Twenty-Ninth Report of the International Whaling Commission

Covering the twenty-ninth fiscal year 1977-1978.
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Cambridge
1979

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

The International Whaling Commission

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Preface

The large volume of material arising from the regular and special meetings of the Commission and Scientific Committee in 1977–78 has resulted in the publication of two volumes:

1. This volume (*Rep. int. Whal. Commn 29*) contains the materials from the 30th Annual Meeting and the Chairman's Report of the Special Meeting of the Commission in Tokyo 1977.

   A second section contains the Report of the Special Meeting of the Scientific Committee on Southern Hemisphere minke whales and associated papers (Seattle, May 1977), together with the minke whale papers from the Scientific Committee meeting in June 1978.

2. A Special Issue on Sperm Whales (*Rep. int. Whal. Commn* (Special Issue 2)) contains the Reports of the Special Meetings of the Scientific Committee on North Pacific Sperm Whale Assessments (Cronulla, December 1977) and Sperm Whale Stock Assessments (La Jolla, November–December 1978) together with the sperm whale papers from the Scientific Committee meeting in June 1978.

GREG DONOVAN
Scientific Editor

Contents

Minke Whale Section

List of Members of the Commission

Contracting Government	*Commissioner*
Argentina	Mr H. R. Basso
Australia	Mr A. G. Bollen (*Chairman*)
Brazil	Dr S. J. De Moura
Canada	Mr B. Applebaum
Denmark	Mr E. Lemche
France	Dr C. Roux
Iceland	Mr T. Asgeirsson (*Vice-Chairman*)
Japan	Mr K. Yonezawa
Mexico	Mr I. Villasenor
Netherlands	Dr P. J. H. van Bree
New Zealand	Mr J. V. Scott
Norway	Mr I. Rindal
Panama	Mr R. Decerega
South Africa	Dr B. V. de Jager
USSR	Dr I. V. Nikonorov
UK	Mr J. G. Kelsey
USA	Mr R. A. Frank

Dr R. Gambell
Secretary to the Commission
June 1978

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Chairman's Report of the Special Meeting, Tokyo, December 1977

1. DATE, PLACE AND PURPOSE

The Special Meeting was held, at the kind invitation of the Government of Japan, at the Ministry of Foreign Affairs, Tokyo on 6 and 7 December 1977.

The proceedings were conducted by the Chairman of the Commission, Mr A. G. Bollen (Australia). He reminded participants that the prime purpose of the Special Meeting was consideration of the management of North Pacific sperm whale stocks including classification, the setting of catch limits and implementation of any recommendations of the Scientific Committee arising from a special meeting of that Committee held specifically to consider the problems and review the assessment of these particular stocks. A second important item for the attention of the Special Meeting was the reconsideration by the Commission of its decision in June to prohibit the take by Alaskan Eskimos of bowhead whales from the Bering Sea stock.

2. REPRESENTATION

Commissioners and delegates attended from fifteen of the seventeen member countries, Brazil and Panama being absent. Observers were present from the Governments of:

Chile
Korea, Republic of
Peru

and the following international organisations:

Food and Agriculture Organisation of the United Nations
International Union for the Conservation of Nature and Natural Resources
African Wildlife Leadership Foundation
Fauna Preservation Society
Friends of the Earth
Friends World Committee for Consultation
Greenpeace Foundation
Innuit Circumpolar Conference
International Transport Workers Federation
Project Jonah
World Federation for the Protection of Animals
World Wildlife Fund

3. ADDRESS OF WELCOME

An address of welcome on behalf of the Japanese Government was given by Mr Imai, Vice-Minister of Agriculture, Forestry and Fishery.

He reviewed briefly the achievements made by the Commission since its establishment and noted its efforts in preserving and conserving whale resources. However, he regretted that there were continuous accusations against the whaling nations which did not give a fair appreciation of the efforts of the IWC. He realised that the aim of the present meeting was to review the provisions of the Schedule with regard to the sperm whale quota in the North Pacific, and in wishing every success to the meeting, hoped that it would arrive at a fair and proper decision based on the assessment of the Scientific Committee.

4. STATEMENTS BY COMMISSIONERS AND OBSERVERS

In order to make the most economical use of the time available Commissioners and Observers had been asked to present written rather than oral statements. These were collated and circulated during the course of the meeting.

5. ADOPTION OF AGENDA

The provisional annotated agenda, circulated sixty days in advance of the meeting in accordance with the Rules of Procedure, based upon a draft agenda distributed 100 days before the meeting, was adopted.

6. REVIEW OF TECHNICAL COMMITTEE MANDATE AND FUNCTIONS

The Technical Committee supported the important initiative contained in a paper put forward by Canada. This outlined the need to develop a truly technical role for this Committee by bringing in all the necessary expertise so that it can act as an intermediary stage between the Scientific Committee and the plenary session. The Commission agreed to establish an *ad hoc* working group to discuss this question, and to develop terms of reference for a reconstituted Technical Committee, together with appropriate rules of procedure and other relevant proposals for Commission action. Canada was asked to convene the working group, which would meet in Cambridge for two days prior to the 30th Annual Meeting and report to that meeting.

7. NORTH PACIFIC SPERM WHALE STOCKS

The Scientific Committee had carried out a detailed review and analysis of the available information at a special meeting of the Committee held in Cronulla, NSW, 21–26 November 1977. Their three recommendations were endorsed by the Technical Committee and adopted by the Commission. The decisions were that:

(1) Management of the North Pacific sperm whale stocks should be based on two Divisions divided by a line from the ice edge south along the 180° West meridian of longitude to 180° West, 50° North, then east along the 50° North parallel of latitude to 170° West, 50° North, then south along the 170° West meridian of longitude to 170° West, 40° North, then east along the 40° North parallel of latitude to 160° West, 40° North,

then south along the 160° West meridian of longitude to the equator.

(2) Stock classifications and catch limits for 1978 should be:

		Classification	Catch limits
Western Division	Male	SMS	2,987
	Female	SMS	784
Eastern Division	Male	IMS	2,118
	Female	IMS	555

The changes in the recommended catch limits since the June 1977 meeting resulted mainly from changes in the estimated current population sizes compared to the original and were not caused by any significant change in the relative population levels in the model. The increased estimated relative populations, particularly for males, were caused principally by the effect of changes in effort modifiers.

(3) In order to protect the breeding bulls during the pairing season, there should be a closed season for males over 45 ft in length south of 40° North for four months, March through June.

Recommendations 1 and 3 were adopted unanimously, and recommendation 2 by 13 votes to 1, with 1 abstention.

The Commission accepted the Scientific Committee's view that with the introduction of these management arrangements it was not necessary to consider step procedures to minimise the economic dislocation resulting from the analyses at this time, but that consideration of the principles involved should be included in the agenda of the 30th Annual Meeting. Further information, particularly on the effect of Asdic, should be made available before that review.

8. AMENDMENT TO RULES OF PROCEDURE, RULE III

The Chairman reported that Commissioners had discussed suggested amendments to Rule III governing the admission of Observers to meetings of the Commission. The matter was still under review and would be put on the agenda of the 30th Annual Meeting. In the meantime there would be no change in the Commission's policy.

9. CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES)

The Secretary reported on the special working session of the CITES held in Geneva, attended by the Chairman and Secretary on 25–28 October 1977. Cross-representation between the two conventions would be of mutual benefit, and the CITES was to offer Observer status to the IWC at meetings of the Parties. The Commission agreed that the CITES should be granted Observer status at its meetings and those of the Scientific Committee.

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

The Commissioner for Denmark extended on behalf of his Government an invitation to hold a preparatory meeting in Copenhagen next year. The Commission accepted this offer with gratitude and considered that a four day meeting, 4–7 July 1978 would be adequate. The Secretary was instructed to circulate the agreed negotiating text to IWC member nations and 10 other whaling nations.

11. BERING SEA STOCK OF BOWHEAD WHALES

Following the total ban agreed by the Commission at its 29th Annual Meeting, the USA presented a proposal for a modest take of bowheads in 1978 to satisfy the subsistence and cultural needs of the Alaskan Eskimos, together with a scientific programme and regulatory measures. The Scientific Committee had reiterated its statement that any take could adversely affect the stock and contribute to preventing its eventual recovery. The Technical Committee, after a number of votes, agreed by a majority to recommend an amendment to the Schedule and a supporting Resolution limiting the bowhead take to 18 struck whales in 1978. The proposal failed to gain the necessary three quarters majority in plenary session (6 votes for, 6 against, 3 abstentions). An amendment by the USA, seconded by Denmark, to limit the take to 15 landed whales failed when it received 5 votes for and 3 against, with 7 abstentions. The Commission then adopted, by 10 votes to 3 with 2 abstentions, the proposal by Norway seconded by the USSR which limited the take to 12 landed or 18 struck whales. The Commission also agreed to the addition of a final paragraph to the Resolution proposed by the UK and seconded by the Netherlands. The Schedule amendment is shown in Appendix 1 and the Resolution in Appendix 2.

12. ACTION RELATIVE TO NON-MEMBER WHALING NATIONS

Japan reported that it is their practice not to authorise the transfer or sale of whaling vessels and equipment to non-member whaling nations. No Japanese firms are involved in Chilean whaling operations. With respect to restrictions on imports of whale products from non-IWC nations, there are difficulties arising from other treaty obligations such as GATT, but steps are being taken to discourage such imports.

The USA put forward three Resolutions dealing with whaling operations in Chile and Peru. Amendments to take note of a statement by the Observer for Peru indicating his Government's actions to limit whaling activities, and correction of a misunderstanding were agreed, and the Commission adopted the Resolutions shown in Appendices 3, 4 and 5.

13. CONSTITUTION OF TECHNICAL COMMITTEE

All member nations present.

Chairman: Mr T. Asgeirsson (Iceland).

14. AMENDMENTS TO THE SCHEDULE

The amendments to the Schedule approved by the Commission are shown in Appendix 1.

A. G. Bollen
Chairman

Appendix 1

AMENDMENTS TO THE SCHEDULE

Paragraph 7

Add new sub-paragraph:

(d) Geographical boundaries in the North Pacific

(1) Western Division

West of a line from the ice edge south along the 180° meridian of longitude to 180°, 50° N, then east along the 50° N parallel of latitude to 170° W, 50° N, then south along the 170° W meridian of longitude to 170° W, 40° N, then east along the 40° N parallel of latitude to 160° W, 40° N, then south along the 160° W meridian of longitude to the equator.

(2) Eastern Division

East of the line described in (1).

Paragraph 11

Amend to read (new wording in bold):

Notwithstanding the provisions of paragraph 8 the taking of 10 humpback whales not below 35 feet (10.7 metres) in length, per year is permitted in Greenland waters provided that whale catchers of less than 50 gross register tonnage are used for this purpose, and the taking of gray whales, **and of bowhead whales from the Bering Sea stock,** by aborigines or a Contracting Government on behalf of aborigines is permitted, but only when the meat and products of such whales are to be used exclusively for local consumption by the aborigines **and further provided, with respect to the Bering Sea stock of bowhead whales that:**

(a) in 1978, hunting shall cease when either 18 have been struck or 12 landed.

(b) it is forbidden to strike, take or kill calves or any bowhead whale accompanied by a calf.

TABLE 2. NORTHERN HEMISPHERE

Amend to read as follows (changes in bold):

NORTHERN HEMISPHERE – **1978 season**

	Males		Females	
	Classi-fication	Catch limit	Classi-fication	Catch limit
NORTH PACIFIC				
Western Division	**SMS**	**2,987**	**SMS**	**784**
Eastern Divison	**IMS**	**2,118**	**IMS**	**555**

NORTH ATLANTIC

Total	
Classification	Catch limit
SMS	685

Paragraph 17

Add new sub-paragraph:

(c) It is forbidden to take or kill any sperm whale over 45 feet (13.7 metres) in length in the North Pacific Ocean and dependent waters south of 40° North latitude during the months of March to June inclusive.

