings per hour when all successfully completed trials are used.

Some limited studies have discussed variations in surfacing rates of minke whales. Kimura and Nemoto (1956), while studying a captive North Pacific minke whale, noted that respiration rates changed with time of day, with minimum surfacing rates in the afternoon and evening, and maximum surfacing rate obtained in the early morning (around 0100 hrs).

Joyce (1982) examined the effect of diurnal patterns on surfacing rates of minke whales in the Antarctic but found no significant trends. However, it is doubtful that any trends would become apparent with such a small sample size (15 groups, total time 200.5 mins), particularly since no other factors (behavior, environmental conditions) were incorporated into the analysis.

Tomilin (1957) reported that the surfacing rate of minke whales in the Bering Strait varied with changes in both environmental conditions and the animals' activities.

If surfacing rates are to be used to 'correct' survey data, they must be examined to see if changes in them are correlated to diurnal patterns, environmental factors and whale behavior. This will require much larger sample sizes than studies to date and may require a different approach to data collection.

Even the determination of a simple mean surfacing rate that does not consider the effects of specific conditions requires a much larger sample size. The results of this experiment indicate, but do not prove, that the surfacing rate of minke whales in the Norwegian Sea and off Svalbard may be higher than that for the Antarctic. Confirmation of this will require many additional observations, with the observations dispersed throughout the day, and in various environmental conditions and locations.

ACKNOWLEDGEMENTS

The research could not have been conducted without the full cooperation of the captains and crews of the ships. We also thank the other researchers in the program who contributed much to the experiment: I. Christensen, S. Hartvedt, T. Øritsland, K. Tellness and B. Troutman. Funding for this research was provided by the Norwegian Government and the Nordic Council; participation of US scientists was made possible by funding from National Marine Fisheries Service, Washington, DC. M. Moon did her usual excellent job in editing this paper. Thanks are also due to G. Donovan and an anonymous reviewer.

REFERENCES

Anonymous. 1987. Report of the North Atlantic Sighting Survey planning meetings, February 18–19 and March 21–22 1987. Paper SC/39/O 14 presented to the IWC Scientific Committee, May 1987. 18pp. (Unpublished.)

Øritsland, T., Øien, N., Calambokidis, J., Christensen, I., Cubbage, J.C., Hartvedt, S., Jensen, P.M., Joyce, G.G., Tellnes, K. and Troutman, B.L. 1989. Norwegian whale sightings surveys in the North Atlantic, 1987. Paper SC/40/O 9 (published in this volume).

Gunnlaugsson, Th., Sigurjónsson, J. and Donovan, G. 1988. Aerial survey of cetaceans in the coastal waters off Iceland, June-July 1986. *Rep. int. Whal. Commn* 38:489–500.

Hiby, A.R. and Ward, A.J. 1986. Analysis of cue counting and blow rate estimation experiments conducted during the 1984/85 minke whale assessment cruise. *Rep. int. Whal. Commn* 36:459–70.

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. *Rep. int. Whal. Commn* (special issue 11).

International Whaling Commission. 1988. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38:32–155.

Joyce, G.G. 1982. Blow patterns as sighting cues for censusing minke whales in Antarctic waters. *Rep. int. Whal. Commn* 32:787–90.

Kimura, S. and Nemoto, T. 1956. A note on a minke whale kept alive in an aquarium. *Sci. Rep. Whales Res. Inst., Tokyo* 11:181–9.

Miyashita, T. 1986. Abundance of Baird's beaked whales off the Pacific coast of Japan. *Rep. int. Whal. Commn* 36: 383–6.

Tomilin, A.G. 1957. *Zveri SSSR i prilezhaschikh stran. Zveri vostochnoi Evropy i sevornoi Azii. IX. Kitoobrazyne*. Akad. Nauk, Moscow, 756pp. [Translated in 1967 as *Mammals of the USSR and Adjacent Countries. Vol.IX. Cetacea* by the Israel Program for Scientific Translations, Jerusalem, 717pp.]

Ward, A.J. and Hiby, A.R. 1987. Analysis of cue counting and blow rate estimation experiments carried out during the 1985/86 IWC/IDCR minke whale assessment cruise. *Rep. int. Whal. Commn* 37:359–62.

SC/40/Mi23

Report on Icelandic Minke Whale Surfacing Rate Experiments in 1987

Thorvaldur Gunnlaugsson

Programme for Whale Research, Marine Research Institute, P.O. Box 1390, Skulgata 4, 121 Reykjavík, Iceland.

ABSTRACT

For interpretation of sightings data obtained in aerial surveys off Iceland in 1986 and 1987 (correction for below surface animals), the need for exact information on surfacing rates of minke whales in this area became evident. The present note describes dive time experiments that were conducted from several platforms in 1987. From completed experiments the average number of surfacings for 16 pods (including one of 4 animals) was 26.31 which gives an average dive-time interval of 68.3 seconds (CV 0.056).

INTRODUCTION

Dive time experiments on minke whales have been conducted in the Southern Hemisphere in conjunction with experiments aimed at estimating abundance by the cue counting method (Joyce, 1982; Hiby and Ward, 1986; Ward and Hiby, 1987; Ward, 1988). When analysing the aerial survey data obtained in Icelandic coastal waters in 1986 and 1987 (Gunnlaugsson, Sigurjónsson and Donovan, 1987; Donovan and Gunnlaugsson, 1989), it became clear that blow rate information was essential for interpretation of the results for stock abundance estimation. Information on dive-pattern is also needed for correcting for diving animals in shipboard surveys where cue counting information has not been collected. During the planning of the 1987 North Atlantic Sightings Survey (NASS-87) a decision was therefore made to conduct dive-time experiments onboard Icelandic and Norwegian shipboard surveys (Anon., 1987). Four experiments were successfully completed onboard the three Icelandic survey vessels (Sigurjónsson, Gunnlaugsson and Payne, 1989).

Additional experiments were conducted during a separate sightings survey onboard a whaling vessel southwest of Iceland in August 1987 and in the same period aboard two minke whaling vessels in shallow waters to the north and east of Iceland. The present paper reports on and discusses the results of these experiments.

MATERIALS AND METHODS

The experiments were carried out in July 1987 onboard the three NASS-87 sightings vessels m/v *Skirnir* AK, m/v *Keflvikingur* KEF and r/v *Arni Fridriksson* RE, the whaling vessel *Hvalur 9* RE and the minke whalers m/v *Njördur* EA and *Eyglo* NK during August 1987 (Table 1).

Generally, the procedures used were similar to those described by Hiby and Ward (1986) in the Antarctic. The animals were kept at close range (a few hundred meters), while not disturbing their behaviour. The surfacings were monitored from the upper bridge or the roof (on the minke whaling vessels) and timing between surfacings or only the number of backs seen were recorded. An experiment was not considered completed unless the animal had been monitored for at least 30 minutes starting at five minute intervals. In order to minimise the risk of not detecting surfacing animals, only well trained observers (mainly experienced whalers) participated in the experiments. This proved extremely important for a successful completion of each experiment.

RESULTS

A number of experiments were abandoned due to disturbances caused by sightings of other animals, when the experimental animal moved in unpredictable directions into glare or out of the area of optimal sightability, or when the animals were simply lost before the completion of the experiment.

A total of 16 experiments were completed (Table 1), all but one of single animals. The inter-surfacing time frequencies for some of the animals are given in Table 2. From all completed experiments, the average number of surfacings (backs) for the 19 animals (16 pods, including one of 4 animals) was 26.31. This gives an average dive-time interval of 68.3 seconds (CV 0.056).

Most of the experiments were conducted in shallow waters on animals that were apparently feeding. The single animal measured on *Hvalur 9* in the deeper open waters had the longest dive times recorded and it surfaced only two or three times between deep dives. On one occasion a slick was seen and the animal was seen underwater from the barrel after about three minutes, but did not surface until four minutes later.

Table 1

Minke surfacing-rate experiments conducted off Iceland, July–August 1987

Vessel	Area	Depth (m)	Date	Time	Pod size	No. backs
Skirnir	East Greenland coast	300	4/7/87	1038	1	24
Skirnir	Faxafloi, SW Iceland	350	26/7/87	1820	1	37
Keflvikingur	Faxafloi, SW Iceland	40	27/7/87	1610	1	21
Arni Fridriksson	Breidafjord, W Iceland	200	28/7/87	1425	1	18
Njordur	Eyjafj, N Iceland	150	29/8/87	1223	1	23
Njordur	Eyjafj, N Iceland	80	29/8/87	1358	1	26
Njordur	Eyjafj, N Iceland	80	29/8/87	1448	1	33
Hvalur 9	Reykjanes ridge	1,800	30/8/87	1543	1	16
Eyglo	Seydisfjord, E Iceland	80	10/8/87	1025	4	92
Eyglo	Seydisfjord, E Iceland	80	11/8/87	0932	1	28
Eyglo	Seydisfjord, E Iceland	50	11/8/87	1156	1	28
Eyglo	Seydisfjord, E Iceland	60	11/8/87	1602	1	36
Eyglo	Seydisfjord, E Iceland	60	11/8/87	1709	1	29
Eyglo	Seydisfjord, E Iceland	50	11/8/87	1740	1	37
Eyglo	Seydisfjord, E Iceland	100	12/8/87	1251	1	24
Eyglo	Seydisfjord, E Iceland	80	12/8/87	1426	1	29

Table 2

Inter-surfacing time frequencies measured for minke whales in July–August 1987. In addition the following 14 longer dives are given in seconds: 247, 261, 270, 300, 303, 305, 310, 312, 319, 322, 328, 349, 353, 420
Total 269 recorded intervals

Interval (6 secs)	Number of backs	Interval (18 secs)	Number of backs
0 - 5	3	54 - 71	11
6 - 11	25	72 - 89	7
12 - 17	47	90 - 107	7
18 - 23	48	108 - 125	4
24 - 29	25	126 - 143	6
30 - 35	21	144 - 161	11
36 - 41	9	162 - 179	6
42 - 47	8	180 - 195	4
48 - 53	3	196 - 215	6
		216 - 233	4
Total	189		66

Surface times (i.e. when any part of the animal was visible at the surface) were recorded for one animal on *Skirnir* on the 26th of July by F. Kasamatsu. The average was 2.66 seconds for 27 surfacings. The range was from 1.5 to 3.6 seconds.

DISCUSSION

No attempt has been made to assess possible bias due to surfacings ignored by observers.

It is possible that the dive-rhythms obtained from the experiments completed are of animals which were relatively easy to keep track of since they were usually feeding and may therefore not be representative of the total population. Most of the observations were made in the sheltered fjords with a bottom topography that is very different from that at greater depth and distance from land. The vertical distribution of the prey in these different habitats is likely to differ. This may influence the dive-time rhythm of the whales. Such a difference in behaviour is frequently noted by minke whalers in Iceland and has been seen by the present author.

It is evident that substantial efforts are needed to obtain reliable measure of the dive-time rhythm in minke whales off Iceland. Due to the infrequent blows detected in this species off Iceland, experiments could only be conducted under favourable sightings conditions, i.e. in calm sea states and good visibility. Given the limited data obtained during the above experiments, it is questionable whether similar efforts should be continued as these would also need to include the areas outside the fjord inlets and shallow waters. Unfortunately, weather conditions are often unfavourable in these open waters, but if such experiments are planned, thought should be given to the possibility of independent observer effort to obtain some information on the possible bias due to cues being missed. The approach developed by Ward (1988) to correct for missed surfacings, where groups of different size are compared, was not applicable in the present study, since only one experiment is of more than one animal. A different approach to this problem is radio-tagging of individual minke whales, which would possibly give information on both shallow and deep water behaviour.

It is noteworthy how similar the present results are to those obtained in other ocean areas such as the Antarctic (Joyce, 1982; Hiby and Ward, 1986; Ward and Hiby, 1987; Ward, 1988) and northeast Atlantic (Joyce, Øien and Øritsland, 1989). The final conclusion might therefore be that dive times are less variable from between areas than between individuals.

ACKNOWLEDGEMENTS

Thanks are due to the keen scientists, observers and crews onboard the experimental vessels, who helped in collecting the data, particularly Fujio Kasamatsu, Oddur Ingólfsson, Sigurdur Gunnarsson, Ólafur Gunnarsson, Gunnar Vilmundarson, Michael Payne, Jon Francine, Michael Newcomer and Birgir Stefánsson. Thanks are due to Allan Ward of Sea Mammal Research Unit, UK and an anonymous reviewer for useful suggestions on an early draft of this paper.

REFERENCES

Anon. 1987. Report of the third planning meeting of 1987 North Atlantic Sightings Survey, Bournemouth, 18 June 1987 5pp. + appendices. (Unpublished).

Donovan, G.P. and Gunnlaugsson, Th. 1989. North Atlantic Sightings Survey 1987: Report of the aerial survey off Iceland. Paper SC/40/O 10 (published in this volume).

Gunnlaugsson, Th., Sigurjónsson, J. and Donovan, G.P. 1987. Aerial survey of cetaceans in the coastal waters off Iceland, June-July 1986. *Rep. int. Whal. Commn* 38: 489–500.

Hiby, A.R. and Ward, A.J. 1986. Analysis of cue-counting and blow rate estimation experiments carried out during the 1984/85 IDCR minke whale assessment cruise. *Rep. int. Whal. Commn* 36: 473–5.

Joyce, G. 1982. Preliminary results of the experimentation of blow patterns as sighting cues for minke whales in the Antarctic. *Rep. int. Whal. Commn* 32: 787–90.

Joyce, G., Øien, N. and Øritsland, T. 1989. Surfacing rates of minke whales in Norwegian waters. Paper SC/40/Mi15 (published in this volume).

Sigurjónsson, J., Gunnlaugsson, Th. and Payne, M. 1989. NASS-87: Shipboard sightings surveys in Icelandic and adjacent waters June-July 1987. Paper SC/40/O 29 (published in this volume).

Ward, A.J. 1988. Accounting for the effect of pod size in the estimatiuon of blow rates: analysis of data from the 1984/85, 85/86 and 86/87 IDCR minke whale assessment cruises. *Rep. int. Whal. Commn* 38: 265–8.

Ward, A.J. and Hiby, A.R. 1987. Analysis of cue-counting and blow rate estimation, 1985/86 IWC/IDCR minke whale assessment cruise. *Rep. int. Whal. Commn* 37: 259–62.

SC/40/O 10

North Atlantic Sightings Survey 1987: Report of the Aerial Survey off Iceland

G.P. Donovan,
International Whaling Commission, The Red House, Histon, Cambridge, England
Th. Gunnlaugsson
Marine Research Institute, PO Box 1390, Skulagata 4, Reykjavík, Iceland

ABSTRACT

A report of the aerial survey undertaken in Icelandic coastal waters as part of the wider 1987 North Atlantic sightings survey is given. The practical methodology for the cue counting technique used is summarised and sightings results presented. The distribution of whales seen is discussed. Data required for population estimation are presented. These were used by Hiby *et al.* (1989) to obtain an estimate of the minke whale population of 8,645 (CV 0.202). Improvements in survey techniques and equipment are discussed.

INTRODUCTION

Gunnlaugsson, Sigurjónsson and Donovan (1988) reported on the first systematic aerial survey for minke whales carried out in Icelandic waters. As a result of experience gained during that survey, which used traditional line transect theory, they concluded that the 'cue counting' approach (Hiby and Hammond, 1989) was better suited for aerial surveys of minke whales off Iceland. This approach was used in 1987, where again the target species was the minke whale.

The 1987 aerial survey was carried out as part of the North Atlantic Sightings Survey (NASS-87), a multi-national vessel and aircraft survey of the northern North Atlantic (Anon., 1987).

The report which follows deals relatively briefly with methodology and concentrates on those aspects specific to the Icelandic survey. It complements the analysis paper of Hiby, Ward and Lovell (1989).

MATERIALS AND METHODS

Cruise track

The survey area and blocks chosen were essentially those described by Gunnlaugsson *et al.* (1988). For this survey, track design followed that proposed by Cooke (1986). In essence this method uses an objective function to specify the drawing of the tracks such that the probability of any given point being covered can be calculated as a function of its position. The estimated population size is then the sum of the reciprocals of the coverage probabilities for all sightings. The planned track is shown in Fig. 1.

The aircraft

As last year, a twin-engined high winged *Partenavia P-68 Observer*, with a clear plexiglass nose and a 61cm plexiglass bubble window on each side, was used. Way points were stored in the *Omega* navigation system. The survey speed was kept at about 90 n.miles per hour (167km per hour)

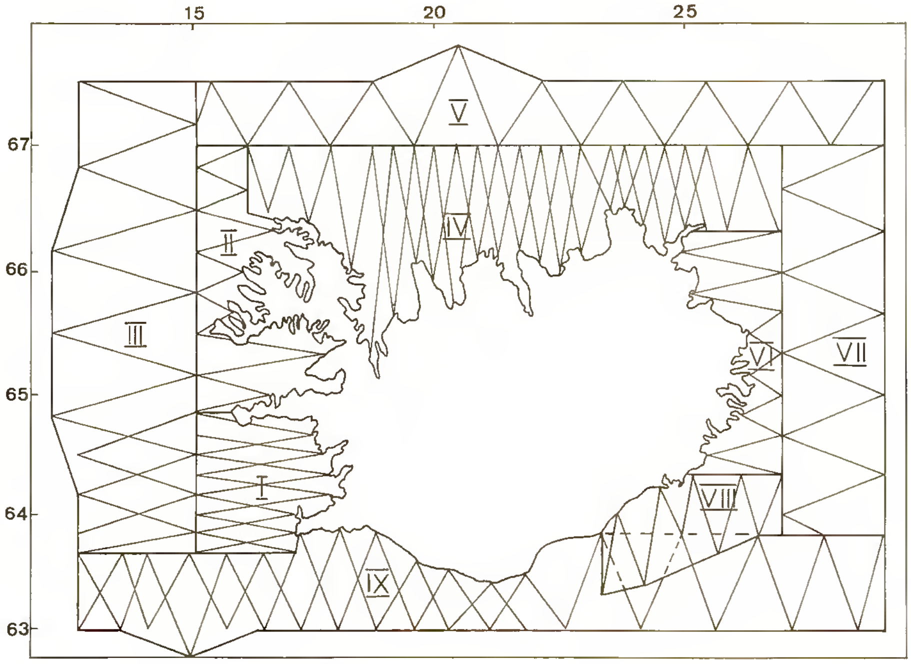


Fig. 1. Original survey plan.

which gave the aircraft an endurance of 7.5hrs. Survey height was 750ft where conditions allowed (a radar altimeter was fitted to the plane).

Data collection

The crew comprised the pilot, co-pilot (usually the 'cruise' leader) and one observer positioned behind them on each side. All four searched for whales (the pilot had considerable experience in such surveys). This year all data related to a sighting were recorded by the observer onto a cassette recorder. The four microphone activated stereo cassette recorders were connected to a *Epson HX-20* computer which transmitted a time signal onto one of the stereo channels while the observer's comments were recorded onto the other. Time was displayed on the *Epson* LED during playback of the tapes.

For the purposes of the cue counting technique, the cue was the dive of the animal (blows of minke whales are rarely visible in the North Atlantic). The following information was recorded for each minke whale sighting: time of first dive; angle of declination to the position of the first dive; time at which the angle was recorded; angle from head of the aircarft the inclinometer reading was obtained; time at which the animal passed abeam; times of subsequent dives; species; school size; initial cue. If the whale was first seen near the abeam line then the angle of declination was taken when abeam. If whales were seen underwater but did not dive this was recorded but the data not used in the analysis. A more limited data set was collected for the other species seen (the cue counting approach is not suitable for large schools of small cetaceans, for example).

In addition to this, the cruise leader recorded the following information for each line: times and positions for start of line, end of line, interrupted effort due to investigation of sighting, interrupted effort due to bad weather, return to on-effort, changes in weather conditions; angular range of significant glare; sea state (Beaufort); cloudiness; visibility; sightability. Sightability is a subjective judgement on the part of the crew as to whether the chances of seeing a minke whale if it is present at the surface are good, moderate or poor.

The times on the *Epson*, the *Omega* and the cruise leader's stop watch were synchronised at the beginning of each flight.

An independent observer experiment was carried out on one of the tracks in Faxaflói, using one observer in the co-pilot's seat and one immediately behind him in the observer's seat. They were isolated from each other both visually and acoustically.

Survey itinerary

The survey began on 1 July 1987 in Block I and finished on 20 July 1987 in Block IX. The original survey plan was somewhat ambitious in terms of expectations of weather and transit time. In view of the apparent effect of sea state on sighting rate found by Gunnlaugsson *et al.* (1988), it was decided that, where possible, lines would be flown in Beaufort 3 or less. Effort was abandoned if the sea state equalled or exceeded Beaufort 4.

The survey lines actually flown are shown in Fig. 2. Poor weather made it impossible to cover the outer western block (high winds) and the seas of eastern Iceland (fog). Further details are given in Table 2.

Analysis

The estimation procedures follow those for the cue counting method described in Hiby and Hammond (1989) and Hiby *et al.* (1989). Estimation of the effective search area is described in the latter paper. In this paper we restrict ourselves to calculating those parameters required for estimating the population size in Hiby *et al.* (1989) i.e. the survey time in seconds, the number of cues, cps (number of cues × area divided by time in seconds) and its associated variance.

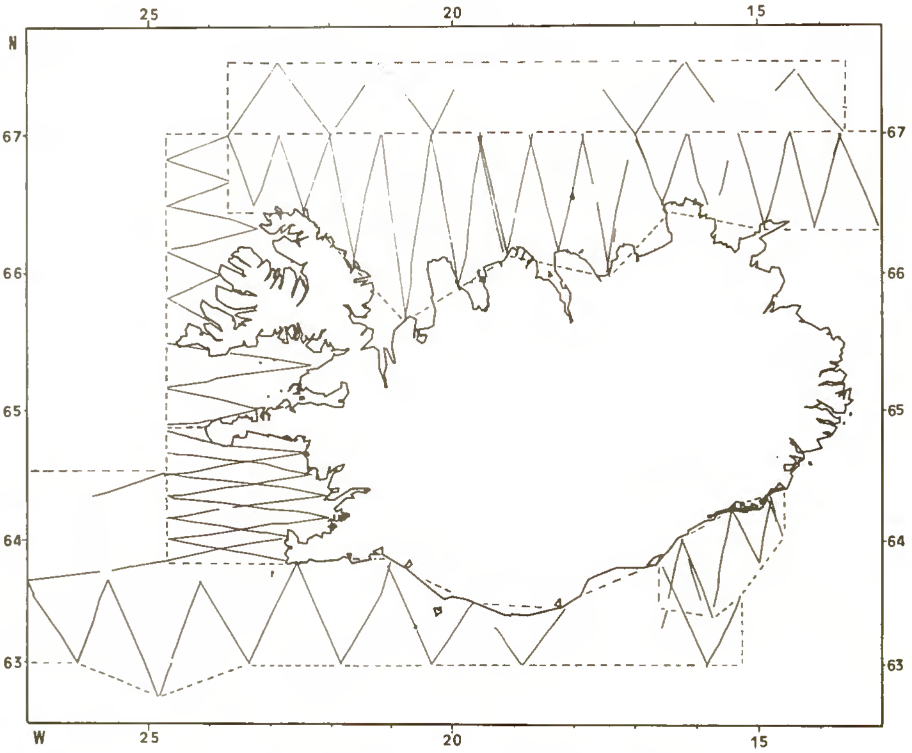


Fig. 2. Survey tracks flown during the 1987 survey.

RESULTS

Distribution

A summary of sightings made is given in Table 1. Sighting positions are shown in Figs 3–7. Ten schools of blue whales were seen comprising 20 animals, all near the Snaefellsnes peninsula (Fig. 4). Ten schools of humpback whales were seen, including one cow/calf pair, all off the western coast (Fig. 4). No fin whales were seen this year, reflecting the fact that the survey did not cover the deeper waters off the western coast of Iceland.

Table 1

Sightings made during the 1987 Icelandic survey

Species	Primary		Mean school size	Total animals	Calves
	Sightings	Animals			
Sperm	1	1	1.0	2	–
Blue	9	17	1.9	20	–
Humpback	6	13	2.2	26	1
Minke	172	190	1.1	205	–
Pilot	3	60	20.0	60	–
Unidentifed medium sized whales	2	2	1.0	2	–
White-sided dolphins	74	650	8.8	657	–
Whitebeaked dolphins	2	9	4.5	9	–
Unspecified dolphins	3	8	–	8	–
Harbour porpoise	32	51	1.6	52	2

As in 1986, minke whales were seen in all areas surveyed. A summary of sightings by Block is given in Table 2. Densities were highest in Faxaflói, off the Reykjanes peninsula and off the southeastern coast (Fig. 3). Again this is similar to the situation in 1986.

Table 2

Survey information and parameters needed for population estimation (see text)

Block	Survey time		Speed (kts)	Distance (nm)	Area $(nm)^2$	Sigh- tings	Ani- mals	cues	cps	CV
	Secs	Hrs								
1	14,415	4.00	87.1	348.8	3,734	39	42	35	9.066	0.205
1 io	13,464	3.74	84.0	314.2	3,734	43	48	39	10.816	0.200
2	19,583	5.44	90.9	494.5	3,928	12	14	12	2.407	0.389
4	51,510	14.31	86.5	1,237.7	12,357	27	28	23	5.518	0.234
5	11,346	3.15	89.0	280.5	6,944	3	3	3	1.836	0.508
8	10,120	2.81	95.3	267.9	1,659	33	39	39	6.393	0.306
9	25,273	7.02	86.2	605.1	16,617	15	16	16	10.520	0.325
Total	145,711	40.48	87.7	3,549.7	45,239	172	190	167	36.645	0.110

Only two sperm whales were seen, both off central northern Iceland. In 1986 12 animals had been seen, again mainly off northern Iceland.

Other toothed whales seen were three schools (60 animals) of pilot whales off southeastern Iceland, 74 schools of white-beaked dolphins, 2 schools of white-sided dolphins and 32 schools of harbour porpoises. The white-beaked dolphins were seen mainly in Faxafloi and off the central north and northeastern coasts (Fig. 5) as they had been in 1986 where they were also seen off the eastern and southeastern coasts. Although fewer harbour porpoises were seen than in 1986, the distribution in both years was similar (Fig. 6).

In the off-effort sighting made on 20 July (63°13′N, 19°10′W), a group of nine killer whales was observed 'herding' a group of 20 bottlenose dolphins and 20–30 pilot whales. The latter group was fleeing at considerable speed

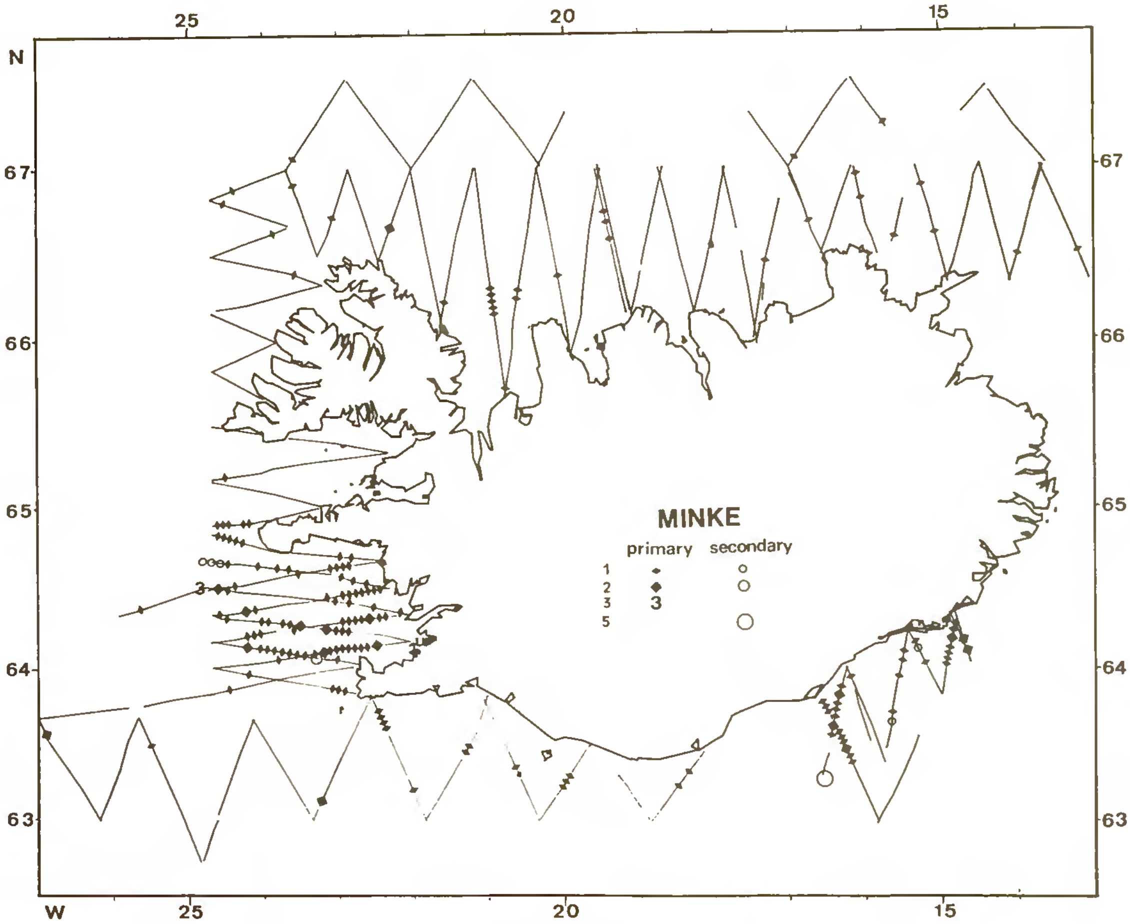


Fig. 3. Sightings of minke whales.

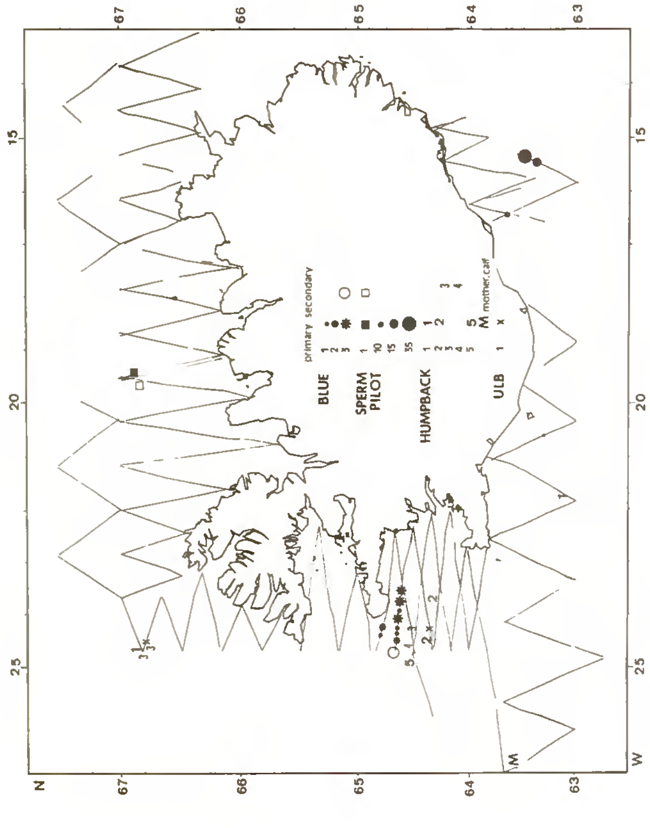


Fig. 4. Sightings of blue, humpback, sperm and pilot whales.

Fig. 5. Sightings of white-beaked dolphins.

Fig. 6. Sightings of other dolphins (UMSC = unidentified medium sized whales).

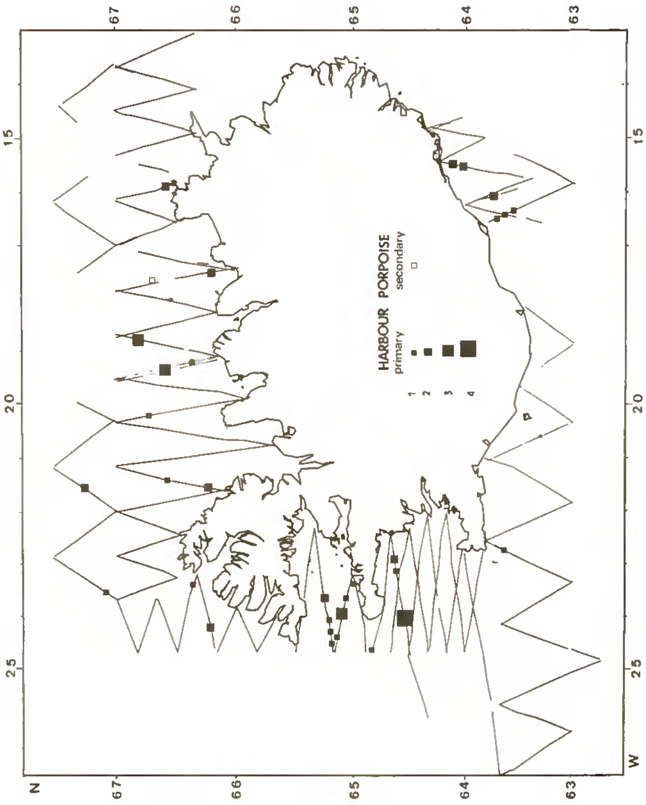


Fig. 7. Sightings of harbour porpoises.

and the initial cue was the churning of the water some three miles from the aircraft. Three of the killer whales were seen to attack the rear group of five pilot whales and blood was seen at the water surface.

The reader is referred to Gunnlaugsson *et al.* (1988), for a more detailed description of the distribution of these species around Iceland.

Population estimate

Results of the parameters discussed under the methodology section are given in Table 2. As noted earlier, these have been incorporated into the analysis of Hiby *et al.* (1989) who estimate the population size in the surveyed area (Blocks 1,2,4,5,8 and 9 excluding the area east of 13°W) to be 8,645 minke whales (CV=0.202).

DISCUSSION

Improvements in survey equipment and procedures

The use of tape recorders to collect the data worked reasonably well. The major problem which arose was a result of having to use a lower power battery than recommended. While this did not affect the speed of the tape (constant checks were made during playback), the resultant poor signal-to-noise ratio meant that some data were lost. More robust connections are also needed between the tape recorders and microphones. A further problem was the time delay between activation of the microphone and the beginning of recording. This resulted in a loss of angular data for a small number of sightings.

The other problem which occurred was the result of a tendency of one observer to round angles. The use of inclinometers with digital readouts would avoid this problem. As discussed in Hiby *et al.* (1989), the robustness of the estimation of the effective search area is improved if estimates of error in the position of a sighting can be obtained. In the present survey one experimental leg was run in 'independent' mode. In future surveys it would be sensible to use independent mode whenever feasible. Ideally this would entail two observers, one behind the other on the same side with almost identical viewing conditions (i.e. from bubble windows). Whether an additional bubble window can be fitted in the rear of the plane needs to be investigated.

ACKNOWLEDGEMENTS

We would like to thank Halli and Gulli, the two observers, and Leif Petersen, the pilot, Minna Raskinen and all those involved in the planning of the North Atlantic Sightings Survey, 1988. We would also like to thank the Sea Mammal Research Unit, UK, who designed the recording system and in particular Lex Hiby for advice carrying out the survey using his cue counting technique and for comments on an earlier draft of the manuscript. Finn Larsen and Randall Reeves are also thanked for their comments.

REFERENCES

Anonymous. 1987. Report of the North Atlantic Sightings Survey planning meetings, February 18–19 and March 21–22. Paper SC/39/O 14 presented to the IWC Scientific Committee, June 1987 (unpublished). 18pp.

Cooke, J. 1986. Estimation of the population of minke whales in Antarctic Area IVW in 1984/85. Paper SC/38/Mi21 presented to the IWC Scientific Committee, June 1986.

Gunlaugsson, T., Sigurjónsson, J. and Donovan, G.P. 1988. Aerial survey of cetaceans in the coastal waters of Iceland, June-July 1986. *Rep. int. Whal. Commn* 38: 489–500.

Hiby, A.R., Ward, A. and Lovell, P. 1989. Analysis of the North Atlantic Sightings Survey 1987: Aerial Survey Results. Paper SC/40/O 12 (published in this volume).

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating current abundance of cetaceans. *Rep. int. Whal. Commn.* (special issue 11).

SC/40/O 11

North Atlantic Sightings Survey 1987: Report of the West Greenland Aerial Survey

F. Larsen

Greenland Fisheries Research Institute, Tagensvej 135, DK-2200 Copenhagen N., Denmark

A.R. Martin

Sea Mammal Research Unit, Madingley Road, Cambridge, CB3 0ET, United Kingdom

and

P.B. Nielsen

Greenland Environmental Research Institute, Tagensvej 135, DK-2200 Copenhagen N., Denmark

ABSTRACT

The paper presents the results of an aerial survey off West Greenland conducted as part of the North Atlantic Sightings Survey 1987. Baleen whale sightings include 2 blue, 53 fin, 39 humpback and 38 minke whales. In addition 8 sperm, 6 beaked and 460 pilot whales were observed.

Cue counting data collected for population estimation are presented. These data were used by Hiby *et al.* (1989) to obtain an estimate of the minke whale population of 1,153 (CV = 0.417) and of the fin whale population of 1,693 (CV = 0.47).

INTRODUCTION

During recent years, several sightings surveys have been conducted off West Greenland, with the aim of collecting data for estimation of stock size using traditional line transect methodology, primarily for minke and fin whales (Larsen, 1985; 1986; 1987). Although useful distibutional data were collected none of the surveys resulted in reliable estimates of stock size.

In planning the North Atlantic Sightings Survey (NASS-87), a multi-national vessel and aircraft survey of the northern North Atlantic (Anon., 1987), it was recommended that aerial surveys be preferred to shipboard surveys especially in areas of expected high densities of whales. It was also recommended that the surveys should employ the 'cue counting' procedure described by Hiby and Hammond (1989) for collecting data on minke and fin whales.

The present paper reports on the West Greenland aerial survey and presents distributional data for all cetacean species observed. It complements the analysis paper of Hiby, Ward and Lovell (1989).

MATERIALS AND METHODS

Survey design

The area to be surveyed was defined on the basis of the distribution of minke and fin whales as known from catches (Larsen and Kapel, 1982) and sightings (Kapel, 1984; Kapel and Larsen, 1982; 1983; Larsen, 1981; 1985; 1986; 1987), except that it was decided not to survey north of 71°30′N. Both minke and fin whales do occur north of 71°30′N, but the lack of airfields between Jakobshavn (appr. 69°15′N) and Thule Air Base (appr. 76°30′N) makes surveying north of 71°30′N impractical. Similarly for practical reasons surveying west of 57°W was not attempted although minke whales are known to occur west of 57°W between 67°N and 68°15′N (Larsen and Kapel, 1982).

The survey area was further divided into six separate blocks, primarily for logistical reasons and based on the availability of airfields (see Fig. 1).

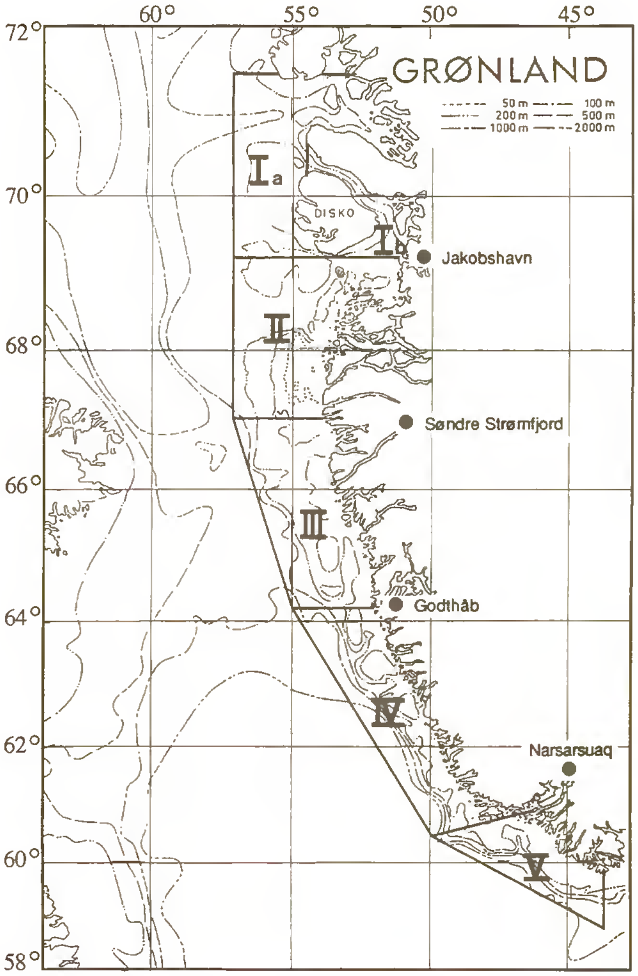


Fig. 1. Blocks surveyed and airfields available during aerial survey off West Greenland, 1987.

The track design followed the procedure recommended by Cooke and Hiby (1987; see also Hiby and Hammond, 1989) as described by Donovan and Gunnlaugsson (1989).

The aircraft and data collection procedure was as described by Donovan and Gunnlaugsson (1989), except that the survey ground speed was kept at 100 n. miles per hour (185.2 km per hour). The complete survey was conducted as an independent observer experiment using the observer in the co-pilot's seat and the observer immediately behind him.

Survey itinerary

The first survey was flown on 28 July. It included only one leg of the first track in block 4, and was intended for testing the data collection procedures and equipment. Because of fog and high winds further surveying had to be abandoned until 2 August. During the next 10 days the six blocks were surveyed two times each in the sequence: 4, 5, 5, 4, 3, 2, 1a, 1b, 1a, 1b, 2 and 3 (see Fig. 2). A third survey of blocks 4 and 5 was abandoned because of adverse weather conditions and before the weather would allow further surveying, the aircraft had to leave because of other commitments.

A total of around 70 hours were spent in survey and transit flights to and from the blocks. The total surveyed track was 4,423 n. miles.

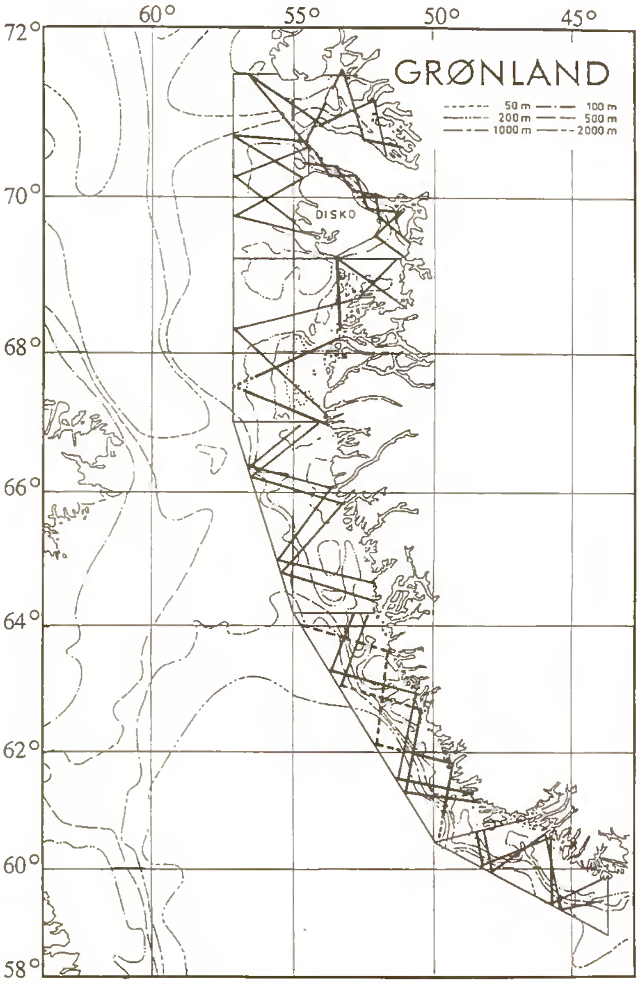


Fig. 2. Lines surveyed in each block during aerial survey off West Greenland, 1987.

Analysis

The estimation procedures follow those for the cue counting method described in Hiby and Hammond (1989) and Hiby *et al.* (1989). Estimation of the effective search area is described in the latter paper. In this paper we restrict ourselves to calculating those parameters required for estimating the population size in Hiby *et al.* (1989).

Coverage probabilities for each block were calculated simply as the area covered by the survey (assuming a nominal effective strip width of 1 n. mile) divided by the total area of the block.

The average number of cues per line in each block was calculated as:

$$n = \sum_{i=1}^{m} n_i/m$$

where m is the number of lines within the block and n_1 the number of cues counted on line no. i in the block.

The associated variance was calculated as:

$$\sum_{i=1}^{m} (n_i - n)^2/(m - 1)$$

where n is the block average defined above.

RESULTS

Distribution

Four species of baleen whales were identified: 2 blue whales, 53 fin whales, 39 humpback whales and 38 minke whales. In addition 1 unidentified baleen whale was observed.

The geographical distribution of the baleen whale sightings is shown in Figs 3–5.

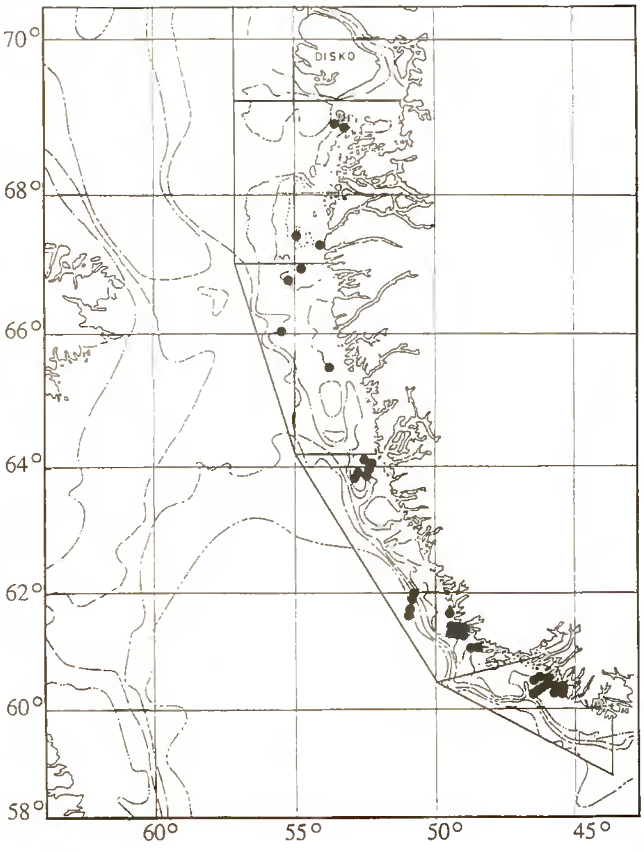


Fig. 3. The distribution of minke whale sightings made during aerial surveys off West Greenland, 1987.

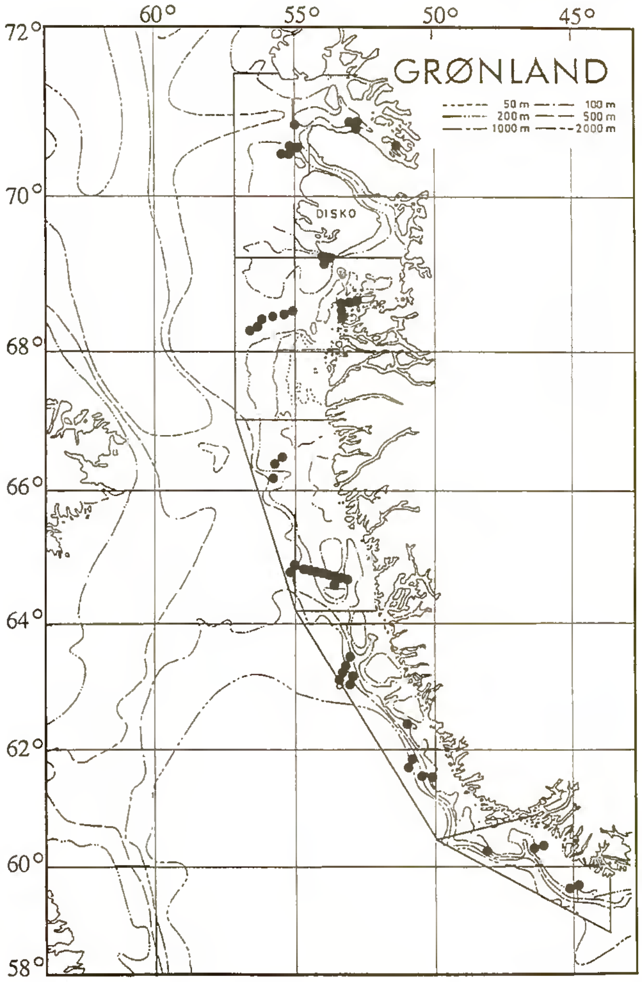


Fig. 4. The distribution of fin whale sightings made during aerial surveys off West Greenland, 1987.