Appendix 2

Bering Sea Bowhead Whales

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 1977 SPECIAL MEETING

WHEREAS it is the purpose of the International Whaling Commission to provide for the effective conservation and management of whale stocks,

WHEREAS at its 29th Annual Meeting, held in Canberra, Australia in June 1977, the Commission, acting upon the advice of its Scientific Committee, agreed on the establishment of a total moratorium on the hunting of bowhead whales,

WHEREAS the Commission has recognised that these stocks are seriously depleted, and that information is at present inadequate to provide any satisfactory guide to management of this population with a non-zero quota,

WHEREAS the Commission has reviewed its June 1977 decision as regards the Bering Sea bowhead stock, taking into account representations made concerning aboriginal subsistence and cultural needs, the degree of risk inherent in related proposals, and the management and research program prepared by the USA,

WHEREAS the Commission has concluded that a harvest, limited to the striking of 18 whales or the landing of 12, should be permitted from this stock for 1978, and has noted that, pursuant to undertakings by the Governments of Canada and the USSR, this harvest will be taken exclusively by persons under the jurisdiction of the Government of the United States,

BE IT HEREBY RESOLVED by the International Whaling Commission

(a) that the Commission calls upon the Government of the United States to take all necessary measures to minimise adverse effects upon the Bering Sea stock resulting from the aboriginal hunt, through controls on hunting techniques and equipment, size limits, seasons, and the kill or striking of calves, and females accompanied by calves,

(b) that the Commission welcomes the undertaking of the Government of the United States to implement management and research programs of the comprehensiveness of those tabled at the meeting of the Scientific Committee held in Australia in November of 1977, and to establish surveillance and enforcement measures for the 1978 hunt adequate to ensure that the number of whales struck does not exceed the limit established by the Commission,

(c) that the status of the Bering Sea bowhead whale stock be reviewed at the Commission's 30th Annual Meeting in June, 1978 in the light of information resulting from the proposed research program, with a view to establishing regulations based on the advice of the Scientific Committee, which should include comment on risks associated with different levels of removals from the stock,

(d) that all necessary measures be taken to ensure that the reduction in the take of bowhead whales does not affect the take of beluga whales to any significant degree,

(e) that all necessary measures be taken to preserve the habitat of bowhead and beluga whales.

Appendix 3

Bryde's Whales in the South Pacific Ocean

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 1977 SPECIAL MEETING

WHEREAS it is the purpose of the International Whaling Commission to provide for the effective conservation and management of whale stocks,

WHEREAS the Commission has classified the stock of Bryde's whales in the South Pacific Ocean as an Initial Management Stock and recommended that, until estimates of stock sizes are completed, catching effort on this stock should not be increased,

WHEREAS the Commission has noted that this stock is exploited primarily by Peru which is not a member of the Commission, and by Japan and the Union of Soviet Socialist Republics which are members of the Commission and take a certain number for scientific research as authorised by the relevant provisions of the International Convention for the Regulation of Whaling,

WHEREAS member countries have agreed to take no Bryde's whales in the South Pacific until estimates of stock sizes are completed,

BE IT HEREBY RESOLVED by the International Whaling Commission

(a) that all necessary measures should be taken to ensure that catching effort on Bryde's whales in the South Pacific does not exceed present levels; and

(b) that all Governments concerned be encouraged to provide to the Commission, concerning the Bryde's whale stocks in question, biological data and catch per unit of effort data from their whaling activities.

The Commission requests that the Chairman transmit the text of this resolution to the Government of Peru requesting with regard to the conservation of the Bryde's whale stocks of the South Pacific Ocean the development of scientific information related to these stocks, and urging them to join the Commission.

Appendix 4

Sperm Whales in the South Pacific Ocean

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 1977 SPECIAL MEETING

WHEREAS it is the purpose of the International Whaling Commission to provide for the effective conservation and management of whale stocks,

WHEREAS the Commission has adopted a regulation related to the taking of sperm whales in the South Pacific Ocean, and has declared the sperm whale stock in the area bounded by the ice edge of Antarctica and the Equator and by 100° West longitude and 60° West longitude, to be a Protection Stock, or one from which no animals may safely be taken, using information now available,

WHEREAS the Commission has noted that this stock is exploited by vessels under the jurisdiction of Chile and Peru, which are not members of the Commission,

WHEREAS the Commission has noted with appreciation the statement of the observer representing the Government of Peru at the Commission's 29th Annual Meeting, describing Peruvian whaling activities,

BE IT HEREBY RESOLVED by the International Whaling Commission that all necessary measures should be taken to ensure that no sperm whales are taken in the area of the South Pacific Ocean described above in the 1978 season.

The Commission requests that the Chairman transmit the text of this resolution to the Governments of Chile and Peru, requesting their cooperation with regard to the conservation of the sperm whale stocks of the South Pacific Ocean and the development of scientific information related to this stock, and urging them to join the Commission.

Appendix 5

Sei Whales in the South Pacific Ocean

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 1977 SPECIAL MEETING

WHEREAS it is the purpose of the International Whaling Commission to provide for the effective conservation and management of whale stocks,

WHEREAS the Commission has adopted a regulation related to the taking of sei whales in the South Pacific Ocean in the area bounded by the ice edge of Antarctica and the Equator, and by 120° West longitude and 60° West longitude, establishing a catch limit of 353 animals as the number which can be safely removed from this stock, using information now available,

WHEREAS the Commission has noted that this stock is exploited by vessels under the jurisdiction of Japan and the Union of Soviet Socialist Republics, members of the Commission, and by vessels under the jurisdiction of Chile and Peru, which are not members of the Commission.

WHEREAS the Commission has noted with appreciation the statement of the observer representing the Government of Peru at the Commission's 29th Annual Meeting, describing Peruvian whaling activities,

WHEREAS the Commission has further noted with appreciation the statement of the observer representing the Government of Peru at the Commission's Special Meeting in December 1977 describing the action taken by Peru to establish a limitation on whaling activities,

BE IT HEREBY RESOLVED by the International Whaling Commission

(a) that all necessary measures should be taken to ensure that catches of sei whales in the South Pacific Ocean in 1978 do not exceed the catch limit which has been established by the Commission, to prevent the over-exploitation of this stock; and

(b) that the Governments of Chile and Peru be encouraged to undertake appropriate research programs on South Pacific sei whales, and provide the Commission with the results of these programs.

The Commission requests that the Chairman transmit the text of this resolution to the Governments of Chile and Peru, requesting their cooperation with regard to the conservation of the sei whale stocks of the South Pacific Ocean and the development of scientific information related to these stocks and urging them to join the Commission.

International Whaling Commission Report 1977–78

This report covers the twenty-ninth Annual Meeting of the Commission, held in Canberra 20–24 June 1977, the Special Meeting held in Tokyo 6–7 December 1977, both under the Chairmanship of Mr A. G. Bollen (Australia), and developments during the year ended 31 May 1978. The Chairman's Report of the 29th Annual Meeting was published in the twenty-eighth annual report of the Commission (*Rep. int. Whal. Commn* 28: 18–37, 1978), and the report of the Special Meeting can be found on pp. 2–6 of this volume.

The catches of whales reported relate to the 1977/78 Antarctic season and the 1977 season elsewhere.

CLASSIFICATION OF STOCKS AND THEIR MANAGEMENT

At the 29th Annual Meeting the Commission decided that the present three categories which form the basis of its management policy should remain the same for the coming year. However, it did consider the questions of the adequacy of the margin of safety already recognised in the management criteria, the ecological aspects of management and the conservation and monitoring of the resource, and possible additional categories to cover stocks for which sufficient stock assessment information does not exist. These matters will be examined further at the next Annual Meeting, including the particular problems of the inter-specific effects posed by sei and minke whales.

The classification of the whale stocks adopted by the Commission for the 1977/78 Antarctic season and the 1978 seasons elsewhere is shown in Tables 1 and 2.

CATCH LIMITS

The appropriate catch limits approved by the Commission following the classification of the whale stocks are also shown in Tables 1 and 2. A 10% flexibility allowance in the Southern Hemisphere quotas by Areas and Divisions was agreed, but in no circumstances could the sum of the catches exceed the overall catch limit for each species.

SPECIAL MEETING OF THE COMMISSION

A Special Meeting of the Commission was held in Tokyo in December 1977 to reconsider the classification and catch limits for North Pacific sperm whales in 1978. This followed a review of the evidence on the state of the stocks carried out by the Scientific Committee at a meeting held in November 1977. As a result, the Commission agreed that the North Pacific should be separated into Eastern and Western management divisions, with the catch limits shown in Table 2. In addition, protection for the breeding bulls during the pairing season will be provided by a closed season for males over 45 feet in length south of 40° N from March to June.

At the 29th Annual Meeting the Commission was advised by its Scientific Committee that the Bering Sea stock of bowhead whales was in danger of extinction through increasing kills by Alaskan Eskimos. Such hunting was then totally prohibited, but the Government of the United States of America made representations concerning the subsistence and cultural needs of the Eskimos. The Commission could not accept the US proposals as they stood but agreed to a limited and strictly controlled hunt for 1978 only of 18 struck or 12 landed whales, and complete protection for calves and any accompanying whale. The whole matter will be reviewed at the 30th Annual Meeting.

SOUTHERN HEMISPHERE CATCH, 1977/78 AND 1978 SEASONS

The catches taken by IWC member nations in the 1977/78 and 1977 seasons in the Southern Hemisphere are shown in Table 3.

The distribution of the pelagic catches by geographical area is given in Table 4 for baleen whales and Table 5 for sperm whales.

NORTHERN HEMISPHERE CATCH, 1977

The catches taken by IWC member nations in the 1977 seasons in the North Atlantic and North Pacific are shown in Table 6.

INTERNATIONAL OBSERVER SCHEME

Observers nominated by member countries who are parties to agreements reached under paragraph 20(c) of the Schedule to the Convention were appointed by the Commission for the 1977/78 and 1977 seasons as follows:

Southern Hemisphere	– pelagic	3
	– coastal	1
North Pacific	– pelagic	4
	– coastal	2
North Atlantic	– coastal	1

Reports by the Observers appointed for the preceding season were examined at the 29th Annual Meeting. All Observers noted almost complete adherence to the provisions of the Schedule and punishment for infractions, and received excellent co-operation from their hosts including all necessary explanations.

Consideration was given during the year to the extension of the Observer Scheme to cover the minke whale fisheries in the North Atlantic and North Pacific, and to the introduction of programmes in Greenland and Alaska with respect to Arctic bowhead whales. Proposals resulting from these discussions will be presented to the 30th Annual Meeting.

INFRACTIONS

Contracting Governments provided reports on the infractions of the Commission's regulations for the 1977/78 Antarctic season and 1977 seasons elsewhere. These are summarised in Table 7.

Reports from the preceding season were examined at the 29th Annual Meeting. It was noted that the number of infractions as percentages of total catches had decreased compared with previous years, and very few infractions take place in the whale harvest covered by the IWC.

SCIENTIFIC COMMITTEE ACTIVITY

At its June meeting (reported in full in *Rep. int. Whal. Commn* 28, 38–92, 1978) the Scientific Committee reviewed the Commission's classification of whale stocks, including the relationship to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. It considered questions of the safety margins and ecological aspects of the present IWC management policy, and provided advice on the appropriate catch limits in accordance with this policy.

The Committee also made recommendations for the collection of biological data and specimens from each whale taken, and similar collections from small-type whaling operations. Small-type whaling was re-defined to include bottlenose, beaked, pilot and killer whales as well as minke whales. All these proposals were incorporated into the Schedule, while reporting requirements for the direct and incidental take of small cetaceans were adopted in the form of a resolution by the Commission.

Special meetings of the Scientific Committee were held in Cronulla, 21–26 November 1977, to re-assess the North Pacific sperm whale stocks and in Seattle, 17–25 May 1978, to analyse all existing data on Southern Hemisphere minke whales. The Commission also joined in the sponsorship of a Workshop on Historical Whaling Records held at the Kendall Whaling Museum, Mass., 12–16 September 1977, and which was attended by a number of members of the Scientific Committee.

SPECIAL PERMIT TO TAKE WHALES FOR SCIENTIFIC PURPOSES

The Scientific Committee can now review Special Permit applications prior to their issue by member governments. Japan forwarded such an application for a research programme for Bryde's whale stocks in the South Pacific including a catch of 120 Bryde's whales in the 1977/78 season, which was then subsequently granted. The Commission was also informed that the Government of the USSR had given permission for five Bryde's whales to be taken for scientific purposes in the Southern Hemisphere in the 1977/78 season.

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

A revised text was collated at a meeting of the Working Group held on 16 June 1977. At the 29th Annual Meeting the Commission accepted this document for distribution to countries which have stocks of cetaceans off their coasts, as a basis for convening a meeting of plenipotentiaries to elaborate a new Convention. However, at the Special Meeting held in December 1977 the Secretary was instructed to circulate the agreed negotiating text to IWC members and ten other whaling nations.