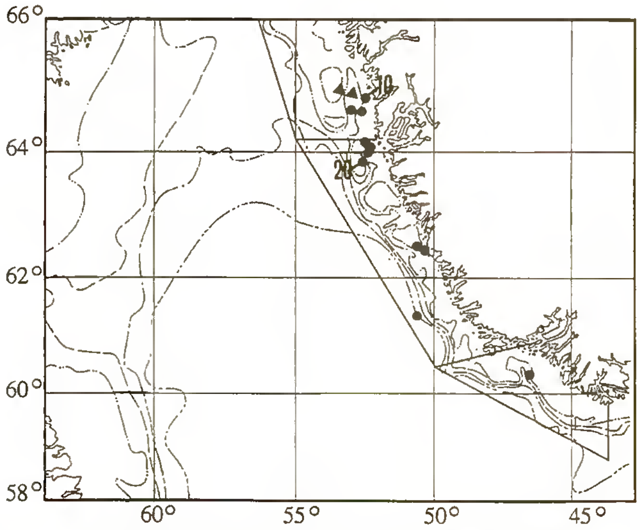


Fig. 5. The distribution of humpback (dots) and blue whale (triangles) sightings made during aerial surveys off West Greenland, 1987.

Most of the minke whale sightings were made in blocks 4 and 5, the majority in nearshore waters. No minke whales were seen in blocks 1a and 1b. Most (30) of the sightings were of single animals; only 4 sightings were of pods of two animals.

Fin whales were observed in all blocks (except 1b), inshore as well as offshore. The sightings were of 15 single animals, 15 pods of two and 4 pods of three animals.

The majority of the humpback whale sightings were made in blocks 3 and 4, just west and northwest of Godthab on Fyllas Banke and Tovqussaq/Sukkertoppen Banke. The humpback sightings were of a loose aggregation of 20 animals, 2 pods of three, 6 pods of two and 3 single animals.

The two blue whales were seen together at Tovqussaq/Sukkertoppen Banke close to the aggregation of humpbacks observed there.

Four species of odontocetes were observed during the survey: 8 sperm whales, 6 beaked whales (probably northern bottlenose whales), approximately 460 pilot whales and 3 harbour porpoises.

The geographical distribution of the odontocete sightings is shown in Figs 6 and 7.

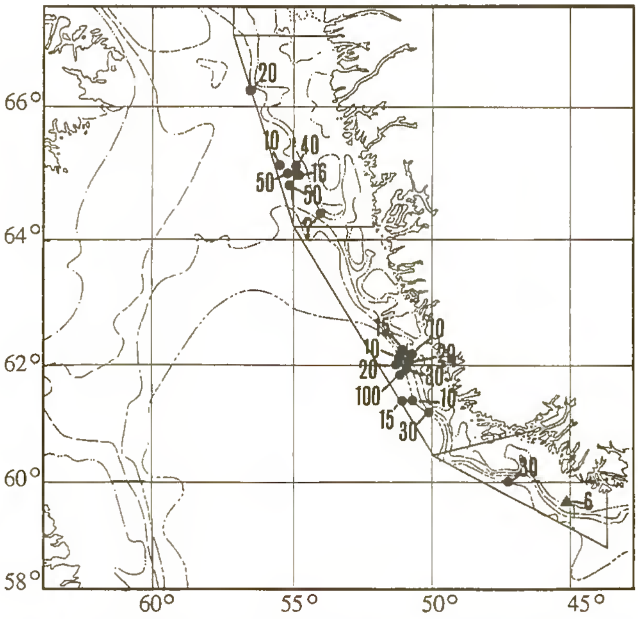


Fig. 6. The distribution of pilot whale (dots) and beaked whale (triangles) sightings made during aerial surveys off West Greenland, 1987.

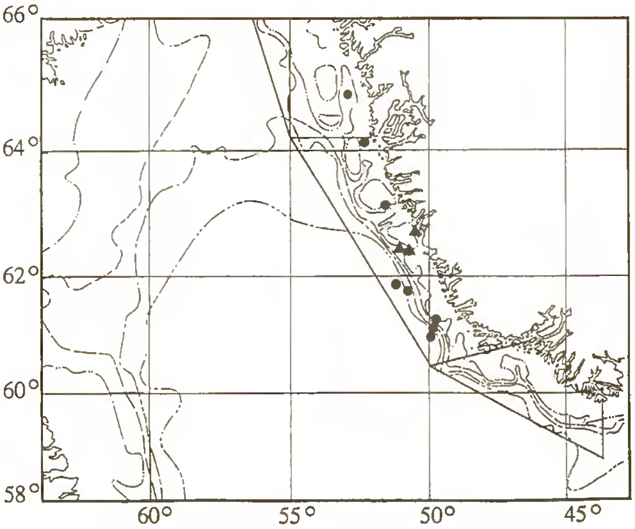


Fig. 7. The distribution of sperm whale (dots) and harbour porpoise (triangles) sightings made during aerial surveys off West Greenland, 1987.

One sperm whale was observed in block 3. The other sightings of this species, all of single animals, were made in block 4.

A pod of six beaked whales was observed in the deep waters southwest of Kap Farvel. They were tentatively identified as northern bottlenose whales.

By far the most numerous odontocete species was the pilot whale, with sightings of 18 pods comprising approximately 460 animals. Pod size ranged between 10 and 100 individuals. All pilot whale sightings were made along the steep outward slopes of the fishing banks between 60°N and 66°15′N, with high concentrations around 62°N and 65°N.

The harbour porpoise sightings were of a single animal and a mother with a calf. The two sightings were made rather close to each other in block 4, but on different days.

Population estimate

Table 1 presents data for each block on the total area of the block, the percentage coverage for each block, the total line length covered within a block and the number of cues for minke and fin whales recorded.

Table 1

Total area of each block, coverage, total line length surveyed on effort within a block and the number of cues for minke and fin whales recorded on each line during aerial surveys off West Greenland, 1987

Block no.	Area (km^2)	Number of lines	Line length (km)	Coverage	Minke cues	Fin cues
1A	28,772	13	1,915	0.067	0	6
1B	5,358	11	728	0.136	0	0
2	39,883	7	1,153	0.029	4	8
3	42,399	8	1,417	0.033	2	21
4	49,430	10	1,860	0.038	20	18
5	33,400	8	1,118	0.033	14	14

As noted earlier, these have been incorporated into the analysis of Hiby *et al.* (1989), who estimate the population sizes in the surveyed area to be 1,493 (CV = 0.43) and 1,985 (CV = 0.46) for minke and fin whales respectively.

DISCUSSION

Distribution

The distribution of the sightings made in this survey is well in accordance with findings from the aerial surveys in 1984 and 1985 (Larsen, 1986; 1987), except that no pilot whales were observed in 1984 and 1985. It is worth noting that as in 1984 and 1985, no minke whales were observed along the outward slopes of Store Hellefiskebanke (between 66°15′N and 68°15′N) and only one was observed along the outward slopes of Lille Hellefiskebanke (between 64°15′N and 66°15′N) in 1987, although these areas were the primary whaling grounds for the Norwegian operations between 1979 and 1982 (Larsen and Kapel, 1982).

The high number of pilot whales observed in 1987 is not entirely explained by the extension of the survey area westward relative to the 1984 and 1985 surveys, as a substantial number of the sightings were made within the 1984/85 survey area. Additional aerial surveys planned for 1988 and 1989 may throw more light on the occurrence of the pilot whale off West Greenland.

REFERENCES

Anonymous. 1987. Report of the North Atlantic Sightings Survey planning meetings, February 18–19 and March 21–22. Paper SC/39/O 14 presented to the IWC Scientific Committee, June 1987 (unpublished). 18 pp.

Cooke, J.G. and Hiby, A.R. 1987. Some suggestions for survey design for the North Atlantic Sightings Survey summer 1987. Appendix 1. In: 3rd Planning meeting of the 1987 North Atlantic Sightings Survey (unpublished).

Donovan, G.P. and Gunnlaugsson, T. 1989. North Atlantic Sightings Survey 1987: Report of the aerial survey off Iceland. Paper SC/40/O 10 (published in this volume).

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating current abundance of cetaceans. *Rep. int. Whal. Commn* (special issue 11).

Hiby, A.R., Ward, A. and Lovell, P. 1989. Analysis of the North Atlantic Sightings Survey 1987: Aerial Survey Results. Paper SC/40/O 12 (published in this volume).

Kapel, F.O. 1984. Whale observations off West Greenland in June–September 1982. *Rep. int. Whal. Commn* 34: 621–8.

Kapel, F.O. and Larsen, F. 1982. Whale sightings from a Norwegian small-type whaling vessel off West Greenland, June–August 1980. *Rep. int. Whal. Commn* 32: 521–30.

Kapel, F.O. and Larsen, F. 1983. Whale sightings off West Greenland in June–September 1981. *Rep. int. Whal. Commn* 33: 657–66.

Larsen, F. 1981. Observations of large whales off West Greenland, 1979. *Rep. int. Whal. Commn* 31: 617–24.

Larsen, F. 1985. Preliminary report of a survey for large cetaceans off West Greenland, 1983. *Rep. int. Whal. Commn* 35: 539 (résumé).

Larsen, F. 1986. Preliminary results of an aerial survey off West Greenland, 1984. *Rep. int. Whal. Commn* 36: 508 (résumé).

Larsen, F. 1987. Preliminary results of an aerial survey off West Greenland, 1985. *Rep. int. Whal. Commn* 37: 401 (résumé).

Larsen, F. and Kapel, F.O. 1982. Norwegian minke whaling off West Greenland, 1976–80 and biological studies of West Greenland minke whales. *Rep. int. Whal. Commn* 32: 263–74.

SC/40/O 12

Analysis of the North Atlantic Sightings Survey 1987: Aerial Survey Results

Lex Hiby, Allan Ward
Sea Mammal Research Unit, c/o BAS, High Cross, Madingley Rd, Cambridge CB3 0ET, UK
and
Phil Lovell
Conservation Research Group, PO Box 114, Cambridge CB4 1YJ, UK

ABSTRACT

Estimates of abundance based on cue counting analysis of aerial survey data are presented for minke whales in West Greenland, Iceland, North Norway and Svalbard and for fin whales in West Greenland. For minke whales the estimates are 1,493 for West Greenland (CV 0.43), 8,645 for Iceland (CV 0.202), 244 for North Norway (CV 0.517) and 817 for Svalbard (CV 0.451). The estimate for fin whales in West Greenland is 1,985 (CV 0.46).

INTRODUCTION

This paper presents an analysis of sightings data collected for minke whales during the aerial surveys conducted in 1987 in Icelandic and Norwegian coastal waters and for minke and fin whales during the aerial survey in West Greenland. The data were collected using the cue counting (CC) sampling procedure. CC sampling and analysis are described in Hiby and Hammond (1989). This paper presents effective search areas (esa) and estimates of abundance for each survey. The reader should refer to the reports of the individual surveys for the location of the survey blocks and tracks (Calambokidis, Christensen, Cubbage, Hartvedt, Jensen, Joyce, Øien, Øritsland, Tellnes and Troutman, 1989; Donovan and Gunnlaugsson, 1989; Larsen, Martin and Nielsen, 1989).

DATA COLLECTION

For CC analysis, observers record the distance to each cue seen within a defined observation sector. The chosen observation sector was the area ahead of the abeam line on both sides of the aircraft. Because blows from minke whales are rarely visible in the North Atlantic, dives were chosen as the cue to be recorded. The distance to each dive was recorded using a declinometer. In order to compensate for the movement of the aircraft during the interval between occurrence of the dive and the time at which the declinometer reading was obtained, all data were recorded onto one track of a twin-track audio tape along with a continuous time signal on the second track which allowed the time interval to be measured. A correction for the distance to the point at which the dive occurred was calculated using an estimate of the ground speed of the aircraft and an estimate of the angle from head to the position at which the declinometer reading was obtained.

Each aircraft contained the pilot, co-pilot and one other observer on each side in the rear. The use of separate audio tape recorders for each observer, linked to a common time signal, allowed those cues detected independently by different observers to be identified. During the West Greenland survey observers searched for cues independently throughout the survey – in Iceland this procedure was restricted to an experimental period. In Norway, where problems were encountered with navigation, it was not possible to conduct effective sighting effort from either the pilot or co-pilot positions, so that no duplicate cues between observers on the same side of the aircraft were identified. Duplicate cues in West Greenland and Iceland were used both to estimate the accuracy of recorded distances to cues and to quantify sighting probabilities (see below).

A number of effort and weather codes were also recorded, including glare, cloud cover, sea state and 'sightability' (good, moderate and poor). Where possible, results are presented stratified by both sea state and sightability. However, we have not had time to analyse the effects of cloud cover or glare.

SPATIAL DISTRIBUTION OF CUES

All results presented in this paper refer to the spatial distribution of cues with respect to the observation sector. The geographical distributions of sightings are given in the reports of the individual surveys.

Figs 1a-e are from the Greenland survey. The first three figures show the spatial distribution with respect to forward and perpendicular distance from the aircraft, the left and right sides of the observation sector having been folded together. Because dives from minke whales were seen closer than those from the larger whales, Fig. 1c gives the results for minke whales only at a larger scale. Fig. 1d compares the positions allocated to the eight duplicate cues seen during the survey: three of these are dives from minke whales, the other five from fin whales. Duplicates were identified purely on the basis of the time of occurrence of the dive recorded by each observer. Fig. 1e plots the number of duplicates identified in this way against the time difference allowed. The plot shows no increase in the number of duplicates identified when the time difference is increased beyond two seconds, suggesting that there were eight duplicates and that a time difference of two seconds is sufficient for identification of all duplicates from the data recorded.

Figs 2a-d give the equivalent results for the Iceland survey; 2e-h compare the distribution of minke sightings by different observers. Observers 1 and 2 correspond to pilot and co-pilot for almost all the survey.

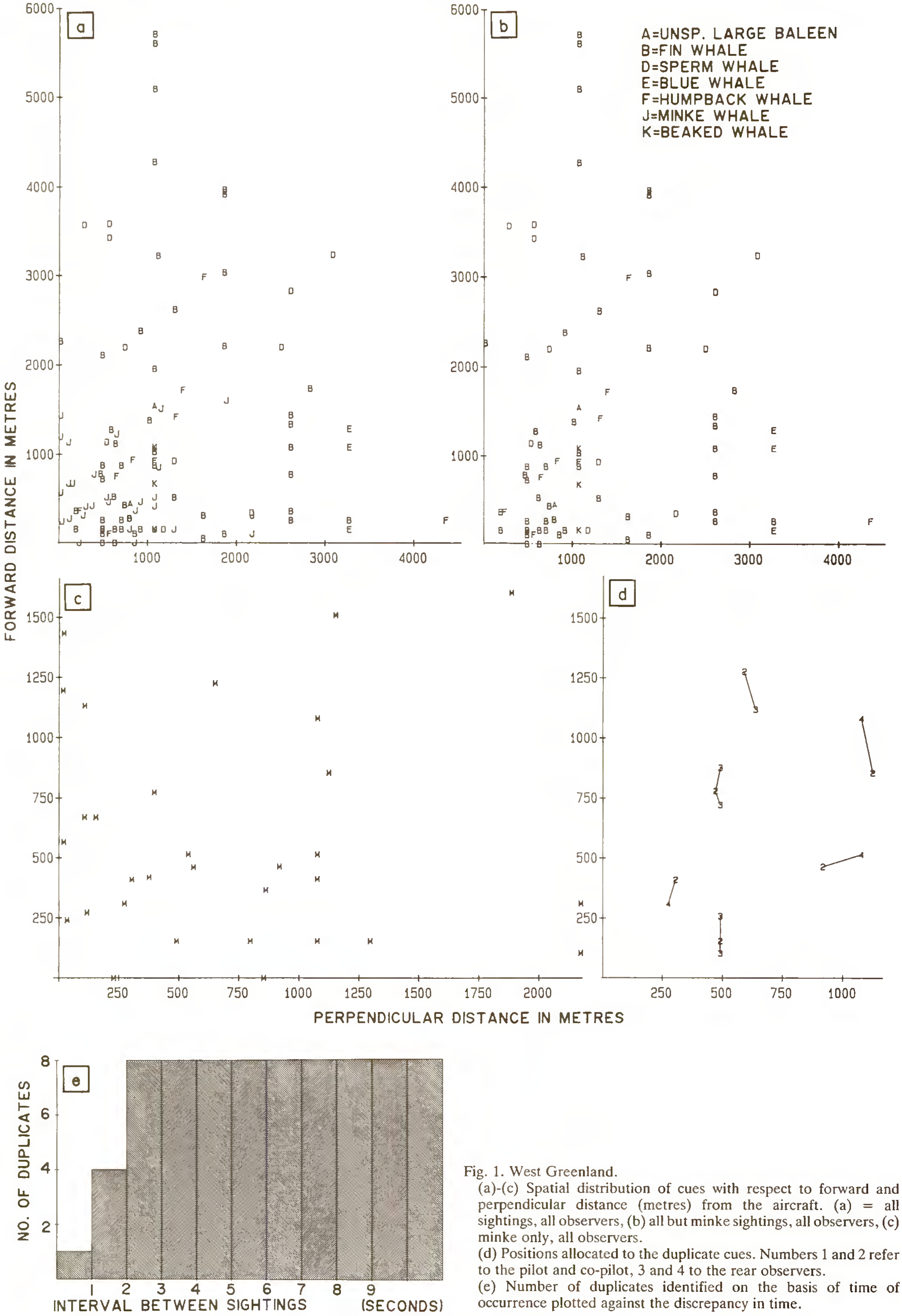


Fig. 1. West Greenland.

(a)-(c) Spatial distribution of cues with respect to forward and perpendicular distance (metres) from the aircraft. (a) = all sightings, all observers, (b) all but minke sightings, all observers, (c) minke only, all observers.

(d) Positions allocated to the duplicate cues. Numbers 1 and 2 refer to the pilot and co-pilot, 3 and 4 to the rear observers.

(e) Number of duplicates identified on the basis of time of occurrence plotted against the discrepancy in time.

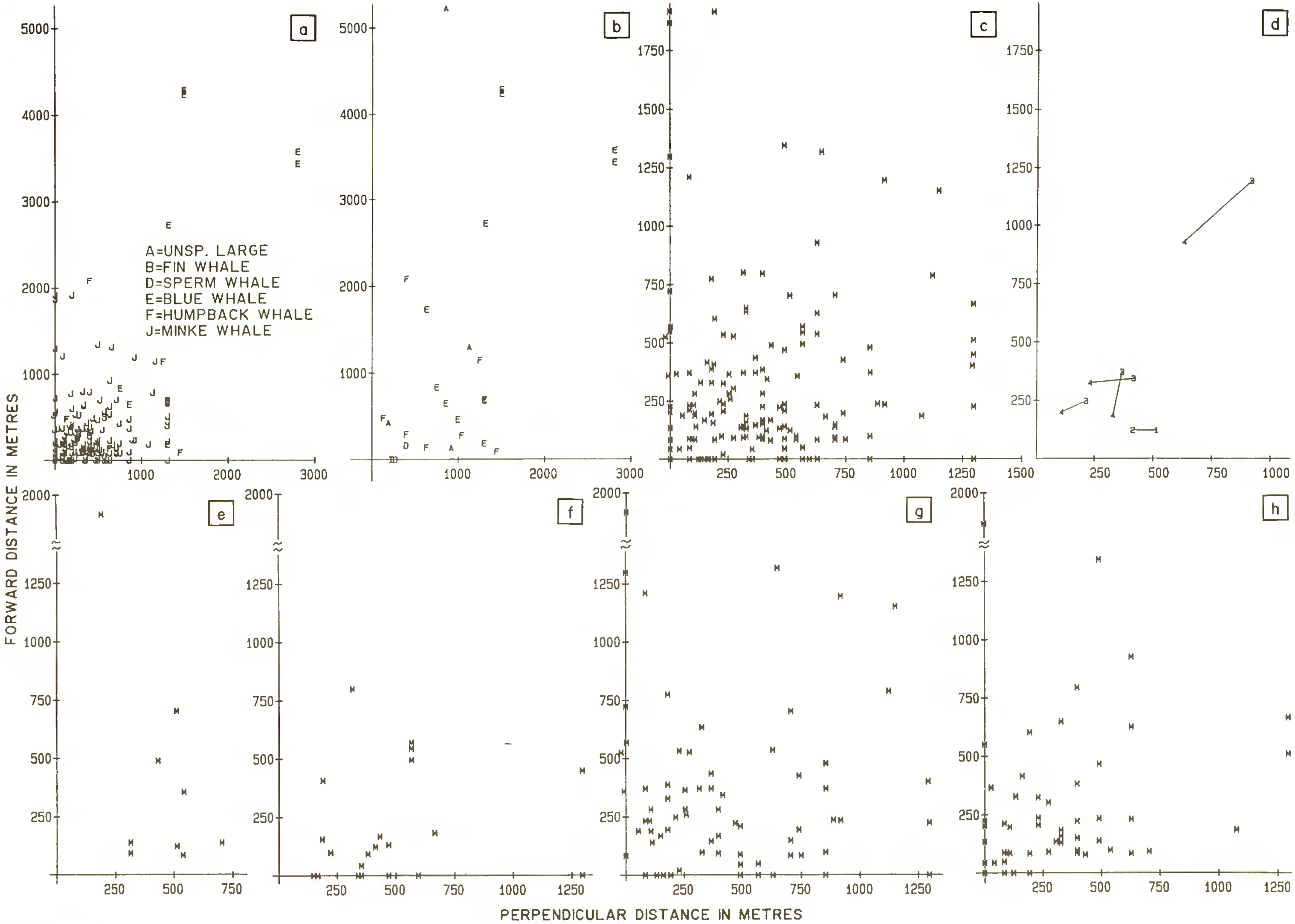


Fig. 2. Iceland.
(a)-(d) As for Fig. 1.
(e)-(h) Comparison of the spatial distribution of minke cues by different observers: Observer 1 (e) was the pilot, observer 2 (f) the co-pilot (except during the short independent observer experiment) and observers 3 (g) and 4 (h) were the rear observers.

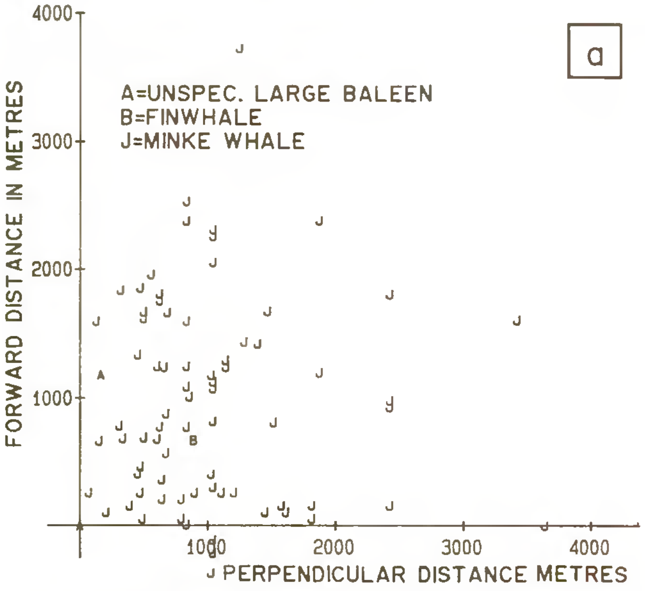


Fig. 3. Norway.
Spatial distribution of cues, all species and all observers.

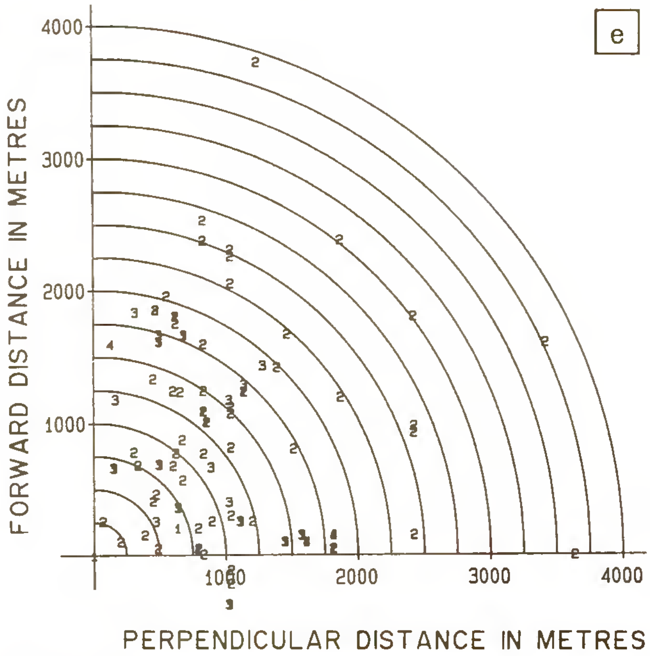


Fig. 4(e). Spatial distribution of minke cues under different sea states (Beaufort 1–4), Norway.

Fig. 3 shows the distribution of all sightings during the Norwegian survey.

Figs 4a-d split the minke records for Iceland by sea state and, for comparison, Fig. 4e gives the same information for the Norwegian sightings.

ESTIMATION OF EFFECTIVE SEARCH AREAS

Available data are presented as a two-dimensional matrix, O, of sighting locations: $O_{i,j}$ represents the number of cues allocated by the rear observer to the i^{th} distance interval which are also detected by the front observers and allocated to the j^{th} distance interval. The i^{th} row thus refers to cues detected by the rear observers and allocated by them to the i^{th} distance interval, and the j^{th} column refers to cues detected by the front observers and allocated by them to the j^{th} interval. If distances are allocated to m intervals, then $O_{i,m+1}$ represents the cues allocated to the i^{th} interval by the rear observers which were not seen by the front observers; analogously for $O_{m+1,j}$. Given the total number of cues seen, say n, the numbers in the O matrix are assumed to follow a multinomial distribution with cell probabilities given by sighting functions $g_f(r)$ and $g_r(r)$ for front and rear observers and a distance allocation function

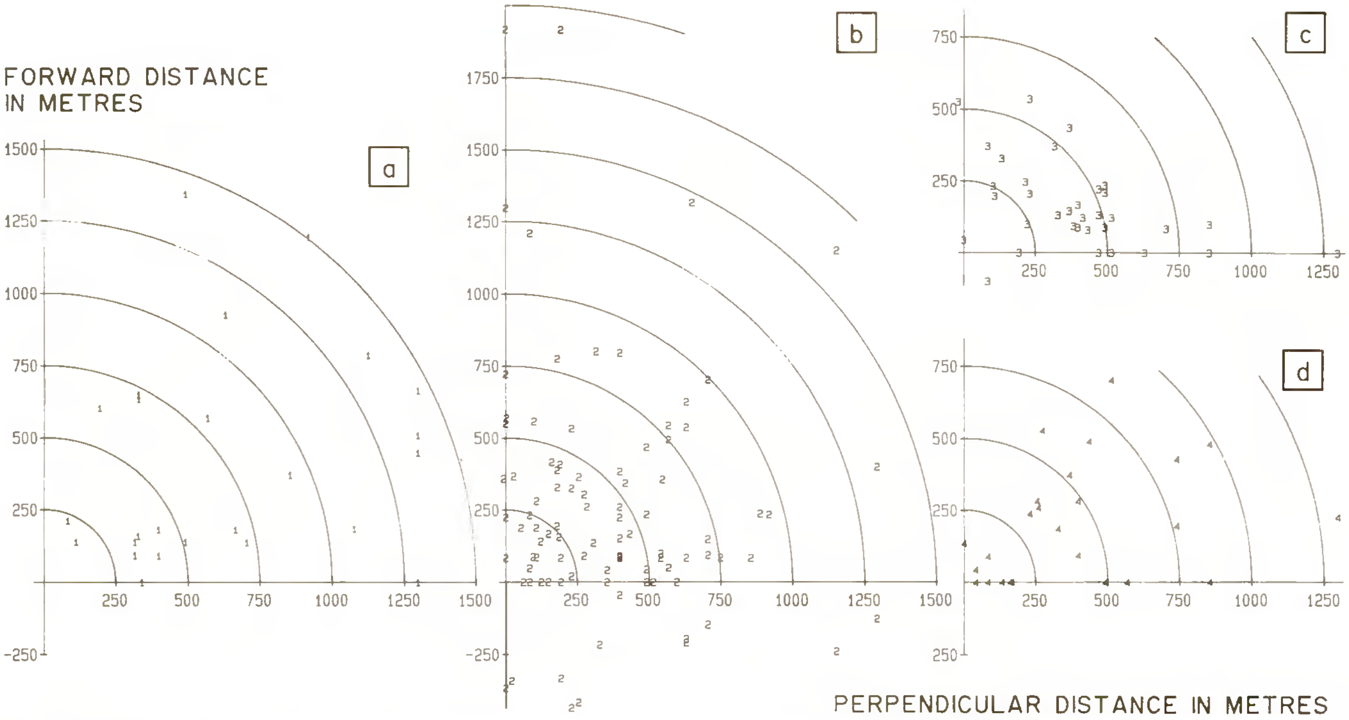


Fig. 4(a)–(d) Spatial distribution of minke cues under different sea states. Iceland: (a) Beaufort 1, (b) Beaufort 2, (c) Beaufort 3, (d) Beaufort 4.

common to both. The sighting functions are assumed to follow the 'hazard rate' form proposed by Buckland (1987),

$$g(r)=g(0)\ (1-\exp(-(r/a)^{-b})).$$

The distance allocation function makes allowance for errors in distance estimation, assigning a probability f(i,r) to the allocation of a cue occurring at r to interval i. f(i,r) is the integral of the normal density $N(r,(er)^2)$ between the cut points for the i^{th} interval; thus distance estimation is assumed to be unbiased with relative error standard deviation e. The probability that a cue detected in the sector within maximum distance r_{max} contributes to $O_{i,j}$ is

$$P_{i,j} = (2/r^2_{max}) \int_0^{r_{max}} g_r(r)\ f(i,r)\ g_f(r)\ f(j,r)\ r\ dr$$

for i and j from 1 to m (for j=m+1, replace $g_f(r)f(j,r)$ by $1\text{-}g_f(r)$; similarly for i=m+1). The log likelihood of the data, $\Sigma O_{ij}\ \ln(P_{ij})$, is then maximised with respect to the parameters of the f and g functions and the ML estimate for the probability of detection for a cue occurring within the sector (i.e. the sum of the $P_{i,j}$ over the entire array, excluding $P_{m+1,m+1}$) obtained. The esa is simply the product of this probability and the area of the sector, $\pi r^2_{max}/2$. By scaling the $P_{i,j}$'s in various ways, conditional estimates can be derived. For example, suppose we were only interested in the parameters of the g_r function, sightings by the front observers being used only to quantify the sighting function for the rear observers. We could then condition on the number of front observer sightings allocated to each distance interval by scaling the $P_{i,j}$'s in each column to sum to 1. The resulting ML estimates for the g_r parameters would then be almost independent of the parameter values set for g_f (not totally independent because, in the presence of some error in distance estimation, the parameters set for g_f influence the probability density for the true distance to cues allocated to each interval by the rear observers). To carry out a non-duplicate analysis using an assumed value for $g_r(0)$, the last row of the O matrix (surfacings missed by the rear observers) is omitted and the remaining rows summed to form the vector O_i. The log likelihood is then $\Sigma O_i\ \ln(P_i)$, where P_i is the vector of row sums of the matrix P_{ij}.

The results of applying these procedures to each data set in turn are given below.

West Greenland

The parameter, e, of the allocation function was first estimated, conditioning on the number of sightings allocated by the rear observers to interval i which were also seen by the front observers. For this the minke and fin whale records were combined, and an estimate for e of 0.08 was obtained, equivalent to a distance estimation accuracy of within 16% for 95% of estimates. Using this estimate for e, g(r) parameters were estimated for minke and fin whales separately.

Minke

Using a non-duplicate analysis (i.e. summing the rows of the O matrix and assuming a g(0) of 1) gave an esa for the rear observers of 2.69km² (CV 0.29). Using a duplicate analysis (i.e. conditioning only on the total number of cues detected) gave estimates for g(0) of 0.71 (rear) and 0.10 (front) and reduced the esa for the rear observers to 1.75km² (CV 0.34) and gave an esa for all observers combined of 2.08km² (CV 0.31) (see Fig. 8 for a comparison of observed and predicted number of cues). Conditioning on the number and position of front sightings caused a further reduction of 9% in the esa for the rear observers. The CV on each estimate of esa was estimated using the matrix of partial derivatives of the log likelihood with respect to the vector of free parameters used.

The results of the duplicate analyses are presented here to illustrate the technique. However, duplicate effort in all three surveys was very limited and the sample size is very small, so in calculating the estimates of abundance for each survey presented below, the non-duplicate esa estimates have been used.

Fin

Using the non-duplicate analysis gave an estimated esa for the rear observers of 4.92km² (CV 0.30). Including the duplicates changed the esa by less than 1.5% with estimates of g(0) of 1.13 and 0.27 for rear and front observers. Conditioning on the number and position of front sightings caused no further change in the esa for the rear observers (Fig. 9).

Iceland (minke)

Judging by Fig. 2d, distance estimates from the Iceland survey were less precise, and the estimate for parameter e indeed increased to 0.35. The non–duplicate analysis then gave an estimated esa of 0.83km² (CV 0.15) (Fig. 10c). Including the data from the duplicate experiment as a separate term in the likelihood gave estimates of 0.91 and 0.97 for g(0) for the rear and front observers respectively and reduced the estimated esa by 20%. The esa's are for all observers combined because in Iceland independent-observer sighting effort was maintained only for an experimental period. This also explains the difference in g(0) for front observers between Greenland and Iceland – in West Greenland independent effort was maintained by the front observer throughout the survey but was at a reduced level because the front observer was also involved in navigation and data recording.

The non-duplicate analysis was repeated, stratifying the data by sea state into three classes: Beaufort 0–1, 2 and 3–4. Rather than estimating different g(r) functions for each class, only the distance scale parameter a in the hazard rate model was allowed to vary by sea state. Compared to Beaufort 3–4, a was increased by 71% under Beaufort 0–1 and by 18% under Beaufort 2. Corresponding esa estimates were 0.66km² (Beaufort 3–4), 0.92km² (Beaufort 2) and 1.92km² (Beaufort 0–1). The plots in Figs 4a-d and histograms in Figs 5a-d suggest that the main effect of Beaufort >2 on the shape of g(r) is the loss of sightings beyond 1km. A similar stratification by 'sightability' gives estimated esa's of 0.69km² (poor), 0.95km² (moderate) and 0.85km² (good). Corresponding histograms are shown in Figs 6a-c. Comparison of Figs 6a and 6b seems to contradict the esa estimates for good and moderate sightability. However, because it takes account of the large errors in distance estimation, the analysis in effect smears the data beyond the 250m distance intervals used in the plots; plotted with a 500m distance interval the histogram in Fig. 6b is slightly flatter than that in 6a.

The estimated esa's for minke whales in Iceland and West Greenland are very different: Figs 7a–c show that the distribution of distances to minke cues in Iceland falls off more quickly than in West Greenland or Norway. One contributory factor may be the difference in sighting conditions experienced during the surveys. For example, using the proportion of sightings under different sea states in West Greenland to form a weighted mean of the Iceland

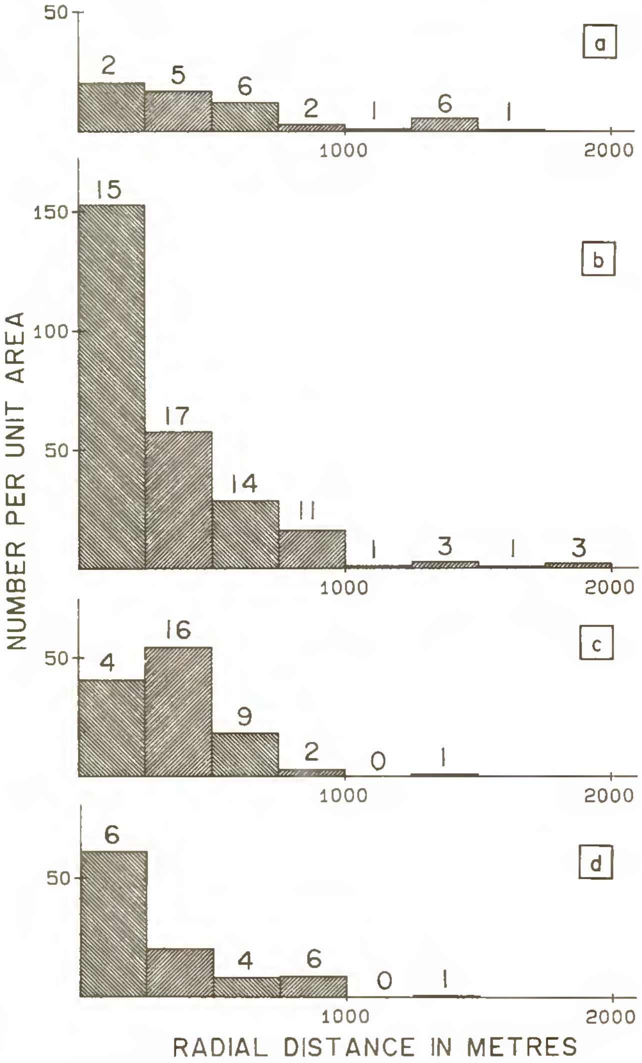


Fig. 5. Iceland.
Number of minke cues allocated to each 250m distance interval, expressed as number per km^2. The actual number of cues allocated to the interval is shown above each bar. (a) Beaufort 0–1, (b) Beaufort 2, (c) Beaufort 3, (d) Beaufort 4.

stratified esa's produces an esa for West Greenland of 1.62km^2. However, this is still well short of the actual estimates from the West Greenland data. Another difference between the surveys is that a large proportion of Icelandic minke sightings were positioned on the abeam line (see Fig. 2c) in contrast to West Greenland and Norway (Figs 1c and 3) where the observers had access before the survey to a simulator program designed for practising the CC sampling procedure. The Iceland data may therefore contain biases in the distance estimates which contribute to the observed differences in esa. Another possible explanation is that the distribution of search effort with respect to distance from the aircraft differed between the surveys – observers in Iceland concentrating effort at shorter distances. The differences in g(0) estimates, although not statistically significant, would support this view, as would the fact that observers in West Greenland were also searching for fin whales which are detectable at longer range. A further supporting factor is the considerably higher density of minke whales off Iceland; observers were frequently seeing whales close to the aircraft reinforcing a searching pattern in that area, whereas off Greenland sightings were infrequent and one would expect observers to search a wider area.

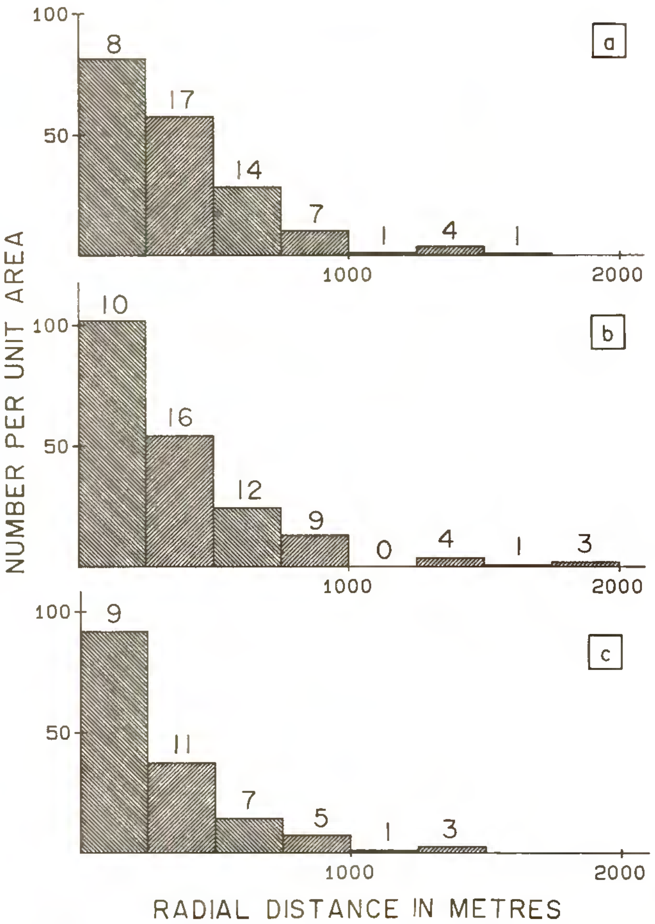


Fig. 6. Iceland.
Number of minke cues allocated to each 250m distance interval, expressed as number per km^2. (a) Sightability 1, (b) Sightability 2, (c) Sightability 3.

Norway (minke)

Unfortunately, no duplicate sightings were available from the Norwegian data to estimate accuracy of distance estimation. Using non-duplicate analysis, assuming g(0)=1, gave an estimated esa of 7.89km^2. With no duplicates there is no way of quantifying the actual g(0) values. Certainly the estimate for Norway seems inconsistent with those for Greenland and Iceland, corresponding as it does to an increase of 71% in effective sighting range over that for West Greenland. A difference in search strategy is the most likely explanation, and g(0) for the Norwegian survey may be relatively low.

ESTIMATES OF ABUNDANCE

Each of the survey areas was divided into a number of non-overlapping regions called blocks. Survey lines were laid out within each block in a zig-zag track with pseudo-random start point. Some blocks were surveyed more than once using different start points for each track, allowing replicate estimates for a block to be compared. Otherwise, the only way to judge the reliability of the abundance estimate for a block is to use the contribution of each line in the track to form a pseudo-random sample. Abundance can be calculated according to the formula

$$\hat{N} = \sum_{i=1}^{n} v_i/(B\ p_i\ esa_i).$$

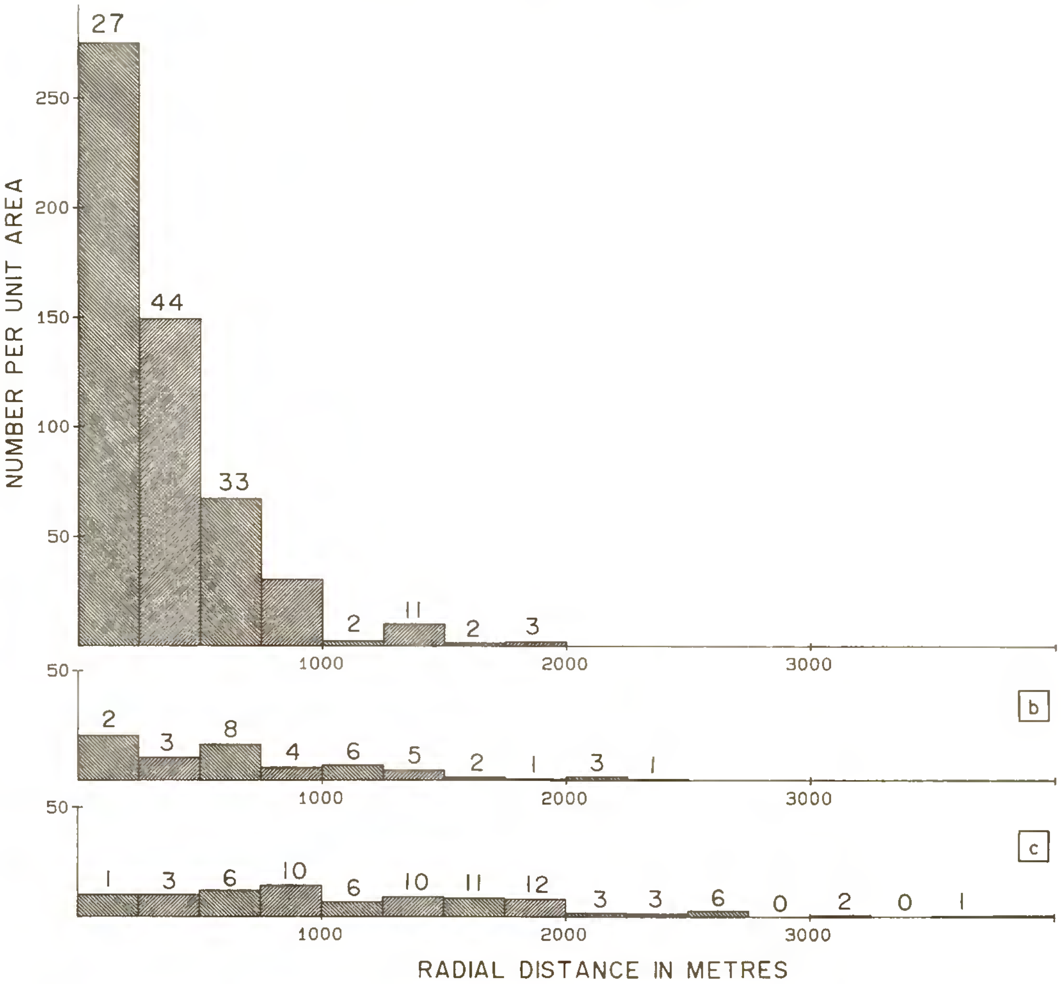


Fig. 7. Number of minke cues allocated to each 250m distance interval under all conditions, expressed as number per km². (a) Iceland, (b) West Greenland, (c) Norway.

If esa refers to the effective search area on both sides of the aircraft, as it does in this paper, p_i' is the coverage probability for the i^{th} cue assuming a total track width of one distance unit (i.e. 1km). B is the population mean surfacing rate (surfacings per whale per hour), n is the total number of cues seen within the sector on effort and may include some cues for which no distance was obtained, and v_i is aircraft ground speed (km/h) at the time of the i^{th} cue.

Iceland

Table 1 illustrates the calculation of abundance by this formula for Iceland minke whales. The second column shows the number of lines surveyed on effort within each track, and the number of cues seen. The third column gives the term $1/(B\ p_i')$ which varies between blocks because of changes in the spacing of the lines. Because of irregularities in the coastal border of each block, p_i' actually varies within blocks, but these latter variations are small and we have calculated values of p_i' for each block as $1/(w\cos\theta)$ where w is the inter-line spacing and θ is half the average angle between successive lines (see Fig. 11). The estimate used for B is 53 surfacings per whale per hour, from the 'blow-rate' experiments carried out on board the Icelandic and Norwegian vessels (Gunnlaugsson, 1989; Joyce, Øien and Øritsland, 1989). The fourth column tabulates the term $\Sigma v_i/esa_i$ by track using esa's stratified by Beaufort as described in the section covering estimation of esa. The final column gives the corresponding population estimates by track, assuming all lines were surveyed on effort. The CV is based on the inter-line variability in $\Sigma v_i/esa_i$ (but does not include contributions from errors in the estimation of surfacing rates or esa).

Table 1

Estimation of minke whale abundance for each Icelandic aerial survey block using the formula:

$$\hat{N} = \sum_{i=1}^{n} v_i/(B\ p_i'\ esa_i).$$

Two tracks were flown in each of blocks 1, 4 and 8; the last column thus provides replicate estimates for these blocks. However, because the formula assumes all lines in a track were surveyed on effort the last column does not allow for variation in the number of lines actually surveyed (shown in the second column). The estimates of total abundance given in the text do allow for unsurveyed lines.