The Government of Denmark has offered to host a preparatory meeting in Copenhagen in July 1978.

ADHERENCE OF NON-MEMBER COUNTRIES TO THE CONVENTION

At the 29th Annual Meeting the Commission adopted four resolutions dealing with whale stocks exploited by non-member countries. These urged limitation of catches in line with the Commission's management procedure and the development of scientific research on the stocks, and were transmitted by the Chairman to the People's Republic of China, the Democratic People's Republic of Korea, the Republic of Korea, Spain and Portugal. Three further resolutions were adopted at the Special Meeting of the Commission addressed in similar terms to Chile and Peru, and all the countries were invited to join the Commission.

The Commission noted the statements made by their Observers indicating the willingness of the Government of Spain to co-operate and the actions taken by the Government of Peru to limit whaling activities. Subsequently the Governments of Peru and the Republic of Korea have been in contact with the Commission seeking clarification of their obligations should they decide to join the IWC.

A resolution to encourage whaling nations outside the IWC to join the Commission by preventing their whale products from being imported by IWC members was also adopted at the 29th Annual Meeting, together with a resolution prohibiting the transfer of whaling vessels, equipment and expertise from members to non-members. Reports on the implementation of these measures will be presented at the next Annual Meeting.

CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA

The Commission offered to act as an adviser to the CITES on cetaceans, and the Chairman and Secretary attended the special working session of the CITES held in Geneva, 25–28 October 1977. Because of the mutual profit resulting from co-operation between the two Conventions, cross-representation at observer level has been granted by each to the other. In addition, the IWC Secretariat is providing direct assistance to the relevant UK authority which has offered to undertake a review of cetacean species for the Appendices to the CITES.

CO-OPERATION WITH OTHER ORGANISATIONS

Observers represented the Commission at meetings of the International Council for the Exploration of the Sea, sion, October 1977, International Commission for the Conservation of Atlantic Tunas, November 1977; and International Commission for Southeast Atlantic Fisheries, November/December 1977.

Table 1

Baleen whale stock classifications and catch limits

SOUTHERN HEMISPHERE – 1977/78 pelagic season and 1978 coastal season

		Sei		Minke		Bryde's		Fin		Blue	Hump-back	Right	Gray	Bottle-nose
Area	Longitudes	Classi-fication	Catch limit	Classi-fication	Catch limit	Classi-fication	Catch limit	Classi-fication	Catch limit	Classi-fication	Classi-fication	Classi-fication	Classi-fication	Classi-fication
I	120° W– 60° W	SMS	388	–	704	IMS	0	PS	0	PS	PS	PS	PS	–
II	60° W– 0°	PS	0	–	1,150	IMS	0	PS	0	PS	PS	PS	PS	–
III	0° – 70° E	PS	0	–	1,826	IMS	0	PS	0	PS	PS	PS	PS	–
IV	70° E –130° E	SMS	460	–	963	IMS	0	PS	0	PS	PS	PS	PS	–
V	130° E –170° W	PS	0	–	930	IMS	0	PS	0	PS	PS	PS	PS	–
VI	170° W–120° W	PS	0	–	688	IMS	0	PS	0	PS	PS	PS	PS	–
Total catch not to exceed			771		5,690		0*		0	0	0	0	0	–
NORTHERN HEMISPHERE – 1978 season														
NORTH PACIFIC														
Whole Region		PS	0	–	–	IMS	524	PS	0	PS	PS	PS	PS	–
Okhotsk Sea–West Pacific Stock		–	–	SMS	400	–	–	–	–	–	–	–	–	–
Sea of Japan Stock		–	–	SMS	–	–	–	–	–	–	–	–	–	–
Remainder		–	–	IMS	0*	–	–	–	–	–	–	–	–	–
NORTH ATLANTIC														
Whole Region		–	–	–	–	–	–	–	–	PS	PS	PS	PS	PS[++]
West Greenland Stock		–	–	SMS	397***	–	–	SMS***	4	–	–	–	–	–
Newfoundland–Labrador Stock		–	–	–	–	–	–	IMS	90	–	–	–	–	–
Canadian East Coast Stock		–	–	SMS	48	–	–	–	–	–	–	–	–	–
Nova Scotia Stock		PS	0	–	–	–	–	PS	0	–	–	–	–	–
East Greenland–Iceland–Jan Mayen Stock		–	–	SMS	320	–	–	–	–	–	–	–	–	–
East Greenland–Iceland Stock		–	–	–	–	–	–	SMS	304**	–	–	–	–	–
Iceland–Denmark Strait Stock		SMS	84	–	–	–	–	–	–	–	–	–	–	–
Spain–Portugal–British Isles Stock		–	–	SMS	–	–	–	SMS[+]	–	–	–	–	–	–
Svalbard–Norway–British Isles Stock		–	–	–	1,790	–	–	–	–	–	–	–	–	–
West Norway–Faroe Islands Stock		–	–	–	–	–	–	PS	0	–	–	–	–	–
North Norway Stock		–	–	–	–	–	–	SMS***	61	–	–	–	–	–

* Pending a satisfactory estimate of stock size.
** The total catch of fin whales shall not exceed 1,524 in the six years 1977 to 1982 inclusive.
*** Provisionally listed as SMS for 1978, pending the accumulation of sufficient information for classification.
+ Provisionally listed as SMS for 1978, catches not to exceed present catch levels.
++ Provisionally listed as PS for 1978, pending the accumulation of sufficient information for classification.

HUMANE KILLING

Following discussions in the Scientific Committee on the available information it was agreed that an annotated, indexed bibliography should be prepared in Canada. This document will be submitted to the 30th Annual Meeting so that a specific programme of research can be developed based on the recommendations of the Scientific Committee. Data on whales struck but lost by native peoples and death times in all whaling operations were also collected for review at the June 1978 meeting in this context.

FINANCE

The Commission approved the statement of income and expenditure for the year ended 31 May 1977 at its 29th Annual Meeting. The audited statement appears on p. 000. It also approved the estimated budget for the financial year 1977/78, which even with a 10% contingency component contained provision for essentials only. Account was taken of revised research priorities identified by the Scientific Committee which entailed the designation of £5,000 from the Research Fund towards the supply of guns and marks. A further £3,000 was set aside for any additional costs arising from subsequent developments within the activities of the Commission.

Contributions from Contracting Governments to realise this figure were assessed by a new formula comprising a 50% flat rate component, 30% by areas of interest and 20% based on the weight of whales caught by member countries in the previous season. This approach was designed to achieve a more equitable and flexible system.

A copy of the audited account for the year appears on pages 12 and 13.

SECRETARIAT ACTIVITY

The workload on the Secretariat has continued to increase since the permanent office was set up in Cambridge in August 1976. The organisation of the Commission's activities and the implementation of its decisions has called for greater communication with Commissioners, Contracting Governments and the Scientific Committee. There has also been extensive correspondence from and with the general public. As a result, a Scientific Editor was appointed in October to deal with the preparation and publication of the 28th Report and the Special Issue on the 1974 sei and Bryde's whale meeting and an additional clerk/typist has worked part-time since July and full-time since February.

The Secretary has given a number of lectures and talks and has contributed to radio and TV programmes. He visited New Zealand for a week in November/December as a guest of government for discussions with officials and to address public meetings.

NATIONAL QUOTAS

The Commission was informed of the following arrangements for the allocation of catches made between the countries concerned for the 1977/78 Antarctic season and the 1978 seasons elsewhere:

	Sei	Bryde	Minke	Sperm Male	Sperm Female
Southern Hemisphere					
Australia	–	–	–	536	177
Brazil	–	–	690	7	17
Japan	460	–	2,400	704	226
USSR	311	–	2,600	3,291	950
North Pacific					
Japan	–	262	400	2,182	572
USSR	–	262	0	2,923	767

R. Gambell
Secretary to the Commission

Table 2

Sperm whale stock classifications and catch limits

SOUTHERN HEMISPHERE – 1977/78 pelagic season and 1978 coastal season

		Males		Females	
Divisions	Longitudes	Classification	Catch limit	Classification	Catch limit
1	60° W– 30° W	SMS	333	SMS	111
2	30° W– 20° E	IMS	889	IMS	295
3	20° E– 60° E	SMS	1,035	SMS	343
4	60° E– 90° E	IMS	623	PS	0
5	90° E–130° E	SMS	590	IMS	195
6	130° E–160° E	IMS	304	IMS	101
7	160° E–170° W	SMS	257	SMS	143
8	170° W–100° W	IMS	961	IMS	319
9	100° W– 60° W	PS	0	PS	0
Total quota not to exceed			4,538		1,370
NORTHERN HEMISPHERE					
North Pacific (as adopted in June 1977)		PS	0	SMS	763
Western Division		SMS	2,987	SMS	784
Eastern Division (as amended in December 1977)		IMS	2,118	IMS	555
			Total Classification	Total Catch limit	
North Atlantic			SMS	685	

Table 3

Catches by IWC Member Nations in the Southern Hemisphere, 1977 and 1977/78 seasons
(previous season in parentheses)

	Sei		Bryde		Minke		Sperm		No. of expeditions	No. of catchers	Oil produced (barrels)	
Australia	–	(–)	–	(–)	–	(–)	624	(995)	1 (1) shore station	3 (3)	23,123	(33,773)
Brazil	5	(3)	–	(–)	1,000	(776)	25	(9)	1 (1) shore station	2 (1)	5,355	(4,423)
Japan	254	(1,237)	114	(225)	2,400	(3,950)	296	(234)	1 (2) factory ship	10 (18)	19,494	(39,612)
USSR	311	(621)	5	(–)	2,600	(3,950)	4,241	(3,841)	2 (2) factory ship	24 (25)	182,570	(173,317)
Total	570	(1,861)	119	(225)	6,000	(8,676)	5,186	(5,079)	5 (6)	39 (47)	230,542	(251,125)

Table 4

Pelagic catches of baleen whales by Areas in the Southern Hemisphere 1977/78 season (1976/77 in parentheses)

Area	Sei	Minke	Bryde
I	311 (298)	463 (943)	0 (0)
II	0 (83)	362 (865)	0 (0)
III	0 (0)	1,801 (2,876)	5 (105)
IV	254 (383)	963 (1,600)	0 (0)
V	0 (556)	884 (1,467)	114 (120)
VI	0 (538)	527 (149)	0 (0)
Total	565 (1,858)	5,000 (7,900)	119 (225)
Av. length (ft)	49.0 (47.7)	28.3 (28.2)	

Table 5

Pelagic catches of sperm whales by Divisions in the Southern Hemisphere 1977/78 season (1976/77 in parentheses)

Division	Male	Female	Total
1	325 (296)	94 (62)	419 (358)
2	731 (785)	292 (194)	1,023 (979)
3	753 (632)	283 (183)	1,036 (815)
4	531 (590)	0 (0)	531 (590)
5	44 (47)	0 (23)	44 (70)
6	80 (213)	0 (3)	80 (216)
7	229 (0)	101 (94)	330 (94)
8	783 (745)	291 (208)	1,074 (953)
9	0 (0)	0 (0)	0 (0)
Total	3,476 (3,308)	1.061 (767)	4,537 (4,075)
Av. length (ft)	47.0 (46.0)	35.3 (34.1)	46.7 (45.2)

Table 6

Catches by IWC Member Nations in the North Atlantic and North Pacific in the 1977 seasons (1976 in parentheses)

	Fin	Sei	Bryde	Minke	Sperm	Others	No. of expeditions	No. of catchers	Oil production (barrels)
NORTH ATLANTIC									
Denmark (Greenland)	9 (6)	0 (2)	– (–)	228 (169)	– (–)	10[1] (5)[1]	aboriginal catch		– (–)
Iceland	144 (275)	132 (3)	– (–)	194 (197)	110 (111)	– (–)	1 (1) shore station	4 (4)	9,417 (13,034)
Norway	– (–)	– (–)	– (–)	1,772 (2,146)	– (–)	– (–)	small whale fishery		– (–)
Total	153 (281)	132 (5)	– (–)	2,194 (2,512)	110 (111)	10[1] (5)[1]	1 (1)	4 (4)	9,417 (13,034)
NORTH PACIFIC									
Japan	– (–)	– (–)	500 (661)	248 (360)	3,078 (3,540)	– (–)	1 (1) factory ship 4 (5) shore stations	8 (9) 7 (12)	83,639 (89,295)
USSR	– (–)	– (–)	275 (679)	– (–)	3,266 (3,671)	186[2] (163)[2]	2 (2) factory ships	24 (31)[4]	95,789 (102,142)
USA	– (–)	– (–)	– (–)	– (–)	– (–)	293 (56)[3]	aboriginal catch		
Total	– (–)	– (–)	775 (1,340)	248 (360)	6,344 (7,211)	215[2,3] (219)[2,3]	7 (8)	39 (52)[4]	179,428 (191,437)

[1] Humpback whales.
[2] Aboriginal catch of gray whales.
[3] Right whales.
[4] Some catchers used for only part of season.