Block/Track	Lines/Cues on effort	$\frac{1}{B\ p_i'}$	$\Sigma v_i/esa_i$	$\hat{N}$
1/1	6/31	0.343	6,478	2,222 (0.36)
1/2	5/38	0.343	6,924	2,375 (0.18)
2/1	12/10	0.343	1,212	416 (0.50)
4/1	25/18	0.343	2,871	985 (0.35)
4/2	3/1	0.343	208	71 (1.00)
5/1	10/2	0.582	248	144 (0.71)
8/1	6/17	0.324	3,636	1,178 (0.42)
8/2	4/12	0.324	2,483	804 (0.60)
9/1	15/14	0.604	3,141	1,898 (0.38)

Fig. 8. West Greenland minke.
Surface plot of (a) observed and (b) predicted $O_{i,j}$ values using the duplicate analysis. $O_{i,j}$ is the number of cues allocated to the ith distance interval by the rear observers and to the jth interval by the front observers. $O_{i,9}$ represents the number of cues allocated to the ith interval by the rear observers which were not seen by the front observers; similarly for $O_{9,j}$. The height of the maximum peak in (a) is 7 observed cues – (b) is plotted to the same scale.
For the non-duplicate analysis, (c) shows the observed (solid line) and predicted (dashed line) number of cues allocated to each distance interval, expressed as number per km².
The distance intervals are: 0–250m, 250–500m, 500–750m, 750–1,000m, 1,000–1,250m, 1,250–1,500m, 1,500–1,750m, 1,750–3,000m.

Fig. 9. West Greenland fin.
(a) As for Fig. 8(a), except that non-duplicate cues occupy $O_{i,13}$ and $O_{13,j}$ with distance intervals 0–250m, 250–500m, 500–750m, 750–1,000m, 1,000–1,250m, 1,250–1,500m, 1,500–2,000m, 2,000–2,500m, 2,500–3,000m, 3,000–3,750m, 3,750–4,500m, 4,500–6,000m.
(b) Predicted $O_{i,j}$ values from the duplicate analysis conditioning on the number and position of front sightings.
The height of the maximum peak in (a) is 11 observed cues – (b) is plotted to the same scale.

Fig. 10. Iceland minke.
As for Fig. 8. The height of the maximum peak in (a) is 9.

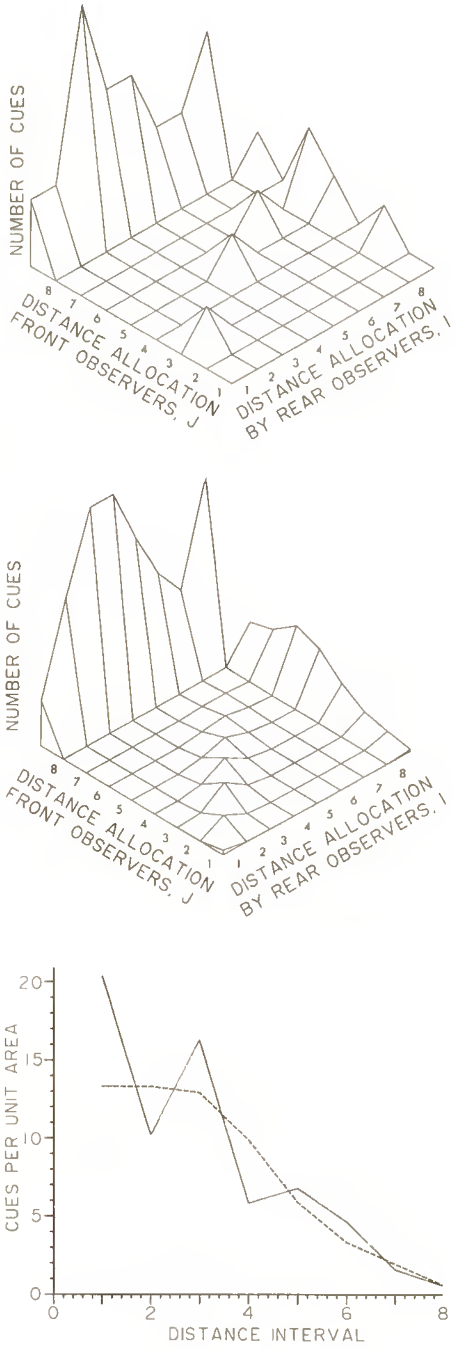


Fig. 8.

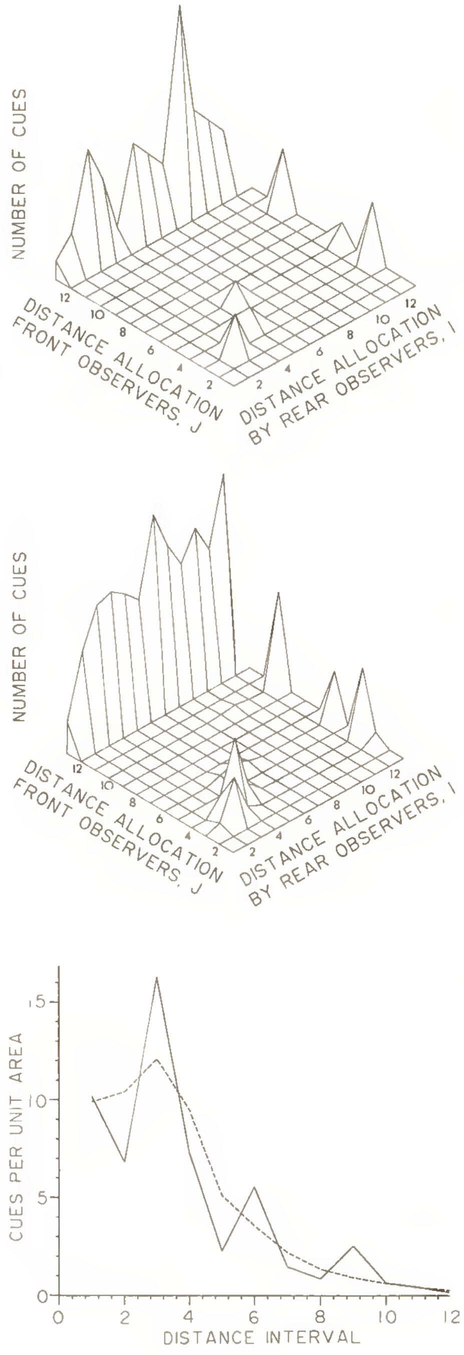


Fig. 9.

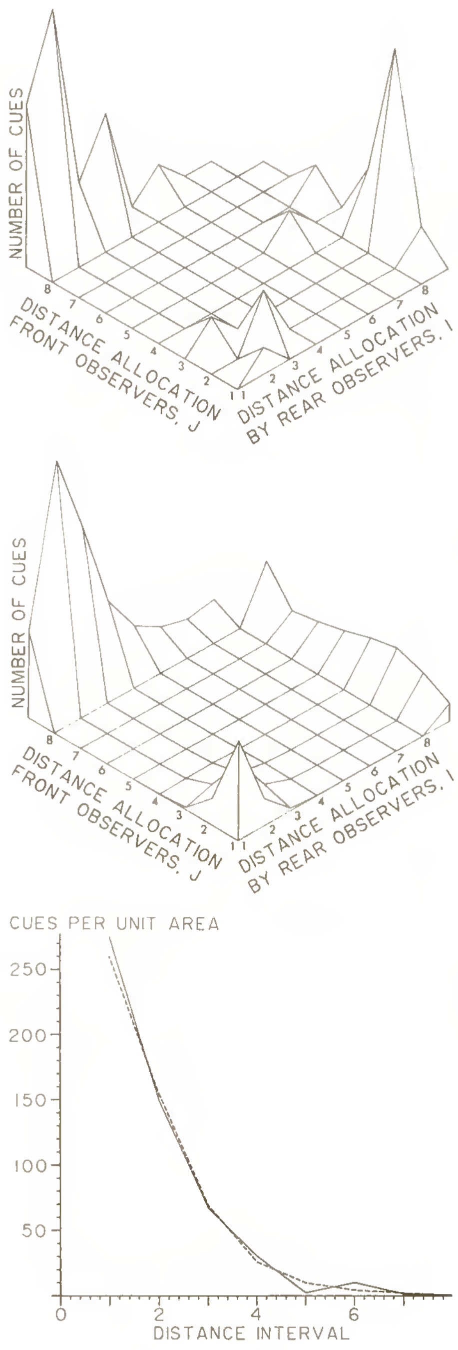


Fig. 10.

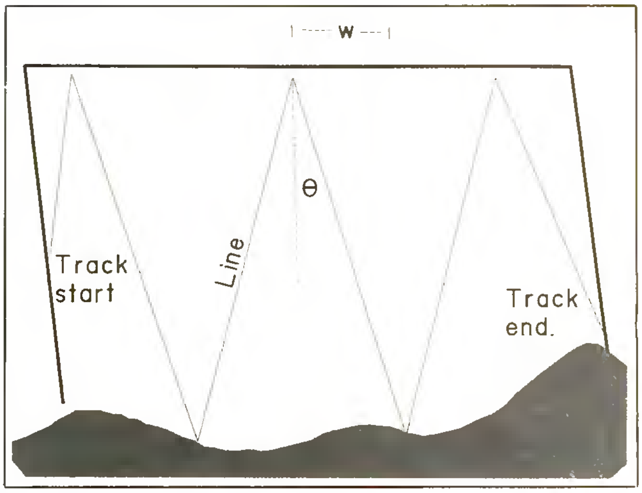


Fig. 11. Diagram of the arrangement of lines and tracks within a survey block to illustrate the calculation of coverage probability p_i'.

The results show good agreement between the abundance estimates for replicate tracks in the same block, once allowance is made for the unsurveyed lines in some of the tracks. Combining data from all blocks and allowing for unsurveyed lines gives a total population estimate of 8,645 minke whales. This estimate refers to the area covered by blocks 1, 2, 4, 5, 8 and 9 excluding the area east of 13°W which was not covered by any transects. The CV on this estimate, including contributions from the errors in the estimates of surfacing rates and esa, was 0.202.

Norway

Similar calculations for the Norwegian data give abundance estimates of 817 minkes (CV 0.451) for Svalbard and 244 (CV 0.517) for North Norway (south of 71°N).

West Greenland

For Greenland the p_i' values were obtained from the data presented in Table 1 of Larsen *et al.* (1989), with 'coverage' adjusted to represent a total track width of 1km rather than the 2 nautical miles used there. The abundance estimate obtained was 1,493 minke whales (CV 0.43). A total population estimate of 1,985 fin whales (CV 0.46) was obtained using a mean surfacing rate of 36 surfacings per whale per hour (Hiby *et al.*, 1984).

ACKNOWLEDGEMENTS

We thank Steve Buckland, Douglas Butterworth, Greg Donovan, Phil Hammond and Joe Horwood for their comments on this manuscript.

REFERENCES

Buckland, S.T. 1987. An assessment of the performance of line transect models for fitting IWC/IDCR cruise data, 1978/79 to 1984/85. *Rep. int. Whal. Commn* 37:263–8

Calambokidis, J., Christensen, I., Cubbage, J.C., Hartvedt, S., Jensen, P.M., Joyce, G.G., Øien, N., Øritsland, T., Tellnes, K. and Troutman, B.L. 1989. Norwegian whale sightings survey in the North Atlantic, 1987. Paper SC/40/O 9 (Published in this volume).

Donovan, G.P. and Gunnlaugsson, T. 1989. North Atlantic Sightings Survey 1987: Report of the aerial survey off Iceland. Paper SC/40/O 10 (Published in this volume).

Gunnlaugsson, T. 1989. Report on Icelandic minke whale surfacing rate experiments in 1987. Paper SC/40/Mi23 (Published in this volume).

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. Paper SC/39/O 8 presented to the IWC Scientific Committee, June 1987.

Hiby, A.R., Martin, A.R. and Fairfield, F. 1984. IDCR Cruise/Aerial Survey in the North Atlantic 1982: Aerial Survey Report. *Rep. int. Whal. Commn* 34:633–45

Joyce, G.G., Øien, N. and Øritsland, T. 1989. Surfacing rates of minke whales in Norwegian waters. Paper SC/40/Mi15 (Published in this volume).

Larsen, F., Martin, A.R. and Nielsen, P.B. 1989. North Atlantic Sightings Survey 1987 Report of the West Greenland aerial survey. Paper SC/40/O 11 (Published in this volume).

Résumé Section

This section includes Résumés of those papers presented to the Scientific Committee but not published in this volume. They are provided for information only and do not constitute publication; and as such should not be cited in papers without consultation with authors. Copies of the full papers are available at cost price from the IWC Secretariat.

Common dolphin off the coast of Spain, September 1981.
Photograph by G. Donovan.

Sperm Whales

SC/40/Sp1. BEHAVIOUR AND VOCALISATION OF TWO SINGLE SPERM WHALES, *Physeter macrocephalus*, OFF NOVA SCOTIA. *Julia Mullins, Hal Whitehead and Linda S. Weilgart, Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1.*

During June 1986 two male sperm whales (*Physeter macrocephalus*) on the Scotian Shelf were tracked by listening for their clicks with a directional hydrophone for periods of 12.5 and 7hrs respectively. Each whale travelled along the edge of the shelf at about 2 knots (3.6km/hr), and one whale on two occasions, at least, dived to the ocean floor. After about 30mins underwater, the whales spent approximately 9mins at the surface breathing. When the whales were visible at the surface they were silent, except on one occasion when 'slow clicking' (mean inter-click interval of 4.6s) was heard from Whale 2. While underwater, most of the sound production consisted of 'usual clicks' (mean inter-click interval 0.96s and 0.69s for the two whales) interrupted by frequent short silences (mean duration 21.06s and 27.82s), and occasional 'creaks' (with inter-click intervals less than 0.2s) and 'slow clicks'. No 'codas' (stereotyped patterns of clicks) were heard from these two single whales. These results are consistent with the hypotheses that 'usual clicks' and 'creaks' are used for echolocation and 'codas' for communication.

SC/40/Sp4. SPERM WHALES AND EL NINO OFF THE GALAPAGOS ISLANDS. *Hal Whitehead[1], Vassili Papastavrou[2] and Sean Smith[3]. [1] Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1. [2] IUCN Coastal Zone Management Project, c/o Department of Tourism, Ministry of Commerce and Industry, P.O. Box 550, Muscat, OMAN. [3] Department of Biology, Acadia University, Wolfville, Nova Scotia, Canada, BOP 1XO.*

Sperm whales (*Physeter macrocephalus*) were observed off the Galapagos Islands between late February and April 1985, a year of cool sea-surface temperatures (SST), and January to June 1987, an 'El Nino' year of warm SST. The distribution, abundance and diet of sperm whales were similar in both years. However, in 1987 the sperm whales dived to shallower depths and appeared to have a lower feeding success, as indicated by a reduced rate of observing faeces. Excretion rates were negatively related to SST.

SC/40/Sp5. SPERM WHALES KILLED IN THE AZORES DURING 1987. *Petra Deimer, Grube 2, 2000 Hamburg 55, Federal Republic of Germany, Jonathan Gordon, Department of Zoology, University of Cambridge, Downing Street, Cambridge, CB2 3EJ and Tom Arnbom, Department of Zoology, University of Stockholm, S-106 91 Stockholm, Sweden.*

Commercial whaling ceased in the Azores in 1984 when the last factory, at Cais do Pico, closed down. Interest in the activity of whaling continued in some quarters however, especially in the village of Larges which has a long history of involvement in the whaling industry. Ironically the men of Larges had ceased whaling some two years before the closure of the factory at Cais. In 1987 plans were made to resume whaling. Whaling vessels and gear were overhauled and a vigia was employed to look out for whales in the traditional way. Arrangements were also made by the Whaler's Museum in Larges to take fee-paying tourists, journalists and film-makers out to witness the hunt. Apparently the Department of Fisheries granted a permit for five large males to be taken during 1987.

Minke Whales

SC/40/Mi2. REPORT OF THE 1987–88 IWC/IDCR SOUTHERN HEMISPHERE MINKE WHALE ASSESSMENT CRUISE, AREA III. *G. Joyce, F. Kasamatsu, P. Ensor, S. Nakanishi, R. Rowlett, H. Shigemune, B. Troutman and K. Yamashita.*

The tenth cruise in this series was conducted from 10 December – 8 February 1988, with research conducted in Antarctic Area III (0°-70°E) from 20 December — 25 January. Home ports for the cruise were Fremantle, W. Australia and Port Louis, Mauritius. Serious revisions were made to the standard procedures since only two ships were available for the research, the *Shonan Maru* and *Shonan Maru 2*, instead of the three or four ships used in the previous cruises. The Area was divided into two sectors, the Eastern (35°E-70°E) and the Western (0°-35°E), with the Eastern sector surveyed first. Each sector was divided into two strata, a northern and a near-ice (southern) stratum. The boundary of the pack ice was determined by satellite imagery and occasional visual spot-checking since there was not a third vessel to map the ice-edge. The cruise track construction was similar to that of recent cruises, using a zig-zag design. The survey was conducted in two standard searching modes, the passing with independent observer (IO) and the closing modes (NSC), and two experimental modes, the independent observer with tracking (IOT) and the closing with independent observer (CIO) modes. The IOT and CIO experiments were conducted aboard the *Shonan Maru*, with the CIO experiment conducted only during the first half of the cruise. The estimated distance and angle experiment was conducted in a similar manner to previous cruises, except for the addition of trials conducted with the ship underway instead of being stationary. The natural marking experiment and marine debris surveys were also conducted. The cruise was conducted earlier than previous cruises in an attempt to avoid stormy conditions in the Area during the latter part of the season. The research was successfully completed, but, unfortunately, poor weather conditions were frequently encountered throughout much of the cruise and limited the survey to only 40–60% of the available research time. Starting future cruises at earlier dates was not recommended as this procedure does not appear to increase the percentage of available survey time and may produce serious problems in comparing data from different cruises. The periods of strong winds encountered during the cruise also caused the pack ice boundary to rapidly shift which created difficulties in constructing the cruise tracks and major distortions of the near-ice strata track lines. New cruise track construction methods should be explored if future cruises are to be conducted without a vessel dedicated to mapping the positions of the pack ice boundary. The execution of the CIO experiment was also limited by a paucity of minke whale sightings during the experimental trials (n=6). All other procedures and experiments were successfully concluded but concern was expressed about the feasibility of conducting extensive trials of the IOT and CIO experiments in any future cruises. The moving estimated distance and angle experiment was thought to be superior in representing normal whale sighting conditions than the stationary experiment. Identified whale species during the cruise were blue, fin, sei, minke, humpback, right, sperm, killer, Southern bottlenose, Gray's beaked, strapped–toothed and pilot. Dolphins identified were Cruciger's, dusky, common, bottlenose and spinner.

SC/40/Mi4. ESTIMATION OF MINKE WHALE ABUNDANCE USING CUE COUNTING RESULTS FROM *SHONAN MARU No. 2* IN AREA II, 1986/87. *A.R. Hiby and A. Ward, Sea Mammal Research Unit, Madingley Road, Cambridge, UK.*

This paper presents an analysis of cue counting data collected during the 9th IWC/IDCR Southern Hemisphere Minke Whale Assessment Cruise. Data were collected from the bridge (aided by topmen's sightings) during all passing mode transects and also, on half of those transects, from the Independent Observer Platform. Duplicate cues were identified and used, in the analysis, to estimate accuracy of distance estimation and the parameters of the sighting function $g_B(r)$ and $g_{IO}(r)$. These gave estimates of effective search area for minke blow/body cues of $2.9nm^2$ for both platforms combined and $2nm^2$ for the bridge ($CV = 0.15$). Combining these estimates with the numbers of cues recorded on effort and an estimate of mean blow rate gave an estimate of mean whale density of 0.09 whales/nm^2 ($CV = 0.33$). A non-duplicate analysis using only data collected from the bridge and assuming certain detection of 'near' cues (i.e. $g_B(o) = 1$ within the 90° observation sector) increased the density estimate to 0.116 whales/nm^2. The duplicate method of analysis was found to be more robust to choice of sighting function and the degree of error in distance estimation.

SC/40/Mi5. ANALYSIS OF BRAZILIAN MINKE WHALE DATA FROM 1966–85. *Samuel Zahl, Dept of Statistics, Univ. of Connecticut, U-120, Storrs, Connecticut 06268, USA.*

An analysis of variance of the CPUE of the Brazilian minke whale data from 1966 to 1985 is given with respect to the following factors: year; off-minke catch; change in boats; and median distance to the whaling grounds. Most of the variation in the CPUE, which is the catch per day worked, can be accounted for by all the factors omitting year. The additional variation accounted for by year is not significant and, in fact, is virtually zero. Thus the existence, or not, of a trend in the CPUE cannot be determined from this data. The causes are examined in some detail and suggestions, some radical and involving further work, are made for making the CPUE more responsive.

SC/40/Mi7. A PROGRAM TO STUDY AND MONITOR NORTHEAST ATLANTIC MINKE WHALES, 1988–1992. *Sea Mammal Section, Institute of Marine Research, Bergen, Norway.*

This paper outlines the objectives, problems to be studied and research projects of a research programme to study and monitor northeast Atlantic minke whales. The objectives can be summarised under three headings: stock identification; stock assessment; and the quantification of the role of the minke whale in the ecosystem(s) of the Barents and Norwegian Seas. The paper discusses the problems associated with these objectives and examines potential methodologies for addressing them. A series of 19 research proposals are described, four of which require the taking of whales in 1988: the feasibility of radiomarking; the study of food selection and intake; the study of food digestion; and the study of body composition. A total take of 35 minke whales is required. The paper concludes with a discussion of the relationship of the programme to the IWC criteria for review of research programmes.

SC/40/Mi10. VARIABILITY OF THE QUANTITY OF VIBRISSAE IN ANTARCTIC MINKE WHALES. *S. G. Bushuev, Odo Azcherniro, Odessa, USSR.*

Variability in the numbers of vibrissae in four groups (bundles) on the heads of Antarctic minke whales and also the total number of vibrissae is discussed. The six samples (2,835 whales) examined were taken in three Areas of the Antarctic (I, III and IV) during seasons 1982/83 and 1983/84. In order to investigate the character of inheritance, the number of vibrissae has been calculated for 107 'mother foetus' pairs killed in Areas I, III and IV in 1984/85 and 1985/86. Dependency of the variability in numbers of vibrissae with age as well as the phenomenon of bilateral asymmetry in the positioning of vibrissae was examined for 100 males and 100 females from Area III (1983/84). No significant correlation was found between the quantity of vibrissae and the age of whales (as determined from the number of layers in the earplug, and for females, also by the number of corpora in the ovaries). A close positive correlation (0.66–0.80) of the numbers of vibrissae has been observed in all groups between the right-hand and left-hand sides of the body ($p<0.001$). A weak positive correlation of about 0.30 ($p<0.05$) was found between the number of vibrissae for a mother and her foetus (independently of the foetus's sex). Differences between average values with regard to mothers and their calves were not statistically significant ($p>0.05$). No significant ($p>0.05$) differences were found between average values of the numbers of vibrissae: by sex; between samples taken in the same Areas in different seasons; or between samples from different, geographically distant areas. Data on the variability in numbers of vibrissae can not be used for identification of populations since the average values, despite the wide range in values, are statistically similar in all the investigated samples, which may also indicate the genetic relationship between the investigated groupings.

SC/40/Mi13. OCCURRENCE OF ECTOPARASITES AND COMMENSALS ON BODIES OF ANTARCTIC MINKE WHALES AS A MARKER OF NATURAL WHALE GROUPINGS. *S.G. Bushuev, USSR, Odessa, Mechnikov St, 53, Odo AzCherNIRO.*

This paper investigates the occurrence of ectoparasites and commensals (Amphipoda, Copepoda, Cirripedia) on Antarctic minke whales. During seasons 1983/1984 to 1985/1986, 13 samples (6,401 whales) were examined in four whaling Areas of the Antarctic (I, II, III and IV). No significant relationship was found between the level of infestation by the two most frequently occurring species of ectoparasites (*Xenobalanus globicipitis, Cyamus balaenoptera*) and the age of minke whales or the month and season when the animal was killed. Samples with high occurrence of *X. globicipitis* (Areas III and IV) showed a significantly higher level of infestation in females over males. For the three seasons, stable, reliable differences ($p<0.001$) in occurrence of Cirripedia (*X. globicipitis* in particular) were found among samples from geographically distant areas. The highest level of infestation was for samples from Area III and the eastern part of Area II. A much lower level was observed in samples from Area IV while the lowest levels were from Area I and the western part of Area II. This suggests that minke whales feeding in Area III and the eastern part of Area II, in Area IV and in Area I belong to different 'herds' and winter in different areas of the Southern Hemisphere, in which the probability of contamination by Cirripedia differs significantly. The available data suggest approximate feeding area boundaries for the 'Indo-Atlantic' herd (high contamination by Cirripedia): the eastern boundary of which almost coincides with the boundary between Areas III and IV (approximately 60°E) and a western boundary in the middle of Area II (samples from the extreme eastern and western Area II differ sharply from one another).