Income and Expenditure Account for the Year Ended 31 May 1978

		1978		*1977*
INCOME				
Contributions		63,891		*61,952*
Interest on investments		2,221		*3,538*
Sales		4,384		*8*
Voluntary contributions to research		7,664		*10,281*
		78,160		*75,779*
EXPENDITURE				
Salaries and national insurance	31,222		*25,996*	
Pension scheme	3,282		*3,306*	
Travelling expenses	2,300		*4,753*	
Office rent, heating and maintenance	4,171		*3,513*	
Stationery	1,813		*1,066*	
Printing	8,343		*242*	
Postages	1,789		*860*	
Telephone	840		*621*	
Insurance	657		*62*	
Office furniture and equipment				
Purchases	1,794		*9,481*	
Leasing	1,179		–	
Maintenance	82		*130*	
Professional fees	1,253		*627*	
General expenses	249		*294*	
Provision against outstanding contribution	2,296		–	
Administration expenses charged by the Ministry of Agriculture, Fisheries and Food	–		*1,157*	
Meeting expenses				
28th meeting	–		*5,419*	
29th meeting	3,870		–	
30th meeting	1,407		–	
Special meetings	3,114		–	
Bergen Scientific consultation	–		*550*	
Printing annual report	14,321		–	
Research expenditure				
Whale marking	4,500		–	
Historical studies (logbook workshops)	1,356		–	
		89,838		*58,077*
EXCESS OF EXPENDITURE OVER INCOME		(11,678)		–
EXCESS OF INCOME OVER EXPENDITURE		–		*17,702*
NET TRANSFERS TO FUNDS				
Research fund	3,901		*12,281*	
Working capital fund	6,512		*3,546*	
		10,413		*15,827*
(DEFICIT) SURPLUS FOR THE YEAR		£(22,091)		*£1,875*

Balance Sheet 31 May 1978

	1978	*1977*
CURRENT ASSETS		
Cash at bank		
Current account	1,826	*2,000*
Ordinary deposit account	29,254	*26,300*
Special deposit account	5,187	*17,000*
Cash in hand	6	*24*
Outstanding contributions from members	3,621	*3,826*
Payment in advance		
Printing of 27th Annual Report	–	*10,000*
Other debtors and prepayments	7,554	*5,598*
	47,448	*64,748*
LESS		
CURRENT LIABILITIES		
Creditors	1,487	*1,314*
Bank overdraft	–	*11,882*
	1,487	*13,196*
NET ASSETS	£45,961	*£51,552*
FINANCED BY		
FUNDS (note 2)		
Working capital	20,058	*13,546*
Miscellaneous	6,087	*7,710*
Research	14,182	*10,281*
General	5,634	*20,015*
	£45,961	*£51,552*

RAY GAMBELL
Secretary, International Whaling Commission

NOTES TO THE ACCOUNTS 31 MAY 1978

1. Accounting Policies
The accounting policies adopted by the Commission in the preparation of these accounts are as set out below.

(a) 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.

(b) Annual Reports
The full cost of printing the 27th Annual Report is written off in the year and no account is taken of stocks of the report which remain unsold at the balance sheet date.

2. Funds

	Working capital	Miscellaneous	Research	General	Total
Transfers (to) from Income and Expenditure Account					
Voluntary contributions to research			7,664		7,664
Allocation for whale marking			2,000		2,000
Interest on investments	2,221				2,221
Sales	4,291		93		4,384
Research expenditure			(5,856)		(5,856)
	6,512	–	3,901	–	10,413
Transfer in accordance with Financial Regulation V(12)		(7,710)		7,710	–
Staff assessments		6,087			6,087
Deficit for the year				(22,091)	(22,091)
Balances at 1 June 1977	13,546	7,710	10,281	20,015	51,552
Balances at 31 May 1978	£20,058	6,087	14,182	5,634	£45,961

REPORT OF THE AUDITORS TO THE COMMISSION

We have examined the accounts set out above. In our opinion these accounts give a true and fair view of the state of affairs of the Commission at 31 May 1978 and of the deficit for the year ended on that date.

Leda House, Station Road, Cambridge.
27 September 1978

SPICER AND PEGLER
Chartered Accountants

Summary of Infractions

ANTARCTIC SEASON 1977/78

Species of whale	Total catch	Undersized whales		Oversized whales		Lactating whales		Other		Total infractions	
		No.	%	No.	%	No.	%	No.	%	No.	%
Bryde's	0	–	–	–	–	–	–	–	–	–	–
Fin	0	–	–	–	–	–	–	–	–	–	–
Sei	311	0	0	N/A		0	0	0	0	0	0
Minke	5,000	N/A		N/A		0	0	0	0	0	0
Sperm	4,537	5	0.11	11	0.24	18	0.40	0	0	34	0.75
Protected	0	–	–	–	–	–	–	–	–	–	–
Total	9,848	5	0.10	11	0.24	18	0.18	0	0	34	0.52

OUTSIDE ANTARCTIC 1977

Species of whale	Total catch	Undersized whales		Oversized whales		Lactating whales		Other		Total infractions	
		No.	%	No.	%	No.	%	No.	%	No.	%
Bryde's	775	12	1.55	N/A		1	0.13	0	0	13	1.68
Fin	144	3	2.08	N/A		3	2.08	0	0	6	4.16
Sei	137	0	0	N/A		1	0.73	1[1]	0.73	2	1.46
Minke	994	N/A		N/A		0	0	0	0	0	0
Sperm	7,103	16	0.22	28	0.39	12	0.17	5[2]	0.07	61	0.86
Protected	0	–	–	–	–	–	–	–	–	–	–
Total	9,153	31	0.38	28	0.39	17	0.24	6	0.06	82	1.07

[1] Lost whale.
[2] 1 lost whale.
1 female taken in excess of national quota.
3 whales remaining in sea for more than 33 hours.

Thirtieth Meeting
June 1978 – London
List of Delegates and Observers Attending

Argentina

Mr E. H. Iglesias	Commissioner
Mr J. F. Mermoz	Adviser

Australia

Mr A. G. Bollen	Commissioner
Mr E. A. Purnell-Webb	Adviser
Dr J. D. Ovington	Adviser
Mr G. R. V. Anderson	Adviser
Dr K. R. Allen	Adviser
Dr G. P. Kirkwood	Adviser
Mr J. L. Bannister	Adviser
Sir S. T. Frost	Adviser
Mr A. Struik	Adviser
Mr A. E. Caton	Adviser
Mr G. M. Reilly	Adviser
Mr J. W. Saleeba	Adviser
Mr E. D. Letts	Adviser
Mrs J. Lee	Adviser

Brazil

Dr S. J. C. de Moura	Commissioner
Mr R. Almeida	Adviser
Ms D. Flusser	Adviser

Canada

Mr M. C. Mercer	Commissioner
Dr W. R. Martin	Adviser
Dr E. D. Mitchell	Adviser
Mr J. H. Hitchcock	Adviser
Mr R. E. Hage	Adviser

Denmark

Mr E. Lemche	Commissioner
Dr F. Kapel	Adviser
Mr N. Mikkelsen	Adviser
Mr S. Alibak	Adviser

France

Dr C. Roux	Commissioner
Mr M. Marchand	Adviser

Iceland

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

Japan

Mr K. Yonezawa	Commissioner
Mr K. Komura	Adviser
Mr M. Hazumi	Adviser
Dr Y. Fukuda	Adviser
Mr T. Saito	Adviser
Mr I. Fujita	Adviser
Mr M. Tanaka	Adviser
Mr N. Yanagihara	Adviser
Mr M. Inagaki	Adviser
Mr S. Hasui	Adviser
Mr T. Noda	Adviser
Mr M. Takemoto	Adviser
Mr Y. Takase	Adviser
Dr T. Doi	Adviser
Dr S. Ohsumi	Adviser
Mr R. Suzuki	Adviser
Mr Y. Shimadzu	Adviser
Mr K. Sorimachi	Adviser
Mr K. Yamamura	Adviser
Miss S. Kimura	Adviser
Mr Y. Yoshinari	Adviser
Mr R. Kiyomiya	Adviser
Mr Y. Yamato	Adviser

Mexico

Dr A. Rozental	Commissioner
Mr I. Villasenor	Adviser
Mr P. Mercado	Adviser
Mr J. Frias	Adviser

Netherlands

Mr F. H. J. von der Assen	Commissioner
Dr P. J. H. van Bree	Adviser
Mr M. C. H. Wagemans	Adviser

New Zealand

Mr B. J. Lynch	Commissioner
Mr T. B. Caughley	Adviser
Mr M. W. Cawthorn	Adviser

Norway

Mr I. Rindal	Commissioner
Mr I. Christensen	Adviser
Dr A. Jonsgard	Adviser
Mr C. J. Rorvik	Adviser
Mr E. Aas	Adviser

Panama

Mr R. Decerega	Commissioner
Mr D. Johnson	Alternate
Mr J. P. Fortom-Gouin	Adviser
Mrs F. Perez	Adviser

South Africa

Dr D. G. Newman	Commissioner
Dr P. B. Best	Adviser
Mr D. J. Jordaan	Adviser
Mr T. F. Wheeler	Adviser

USSR

Dr I. V. Nikonorov	Commissioner
Dr V. G. Lafitsky	Adviser
Dr M. V. Ivashin	Adviser
Mr G. V. Weiner	Adviser
Mr R. G. Borodin	Adviser
Mrs L. G. Nazarova	Adviser

UK

Mr R. C. Gurd	Commissioner
Mr D. J. Garrod	Adviser
Mr J. Horwood	Adviser
Mr S. G. Brown	Adviser
Mrs C. Lockyer	Adviser
Mr A. J. B. Rudge	Adviser
Dr M. Klinowska	Adviser
Ms J. Gordon Clark	Adviser
Mr W. F. W. Hendrey	Adviser

USA

Mr R. Frank	Commissioner
Mr T. Garrett	Adviser
Mr P. McCloskey	Adviser
Mr J. Adams	Adviser
Ms J. Alvarez	Adviser
Dr W. Aron	Adviser
Ms J. Barnes	Adviser
Mr A. Brower	Adviser
Dr R. Brownell	Adviser
Dr D. G. Chapman	Adviser
Mr R. Eisenbud	Adviser
Mrs P. Fox	Adviser
Mr E. Greenberg	Adviser
Dr E. Hopson	Adviser
Dr T. Kimball	Adviser
Mr C. H. Meacham	Adviser
Ms M. McCloskey	Adviser
Dr E. Stahr	Adviser
Dr M. Tillman	Adviser
Mr J. Gilliland	Adviser
Mr S. Perles	Adviser
Mr J. Breiwick	Adviser
Miss M. Mannix	Adviser

Belgium

Mr W. M. A. de Smet	Observer

Chile

Dr J. Berguno	Observer

Republic of Korea

Mr Y. Gong	Observer
Mr C. Lee	Observer
Mr I. Choi	Observer

Peru

Dr A. San Martin	Observer
Dr A. Ramirez-Lituma	Observer
Mr J. Valdez	Observer
Dr J. E. Valdivia	Observer

Spain

Mr E. de Salas	Observer
Mr J. Serrat	Observer

Sweden

Mr U. Svensson	Observer

Convention on International Trade in Endangered Species of Wild Fauna and Flora

Mr J. Berney	Observer
Mr P. H. Sand	Observer

Food and Agriculture Organisation of the United Nations

Dr S. J. Holt	Observer

Inter-American Tropical Tuna Commission

Dr R. Allen	Observer

International Commission for South-east Atlantic Fisheries

Dr G. G. Newman	Observer

International Council for the Exploration of the Sea

Dr F. Kapel	Observer

United Nations Environment Programme

Dr S. Evteev	Observer
Ms M. Bjorklund	Observer
Miss S. Kuwabara	Observer

International Union for the Conservation of Nature and Natural Resources

Mr A. J. Mence	Observer

African Wildlife Leadership Foundation

Mrs C. Stevens	Observer

Center for Environmental Education

Mr W. J. Kardash	Observer

Fauna Preservation Society

Mr R. Fitter	Observer

Friends of the Earth

Ms C. Durrant	Observer
Mr J. W. Knight	Observer (alternate)

Greenpeace

Mr M. J. M'Gonigle	Observer

Innuit Circumpolar Conference

Mr C. Edwardsen	Observer

International Federation of Institutes for Advanced Studies

Dr J. E. Kelly	Observer

International Institute for Environment and Development

Mr R. Sandbrook	Observer
Mrs P. Birnie	Observer (alternate)

International Ocean Institute

Mr J. Barzdo	Observer
Mr T. Burke	Observer (alternate)

International Society for the Protection of Animals

Mr N. Carter	Observer
Mr T. H. Scott	Observer (alternate)

International Transport Workers' Federation

Mr H. Aso	Observer
Mr I. Englund	Observer (alternate)
Mr A. G. Selander	Observer (alternate)

International Youth Federation for Environmental Studies and Conservation

Mr J. G. Cooke	Observer
Mr B. H. Johansen	Observer (alternate)

Project Jonah

Ms I. Roberts	Observer

Sierra Club

Mr E. Dawson	Observer

Whale Centers International

Mr R. Storro-Patterson	Observer

World Federation for the Protection of Animals

Ms P. Forkan	Observer

World Wildlife Fund

Mr P. Scott	Observer
Mr J. W. Barber	Observer (alternate)

Agenda of the Thirtieth Annual Meeting

1. Address of Welcome.

2. Opening Statements
   2.1 Member Governments
   2.2 Observers from Other Countries
   2.3 Accredited International Organisations.

3. Adoption of Agenda.

4. Admission of the Press and Accredited Observers to Plenary and Technical Committee
   4.1 Proposed Amendment to Rule III of the Rules of Procedure
   (Chairman's Report of Tokyo Special Meeting, paragraph 8)
   4.2 Consideration of New Rule IV of the Rules of Procedure
   (Any changes may require amendment of the Rules of Procedure, Rule III, addition of new Rule IV and renumbering of following Rules.)

5. Arrangements for Meeting.

6. Appointment of Committees
   (Rules of Procedure, Rule XVII.)

7. Review of Technical Committee Mandate and Functions
   (Chairman's Report of Tokyo Special Meeting, paragraph 6.)
   7.1 Report of Working Group (Paper IWC/30/5)
   7.2 Action arising
   (Any changes may require amendment of the Rules of Procedure, Rule XVII.)

8. Terms of Reference for Infractions Sub-Committee
   (Any changes may require amendment of the Rules of Procedure, Rule XVII.)

9. Withdrawn.

10. New Whale Management Procedure.

11. Review of the Present Management Procedure
   (Chairman's Report of 29th Meeting, paragraph 9(i)(a))
   11.1 Report of the Scientific Committee
   11.2 Acting arising
   11.2.1 Review of criteria for management including
   (a) consideration of the adequacy of present safeguards
   (Chairman's Report of 29th Meeting, paragraph 8(a))
   (b) effects of changes in carrying capacity
   (c) alternative management strategies
   11.2.2 Review of stock categories
   (Chairman's Report of 29th Meeting, paragraph 8(b))
   11.2.3 Quotas for Initial Management Stocks of male sperm whales
   (Chairman's Report of 29th Meeting, paragraph 9(i)(a))
   11.2.4 Consideration of step procedures and other measures of minimising fluctuations in the quota including "duration of quota" and "block quota"
   (Chairman's Report of Tokyo Special Meeting, paragraph 7)
   11.2.5 Transition from 5% of Initial Management Stock rule to 90% of MSY, for Initial Management Stock approaching the Sustained Management category
   (*Rep. Int. Whal. Commn* 29, p. 64)
   (Changes in criteria, stock categories, or procedures will require amendment of the Schedule, including paragraph 8.)

12. Whale Stocks and Catch Limits, 1978/79 Southern Hemisphere Pelagic Season and 1979 Pelagic and Coastal Seasons Elsewhere
   (Chairman's Reports of the 29th Meeting, paragraphs 9 and 21(c) and Tokyo Special Meeting, paragraphs 7 and 11)
   12.1 Report of Scientific Cómmittee
   12.2 Action arising
   (Changes of catch limits, of effort limitations, of areas or subareas, or of size limits will require amendment of the Schedule including paragraphs 2, 3, 7, 9, 10, 11, 13, 14, 15, 17)
   12.2.1 Southern Hemisphere
   12.2.2 North Pacific
   12.2.3 North Atlantic
   12.2.4 Arctic.

13. Review of Subsistence/Aboriginal Whaling
   13.1 Definition of Terms
   (Any definition of terms will require amendment of the Schedule, paragraph 1)
   13.2 Report of Scientific Committee
   13.3 Action arising
   13.3.1 Bering Sea stock of bowhead whales
   (Chairman's Reports of 29th Meeting, paragraph 9(iv) and Tokyo Special Meeting, paragraph 11)
   13.3.2 Review of exemption allowing capture of 10 humpback whales in Greenland waters
   (Chairman's Report of 29th Meeting, paragraph 9(iii)(f)(2))
   13.3.3 Gray Whales including Reports by Mexico and USA on Action Taken
   (Chairman's Report of 29th Meeting, paragraph 9(ii)(d))
   (Any changes will require amendment of the Schedule, paragraph 11.)

14. Stocks of Small Cetaceans
   (Chairman's Report of 29th Meeting, paragraphs 12 and 9(iii)(e))
   14.1 Report of Scientific Committee, subcommittee on small cetaceans

14.2 Action arising
(The classification of stocks and the regulation of catches would require amendment of the Schedule including paragraphs 1, 21, 22 and 23, or additional paragraphs.)

15. International Decade of Cetacean Research
(Chairman's Report of 29th Meeting, paragraph 13)
15.1 Report by Secretary of Action Taken (Paper IWC/30/7)
15.2 Reports of Activities by Member Governments
15.3 Report by Scientific Committee
15.4 Action arising.

16. Review of Scientific Permits
(Chairman's Report of 29th Meeting, paragraph 14)
16.1 Report of Scientific Committee
16.2 Proposed Amendment to Schedule
(Such amendment would require insertion of new material in the Schedule in Section III and possibly Sections IV, V and VI.)

17. Consideration of the Ethics of Killing Cetaceans.

18. Humane Killing
(Chairman's Report of 29th Meeting, paragraph 22)
18.1 Report of Scientific Committee
18.1.1 Value of data presently being collected and the need for additional information
18.1.2 Review of Bibliography (Paper to be available as Scientific Committee Document)
18.1.3 Programme of research to be promoted by the Commission
18.2 Reports from Member Nations on Data Collected in Consistence with the IWC Resolution of 1977 (and possible Schedule changes related to reporting)
(Any changes may require amendment of the Schedule, including Section VI, Information Required)
18.3 Action arising
(Direct active involvement with research will require a specific allocation of monies to the International Whaling Commission Research Fund.)

19. International Observer Scheme
(Chairman's Report of 29th Meeting, paragraph 21)
19.1 Reports from Observers on 1977 and 1977/78 Seasons, including Reports on Systems of Remuneration and Penalties (Paper IWC/30/8)
19.2 Review of Availability of Observers' Reports, including a proposed new Rule of Procedure
(Any changes may require amendment of the Rules of Procedure, Rule XI)
19.3 Introduction of New Observer Schemes – Reports by Member Governments
19.3.1 North Pacific – minke whales
19.3.2 North Atlantic – minke whales
19.3.3 Arctic – bowhead whales
19.3.4 Southern Hemisphere Land Stations
19.3.5 Aboriginal Whaling
19.4 Action arising.

20. Infractions
(Chairman's Report of 29th Meeting, paragraph 21)
20.1 Reports from Contracting Governments (Paper IWC/30/9)
20.2 Action arising

21. Adoption of Report of the Scientific Committee (to be circulated as Paper IWC/30/4).

22. Adoption of Report of the Technical Committee (to be circulated as Paper IWC/30/6).

23. Finance and Administration
(Chairman's Report of 29th Meeting, paragraph 23)
23.1 Review of Provisional Financial Statement, 1977/78 (Paper IWC/30/10)
23.2 Consideration of Estimated Budget and Contributions from Member Governments 1978/79 (Paper IWC/30/11)
23.3 Confirmation of Secretary's Contract including consideration of pension and severance arrangements
23.4 Miscellaneous Provisions (Paper IWC/30/12)
23.4.1 The suitability of the meeting place and costs
23.4.2 Rules of debate
23.4.3 Legal advice to the Commission
23.4.4 Distribution of Commission documents
23.4.5 Publicity for IWC by member governments
23.5 Adoption of Report of Finance and Administration Committee (to be circulated as Paper IWC/30/13).

24. Date and Place of Next Meeting
(Rules of Procedure, Rule II.)

25. Amendments to the Schedule
25.1 Revision in the Light of Legal Opinion
25.2 Revision of Interpretation section
(Any changes will require amendment of the Schedule, paragraph 1)
25.3 Review of Information Required section
(Any changes will require amendment of the Schedule, paragraph 26)

26. Adherence of Non-Member Whaling and Other Countries to the Convention
(Chairman's Reports of 29th Meeting, paragraphs 17 and 19 and Tokyo Special Meeting, paragraph 12)
26.1 Report by Chairman of Action Taken
26.2 Prohibition of Importation of Whale Products from Non-Member Countries including Reports by Commissioners
26.3 Prohibition on the Transfer of Whaling Vessels and Equipment and Other Types of Assistance from IWC Member Countries to Non-Member Countries including Reports by Contracting Governments
26.4 Action arising

27. Revision of the International Convention for the Regulation of Whaling 1946
(Chairman's Reports of 29th Meeting, paragraph 16 and Tokyo Special Meeting, paragraph 10)
27.1 Report by Secretary of Action Taken
27.2 Details of Preparatory Conference to be held in Copenhagen 4–7 July 1978.

28. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
(Chairman's Reports of 29th Meeting, paragraph 18 and Tokyo Special Meeting, paragraph 9)

28.1 Report by Secretary of Action Taken
28.2 Action arising.

29. Co-operation with Other Organisations (Paper IWC/30/14)
29.1 Observer's Report on ICES
29.2 Report on IATTC
29.3 Observer's Report on ICCAT
29.4 Observer's Report on ICSEAF
29.5 Report of Meeting to renegotiate the International North Pacific Fisheries Convention
29.6 Report of Special Meeting on Antarctic Marine Living Resources.

30. 29th Annual Report (draft to be circulated as Paper IWC/30/15).

31. Election of Chairman
(Rules of Procedure, Rule VII.)

32. Any Other Business.

Chairman's Report of the Thirtieth Annual Meeting

1. DATE AND PLACE

The thirtieth Annual Meeting of the Commission was held at the Mount Royal Hotel, Marble Arch, London, 26–30 June 1978. The proceedings were conducted by the Chairman of the Commission, Mr A. G. Bollen (Australia).

2. REPRESENTATION

Commissioners and delegates attended from all seventeen member nations and Observers represented the following non-member Governments:

Belgium
Chile
Korea, Republic of
Peru
Spain
Sweden

Observers were also present from:

United Nations Environment Programme
United Nations Food and Agriculture Organisation
Convention for International Trade in Endangered Species of Wild Flora and Fauna
International Council for the Exploration of the Sea
International Commission for the Southeast Atlantic Fisheries
International Union for the Conservation of Nature and Natural Resources
Inter-American Tropical Tuna Commission
African Wildlife Leadership Foundation
Center for Environmental Education
Fauna Preservation Society
Friends of the Earth
Greenpeace Foundation
Innuit Circumpolar Conference
International Federation of Institutes for Advanced Studies
International Institute for Environment and Development
International Ocean Institute
International Society for the Protection of Animals
International Transport Workers' Federation
International Youth Federation for Environmental Studies and Conservation
Project Jonah
Sierra Club
Whale Centers International
World Federation for the Protection of Animals
World Wildlife Fund

3. ADDRESS OF WELCOME

An address of welcome was given on behalf of the Government of the United Kingdom, by the Right Honourable Edward Bishop, Minister of State of the Ministry of Agriculture, Fisheries and Food. In welcoming the delegates Mr Bishop noted that the meeting marked the first occasion on which the Commission's own Secretariat had organised the arrangements in London.