SC/40/Mi14. REVISED ABUNDANCE ESTIMATES FOR MINKE WHALES IN ANTARCTIC AREAS IVW AND V FROM SIGHTINGS ON THE 1978/79, 1984/85 AND 1985/86 IDCR CRUISES.

D.S. Butterworth, Department of Applied Mathematics, University of Cape Town, 7700 Rondebosch, South Africa.

Abundance estimates are revised using the stratification and the methodology to estimate mean school size agreed but not implemented at the 1987 Southern Hemisphere minke whale sub-committee meeting. The resultant total population estimates (with CVs in parenthesis) are:

Area IVW: 1978/79	(Closing mode)	: 33,983 (0.198)
Area IVW: 1984/85	(Closing mode)	: 24,486 (0.227)
	(Passing mode)	: 16,034 (0.245)
Area V : 1985/86	(Closing mode)	: 211,150 (0.174)
	(Passing mode)	: 303,284 (0.172)

When adjustments are made for different area coverage, the closing mode estimates for Area IVW for the two surveys are significantly different (P=0.045), but those for Area V for the 1980/81 and 1985/86 surveys are not. Incorporating DNE g(0) estimates from the Independent Observer experiments increases passing mode abundance estimates by 64% for Area IVW and 33% for Area V, but at the expense of a CV increase of about 0.07 in both cases.

SC/40/Mi16. NOTES ON ABUNDANCE ESTIMATES OF WESTERN NORTH PACIFIC MINKE WHALE.

Fujio Kasamatsu, Institute of Cetacean Research, 3–32–11 Ojima, Koto–ku, Tokyo.

Abundance estimates of minke whales in the Western North Pacific were reviewed by using sightings data from 1978 to 1986. Temporal and spatial occurrence of the minke whales was investigated. The peak of the occurrence of minke whales in the Western North Pacific was observed in July. Density decreases from August, and increases in October in the coastal waters of Japan. In July, minke whales occur in the waters north of 37°N. Density increases substantially from the waters north of 42°N. Because the target species of these surveys were not minke whales but other larger whales, the surveys were sometimes carried out under conditions that were not ideal for sighting minke whales. The effect of this on the abundance estimate was investigated. The sighting rate of minke whales decreased substantially in sea states above Beaufort 4. Abundance estimates were made using the smearing technique and the Hazard-rate model suggested by the Scientific Committee, based on two area stratifications and two sighting conditions. The estimates ranged from 10,695 (CV 0.33) to 15,797 (CV 0.41).

SC/40/Mi19. ESTIMATION OF MINKE WHALE ABUNDANCE FROM THE 1986/87 IWC/IDCR SIGHTINGS CRUISE IN ANTARCTIC AREA II.

D.L. Borchers, International Whaling Commission, The Red House, Station Road, Histon, Cambridge, CB4 4NP, United Kingdom.

The abundance analysis was conducted using methods adopted for previous cruises but fitting the hazard-rate model to the smeared perpendicular distance distribution of whales rather than schools/pods. In cases where bias in angle or distance estimation was detected from the estimated angle and distance experiment, bias was corrected before the data were analysed. The results of the estimated distance and angle experiment indicate possible inadequacies in the model for distance estimation which have made it necessary to remove some of the observations from the experiment to estimate bias in the usual way. A number of problems in applying the whale-based method of estimation were encountered: the occurrence of large schools within 1.5 n.miles of the trackline led to poor fits of the hazard-rate model and as a result, schools greater than 15 whales were excluded in the fitting procedure. The need to correct underestimation of school sizes for unconfirmed schools introduces variance which is difficult to quantify and which has not been taken account of in the results presented. Finally the loss of independence between sightings when whales are the sampling units means that the maximum-likelihood methods of estimating effective search half-width and its variance are not strictly applicable. Results of the analysis indicate that the density estimates from the *Kyo Maru 27* may be upwardly biased as a result of different searching methods on that vessel. This is only slightly compensated for by adjusting for the estimated probability of seeing a whale on the trackline (g(0)). Density estimates from Closing mode data are significantly lower than those obtained from Passing mode with an independent observer (IO). Density estimates from Passing mode data are not significantly different from those obtained from IO Mode survey. Abundance estimates from the 1986/87 survey are not significantly different from estimates obtained from the 1981/82 survey in Area II either when estimates of abundance south of 60°S are compared or when the abundance figures are adjusted to make the two surveys comparable in terms of total area surveyed.

SC/40/Mi20. ESTIMATES OF G(0) FOR MINKE SCHOOLS FROM THE RESULTS OF THE INDEPENDENT OBSERVER EXPERIMENT ON THE 1985/86 AND 1986/87 IWC/IDCR ANTARCTIC ASSESSMENT CRUISES.

D.S. Butterworth, Department of Applied Mathematics, University of Cape Town, Rondebosch 7700, South Africa and D.L. Borchers, International Whaling Commission, The Red House, Station Road, Histon, Cambridge, CB4 4NP, UK.

The independent observer (IO) experiment results from the 1985/86 and 1986/87 Antarctic cruises are analysed using two different methods. The first method (PGHR) using a hazard-rate form for g(y), and the total number of duplicate sightings, provides g(0) estimates for the barrel and IOP combined that are generally close to 1 (average 0.9). However, the other method (DNE) based on the distribution of duplicate sightings with y, produces rather lower values (average 0.63 for the *Shonans*), and suggests a paucity of duplicates close to and an excess far from the trackline compared to what might be expected according to the models usually assumed. The results of the DNE method are tentatively preferred, as the PGHR method predicts y-distributions of duplicate sightings that are at variance with observations; the design of experiments to test for mechanisms that may account for the differences in the estimates provided by the two methods merits consideration. The proportion of duplicates categorised as 'possible' and 'remote' in this experiment (17%) is much smaller than in the earlier parallel ship exercises (43%). Inter-survey stratum differences in g(0) for the same vessel were not detected. The g(0) estimates for the two Shonans appear to be comparable, but possibly significantly lower than those for the *Kyo Maru 27*.

SC/40/Mi22. STUDIES ON AGE AND REPRODUCTION IN MINKE WHALES (*Balaenoptera acutorostra*) IN ICELANDIC WATERS.

Jóhann Sigurjónsson, Marine Research Institute, Programme for Whale Research, PO Box 1390, 121 Reykjavík, Iceland.

The paper presents biological information on minke whales (*Balaenoptera acutorostrata*) caught in Icelandic waters. Over 90% of mature females were determined pregnant and the apparent ovulation rate was 0.97. The study indicates that corpora albicantia persist in the ovaries throughout life in minke whales off Iceland. Of 109 ear plugs investigated for growth layers, 46%

were readable; 30% of the plugs were not found or were in too poor condition to be age read. Readability was the same in both sexes, but increased with age. Age readings from tympanic bullae are discussed and compared with other age related parameters. Growth layers in bulla were generally lower than in ear plugs (about 1 : 2), and did not conform with information on corpora counts in the ovaries. The age at sexual maturity based on both ear plug and bulla layer counts in females is about 6 growth layers (years), while judged from bulla growth layers alone it appears to be 1–2 years earlier in males. 50% maturity level with respect to length was 24.4 and 22.4 feet for females and males, respectively. The repeatability of growth layer counts in the bulla decreases with age. Support for halt of growth layer formation in the bulla is given. It is however, suggested that the application of tympanic bullae for age determination in minke whales needs further examination, and that this method may well be useful for determination of young or immature animals, which usually have lower proportion of readable plugs than older ones.

SC/40/Mi24. NINETEENTH CENTURY MINKE WHALING IN THE NORTH ATLANTIC. *Sidney Holt, Podere 'Il Falco', Loc. Acquaioli, 06062 Citta della Pieve (PG), Italy.*

Recent simulations of the trajectory of the Northeast Atlantic minke whale stock have included an assumption that there was no significant catching before the 1930s (Holt, 1985 (SC/37/Mi4)). Walløe, Anderson, Beverton and Semb-Johansson (1987, *The State of the Northeast Atlantic Minke Whale Stock: Report of the group of scientists appointed by the Norwegian Government to review the basis for Norway's harvesting of minke whales.* Økoforsk, As, Norway. 100pp.) write that 'Norwegian small type whaling ... seems to have occurred from the later part of the 1800s on a somewhat irregular basis'. The catching of minke whales on an organised commercial basis started in the late 1920s and developed gradually through the 1930s. It has generally been assumed that when large species of rorquals were abundant the whalers would not have bothered to hunt the small ones. This might be true for the period of 'modern whaling' after the invention of the Svend Foyn method, but is not necessarily so for the earlier period. Buckland (1876, *Log-Book of a Fisherman and Zoologist.* Chapman and Hall, London, 407pp.) reports in detail conversations he had in 1870 with the captain of a vessel registered in and operating from Peterhead, Scotland. Captain Gray and his vessel, *Eclipse*, are described as 'celebrated for the killing of whales', although in fact they were engaged equally in the harp seal hunt at Jan Mayen. Captain Gray was in the habit of bringing Buckland samples of the animals he was hunting; these included harp and hooded seals and, in one case, a thirteen foot minke whale, which Buckland identified (and illustrated the head) as 'the pike whale, *Balaenoptera rostrata*'. Many of the combined whalers-sealers at that time were using hand-thrown harpoons for whaling but the boats operating from Gray's vessel had a gun 'like a stumpy duck gun with a very large bore' attached to the bow by a universal joint, with a range of up to 20 metres. Gray was reported not to 'approve of explosive harpoons' such as those used at least by German whalers at the time. I do not think it will ever be possible to reconstruct what the catches of minke whales might have been in this period. But is seems to me they might not have been negligible, considering the large number of sealing vessels of British, Danish, Norwegian and German registration that were then operating in the Arctic and at least some of which, other than *Eclipse*, presumably also caught whales. Thus in 1920 the North Atlantic stocks were not necessarily either at their pristine size or with pristine composition. If the early catches had been substantial then the numbers would be somewhat smaller but at least some part of any density-dependent response would already have occurred. It would perhaps be worth while, when these stocks are next assessed, within the Comprehensive Assessment, to examine what the possible effects might be of various hypothetical levels of nineteenth century whaling.

SC/40/Mi25. NOTE ON THE NATURE OF CATCH PER UNIT EFFORT DATA RECORDED FOR MINKE WHALES *Balaenoptera acutorostrata* IN THE CANADIAN EAST COAST LAND STATION WHALE FISHERY, 1965–1972. *Edward Mitchell, Arctic Biological Station, 555 St-Pierre Blvd., Ste-Anne-de-Bellevue, Province of Quebec, Canada, 9X 3R4.*

The Scientific Committee of the International Whaling Commission (IWC) is carrying out a Comprehensive Assessment of world whale stocks, and is examining Catch-Per-Unit-Effort (CPUE) data series for North Atlantic minke whales, *Balaenoptera acutorostrata*. The IWC has requested a detailed description of the methods and strategy of these operations. An administrative request was made of me within the Canadian government for a listing of the minke whale CPUE data collected in the last episode of shore-based whaling in eastern Canada and some comments on the methods and strategy of the fishery along the lines laid out by the IWC Workshop on Catch Per Unit Effort (SC/39/Rep 2). This note is a response to that request.

Baleen Whales

SC/40/Ba2. BRYDE'S WHALES TAKEN BY THE JAPANESE LANDBASED WHALING IN THE BONIN ISLANDS WATERS, 1981–1987. *Motoi Yoshioka, Institute of Cetacean Research, 3-32-11 Ohjima, Koto-ku, Tokyo 136, Japan.*

Catch records of Japanese landbased Bryde's whale fisheries off the Bonin Islands in 1981 to 1987 and off the Pacific coast of Japan proper in 1981 to 1986 were analysed in comparison with biological data from the Bonin whaling in the last two seasons examined by biologists. The proportion of females declined with the years in the Bonin area and the imbalance in the sex ratio was statistically significant in many of the seasons. The sex ratio in the Pacific coast of Japan proper did not differ from parity in any season. The percentage of sexually mature individuals was over 80% for both males and females in the two grounds. The Bonin sample gave mean body lengths at sexual maturity of 36.9ft (males) and 38.4ft (females), which were about one foot smaller than the figures off Japan proper. This agree with the finding that the body length frequencies off the Bonin Islands had peaks about one foot smaller than those off Japan proper, and suggests the possibility that different stocks inhabit the coastal Kuroshio current area and the offshore Kuroshio counter current area. The apparent pregnancy rate, 76.5% was the highest among those previously reported for the species. Foetal length distribution indicated a long breeding season.

SC/40/Ba3. POPULATION ESTIMATE FOR THE BRYDE'S WHALE STOCK IN THE WESTERN NORTH PACIFIC. *Tomio Miyashita, Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu, 424 Japan.*

The sightings data obtained from the 1983 and 1984 summer cruises in the western North Pacific, the smearing technique and the hazard-rate model fitted to the perpendicular distance distribution, gave a population estimate, corrected for animals missed on the trackline in the research area west of 170°E as follows; 12,545 (CV=0.326) in 1983 and 12,258 (CV=0.230) in 1984. Correction for the divergence of trackline that occurred in the latter year gave an estimate of 10,875 individuals in 1984. Adding the estimates for the area between 25–40°N, 170°E-160°W

(2,549, CV=0.298) surveyed from 1974 to 1982, the total population size in the research area was calculated at around 13,000–15,000. The extrapolation of the 1984 result to the unsurveyed area in the entire range of the stock (10–40°N, west of 160°W) resulted in a total population estimate of about 18,000 Bryde's whales. No estimate was available from the sightings data from 1985–1987 because the cruises covered a small portion of the western part of the stock's range.

SC/40/Ba6. MORPHOMETRIC STUDIES ON THE SEI WHALE (*Balaenoptera borealis*) – A PROGRESS REPORT. *Gisli A. Vikingsson, Marine Research Institute, 121 Reykjavík, Iceland.*

This paper reports on biometrical studies on sei whales caught off Iceland in 1986 and 1987. The results indicate a relatively isometric growth, with slight tendency towards positive allometry of the head region. The Icelandic data are closer to North Pacific data than to Southern Hemisphere data.

SC/40/Ba7. CHEMICAL COMPOSITION OF BLUBBER AND MUSCLE OF FIN AND SEI WHALES FROM ICELAND. *Gisli Vikingsson, Marine Research Institute, Programme for Whale Research, P.O. Box 1390, Skulagata 4, 121 Reykjavík, Iceland.*

This paper is a preliminary progress report on chemical analysis of the blubber and muscle of fin and sei whales, caught in 1986 and 1987. Apart from sei whales caught in 1986, the whales seem to be fatter in these two years, than in 1978, and 1981 (in terms of %lipid). For fin whales the females had slightly higher lipid content in 1987, than in 1986, but the reverse was true for the males. More detailed statistical analysis is in progress.

SC/40/Ba9. STUDY OF CARBONIC ANHYDRASE POLYMORPHISM IN FIN WHALES (*Balaenoptera physalus*) CAUGHT OFF ICELAND OVER THE YEARS 1971, 1981–1987. A PROGRESS REPORT. *Arnason, A. and Spilliaert, R., Iceland Programme for Whale Research, The Genetic Division of the Blood Bank, Reykjavík, Iceland.*

This progress report gives the frequencies of carbonic anhydrase (CA) alleles in 968 fin whales caught off Iceland in the years 1971, 1981 – 1987. The CA patterns were in Hardy-Weinberg equilibrium for each year until 1985 and 1986, when this equilibrium was lost, most likely because of incoming young males from other herds. In the animals caught 1987 the CA pattern is in Hardy-Weinberg equilibrium again and we are dealing with a herd that is not inbred. This method of following the CA allele frequencies from year to year is useful to estimate changes when they occur in the herds of fin whales.

SC/40/Ba10. PROGRESS REPORT ON THE STUDY OF GENETIC VARIATION AT ENZYME LOCI IN FIN WHALES (*Balaenoptera physalus*) CAUGHT OFF ICELAND AND OFF SPAIN. *Danielsdottir, A.K., Duke, E.J. and Joyce, P., Department of Zoology, University College, Belfield, Stillorgan Road, Dublin 4 and Arnason, A., The Genetic Division of the Blood Bank, Reykjavík, Iceland.*

This progress report is on the further study of the electrophoretic analysis of the allozymes of fin whales (*Balaenoptera physalus*) and sei whales (*Balaenoptera borealis*) from the North Atlantic Ocean (Danielsdottir *et al.*, 1987). Fin whales caught off Iceland in the years 1985 and 1986 have been screened. Fin whales caught off Spain in 1985 have also been screened for interpopulation comparison. The aims of this study are: (1) to compare the electrophoretic phenotypes of 33 enzyme systems from various tissues of fin and sei whales caught off Iceland. Such data will identify polymorphic loci which may be used to study animals from different areas of the North Atlantic and determine if they belong to the same or different populations; (2) using the data from no. 1 to study the polymorphic loci of fin whales caught off Spain and determine if they are the same or from a different population to those caught off Iceland. At present more fin whale individuals are being screened in all the enzyme systems for comparison of fin whales caught off Iceland versus Spain. Also sei whale individuals are being screened for interspecific comparison.

SC/40/Ba11. A PROGRESS REPORT ON AN ELECTROPHORETIC STUDY OF LIVER ESTERASES IN FIN WHALES (*Balenoptera physalus*) FROM ICELANDIC AND SPANISH WATERS. *R. Spilliaert and A. Arnason, The Icelandic Programme for Whale Research, The Genetic Division of the Blood Bank, Reykjavík, Iceland.*

An electrophoretic study employing starch gel electrophoresis and histochemical staining methods was carried out on liver homogenates from fin whales from Icelandic and Spanish waters (310 caught off Iceland and 46 off Spain). Only fast moving fractions could be used for analysis and the frequency of each fraction was remarkedly constant over the years. The inheritance of these is not known so phenotypes could not be proposed, hence this system is of little value for the time being to compare different populations, except probably on hemispheral level.

SC/40/Ba12. PRELIMINARY NOTE ON TEMPORAL CHANGES IN REPRODUCTIVE DATA FOR FEMALE FIN WHALES CAUGHT OFF SOUTHWEST ICELAND. *Christina Lockyer, c/o Southwest Fisheries Center, P.O. Box 271, La Jolla, CA 92038, USA and Johann Sigurjónsson, Marine Research Institute, P.O. Box 390, Skulagata 4, Reykjavík 121, Iceland.*

Using the presence of at least one ovarian corpus as the criterion for sexual maturity, examination of females with one ovarian corpus indicated an average length of 61ft over the period 1967–87. Over the same time period, the average age at sexual maturity was 8.6 yrs. Differences in mean age were noted between the periods 1967–1973, 1974–1980 and 1981–1987, with a rise from 7.6 yrs through 8.4 yrs to 9.1 yrs, but these values were not significantly different. An average ovulation interval of about 1.3 yrs was estimated for the period 1967–1987. The presence of an active corpus luteum (generally representing pregnancy) in the mature female sample was found to be consistently lower in newly mature females in all years. However, in combined categories of all corpora numbers, there were large differences between the 1967–1973, 1974–1980 and 1981–1987 periods: the middle period being much lower than the early and later periods. This finding and that of a suggested rise in age at sexual maturity are discussed in the light of changing environmental factors during the 21 year period 1967–1987. The stage of pregnancy advances during the period June-September, with a growing predominance of late-term foetuses by September, and an absence of early ones. This finding supports a winter breeding season.

Protected Species

SC/40/PS1. PROGRESS REPORT ON RADIO-TELEMETRIC STUDIES OF THE BEHAVIOUR OF BLUE, FIN AND HUMPBACK WHALES IN MONTEREY BAY AND ALONG THE CENTRAL CALIFORNIA COAST. *S. L. Swartz, Cetacean Research Associates, Inc., 4610 43rd Street, N.W., Washington, D.C. 20016, USA, Randall S. Wells and Susan Kruse, Center for Marine Studies, University of California, 100 Shaffer Road, Santa Cruz, California 95060, USA.*

The following is a summary of the first season of a proposed five year program to utilise VHF-radio tags to investigate the behaviour and habitat use of the Monterey Bay and Central Coast of California by three species of rorqual whales: specifically blue whales (*Balaenoptera musculus*), humpback whales (*Megaptera novaeangliae*), and fin whales (*Balaenoptera physalus*).

SC/40/PS5. MARK RECAPTURE ESTIMATION OF BOWHEAD WHALE, *Balaenoptera mysticetus*, POPULATION SIZE AND OFFSHORE DISTRIBUTION FROM 1986 VISUAL AND ACOUSTIC DATA COLLECTED OFF POINT BARROW, ALASKA. *Judith E. Zeh, Adrian E. Raftery and Patricia E. Styer, Department of Statistics, University of Washington, Seattle, WA 98195, USA*

We estimate the number of bowhead whales passing Point Barrow, Alaska, during the spring migration of 1986 using data collected by two independent methods, visual census and acoustic monitoring. We estimate detection probabilities for both methods as a function of visibility, acoustic condition and distance offshore out to 6km. The estimates indicate that visual detection is unreliable under poor visibility conditions or for whales more than 3km offshore. Acoustic detection is insensitive to acoustic condition out to 6km, shows no significant fall off with distance in this range and can be modelled in terms of the 120° sector in which acoustic locations are possible. Our estimates of both detection functions and whale numbers are based on the single mark release model (Seber, 1982) as presented in Gentleman and Zeh (1987) and Zeh, Turet, Gentleman and Raftery (1988). Since we cannot physically mark and release the whales we sample, a tracking algorithm is used to define recaptures for the mark release model. Allowing speeds of 1 to 7km/hr and deviations from the assumed migration direction of 25° in the tracking algorithm, we obtain a 1986 population size estimate of 7,000 with a standard error of 1,700. The standard error is computed from the jackknife variance estimate described by Efron (1982).

SC/40/PS6. BAYES EMPIRICAL BAYES INTERVAL ESTIMATION OF BOWHEAD WHALE, *Balaena mysticetus*, POPULATION SIZE BASED UPON THE 1985 AND 1986 COMBINED VISUAL AND ACOUSTIC CENSUSES OFF POINT BARROW, ALASKA. *Adrian E. Raftery, Judith E. Zeh and Patricia A. Styer, Department of Statistics, GN-22, University of Washington, Seattle, WA 98195, USA.*

A new method for estimating bowhead whale, *Balaena mysticetus*, population size is developed and used to obtain estimates based on the 1985 and 1986 combined visual and acoustic censuses off Point Barrow, Alaska. It is based on an explicit scientific model of the census process and of whale behaviour and yields a full probability distribution of the number of whales given the data or posterior distribution. It takes account of the imperfection of our scientific knowledge, of errors made by the tracking algorithm used and of uncertainty about the control parameters for the tracking algorithm. Based on the 1985 census, 95% of the posterior probability is concentrated between 4,400 and 10,600, and the posterior mode is 6,500. Somewhat more tentative results based on the 1986 census indicate that 95% of the posterior probability lies between 6,800 and 12,400 , with posterior mode 9,100. Based on the 1985 and 1986 censuses combined, the 95% interval ranges from 6,500 to 11,400 while the posterior mode is 8,600. The main sources of uncertainty are the absence of acoustic monitoring during part of each season, the fact that many acoustic locations have not been computed and uncertainty about the tracking algorithm parameters. Implications for census design and the allocation of future research effort, and possible improvements to the statistical methodology are discussed.