The members of the Commission had, over 30 years, made significant progress towards its objectives, most notably through the new management procedure, but it cannot be ignored that there are many states, some engaged in whaling, which are not members. The influence of the Commission must be increased if conservation is to be properly enforced world-wide.

Mr Bishop welcomed the great upsurge in public interest and concern for whales in the UK and throughout the world and hoped that the Commission's achievements and problems would become even more widely recognised, particularly in view of the challenges facing the present meeting. In closing Mr Bishop paid tribute to the work and energy of Mr Bollen during his three years as Chairman and wished him and his successor well in the years to come.

4. OPENING STATEMENTS

The Chairman thanked Mr Bishop for his welcome and kind remarks and in turn welcomed new Commissioners to the meeting. Statements were then made by the Commissioners for the USA, Canada, Japan, USSR, Argentina, South Africa, the Netherlands, Australia and New Zealand. Statements were also presented by UNEP, FAO and IUCN, the Observer from the Republic of Korea and representatives of the other International Organisations present.

5. ADOPTION OF AGENDA

Panama informed the meeting that it wished to withdraw from the agenda Item 9 containing two proposals for moratoria on whaling. Since only Panama had requested that this be placed on the agenda the Chairman accepted their right to withdraw it. With the deletion of Item 9, the amended Provisional Annotated Agenda, circulated 60 days in advance of the meeting in accordance with the Rules of Procedure, was adopted by the Commission on the proposal of Norway, seconded by Iceland.

6. ADMISSION OF PRESS AND ACCREDITED OBSERVERS TO PLENARY AND TECHNICAL COMMITTEE

The arrangements governing the admission of accredited observers to the meetings of the Commission were reviewed by the Commissioners, and it was agreed to amend the present Rule III of the Rules of Procedure to bring it into line with current practice (Appendix 1).

The Commission also agreed that at the 31st Annual Meeting all Plenary sessions will be open to the press without audio or visual recording equipment, unless the Commissioners decide by a simple majority to close a particular session. The results of this arrangement will be reviewed before the 32nd Annual Meeting of the Commission.

Because of the constraints on space there may have to be a limit on the number of press admitted, any selection required will be by arrangement between the Secretary and press representatives.

7. APPOINTMENT OF COMMITTEES

The Chairman polled the Commissioners to ascertain which member nations wished to be represented on the Scientific and Technical Committees, with the following result:

Scientific Committee
All member nations – Chairman: Dr K. R. Allen (Australia)

Technical Committee
All member nations – Chairman: Mr T. Asgeirsson (Iceland)
– Vice-Chairman: Mrs P. Fox (USA)

In accordance with Rule XVII of the Rules of Procedure, the Chairman nominated five Commissioners to the *Finance and Administration Committee:*

Australia, Japan, USSR, UK, USA – Chairman: Dr W. Aron (USA).

8. REVIEW OF TECHNICAL COMMITTEE MANDATE AND FUNCTION

The Technical Committee had received and reviewed the report of the Working Group set up to discuss the need to develop a truly technical role for this Committee and to develop terms of reference, appropriate rules of procedure and other relevant proposals for Commission action on a reconstituted Technical Committee.

The Commission adopted the proposals as amended by the Technical Committee and agreed accordingly that Paragraph 6 of Rule XVII of the Commission's Rules of Procedure should be replaced by the following mandate:

The Technical Committee shall, as directed by the Commission or the Chairman of the Commission, prepare reports and make recommendations on:

(1) Management principles, categories, criteria, and definitions, taking into account the recommendations of the Scientific Committee, as a means of helping the Commission to deal with management issues as they arise;
(2) technical and practical options for implementation of conservation measures based on Scientific Committee advice;
(3) the implementation of decisions taken by the Commission through resolutions and through Schedule provisions;
(4) Commission agenda items assigned to it;
(5) any other matters.

The Commission also accepted the revised Rules of Procedure for the Technical Committee (Appendix 2) and directed that they should be printed in the Commission's Rules of Procedure and Financial Regulations. In accordance with these Rules, the Technical Committee agreed that the Vice-Chairman of the Commission should be nominated as the Chairman of the new Technical Committee, and that the Vice-Chairman of the new Technical Committee should be Mrs P. Fox (USA).

It was suggested that the following subjects should be considered by the new Technical Committee in the coming year:

humane killing;
the new management procedure;
subsistence whaling;
the sex ratio in minke whale catches;
an expanded Observer scheme.

The Technical Committee will meet for a maximum of one week prior to the Commission's Annual Meeting.

9. TERMS OF REFERENCE FOR INFRACTIONS SUB-COMMITTEE

Although the Technical Committee made no specific recommendation on this item, the Commission noted that the Infractions sub-committee had concluded that it should appropriately consider matters and documents relating to the Observer Scheme and Infractions in so far as they involve monitoring of compliance with the Schedule and penalties for infractions thereof.

10. NEW WHALE MANAGEMENT PROCEDURE AND REVIEW OF THE PRESENT MANAGEMENT PROCEDURE

Australia had proposed the discussion of a new management procedure, based upon a paper prepared by Dr K. R. Allen. This was intended to improve upon the current scheme by overcoming identifiable weaknesses.

The Scientific Committee had reviewed the various factors involved, including the effect of environmental variability and changes in carrying capacity resulting from important interspecies interactions.

Errors in assessment of yields and of population levels arising from model structure and parameter values are generally of greater significance than stochastic environmental effects. Single species models which provide for a changing environment could be an effective approach.

The Scientific Committee believes that the time seems appropriate to develop improvements in the present management procedure. Possible subjects to be considered, including safety factors, optimum target levels and duration of quotas were summarised.

The Commission agreed that a special group of scientists should consider these matters by correspondence during the coming year, with perhaps a short meeting before the next Annual Meeting. The following membership was proposed:

Mr J. F. Mermoz (Argentina)
Dr K. R. Allen (Australia) – convenor
Dr W. G. Doubleday (Canada)
Dr Y. Fukuda (Japan)
Mr D. J. Garrod or Mr J. Horwood (UK)
Dr D. G. Chapman (USA)
Dr S. J. Holt (FAO)
The USSR may also participate.

11. WHALE STOCKS AND CATCH LIMITS

(i) Southern Hemisphere 1978/79 Pelagic Season and 1979 Coastal Season

(a) Sperm whales

The Scientific Committee had insufficient time to carry out a full analysis of the Southern Hemisphere sperm whale Divisions. In the absence of information on which to base recommendations they suggested holding a new meeting or setting interim catch limits pending further analyses. Suggested limits were calculated as:

IMS stocks of males held at the 1977/78 limits;
IMS stocks of females and SMS stocks (except Division 5 males and Division 7 males and females) at 90% of the 1977/78 limits.

It was noted that males in Division 5 and both sexes in Division 7 may need additional protection.

The Technical Committee unanimously recommended the classification by sex for each Division as indicated by the Scientific Committee on the basis of last year's assessments. It noted the Scientific Committee's suggested catch figures, and by majority votes recommended their adoption together with a figure of 75% of last year's catch limits for Division 5 males and Division 7 males and females.

The Commission agreed unanimously to the classifications, and after the defeat by 5 votes to 9, with 3 abstentions, of an amendment by Mexico, seconded by Panama for a zero catch limit for both males and females in Divisions 5 and 7, the recommended figures were adopted by 12 votes to 2, with 3 abstentions. The resulting classifications and catch limits are as follows:

	Males		Females	
Division	Classification	Catch limit	Classification	Catch limit
1	SMS	273	SMS	91
2	IMS	808	IMS	241
3	SMS	847	SMS	281
4	IMS	566	PS	0
5	SMS	402	IMS	159
6	IMS	276	IMS	83
7	SMS	176	SMS	98
8	IMS	874	IMS	261
9	PS	0	PS	0

It was also agreed on the advice of the Scientific Committee that there should be no 10% allowance between Divisions as permitted in previous years. Japan, supported by the USSR, asked that this matter should be considered further by the Scientific Committee at its next meeting.

(b) Sei whales

The Scientific Committee had reviewed catch and sightings data, and the improved analyses indicated that the stocks in Areas II, III, V and VI should remain Protection Stocks. The majority also considered that the stocks in Areas I and IV should be reclassified as Protection Stocks with zero catch limits. However, Japanese scientists considered these results premature and urged that the stocks should be classified as last year.

The Technical Committee, by a majority vote, recommended that the stocks in all Areas should be Protection Stocks with zero catch limits. Japan pointed out that the final analyses had been carried out by the Scientific Committee during the week of the Commission meeting, so that there had been no time for effective evaluation of the data or results. Since the MSY level cannot be defined, it is not possible to classify the stocks under the present management procedure. They proposed, seconded by the USSR, that no classification be made for Areas I and IV, and that catch limits be set of 140 and 200 sei whales respectively, less than half the estimated replacement yields. This amendment was defeated by 2 votes to 10, with 5 abstentions.

The Commission then adopted the classification of all Areas as Protection Stocks with zero catch limits by 14 votes to 1, with 2 abstentions.

The Commission noted that this decision makes discussion of the opening and closing dates of the Antarctic baleen whaling season irrelevant.

(c) Minke whales

Given that the Southern Hemisphere minke whale population was increasing prior to the beginning of exploitation, the Scientific Committee was not able to recommend an appropriate classification of the stocks under the present management procedure. As an interim measure it suggested that the catch limits for 1978/79 might be set at the level of the present replacement yields. However, because of the high but variable proportion of females in the catches, three possible ways of calculating an overall catch limit were put forward which would ensure that for each Area the replacement yield of females was not exceeded. Since it is not possible for the industry to regulate the catches of each sex, the Technical Committee proposed that one of the safest options should be adopted, viz.:

Area	I	II	III	IV	V	VI	Total
Catch limit	671	1,156	2,282	1,263	512	337	6,221

This was accepted by the Commission, together with a recommendation that the Commission may in future wish to consider an appropriate management strategy. This was referred to the newly structured Technical Committee for consideration.

It was also agreed at the request of Japan that the 10% allowance between Areas should continue for Southern Hemisphere minke whales.

(d) Other species

The Technical Committee received the advice of the Scientific Committee on the other species of whales and the Commission endorsed their recommendations as follows:

Right whales – PS

Argentina indicated that it is developing studies on right whales in its waters and will present the data and results to the Scientific Committee.

Blue whales – PS

The Commission asked all member countries having material that might help to clarify the taxonomic and population status of the pygmy blue whale to analyse it and publish the results. It also agreed that a systematic sightings programme should precede any exploitation of these stocks.

Humpback whales – PS

The Commission agreed that the Government of Tonga and FAO should be requested to provide statistics on the aboriginal kill of this species.

Fin whales – PS

It was agreed that a reanalysis of fin whale stocks, especially in Area VI, should be undertaken as soon as possible.

Bryde's whales – IMS

This stock remains with a zero catch limit pending a satisfactory estimate of stock size.

The Commission noted that Peru takes Bryde's whales and urges that there be no increase in catching pending further studies.

(ii) North Pacific 1979 Season

(a) Sperm whales

The Scientific Committee recommended an adjustment of the boundary between the two recognised management stocks as a conservative measure to conform better to the evidence of the biological stocks. This has the effect of moving the boundary between the Eastern and Western Divisions adopted last year 10° to the east, south of 50° N latitude, and was approved by the Commission with the proviso that it should be reviewed at the next meeting. Separate analyses of the two Divisions using improved effort data led to the following classifications and catch limits under the present management procedure:

	Western Division		Eastern Division	
	Males	Females	Males	Females
Classification	SMS	SMS	IMS	IMS
Catch limit	782	231	3,014	667

However, because of the reduced male sex ratio observed in the Western Division in recent years, it is predicted that recruitment will be reduced in the future and the female stock will continue to decline even if no catch is taken.

Japan pointed out the great changes in the estimates in the past 12 months and called for a special meeting to be held in December, which it would ask its Government to host. This should include study of the Japanese coastal fishery data which had not been incorporated at this meeting due to lack of time, together with USSR pelagic data. The Technical Committee accepted the December date by a majority vote and the Commission agreed that a special meeting of the Scientific Committee to consider both the North Pacific and Southern Hemisphere sperm whale assessments, and a special meeting of the Commission to set catch limits for the North Pacific, should be held in December.

The USSR supported this proposal and stated that it will provide the pelagic data it has. The USA offered the computer facilities of its La Jolla laboratory.

The Commission agreed the classification of stocks indicated by the Scientific Committee, on the recommendation of the Technical Committee. By a majority vote the Technical Committee had recommended zero catch limits for males and females in the Western Division, with an annotation in the Schedule:

* Catch limits for 1979 are to be set later by decision of the Commission before operations start;

and catch limits in the Eastern Division of 3,014 males and 667 females, both with an annotation:

** These catch limits may also be reviewed at the December 1978 Special Meeting of the Commission.

This proposal failed to gain the necessary three-quarters majority in the Commission to change the Schedule, receiving 6 votes in favour with 5 against and 6 abstentions. Denmark therefore proposed, seconded by Japan and Norway, that no catch limits should be set but that the Schedule should include the single asterisk annotation as above for each sex in both Divisions. This was agreed by the Commission by 11 votes to 3, with 3 abstentions.

The Commission endorsed the recommendation of the Scientific Committee through the Technical Committee that the closed season regulations should remain unchanged.

(b) Bryde's whales

The Scientific Committee agreed as a temporary measure to divide the area into two stocks separated at 160° W. The Commission accepted this division, together with the recommendation for the following stock classifications and catch limits from the Technical Committee:

	Classification	Catch limit
Western Stock	IMS	454
Eastern Stock	IMS	0*

* Pending a satisfactory estimate of stock size.

(c) Minke whales

The Commission adopted the Technical Committee's recommendations for the following classification and catch limits on the advice of the Scientific Committee:

	Classification	Catch limit
Okhotsk Sea–West Pacific Stock	SMS	400

It is recommended that an examination of the effects on efficiency resulting from the introduction of motorboats be submitted next year.

	Classification	Catch limit
Sea of Japan Stock	SMS	–

It was agreed to set no figure for the catch limit by 8 votes to 1 with 8 abstentions, with the recommendation that the total catching effort is not increased on this stock, and the Government of the Republic of Korea was urged to take appropriate steps to implement this decision until it joins the Commission.

This followed an amendment proposed by France, seconded by the USA, for a figure of 473 whales (the 15 year average catch) which received 8 votes in favour with 3 against and 6 abstentions and so failed to gain the necessary three-quarters majority for an amendment to the Schedule.

	Classification	Catch limit
Remainder	IMS	0*

* Pending a satisfactory estimate of stock size.

(d) Other species

The Commission accepted the classification of the other species as recommended by the Scientific Committee through the Technical Committee:

Right whales – PS
Blue whales – PS
Humpback whales – PS

It is recommended that systematic sightings surveys be carried out for these three species.

Fin whales – PS
Sei whales – PS

(iii) North Atlantic 1979 Season

The Commission adopted the classification and catch limits set out below as recommended by the Technical Committee from the Scientific Committee:

(a) Fin whales

	Classification	Catch limit
Nova Scotia Stock	PS	0
Newfoundland–Labrador Stock	IMS	90
West Greenland Stock	SMS	15

The combined catch limit for fin and humpback whales shall not exceed 15 whales.

It was agreed that a marking scheme should be developed to determine the stock size of humpback whales in West Greenland waters.

	Classification	Catch limit
East Greenland–Iceland Stock	SMS	304 maximum in 6 year block quota of 1,254

It was agreed that log-book data from 1974 should be examined for the development of searching effort data.

	Classification	Catch limit
North Norway Stock	SMS	61

Provisionally listed as SMS for 1979, pending the accumulation of sufficient information for classification.

West Norway–Faroe Islands Stock	PS	0
Spain–Portugal–British Isles Stock	SMS	–

Provisionally listed as SMS for 1979, catches not to exceed present catch levels.

It was agreed that the Commission should make renewed efforts to obtain catch and effort data from the catcher/factory vessel *Sierra* based in the Canary Islands.

(b) Sei whales

	Classification	Catch limit
Nova Scotia Stock	PS	0
Iceland–Denmark Strait Stock	SMS	84

It was agreed that a marking programme should be carried out on this stock as soon as possible.

Iceland described its successful effort regulation in this fishery for the past 30 years, and pointed out that because of the erratic appearance of this less preferred species on the whaling grounds, the catch limits will be progressively reduced under the present averaging procedure. It will raise the subject again next year.

(c) Bryde's whales

Classification	Catch limit
IMS	0*

* Pending a satisfactory estimate of stock size.

(d) Minke whales

	Classification	Catch limit
Canadian East Coast Stock	SMS	48
West Greenland Stock	SMS	394

Provisionally listed as SMS for 1979, pending the accumulation of sufficient information for classification.

East Greenland–Iceland–Jan Mayen Stock	SMS	320
Svalbard–Norway–British Isles Stock	SMS	1,790

It was agreed that the proportion of females in the catches, especially from the West Greenland and Svalbard–Norway–British Isles Stocks should be reduced. Norway indicated that it recognises the problem and will look into the situation, including investigation of the effect of the high take of females on the population.

(e) Sperm whales

Classification	Catch limit
SMS	685

The collection of biological material from catches at Spanish land stations is recommended.

(f) Bottlenose whales

Classification	Catch limit
PS	0

(g) Other species

Right whales – PS

The Commission recommends that non-member countries join the Commission in protecting this species completely.

Blue whales – PS
Humpback whales – PS

The Commission recommends that Spain takes steps to prohibit catches from the very depleted Eastern Atlantic Stock.

(iv) Arctic 1979 Season

Bowhead (Right) whales – PS

On the advice of the Scientific Committee, endorsed by the Technical Committee, the Commission agreed that the bowhead should continue to be classified as a Protection Stock.

(v) Minke whale size limits

The Commission accepted the view of the Scientific Committee that there are no compelling reasons for advocating any particular size limits for minke whales, since it should be possible to maintain an adequate level of recruitment through the adoption of a suitable catch limit.

12. REVIEW OF SUBSISTENCE/ABORIGINAL WHALING

(i) Bering Sea stock of bowheads

The United States of America reviewed the management and scientific programmes implemented in accordance with its commitment undertaken at the December 1977 Tokyo Special Meeting of the Commission. It put forward specific proposals for future action including a catch limit set at the aboriginal subsistence needs but which would be not more than 2% of the stock size, coupled with continued research. These were embodied in a proposed Schedule amendment and Resolution. After extensive discussion the Technical Committee agreed by a majority vote to recommend that Schedule paragraph 11, section (a) should be amended so that the 1979 Alaskan bowhead hunt should end when 24 whales have been landed, but it was unable to agree on the number which could be struck and so made no recommendation on this element.

The USSR, seconded by Denmark, amended the Technical Committee's recommendation so that the hunt should cease when 30 whales have been struck or 24 landed. The Commission voted 7 for, 5 against with 5 abstentions, so this amendment failed to gain the three-quarters majority required for a Schedule change. After the failure of an amendment by Denmark, seconded by Mexico, for 27 whales struck or 20 landed, which received 10 votes for and 4 against with 3 abstentions, and the defeat of a Canadian amendment, seconded by South Africa, for 23 struck and 18 landed, by 2 votes to 4 with 11 abstentions, the Commission adopted by 9 votes to 1, with 7 abstentions, a Norwegian proposal, seconded by Iceland, for the Schedule paragraph to read:

> 'in 1979 hunting shall cease when either 27 have been struck or 18 landed.'

Because of the many problems involved in this matter, the Commission also accepted a resolution from the Technical Committee that a Working Group of the Technical Committee examine the entire aboriginal whaling problem and develop proposals for a regime for the aboriginal bowhead hunt in Alaska and if appropriate a regime or regimes for other aboriginal hunts to be submitted to the Commission for consideration at the next Annual Meeting.

On the proposal of the Netherlands, seconded by the UK and Panama, the Commission re-affirmed the Resolution adopted at the 1977 Tokyo Special Meeting concerning habitat preservation (Chairman's Report Tokyo Special Meeting Appendix 2), and noted the research being undertaken.by Canada and the USA in this area.

Finally, at the very end of the meeting, the USA asked for 2 more bowhead whales to be added to the 1978 catch limit, to be taken during the fall hunt. The USSR, Denmark and Iceland seconded this proposal to amend the Schedule paragraph 11 to read:

> '(a) In 1978, hunting shall cease when either 20 have been struck or 14 landed.'

The Commission adopted this change by 10 votes to 1, with 6 abstentions, but because of the lack of advance information and the unusual circumstances of the proposal, agreed to seek legal advice on the validity of this decision.

(ii) Greenland humpback catch

The Scientific Committee recommended that the present exemption allowing up to 10 humpback whales to be taken in Greenland waters by aborigines be removed. They urged that fin whales should be taken instead.

After discussing the subsistence needs and practical aspects explained by Denmark, the Commission agreed to increase the fin whale catch limit for the West Greenland stock from 4 to 15, with a footnote that the combined catch limit of fin and humpback whales in West Greenland waters shall not exceed 15 whales.

The Commission also adopted a Resolution (Appendix 3) calling upon the Danish Government to attempt to substitute fin whales for humpback whales in the fishery.

(iii) Gray whales

The Commission accepted the Scientific Committee recommendation, endorsed by the Technical Committee, to classify the two stocks as:

The Commission also agreed that a footnote to the catch limit for the Eastern Stock should be added in the Schedule stating:

	Classification	Catch limit
Eastern Stock	SMS	178
Western Stock	PS	0

> 'Available to be taken by aborigines or a Contracting Government on behalf of aborigines pursuant to paragraph 11 but not for commercial purposes.'

It also requested that the Soviet aboriginal fishery should be managed to achieve a more balanced sex ratio and urged non-member nations not to kill any whales from the Western Stock.

No member nation is proposing commercial operations on gray whales and the Commission noted the joint statement by Mexico and the USA on research and conservation measures which they are developing, including complete protection for these stocks within their 200 mile coastal zones. Similar protection occurs within Canadian waters.

13. STOCKS OF SMALL CETACEANS

The Commission received the report of the Scientific Committee through the Technical Committee concerning small cetaceans and endorsed their recommendations as follows:

(1) The northern bottlenose whale *Hyperoodon ampullatus* should have continued provisional classification as a Protection Stock for the entire North Atlantic.
(2) The bottlenose whale research programme as recommended at the 1977 meeting (*Rep. int. Whal. Commn* 28: 66) should be carried out with emphasis on sightings and marking.
(3) Catch statistics on the incidental kill of small cetaceans in the international purse seine fishery by vessels of IWC member nations (Panama, Mexico, Canada and France) should again be requested. Canada reported that it has an observer programme arranged for 1978 to monitor its small catch associated with tuna fishing in the Eastern Tropical Pacific.
(4) Research by member nations into competition between small cetaceans and fishermen should be encouraged.

Reports should be sent to the Secretary of the Commission.

(5) Attention should be drawn to the Scientific Committee's recommendation on the management of small cetaceans at the 1976 meeting (*Rep. int. Whal. Commn* 27: 49, 480) that there is an urgent need for an international body to effectively manage stocks of all cetaceans not covered by the present IWC Schedule.

(6) Statistics and data (as outlined in *Rep. int. Whal. Commn* 27: 480–1) on all types of small cetacean fisheries (including direct, incidental and live capture) should be submitted to the IWC as part of the national scientific progress reports, to be reviewed by the small cetaceans sub-committee of the Scientific Committee and forwarded to the Bureau of International Whaling Statistics. The USA reminded the Commission that it had adopted a Resolution at the 29th Annual Meeting covering some of these requirements (*Rep. int. Whal. Commn* 28: 30).

14. INTERNATIONAL DECADE OF CETACEAN RESEARCH

The Commission noted the progress achieved on the 12 priority programmes identified by the Scientific Committee last year as described in the present report of that Committee.

15. REVIEW OF SCIENTIFIC PERMITS

The Scientific Committee reported on the 114 Bryde's whales taken by Japan in the Southern Hemisphere under a permit reviewed in advance by the Scientific Committee. The USSR had also taken 5 Bryde's whales in the Southern Hemisphere under special permit without prior Scientific Committee review, through a misunderstanding of when the new review procedure came into effect, before they cancelled the permit.

The USA suggested that the requirement for prior review should be written into the Schedule, but the Technical Committee agreed that this subject should be reconsidered again next year when the Secretary has obtained legal advice on such a requirement.