SC/40/PS7. OBSERVATIONS ON THE ANATOMY OF THE STOMACH AND DUODENUM OF THE BOWHEAD WHALE, *Balaena mysticetus*. *Raymond J. Tarpley, Raymond F. Sis, Department of Veterinary Anatomy, College of Veterinary Medicine, Texas A & M University, College Station, Texas 77843, USA, *Thomas F. Albert, Department of Veterinary Science, University of Maryland, College Park, Maryland 20740, USA, Leslie M. Dalton, Department of Health and Social Services, North Slope Borough, Barrow, Alaska 99723 and John C. George, Department of Wildlife Management, North Slope Borough, Barrow, Alaska 99723, USA.*

Gastric and cranial duodenal structure of the bowhead whale (*Balaena mysticetus*) was examined grossly and microscopically. The stomach was arranged in a series of four compartments. The first chamber, or forestomach, was a large nonglandular sac lined by a keratinized stratified squamous epithelium. It was followed by the fundic chamber, a large, somewhat globular and entirely glandular compartment. At the entrance of the fundic chamber, a narrow cardiac gland region could be defined. The remaining mucosa of the chamber contained the proper gastric glands. A narrow tubular connecting channel, the third distinct gastric division, was lined by mucous glands and joined the fundic chamber with the final stomach compartment or pyloric chamber. The fourth chamber was also tubular and lined by mucous glands but was of a diameter considerably larger than the connecting channel. The stomach terminated at the pyloric sphincter which consisted of a well–developed band of circular smooth-muscle bundles effecting a division between the pyloric chamber and small intestine. The small intestine began with the duodenal ampulla, a dilated sac considerably smaller than the fundic chamber of the stomach. The mucosa of this sac contained mucous glands throughout. The ampulla led without a separating sphincter into the duodenum proper which continued the intestine in a much more narrow tubular fashion. The mucosal lining of the duodenum was composed of villi and intestinal crypts. Although their occurence varied among whales, enteroendocrine cells were identified within the mucous glands of the cardiac region, connecting channel, pyloric chamber, and cranial duodenum. The hepatopancreatic duct entered the wall of the duodenum shortly after the termination of the duodenal ampulla and continued intramurally along the intestine before finally joining the duodenal lumen.

* Current address: Department of Wildlife Management, North Slope Borough, Box 69, Barrow, AK 99723, USA.

SC/40/PS8. OBSERVATIONS ON REPRODUCTIVE MORPHOLOGY IN THE FEMALE BOWHEAD WHALE (*Balaena mysticetus*). *R. Tarpley, R. Weeks and G. Stott, Department of Veterinary Anatomy, College of Veterinary Medicine, Texas A & M University, College Station, TX 77843, USA.*

The central role of the reproductive system in questions of population stability has given it priority in several cetacean investigations aimed at sustaining the resources of the commercial whaling industry. Such studies focused on in-depth anatomical analyses of reproductive structures as the most certain guide for functional inferences of the reproductive cycle. Most of these investigations were conducted during historical peak whaling periods when materials suitable for accurate examination were available. Consequently, the literature reflects the species of interest to commercial whaling at the time, and the rorqual group (the balaenopterids) has figured most heavily in discussions of mysticete reproduction. In contrast, commercial exploitation of the right whale group (Balaenidae) of which the bowhead is a part, occurred largely before adequate investigative techniques were available. Consequently, there is a virtual absence of thorough data addressing reproductive questions in balaenids. Such information will be important for decisions on the bowhead issue which must be founded upon the most current indicators of stock replacement, including ovulation frequency, length of gestation, length of lactation and the calving interval. Total body length at sexual maturity needs to be defined as firmly as possible in both sexes to guide management policies designed to protect the reproductively active members of the population. Length at sexual maturity is also significant for any attempt to determine (e.g., by aerial survey) the numbers within the total population which are contributing to stock renewal. Since the early 1980s, collection of reproductive specimens has continued under sponsorship of the North Slope Borough in Barrow, Alaska. This report represents an evaluation of new materials for correlation and comparison with earlier findings.

SC/40/PS9. THE USE OF RADIO TELEMETRY IN INSTRUMENTING WHALE FLOATS AS AN AID IN THE RECOVERY OF STRUCK BUT LOST BOWHEAD WHALES (*Balaena mysticetus*).

Erich H. Follmann and Arthur E. Manning, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska 99775–0180, USA.

A project was initiated in 1983 to determine the feasibility of using radio-telemetry to aid in the recovery of bowhead whales struck during the annual subsistence hunt by Eskimos in northern Alaska. The radio-transmitter was placed in the whaling float to minimise the problem of signal attenuation by marine waters. The stainless steel attachment plates worked flawlessly to stabilise the radio-transmitter inside the float and to seal the hole cut in the float to insert the radio-transmitter. With directional receiving antennas and receiver, floats could be detected at several kilometers from boats and at over 40km from aircraft. Fifteen whaling crews were instrumented for the Fall subsistence hunts beginning in 1983 at Kaktovik and in 1986 at Nuiqsut. Seven of eleven whales were retrieved during the course of this study, one of the seven because it was found by virtue of the radio signal transmitted from the float 48km offshore. The floats attached to the four whales that were lost during this period were all radio-located but the harpoons had pulled out of two of these whales. The other two floats were not attached to whales when found and the distances from shore were too far to safely retrieve the equipment to determine the exact reason for loss. A 64% retrieval rate was achieved during this study, up from 55% had radio-telemetry not been used. Radio-telemetry has proven to be a successful technique to support the subsistence hunt for the bowhead whale, and the Alaska Eskimo Whaling Commission is currently expanding its use to other villages where relatively ice-free waters are conducive to its use.

SC/40/PS12. PRELIMINARY POPULATION ESTIMATE OF GRAY WHALES DURING THE 1987/88 SOUTHWARD MIGRATION.

J.M. Breiwick, D.J. Rugh, D.E. Withrow, M.E. Dahlheim, Northwest and Alaska Fisheries Center, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Bldg. 4, Seattle, Washington 98115, USA and S.T. Buckland, SASS, Aberdeen Unit, Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen, AB9 2QJ, Scotland.

Gray whales were censused during their southbound migration from shore and aerial surveys at Granite Canyon, California, from 10 December 1987 to 7 February 1988. Two independent and concurrent counts were maintained throughout the census period (north and south site, 5m apart). The two sites had equal viewing areas and observers rotated between sites. Sighting data for visibility 5 and 6 were deleted from analyses due to low sighting rates. A total of 2988 pods (6,094 whales) was recorded at south site and 2981 pods (6,000 whales) at north site. More than 99% of the whales sighted from the air were within 3nm from shore. A Hermite polynomial model was fitted to the counts in order to estimate the number of pods passing during night, poor visibility and before and after the census period. This gave a correction factor of 2.535 for the pod count (2,902) at south site. A correction factor based on mark-recapture methodology (1.26) was also applied to the count data to estimate the number of pods missed in the viewing area by each observer. Mean pod size was calculated to be 2.24. The resulting population estimate, based on the number of pods seen at south site, was 21,113 (SE=688).

Small Cetaceans

SC/40/SM6. A REVIEW OF COLOUR PATTERNS AND THEIR ONTOGENETIC VARIATION IN BEAKED WHALES (ZIPHIIDAE, CETACEA).

G.J.B. Ross, Port Elizabeth Museum, P.O. Box 13147, 6013 Humewood, South Africa, P.B. Best, Whale Unit, c/o South African Museum, P.O. Box 61, Cape Town 8000, South Africa, A.N. Baker, National Museum of New Zealand, Wellington, New Zealand and J.G. Mead, Smithsonian Institution, National Museum of Natural History, Washington, D.C. 20560, USA.

Although current studies promise to clarify many of the systematic problems of the family (e.g. Moore, 1968), beaked whales (family Ziphiidae) include some of the least known of all cetaceans. Nearly all museum specimens have been obtained from strandings, and as disintegration of such large soft-skinned animals proceeds extremely rapidly after death it is not surprising that so little is known of their external appearance and biology. All keys for beaked whales published to date concentrate largely on skeletal characters, and the external appearance of one species (*Indopacetus pacificus*) is so far completely unknown. Although the shape and position of the mandibular teeth can be most useful in identifying a species, these only erupt in adult males of most species. There is as yet insufficient information on body shape to give more than a crude separation of half a dozen species. In particular data on colour patterns are very poorly documented, due to the rapidity with which these disappear at death and are darkened by the sun, to be subsequently described as 'black all over' or 'black above, paler below'. Recent evidence collected from fresh animals stranded on the coasts of South Africa, New Zealand and North America, however, indicates that several beaked whale species have very striking and characteristic colour patterns. Furthermore, information gathered from calves and subadults of these species suggest that these colour patterns are typical of adults only, and that younger animals are less strikingly coloured. Documentation of these colour patterns should prove invaluable for future attempts at identifying beaked whales in the flesh, particularly at sea. This paper presents these new data together with a review of published information for 16 of the 17 species of beaked whales currently recognised.

SC/40/SM7. PRELIMINARY ANALYSIS OF LIFE HISTORY OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF CENTRAL JAPAN.

Toshio Kasuya, Far Seas Fisheries Research Laboratory, 5–7–1, Orido, Shimizu-shi, Shizuoka-ken, 424 Japan, Robert L. Brownell, Jr., US Fish and Wildlife Service, P.O. Box 67, San Simeon, CA 93452, USA and Kenneth C. Balcomb, III, 1359 Smuggler's Cove Road, Friday Harbour, WA 98250, USA.

The life history of Baird's beaked whales was analysed using 135 specimens taken by the small-type whaling off the Pacific coast of central Japan in the 1975 and 1985–87 seasons. The deposition rate of cemental layers was assumed as annual, but due to the timing of birth and deposition of stainable layers, the present counts of the annual layers would underbias the true age by about 3/4 year on average. When comparing sexes, males matured at a younger age (6–10 years, 10–14 layers) and at a smaller body length (9.1–9.7 years, 9.8–10.6m), and attained smaller mean asymptotic length (10.1 years, 10.45m). Both sexes ceased growing at 15 layers, soon after sexual maturity. The sex ratio in the catch was nearly equal in juveniles, but females were scarce at 20–54 layers and were absent after that age, while males were common until 84 layers. The apparent pregnancy rate was about 30% and was not indicated to decline with increasing age. Further behavioural studies are required for the interpretation of this age structure of the sample.

SC/40/SM8. DISTRIBUTION OF BAIRD'S BEAKED WHALES OFF JAPAN OBSERVED DURING WHALE SIGHTING CRUISES. *Toshio Kasuya and Tomio Miyashita, Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu-shi, Shizuoka-ken, 424 Japan.*

The distribution of 167 Baird's beaked whale schools, which were sighted through 113,113 n.miles of sightings cruises made between 1982 and 1987 and covering nine months of the year, was compared with the previous analyses of distribution and migration of the species in the waters adjacent to Japan. The results were found to support many of the earlier analyses. The distribution of Baird's beaked whales was limited in the surveyed area to the north of about 34°N, and it suggested three putative stocks: the Sea of Japan stock which summers in the Sea of Japan and possibly remains isolated there throughout the year; the Okhotsk Sea stock which inhabits waters near the ice floes in the Okhotsk Sea and some members of which winter off the coast of northern Hokkaido facing the Okhotsk Sea and perhaps the Pacific; and the Pacific coast stock which probably inhabits coastal waters between the fronts of the Kuroshio and Oyashio Currents, and apparently leaves the summering ground on the continental slope of 1,000–3,000m depth in winter but whose wintering ground is still to be investigated.

SC/40/SM9. PRELIMINARY REPORT OF AN UNIDENTIFIED BEAKED WHALE LIKE *Hyperoodon* SP. IN THE CENTRAL AND THE WESTERN PACIFIC. *Tomio Miyashita, Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu, 424 Japan and Kenneth C. Balcomb, III, Center for Whale Research, 1359 Smuggler's Cove Road, Friday Harbour, WA 98250, USA.*

Eight sightings represented by about 280 individuals of a distinctive but unidentified beaked whale have been made in the central and western North Pacific in 1966–1986. The whales were characterized by a bulging forehead, a cylindrical dark coloured beak and a falcate dorsal fin. The concave side of the blowhole was anteriority. The body colors were full of variety like umber brown or bluish black with pale blowhole band. Maximum length estimates were around 8.0m. These suggest that these whales will most probably belong to genus *Hyperoodon*, which has not been reported from the North Pacific.

SC/40/SM10. TRANSECT ESTIMATORS OF CETACEAN ABUNDANCE; THEORY AND PRACTICE. *E.M. Lynas, Ocean Research Information Society, 2 Sandbar Road, Pt. Pickering (On), L1W 1A1.*

The effects of species-based biological/ecological variables on transect estimators of cetacean abundance are discussed and illustrated, both with respect to the theoretical models themselves and in terms of their field application. Suggestions are offered for improving accuracy and design in future surveys, and areas for further research are delineated.

SC/40/SM11. MASS STRANDING OF *Peponocephala electra* (CETACEA GLOBICEPHALINAE) ON PIRACANGA BEACH, BAHIA, BRAZIL. *L.F. Lodi, S. Siciliano and L. Capistrano, Fundacao Brasileira para a Conservacao da Natureza, Rua Miranda Valverde 103 – Botafogo, 22281 Rio de Janeiro RJ, Brazil.*

On April 16, 1987 a herd of over 240 melon-headed whales, *Peponocephala electra* (Gray, 1846), stranded on Piracanga Beach (14°14′S,39°00′W). Data on body length and sex ratio of 182 carcasses were collected 8 days after the stranding. The herd included at least 81 females and 44 males; 57 individuals could not be sexed due to decomposition and vulture damage.

SC/40/SM13. BEAKED WHALES IN MEXICAN WATERS. *A. Aguayo-L, *J. Urbán-R, M. Salinas-Z, Laboratorio de Vertebrados, Facultad de Ciencias, UNAM, Apartado Postal 70–572, C.P. 04510 Mexico, D.F., Mexico, D. Aurioles, Centro de Investigaciones Biologicas de BCSAC, Apartado Postal 128, La Paz, Baja California Sur, Mexico, O. Vidal and L.T. Findley, Instituto Tecnologico de Monterrey, Campus Guaymas, Apdo. Postal 484, Guaymas, Sonora 85400, Mexico.*

Known records, including recent sightings and strandings, of *Ziphius cavirostris*, *Berardius bairdii*, and unidentified species of *Mesoplodon* in Mexican waters are reviewed. Most of these records are from the Gulf of California and off the Pacific mainland coast, and a few from the Caribbean. In the Mexican Pacific *Z. cavirostris* and *Mesoplodon* spp. occur in all seasons, while *B. bairdii* occurs in summer and autumn. The southern limit of distribution of this latter species is extended to *ca.* 23°N.

* Present address: Depto. de Biologìa Marina, Universidad Autònoma de Baja California Sur, Apdo. Postal 103-B, La Paz, BCS 23000, Mexico.

SC/40/SM14. OBSERVATIONS OF BEAKED WHALES (*Ziphiidae*) FROM THE EASTERN TROPICAL PACIFIC OCEAN. *Robert L. Pitman, David W.K. Au, Southwest Fisheries Center, P.O. Box 271, La Jolla, CA 92038, USA, Michael D. Stott, Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Drive, La Jolla, CA 92038, USA and James M. Cotton, P.O. Box 103, Trinidad, CA 95570, USA.*

We present information on 946 sightings of at least six species of beaked whales in the eastern tropical Pacific (ETP). The bottlenosed whales, *Berardius bairdii* (8 sightings) and *Hyperoodon* sp. (7 sightings), were very rare; the former occurred only off Baja California, and the latter mainly in equatorial waters. *Ziphius* (198 sightings) was widespread throughout the study area but concentrated in near offshore waters along the coast of the Americas, and west along the Equatorial Countercurrent. *Mesoplodon* spp. (1985 sightings) had a similar concentration along the coast of the Americas with a westward extension along latitude 10°N. *Mesoplodon* sightings appeared to involve mainly two species: an easily-recognisable but as yet unidentified species, and *M. densirostris*. These two species apparently occupy adjacent and largely exclusive ranges within the ETP. Unidentified ziphiids (548 sightings) were almost all *Ziphius* and *Mesoplodon*. Though not abundant, we found ziphiids, as a group, to be more common than any other species of large- or medium-sized cetacean in the eastern tropical Pacific. Additional information on biological observations and identification of individual species is also provided.

SC/40/SM15. PRELIMINARY REPORT ON THE PARASITES AND PATHOLOGY OF BAIRD'S BEAKED WHALES TAKEN OFF THE PACIFIC COAST OF CENTRAL JAPAN, 1985–1987. *William A. Walker, Research Associate, Section of Mammalogy, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, USA.*

This report is on a survey of parasites from Baird's beaked whale, *Berardius bairdii* taken off the Boso Peninsula, Chiba Prefecture, Japan during the 1985–1987 fishing seasons. The main focus of this study was to survey select organs of these whales for incidence of parasitism and related pathology in order to assess potential natural mortality factors present in the population. Published accounts on the endoparasites of *B. bairdii* are, at present, in a somewhat confused state. Delyamure (1955) erroneously described and summarised the parasites of *B. bairdii* under the assumption that the North Pacific bottlenose whale was

Hyperodon ampullatus. In addition, he also included parasites previously described from valid *H. ampullatus* from the Atlantic. Dailey and Brownell (1972) took these oversights into account in their checklist but omitted to include the cestode, *Nybeliinia* sp. as a parasite of *B. bairdii* and to cite Rice (1963) as the source for the record of the cestode, *Phyllobothrium delphini* (R.L. Brownell, pers comm. 1985). Of the published accounts only Rice (1963) surveys parasite frequency of occurrence in *B. bairdii* taken off Central California.

SC/40/SM16. PRELIMINARY REPORT ON THE FOOD HABITS OF BAIRD'S BEAKED WHALES TAKEN OFF THE PACIFIC COAST OF CENTRAL JAPAN, 1985–1987. *William A. Walker, Research Associate, Section of Mammalogy, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, USA and James G. Mead, Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560, USA.*

This report is on a three year survey of stomach contents of Baird's beaked whale, *Berardius bairdii* taken off the Boso Peninsula, Chiba Prefecture, Japan. Little in the way of published accounts on the food habits of *B. bairdii* exists in the literature. Pike (1953) and Rice (1963) reported on a total of eight whales taken in the eastern North Pacific, Zenkovich (1939) and Tomilin (1957) gave food habit accounts on a total of five whales presumably taken off the Kamchatka Peninsula (exact localities not given). Nishiwaki and Oguro (1971) summarised findings based on examination of 701 stomachs from whales taken along the Pacific coast of Japan from 34°N north to the northern coast of Hokkaido in the Okhotsk Sea. None of these published accounts focused on species identification of ingested prey. Prey species identification in these accounts was limited to the higher taxa such as "fish and squid" or, at best, only part of the contents were specifically identified. This report presents the preliminary results of a detailed study on 86 stomach samples which is currently in progress.

SC/40/SM17. REIDENTIFICATION OF *Phocoena spinipinnis* SPECIMEN FROM HEARD ISLAND. *Robert L. Brownell, Jr., US Fish and Wildlife Service, Piedras Blancas Field Station, P.O. Box 70, San Simeon, CA 93452, USA, John E. Heyning, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, USA and William F. Perrin, Southwest Fisheries Center, P.O. Box 271, La Jolla, CA 92038, USA.*

Guiler, Burton and Gales (1987) reported a cranium they identified as *Phocoena spinipinnis* from Heard Island (53°S 73°30′E). They noted that *P. spinipinnis* was previously known only from the cold-temperate coastal waters of South America (Brownell and Praderi, 1984). We have examined the photographs and details of this specimen and reidentify it here as *Australophocaena dioptrica* (see Barnes, 1985 for use of *Australophocaena*).

SC/40/SM18. THE HECTOR'S BEAKED WHALE, *Mesoplodon hectori*, OFF SOUTHERN SOUTH AMERICA. *R. Natalie P. Goodall, Sarimento 44, 9410 Ushuaia, Tierra del Fuego, Argentina and Alfredo A. Lichter, Fundacion vida Silvestre Argentina, Defensa 245, (1075) Buenos Aires, Argentina.*

This paper reviews the status of the Hector's beaked whale, *Mesoplodon hectori*, worldwide and presents new information on strandings of the species on the coasts of the southwestern South Atlantic. Details of a mass stranding of two adult females and two calves are given. These animals double the number of adult specimens of this species. The largest known female measured 554cm, the largest male 430cm. The smallest calves are those reported here, at 190 and 202cm. The stranding was in January, the southern summer. Cranial measurements, a distribution map for South America and a stranding by latitude chart are given. The total cranial specimens known for this species is now 22 (18 from the Southern Hemisphere and four from the northern), plus two postcranial samples.

SC/40/SM19. REVIEW OF KNOWLEDGE ON THE SHEPHERD'S BEAKED WHALE, *Tasmacetus Shepherdi*. *R.N.P. Goodall, Sarmiento 44, 9410 Ushuaia, Tierra del Fuego, Argentina. A.N. Baker, National Museum of New Zealand, Wellington, New Zealand.*

The Shepherd's beaked whale, *Tasmacetus shepherdi*, is one of the least known cetaceans. At the time of writing, it has been recorded for only four countries, all in the Southern Hemisphere, through thirteen published strandings and two possible sightings. Most of these were beached animals accidentally stumbled upon by the public; many strandings may have been unreported. Recent interest in cetacean strandings and the development of Southern Hemisphere stranding networks, as well as regular beach surveys, have produced new data, presented here with an update on the state of knowledge of this rare species. Although the sample size is still extremely small, this review should form a base line for new workers in the field.

SC/40/SM20. THE PRESENCE OF THE LAYARD'S BEAKED WHALE, *Mesoplodon layardii*, IN THE SOUTHWEST SOUTH ATLANTIC, WITH A REVIEW OF STRANDINGS WORLDWIDE. *R. Natalie P. Goodall, Christina L. Folger, Sarmiento 44, 9410 Ushuala, Tierra del Fuego, Argentina. Alfredo A. Lichter, Fundacion Australis, Cervino 3126, 1425 Buenos Aires, Argentina.*

Records of strandings of the Layard's beaked whale, *Mesoplodon layardii*, have been compiled, with emphasis on those of the SW South Atlantic. The species has not been found outside the Southern Hemisphere and is considered of austral circumpolar distribution. The northernmost stranding was at 20°07′S in Australia, the southernmost at 55°11′S near Cape Horn. At least 145 specimens are known from, in order of number, Australia, New Zealand, South Africa, and SW South Atlantic, and offshore islands. Thought to occur mainly in cool temperature waters, many new strandings have been from the Subantarctic. More strandings have occurred in summer, which may represent inshore movements in warmer months. This species has been seen only a few times at sea. The pigmentation pattern is striking – gray or white on the upper forward body, dark posteriorly, with a dark eye patch and shoulder/flipper area. Pigmentation of animals from South America confirm this pattern. The largest female measured 615cm, the largest male 584cm. Few external measurements have been published. The teeth in females are low and somewhat triangular, and in males are long and strap-like. A tooth-shape catalog is presented. Few complete skeletons exist in museums. The vertebral count range is Cv7, 09–10, L1-=12, Ca16–20=44=48. The smallest calf was about 250cm, but little else is known about reproduction. Birth may occur in spring. Only two mass strandings, of three animals each, have been noted. We present the first record of stomach contents for this species, a single squid beak. We give a list of specimens world-wide, a summary of length and other data, external and skull measurements and a distribution map for South American animals.

SC/40/SM21. DISTRIBUTION AND EXPLOITATION OF BEAKED WHALES IN THE NORTHERN HEMISPHERE. *James G. Mead, Division of Mammals, NHB Stop 180, National Museum of Natural History, Smithsonian Institution, Washington DC 20560, USA, John E. Heyning, Assistant Curator of Mammals, Natural History Museum of Los Angeles County, 900 Exposition Blvd, Los Angeles, CA 90007, USA and Robert L. Brownell, Jr., US Fish and Wildlife Service, Piedras Blancas Field Station, PO Box 70, San Simeon, CA 93452, USA.*

In this paper we attempt to list all records of beaked whales (Ziphiidae) known from the North Pacific and North Atlantic.

Included are published records, museum specimens and unpublished data compiled at the Smithsonian through the Scientific Events Alert Network (SEAN) and the Marine Mammal Events Program (MMEP). Although we have indubitably overlooked some records, the data presented should provide the best information to date regarding the distribution of these poorly known cetaceans. Sightings at sea of ziphiids are uncommon and sightings that can be identified to species with a high degree of certainty are rare. Therefore we must rely primarily on stranding records for the distribution of most species, keeping in mind the inherent biases regarding the use of stranding data. In the North Atlantic the records of strandings collected have been good along the east coast of the U.S., especially over the last twenty years, but moderate to poor for most of the Caribbean region. Strandings have historically been recorded along the British coasts, with increased interest in specimen collection along the rest of the western European coast over the last 15 years. Records of strandings from the North Atlantic coast of Africa are rare and thus the lack of specimen records from this region may not reflect the actual range of a species in this region. In the North Pacific, the collection of stranding data ranges from moderate to good southward from Alaska to California with almost no records of strandings south of Baja California. Fortunately the eastern tropical Pacific has the most comprehensive sighting data for small cetaceans due to the extensive tuna/porpoise program. In the western North Pacific stranding records are moderate off the Japanese coasts and poor throughout the rest of the region. For the purposes of this paper, we have defined the Northern Hemisphere as all bodies of water that lie north of the equator. This distribution is not a biological boundary and many species that live in warm temperate or tropical waters range from north to south of the equator. We have also summarised the catch data for *Berardius bairdii* and *Ziphius cavirostris*. *Hyperoodon ampullatus* is not included in this paper. Incidental catches, primarily from gill nets, are also listed and discussed.

SC/40/SM22. AGE DETERMINATION AND REPRODUCTIVE BIOLOGY OF CUVIER'S BEAKED WHALE, *Ziphius cavirostris*. *John E. Heyning, Section of Birds and Mammals, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA. 90007.*

Due to the relative rarity of strandings and the lack of commercial interest in most species of beaked whales (Ziphiidae), little is known regarding any aspect of the natural history of this group. Cuvier's beaked whale, *Ziphius cavirostris*, is the most frequently stranded beaked whale and there has been a limited fishery on this species. Thus, besides the two commercially exploited species, *Berardius bairdii* and *Hyperoodon ampullatus*, there are more data available for *Z. cavirostris* than for any other species of ziphiid. Although strandings of *Z. cavirostris* are not uncommon, few specimens have been throughly examined and there is a paucity of data regarding many aspects of the life history of this species. Using the available data to date, I have attempted to corroborate previous statements in the literature regarding sexual dimorphic features and life history parameters.

SC/40/SM23. THE DISTRIBUTION OF BEAKED WHALES IN THE SOUTHERN HEMISPHERE. *G.J.B. Ross, Port Elizabeth Museum, PO Box 13147, Port Elizabeth, 6013 South Africa. A.N. Baker, National Museum of New Zealand, Private Bag, Wellington, New Zealand. R.N.P. Goodall, Centro Austral de Investigaciones Cientificas, 9410 Ushuaia, Tierra del Fuego, Argentina. A.A. Lichter, Fundacion Vida Silvestre Argentina, L.N. Alem 968 PB, Buenos Aires, Argentina and J.G. Mead, Division of Mammals, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA.*

The distribution of most beaked whale species are poorly known, primarily because of the difficulties of observing and identifying them at sea, and almost all available data are derived from stranding records. This restriction is particularly limiting in the Southern Hemisphere, where land masses form a small proportion of the total surface area and interested observers are few and widely spaced. A welcome upsurge in interest in stranded cetaceans in the Southern Hemisphere in recent years has provided abundant new material, from which assessments of distribution patterns have been made on a regional basis in recent papers. This paper describes the distribution patterns for the 13 species of beaked whales presently known from the Southern Hemisphere. These patterns are based on the first attempt to assemble a complete listing of Southern Hemisphere beaked whale specimens, primarily as a database for distribution analyses as well as a catalogue of sources for future taxonomic and biological studies.

Other

SC/40/O 3. SCIENTIFIC COMMITTEE PROCEDURES.

In November 1987 letters from the Commissioners for the USA and Iceland were circulated to all Commissioners, Contracting Governments and members of the Scientific Committee. These dealt with certain aspects of the present procedures and practices of the Scientific Committee, and the way in which special permit proposals are reviewed. Comments received from the Commissioners for Brazil, Seychelles, Netherlands and Australia were also circulated and copies of these, together with a response by Dr S.J. Holt (Seychelles) which was not circulated, are included in this document.

SC/40/O 4. SUGGESTED MECHANISM FOR REVIEWING SCIENTIFIC PERMITS AT SCIENTIFIC COMMITTEE MEETINGS. *G.P. Donovan, International Whaling Commission, The Red House, Station Road, Histon, Cambridge, CB4 4NP, UK.*

The review of proposed scientific permits has taken up an increasing amount of the Committee's time in recent years and the number of Committee and Commission guidelines has proliferated. At the 1987 Special Meeting to review the Japanese feasibility study, it became apparent that there was considerable overlap between the resolutions and the Committee's own guidelines. Treating the guidelines and the resolutions separately was a somewhat cumbersome procedure which led to an unhelpful degree of cross-referencing and an inelegant report. In order to focus discussion, this note suggests a way in which the Scientific Committee review procedure might be streamlined whilst at the same time providing the Commission with the information it requires.

SC/40/O 5. WORKING GROUP ON CATCH-AT-AGE DATA.

This document comprises the Postal-Convenor's Report of Communications in 1987/88.

SC/40/O 7. SPECIAL MEETINGS OF THE SCIENTIFIC COMMITTEE – A BACKGROUND NOTE. *Ray Gambell, Secretary to the Commission, International Whaling Commission, The Red House, Station Road, Histon, Cambridge, CB4 4NP, UK.*

At the Special Meeting of the Scientific Committee held in Cambridge, 15–17 December 1987, there was some discussion of the question of a quorum at meetings of the Scientific Committee. It was decided to draw 'the attention of the Commission to potential problems which may arise out of the fact that the Committee's Rules do not specify a quorum. It was agreed that a rigid rule might be inappropriate for special meetings on specialised subjects, where only a small proportion of the Committee may possess the required expertise and thus wish to attend.' It was agreed to discuss the matter further at the next Annual Meeting of the Scientific Committee, and this document comprises the background note the Secretary was asked to produce on the subject.

SC/40/O 13. ON MECHANISM AND CAUSES OF MASS STRANDING OF CETACEA. *Professor A.G. Tomilin, All-Union Agriculture Institute, Balashikha, Moscow, USSR.*

The stranding phenomenon is characteristic of the entire Cetacean order, of individuals of any species, age and sex. The causes of this phenomenon have a complex nature but motives of herd stranding are more complicated than those of individual stranding. It is proposed that there are three main reasons which cause mass (group) stranding (for individual stranding only the two first reasons are valid): (1) disturbance in orientation during swimming caused by complicated hydrometeorological conditions (storm, surf, wind) and topography (sloping sand shore) which interfere with echo ranging, or other reasons; (2) disease of an individual or several individuals in a herd causing a subconscious desire to contact with the shore (ancestral stimulus); (3) behaviouristic reaction, i.e. a wish to help those individuals of the herd which may suffer from suffocation in water (the instinct of species preservation). The animals of the herd rush to save the distressed individual after having received a signal from it. Their help is based on the use of breathing come-to-the-surface reflex and its effectuated by means of pushing the suffering individual up to the water surface so that the animal could perform a breathing act. The respiratory action starts reflexively as soon as the head of the animal sticks out of water. Should such a saving action occur at a deep place, it would save the animal, but if the place is shallow (near the shore), it results in the stranding of the helpers themselves and, through chain reaction, in the death of the entire herd. All cases of repeat or multiple strandings (both individual and complete herds) are associated with the manifestation of the ancestral stimulus, urging of sick Cetacea towards ground. This reaction stems apparently from remote ancestors who had been assimilating to the water environment and ran aground if jeopardised by suffocation in water. The existence of the ancestral stimulus as a cause of the urging of sick individuals to come close to the shore is corroborated by direct observation of common dolphins (*Delphinus delphis*). The phenomenon of mass stranding may be one of the factors limiting the size of populations of some species of Cetacea.

SC/40/O 16. THE IWC/IDCR SOUTHERN HEMISPHERE MINKE WHALE ASSESSMENT CRUISES: THE FIRST TEN YEARS. *Gerald G. Joyce, 826 NE 80th St., Seattle, WA 98115, USA. Fujio Kasamatsu, Institute of Cetacean Research, 3–31–11, Ojima, Koto-ku, Tokyo, Japan. Richard Rowlett, 170 Melrose Ave., No. 303, Seattle, WA 98102, USA and Lawrence Tsunoda, National Marine Mammal Laboratory, National Marine Fisheries Service, NWAFC, 7600 Sand Point Way NE, Bldg. 4, Seattle, WA 98115-0070, USA.*

The first ten IWC/IDCR Southern Hemisphere minke whale assessment cruises are reviewed. The program has conducted surveys in all six Antarctic management Areas and has resurveyed four of the Areas. Each cruise is briefly summarised. The development of both standard and experimental equipment and the establishment of standard methodologies are reviewed. Special experiments are discussed in regard to their objectives, methodologies, and results. The program has changed from a primarily Discovery marking cruise to a rigidly structured sightings cruise. Thirteen species of Cetacea have been observed in the Antarctic Areas with 2,716 minke whales, 25 sperm whales, and 7 humpback whales marked with Discovery marks during the 1,859 ship-days expended in the program. During the program 30 major experimental studies have been conducted. It is concluded that the program has developed standard procedures that are the best possible compromise between statistical needs and logistic feasibility. Many of these procedures can be adapted to research programs in other parts of the world.

SC/40/O 17. RESULTS AND EFFECTS OF SOME NEW PROCEDURES USED IN THE 1987/88 IWC/IDCR SOUTHERN HEMISPHERE MINKE WHALE ASSESSMENT CRUISE. *Gerald G. Joyce, 826 NE 80th, Seattle, WA 98115, USA. Fujio Kasamatsu, Institute of Cetacean Research, 3–31–11, Ojima, Koto-ku, Tokyo, Japan. Mr Don Barnett, Navy-NOAA Joint Ice Center, 4301 Suitland Road, Washington, D.C. 20390, USA.*

Two major new procedures were used during the 1987/88 IWC/IDCR Southern Hemisphere minke whale assessment cruise: (1) the exclusive use of satellite imagery based analyses to determine the cruise tracks and stratifications and (2) the real-time entry and validation of data aboard the ships. The satellite analysis was used for cruise tracks design but difficulties were encountered in the first half of the cruise. It is suggested that the cruise track construction methods be redesigned so they are less sensitive to variations in the ice. The data entry and validation were performed successfully with little trouble. Errors in data recording were quickly identified and corrected. The data files were also of use for scheduling and cruise track construction.

SC/40/O 18. A NOTE ON THE CONSIDERATION OF THE MSY% IN THE COMPREHENSIVE ASSESSMENT. *D.S. Butterworth, Department of Applied Mathematics, University of Cape Town, Rondebosch 7700, South Africa.*

The matter of MSY% estimation is important and merits more attention. It is suggested that: (i) sources of existing estimates (or opinions) should be listed; (ii) the methods used and assumptions made in reaching these estimates should be critically reviewed, in part because some may no longer be considered to be acceptable; (iii) future research priorities, particularly as regards the development of (absolute or relative) abundance time-series from direct surveys, should be specified.

SC/40/O 19. SIMULATION STUDIES ON ELEMENTS OF A REVISED WHALE MANAGEMENT PROCEDURE. *William K. de la Mare, Marine and Ecological Research, 76 Haldane St. Beaumaris, Victoria, 3193, Australia.*

The standard screening protocol designed at the Comprehensive Assessment Workshop on Management Procedures is applied to a management procedure based on explicit feedback principles. The procedure adjusts catch limits up or down depending on whether the estimate of stock depletion is above or below a specified target level. The procedure includes a method for taking uncertainty in depletion estimates into account by adjusting the target level for depletion by an amount which depends on the width of the confidence interval for the depletion estimate. The results show that the procedure is quite successful at maintaining stocks at, or restoring them to, a level above a protection level. Some suggestions are made for the further development of the procedure.

SC/40/O 21. ONCE MORE ON CYAMID (*CRUSTACEA: AMPHIPODA: CYAMIDAE*) FAUNA OF *CETACEA*. *Kurochkin, Yu.V., The Caspian Research Institute of Fisheries, Astrakhan, 414056, USSR.*

Unfortunately there are omissions, lapses and mistakes in some recent scientific publications on the whale-lice. To stop subsequent spreading of erroneous data in literature the complete systematic list of known whale-lice is presented here with information on cetacean hosts reported, locality records and supporting references. Some comments are given in necessary cases. Now six valid genera and 22 valid species of whale-lice are known in the world fauna.

SC/40/O 22. PRELIMINARY REPORT OF MINKE WHALE SIGHTING SURVEYS IN LOW LATITUDINAL WATERS IN 1987/88.

F. Kasamatsu, Institute of Cetacean Research, 3-32-11 Ojima Koto-ku, Tokyo 100, Japan.

Results from two cruises (23 Nov.–6 Dec. 1987; 11 Feb.–17 Mar. 1988) in low latitudinal waters (100–110°E, 12–40°S) are presented. The surveys were carried out to the north of the Japanese research permit catches. In the first cruise 4 diminutive form minke whales, 3 Antarctic form minke whales and one minke whale unidentified to form were seen. In the second cruise only 1 minke whale unidentified to form was seen. Other cetacean sightings are also presented.

SC/40/O 24. INITIAL SCREENING FOR A WHALE MANAGEMENT PROCEDURE.

Kazumi Sakuramoto, Tokyo University of Fisheries, 4–5–7, Konan, Minato-ku, Tokyo 108, Japan, Syoiti Tanaka, Tokyo University of Fisheries, 4–5–7, Konan, Minato-ku, Tokyo 108, Japan and Tomio Miyashita, Far Seas Fisheries Research Laboratory, 5–7–1, Orido, Shimizu 424, Japan.

A simulation study was conducted according to the Scientific Committee's recommended procedures to test Sakuramoto and Tanaka's approach (1988). In the case where the index of abundance was proportional to the population, all but trials 7 and 8 of the initial screening test were carried out. The information needed to apply this management procedure is the index of abundance, one sighting survey before the whaling is commenced and the age of sexual maturity. The results were as follows: extinction did not occur in any case conducted here. We did not use any information about the reproduction curve, such as MSY or MSYL, but the results suggested that there was a possibility of achieving a suitable management policy according to the true level of MSY or MSYL. However, the efficiency of renewing target level to MSYL was low.

SC/40/O 26. INVESTIGATIONS OF SOME ASPECTS OF A POTENTIAL WHALE STOCK MANAGEMENT PROCEDURE.

A.E. Punt and D.S. Butterworth, Department of Applied Mathematics, University of Cape Town, Rondebosch 7700, South Africa.

The performance of a harvesting algorithm based on fitting a population dynamics model to a time series of CPUE and fishery-independent absolute abundance estimates is investigated. The fitted model is used to set catch limits only if the parameter estimates are consistent with auxiliary information, failing which they are instead set by the Magnusson and Stefansson (1987) procedure. Inter-annual catch fluctuations are limited to 25%. A linear process error estimator, instead of a more appropriate but non–linear observation error estimator, is used in fitting the population model; the former is computationally much more efficient, and the primary objective of the study is to ascertain whether it provides an adequate basis for further simulation tests of the type specified by the Comprehensive Assessment Workshop on Management. The performance of the estimator in conjunction with the harvesting algorithm is found to be enhanced by constraining the range of acceptable estimates of the resilience parameter A, pre-smoothing the CPUE series, and testing the model estimates of initial and final abundance against the input data as a consistency criterion. Partial optimisation over the various control parameters is attempted. It is tentatively concluded that the constrained process estimator provides an adequate basis for setting catch limits for the cases where the initial population size is K, or 0.3K with CPUE data available for the previous 30 years. However, little success is achieved in moving the population towards MSYL for the case of an initial population size of 0.3K and no previous CPUE data.

SC/40/O 27. MEASURING WHALES AT SEA: A SIMPLE STEREOPHOTOGRAPHIC TECHNIQUE.

Phil Lovell, Conservation Research Group, PO Box 114, Cambridge CB4 1YJ, England, Jonathan Gordon, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, England and Lex Hiby, Sea Mammal Research Unit, c/o BAS, High Cross, Madingley Road, Cambridge, CB3 0ET, England.

A technique for determining accurate length and range measurement with ordinary cameras is presented. The method uses no specialised equipment since calibration is achieved photographically, requiring only that a single point is visible on the horizon or at similarly long range. Trials conducted with an object of known length (c. 4m) under field conditions produce length estimates with 95% confidence limits for error of + 2.8% at ranges of 25–55m. Measurements made of sperm whales around the Azores will be presented at a later date when collation with individual photo-identification data is completed.

SC/40/O 28. NORTH ATLANTIC SIGHTINGS SURVEY 1987 (NASS-87). JOINT POST-CRUISE MEETING 18 DECEMBER 1987.

This document summarises discussions of a meeting held to consider the results and practical experiences from the surveys in 1987 and to discuss coordination of further analyses of data.

SC/40/O 31. CANADA – LIST OF RESEARCH ACTIVITIES.

This document summarises research in Canada for the year prior to the 1988 Scientific Committee meeting.

SC/40/O 33. NOTES ON THE DENSITIES AND COMPOSITION OF ZOOPLANKTON AND SURFACE CHLOROPHYLL ON THE WHALING GROUNDS WEST AND SOUTH-WEST OF ICELAND IN 1986 AND 1987.

Olafur S. Astthorsson and Kristinn Gudmundsson, Marine Research Institute, Program for Whale Research, P.O. Box 1390, Reykjavík, Iceland.

One of the projects of the Marine Research Institute's four year programme of whale research for the years 1986–1989 is a study of the distribution and composition of phyto– and zooplankton on the whaling grounds. As a first step of this project one of the whaling vessels (*Hvalur* 8) was during the 1986 and 1987 seasons equipped with apparatus for the filtering of seawater and a winching system which enabled the sampling of zooplankton. This paper gives a brief account of the densities and composition of the zooplankton sampled on the whaling grounds during 1986 along with results from surface chlorophyll measurements in 1986 and 1987.

SC/40/O 34. ANALYSIS OF THE C4 GENE IN THREE SPECIES OF BALEEN WHALES, FIN (*Balaenoptera physalus*), SEI (*B. borealis*) AND MINKE (*B. acutorostrata*) USING A HUMAN cDNA PROBE.

Spilliaert, R., Palsdottir, A. and Arnason, A., Iceland Programme for Whale Research, The Genetic Division of the Blood Bank, Reykjavík, Iceland.

We have used a human cDNA probe to investigate the complement component C4 gene in three species of baleen whales: fin (*Balaenoptera physalus*), sei (*B. borealis*) and minke whales (*B. acutorostrata*). Restriction mapping of genomic DNA suggests the presence of only one gene (locus) in these species. We have used 14 restriction endonucleases to investigate the DNA of fin whales, 12 for that of sei whales and 7 for the minke whale samples. RsaI restriction enzyme gave polymorphism in fin whales and HindIII restriction enzyme showed polymorphism in sei whales, whereas no polymorphism has yet been seen in the minke whales. The study of DNA available from mother-foetus pairs from the two polymorphic species demonstrated simple allele transmission.

SC/40/O 36. A CRITICISM ON PARAMETERS OF STOCK-RECRUITMENT MODEL CURRENTLY APPLIED TO BALEEN WHALES BY THE IWC/SC. *Seiji Ohsumi, Far Seas Fisheries Research Laboratory, 7–1 Orido 5-chome, Shimizu, 424 Japan.*

The evidence from the net recruitment rate of baleen whales collected by direct monitoring of populations suggests strongly that super-compensation does occur in the stock-recruitment relationship. The Scientific Committee of the IWC has applied the Pella-Tomlinson (P-T) model currently for population assessment of various baleen whale stocks. Holt (1985) compared some stock-recruitment models, and he supported the P-T model as conservative. He also proposed that the maximum sustainable yield (MSY) of a baleen whale stock would be no more than 2% and could be substantially less. Since then, many population assessments have been conducted under an assumption that super–compensation does not occur in baleen whale populations. However, this assumption should be supported by evidence. This paper reviews the evidence which has been obtained by direct observation of several baleen whale stocks on the parameters related to the net recruitment rate to criticise the assumption of parameters in the model.

SC/40/O 37. RESULTS OF OBSERVATIONS OF DISTRIBUTION AND NUMBERS OF WHALES ON A WHALER *DOBRY* IN OCTOBER-DECEMBER 1987. *A.A. Berzin and V.L. Vladimirov, Pacific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, 690600 USSR.*

This paper presents the results of the above research cruise. Aggregations of fin whales were found in Bristol Bay and humpback whales off Kodiak Island. Gray whales were seen in the northern Sea of Japan and La Pelouse Strait (Korean-Okhotsk population). Neither bowhead or blue whales were seen. Both forms of Dall's porpoise were commonly seen.

SC/40/O 38. USE OF DNA PROBES FOR STOCK IDENTITY – PROGRESS REPORT FOR THE INTERNATIONAL WHALING COMMISSION APRIL 1988. *W. Amos, Genetics Department, University of Cambridge, Downing Street, Cambridge, England.*

In 1986 the IWC's Scientific Committee identified a need to apply new biochemical techniques to the problem of stock identity during discussions on the implications of discrepancies between 'biological' and 'management' stock boundaries, held at the Special Meeting of the Scientific Committee on Planning for a Comprehensive Assessment of Whale Stocks (SC/38/Rep 1). This requirement was formalised at the IWC meeting in Bournemouth in 1987. The studies described in this paper were carried out under the resulting IWC contract awarded to G.A. Dover. The work itself represents the preliminary stages of probe cloning and sample collection. Much of the information described contains technical information that will not be familiar to many readers. For a more detailed background to the methodologies employed and a discussion of the overall rationale the reader is directed towards Hoelzel and Dover (in press in IWC special issue 11).

SC/40/O 39. CETACEAN RESEARCH BEING CONDUCTED IN THE AZORES BY THE INTERNATIONAL FUND FOR ANIMAL WELFARE. *Jonathan Gordon, Department of Zoology, University of Cambridge, Downing Street, Cambridge, CB2 3EJ, Tom Arnbom, Department of Zoology, University of Stockholm, S-106 Stockholm, Sweden and Petra Deimer, Gesellschaft zum der Meeressaugetiere, Mohlmannweg 2, D-2000 Hamburg 55, W. Germany.*

The International Fund for Animal Welfare (IFAW) is currently conducting a program of cetacean research in the seas around the Azorean archipelago. This note is intended to be a brief report on some work in progress. The main objectives of this project can be summarised under four headings: (1) to determine the occurrence and distribution of cetaceans in the waters around the Azores archipelago and in particular to investigate the feasibility of commercial whale watching in this area; (2) to study aspects of the biology and behaviour of sperm whales, especially those relevant to the species' conservation and welfare; (3) to develop a methodology for assessing cetacean populations acoustically; (4) to continue to develop and demonstrate the effectiveness of minimally disruptive benign research techniques for studying cetaceans.

SC/40/O 40. SIMULATION TRIALS OF A WHALE STOCK MANAGEMENT PROCEDURE. *Justin G. Cooke, Dept of Biology, University of York, Heslington, York YO1 5DD, UK.*

The IWC Comprehensive Assessment Workshop on Management recommended that ideas for whale stock management procedures be subjected to a set of simulation trials as an initial screening procedure (IWC, 1987). A full specification of the trials to be conducted is given in the report of that workshop. This paper reports on the results of the simulation trials on a modification of the management procedure described in SC/A86/CA9 (Cooke, 1986).

SC/40/O 41. SOME ASPECTS OF THE USE OF SIGHTINGS AND OTHER ABUNDANCE DATA FOR THE ASSESSMENT OF WHALE STOCKS. *J.G. Cooke, Dept of Biology, University of York, Heslington, York, UK.*

Some problems of the use of population estimates obtained from sightings surveys for whale stock assessments are identified: (i) not all surveys or estimates are used, leading to selection biases in the remainder that are used; (ii) most surveys fail to cover the entire stock area or are subject to other known sources of unquantified negative bias, which places an asymmetric restriction on their utility for management purposes; (iii) many surveys are not conducted according to an explicit random design, so that a number of arbitrary choices regarding stratification, etc., are to be made at the analysis stage, leaving a considerable degree of freedom with respect to the estimates obtainable; (iv) sequences of sightings estimates for a stock over a series of years have not always been treated in a coherent manner. It is noted that other forms of abundance data, such as mark-recapture of Catch Per Unit Effort data may be subject to additional, potentially worse, problems. Some questions are identified which need to be settled if sightings estimates are to be usable for the Comprehensive Assessment and future management procedures.