The Commission noted that Japan has put forward proposals for a final programme on southern Bryde's whales which were considered by the Scientific Committee. All the results of the Japanese studies will be reviewed before any further programme is developed.

The minimum data requirements for special permit catches developed by the Scientific Committee were endorsed by the Technical Committee and approved by the Commission. They appear under item 5.6 of the Scientific Committee's Report.

16. CONSIDERATION OF THE ETHICS OF KILLING CETACEANS

When this matter was discussed in the Scientific Committee some members felt they were no more qualified than any other body to comment on the general ethics of killing animals, but a sub-committee was set up to consider the subject in relation to management. Their work was limited by constraints of time, and the limited behavioural expertise and reference material available. A minority report expressed disappointment at the failure to give full consideration to the subject.

Panama explained why it believes that whaling is unethical and the Commission endorsed the recommendation of the Scientific Committee that the Secretariat continues to seek information on behavioural studies in relation to assessment and management, enquires into the possibilities of a co-sponsored meeting and encourages outside specialists to provide documents for discussion at the next Annual Meeting.

17. HUMANE KILLING

The Scientific Committee had received the extensive review of bibliography undertaken in Canada and understood that further unpublished material was available.

The Commission accepted the following recommendations endorsed by the Technical Committee:

(1) A systematic investigation and evaluation of the efficiency of present methods of killing whales is needed, in particular observations by suitably qualified veterinarians and other personnel of the rapidity of unconsciousness and death and of the nature of the injuries caused. Such observations should cover examples of at least one pelagic or coastal operation for large whales and one small-type whaling operation.

(2) Following these field observations, and depending on the nature of the conclusions reached, a report-back meeting should be held between the research personnel and the IWC representatives to decide on future action.

(3) Further research by qualified personnel into electrical, pharmacological and explosive methods should be urged on whaling nations in an effort to achieve the most humane methods of killing whales as quickly as possible.

(4) In order to compare results from different fisheries, standard criteria for unconsciousness and death should be formulated.

(5) The information requested in 1977 should continue to be collected and forwarded to the Secretary for analysis.

Canada indicated that Professor H. C. Rowsell, an experienced veterinarian familiar with marine mammals, is willing to undertake items 1, 2 and 4 this year. Iceland offered the necessary facilities for the research. The Commission agreed to allocate necessary funds from the $10,000 given by Canada to the IWC Research Fund for this programme.

In the Technical Committee the USA had proposed that a new paragraph in the 'Information Required' section of the Schedule should be added after the present paragraph 23 to require the reporting of information on the number of harpoons used to kill each whale and the number of whales struck but lost. This was adopted by the Committee for recommendation to the Commission, noting that Denmark would find it very difficult to fulfill in its small-type whaling operations.

In the Commission Denmark pointed out that last year the Scientific Committee had thought that the requirement to record the number of harpoons used to kill each whale might be counter-productive by encouraging gunners to use less harpoons and finish off the animal by other means. The USA, seconded by Iceland, therefore amended the proposal to read:

'24 (a) All whale catchers operating in conjunction with factory ships and land stations shall report the following information on each whale taken:

(1) Methods used to kill a whale, other than a harpoon, and in particular compressed air.
(2) Number of whales struck but lost.

(b) A similar record to that described in sub-paragraph (a) of this paragraph shall be maintained by 'small-type whaling' operations and by native peoples, and all the information mentioned in the said sub-paragraphs shall be entered therein as soon as available.'

The paragraph with this amendment was adopted by the Commission.

The Commission also adopted a resolution on reporting data relative to humane killing (Appendix 4).

18. INTERNATIONAL OBSERVER SCHEME AND INFRACTIONS

The Technical Committee appointed an Infractions sub-committee made up of representatives from Australia, Brazil, Japan, Japan, Iceland, USSR and USA, under the Chairmanship of Mr R. Eisenbud (USA). This sub-committee reviewed the reports from the International Observer Scheme during the previous season and the records of the infractions reported. It was noted that these reports indicated no violations of the catch limits set forth in the Schedule.

The Commission accepted the following recommendations for action:

(1) The Schedule is ambiguous concerning a 'whale taken' or 'lost whale', in that it contains prohibitions that refer to 'taking', 'killing' and 'striking', as well as the definitions in paragraph 1. It was agreed that these terms should be reviewed at the earliest opportunity by the legal group of the new Technical Committee.
(2) The International Observer at the Icelandic whaling station had suggested that it is unreasonable to require that the meat of specific fin whales taken for local consumption be separated during normal operations. He proposed that an amount of meat equal to that produced from the whales taken for local consumption should be allocated to the local market. It was agreed that the Secretary should obtain additional information from the Observer on this matter, in order to evaluate the need for such a change.
(3) The Infractions sub-committee had recommended that the Icelandic Government be urged to organise at least one inspection tour per season to the minke whaling area by the IWC Observer. The Technical Committee supported this proposal and the Commission noted that arrangements are already in hand to implement the scheme. Iceland, Norway and Canada have agreed to consider extension of the present land station Observer programme at Iceland. The International Observers could arrive in Iceland approximately one month earlier than at present so as to observe minke whale operations in North Iceland before the land station operation begins in late May.
(4) To clarify the basis for penalties imposed for infractions, the Commission agreed that Contracting Governments be requested to transmit copies of their laws and regulations, in English, to the Secretary, particularly with explanations of their systems of remuneration and penalty, pursuant to paragraph 27 [old numbering] of the Schedule.

19. FINANCE AND ADMINISTRATION

(i) Financial Statement 1977–78, Budget and Contributions from Member Governments 1978–79

In view of the near doubling of the estimated costs involved in running the Commission compared with last year, the Finance and Administration Committee reviewed in great detail the statement of receipts and payments for 1977–78 and the estimated budget for 1978–79.

The Commission accepted the Committee's conclusion that there was little or no scope for cost-saving and that future budgets would have to reflect these increased costs. New fund-raising techniques might be considered but pending these the increase would have to be met from larger contributions from Contracting Governments.

The Commission accepted the view that the three major areas of expenditure – staff, publications and the Annual Meeting – could not be reduced without impairing the functions of the Commission, and noted that a large part of the increase over the previous year's budget was due to the fact that this was the first time that the Commission had itself borne the entire cost of running its own Annual Meeting.

After very extended discussion the Commission approved, on the proposal of Australia, seconded by the USA, the 'bare-bones' budget of £132,436 and the amount of £118,000 as the sum to be contributed by member governments.

It was considered that this would provide minimum funding for at least the seven months up to the proposed Special Meeting in December 1978 when the matter would be reviewed.

The Secretary was instructed to prepare for that meeting adjusted figures and, if necessary, supplementary estimates on which further contributions by member governments would be based.

In association with the approval of the budget for 1978–79, the Commission adopted the recommendation of the Finance and Administration Committee that, in view of the rapidly increasing size of the budget, the Secretary obtain additional professional advice on budgeting procedures and the Financial Regulations.

A number of ideas for alleviating the Commission's present financial difficulties by the adoption of techniques for reducing or avoiding costs and/or increasing revenue had been developed in the Finance and Administration Committee. The Commission agreed:

(1) That in order to minimise postal and distribution costs, member nations make arrangements with the Secretary, where practicable, to distribute all correspondence from the Commission through their Embassies or High Commissions in London.
(2) That member nations consider seconding a computer expert to the staff of the Commission for periods of 2–3 years. He would work closely with the Scientific Committee during its meetings and prepare data throughout the year. This would significantly reduce the cost to the Commission of a capability considered by the Scientific Committee to be essential, whilst at the same time providing opportunities for the professional development of the seconded specialists.

In addition to the above procedures the Commission discussed ideas for other new funding sources. These included a seat fee, a surtax on the whales caught, and contributions of an amount equivalent to the fines imposed for infractions. There were expressions of support and opposition for each of these ideas and in addition a few countries felt that, despite the new method of calculating contributions agreed at the 29th Meeting, some members were bearing more than their share of the cost of running the Commission. There was a consensus that all these questions should be considered further next year.

(ii) Change of Commission's Fiscal Year

The Finance and Administration Committee had expressed concern that under the present regime the Commission was having to consider and approve a budget including a large portion which was already committed, i.e. the cost of the present meeting estimated at about £25,000. In order that the costs of each Annual Meeting would be met from funding approved at the preceding Annual Meeting the Commission agreed to change its financial year to run from 1 September to 31 August. To achieve this it was further agreed that at the proposed special meeting in December the Commission would approve a budget for a 'transition quarter' (1 June to 31 August 1979) and that the budget for the new full year commencing 1 September 1979 would be considered at the June 1979 Annual Meeting. The necessary changes to the Financial Regulations will be made at the proposed Special Meeting in December.

(iii) Confirmation of Secretary's Contract

A meeting of the Commissioners confirmed the extension of the Secretary's contract on a permanent basis following the expiry of his initial two year period of appointment. It also approved the revision of pension arrangements and the introduction of severance pay arrangements for members of the Secretariat, subject to review by the UK Government.

(iv) Miscellaneous Finance and Administration Matters

(a) Suitability of Meeting Place and Costs

In view of the very heavy expenses involved when the Commission bears the entire cost of an Annual Meeting, the Commission endorsed the recommendation of the Finance and Administration Committee that member nations should consider the possibility of hosting such meetings more frequently. In order to make this possible the Commission agreed in principle to amend Rule II of the Rules of Procedure so that Annual Meetings could be held 'in such place as the Commission may determine'.

The Commission also endorsed a further recommendation that member nations continue to host mid-year meetings of the Scientific Committee and scientific workshops.

In order to give the Secretariat the greatest scope for minimising expenditure when organising Meetings, the costs of which fall to the Commission, it was agreed that the Secretary be authorised to make appropriate arrangements using any effective room layout.

(b) Rules of Debate

It had been suggested at the 29th Annual Meeting that considerations be given to the introduction of formal Rules of Debate for the conduct of the Commission's meetings. On the recommendation of the Finance and Administration Committee the Commission agreed to adopt the procedures used by the Convention on International Trade in Endangered Species of Wild Fauna and Flora except that the Commission's present procedure of voting on several amendments to a motion in reverse order of their presentation should be maintained. The Rules of Debate as adopted by the Commission are given in Appendix 5.

(c) Legal Advice to the Commission

The Finance and Administration Committee had given some consideration to the legal advice available to the Commission on matters relating to the interpretation of international law and practice. It recommended, and the Commission agreed, that short term legal advice continue to be obtained from a legal firm in the United Kingdom as necessary.

(d) Distribution of Commission Documents

(1) Annual Reports and Special Publications

The cost of printing these publications had been identified as a major component of expenditure but it was considered that this expenditure could not be restricted without incurring an unacceptable loss of quality. The Commission agreed, therefore, that the quality should be maintained but that an attempt should be made to partially offset the cost by:

(a) limiting the free distribution to 2 copies to each Contracting Government and one to each member of the Scientific Committee, and selling all other copies at cost,
(b) eliminating the subsidy applied in 1977,
(c) member nations considering buying additional copies of the Annual Report at cost for their own use or distribution,
(d) member nations considering ways of increasing the sales of publications in their own countries.

(2) Verbatim Record and Other Meeting Documents

The Commission took note of the high cost of transcribing and distributing a written verbatim record of plenary sessions and decided that after the 30th Meeting the Secretariat should continue to produce the Verbatim Tape Recording. Each member nation will receive one free copy of the Verbatim Recording if it so desires. All other copies will be sold at a price that will recover the costs of preparation, duplication and distribution of the Recording, and the Recording will be made available to anyone who requests it at such a price.

The Finance and Administration Committee had pointed out that duplication of documents, especially for the Scientific Committee during the Annual Meeting, represented a large expenditure in supplies, equipment and staff. The Commission accepted its recommendation that to minimise these costs member nations, and members of other bodies, should provide the Secretariat with sufficient copies of scientific and other papers prepared by that Government or body for distribution to the Scientific Committee and the Commission as appropriate. The Secretariat should continue to issue guide-lines on format, page-size and time of submission for scientific and other papers submitted to the Commission.

(e) Publicity

Following suggestions made in the Finance and Administration Committee at the 29th Meeting, the Secretariat had investigated a number of ideas for publicising the Commission's work. The Commission agreed that, while publicity concerning its activities is important, increased costs should not be incurred by the Commission at this time for this purpose. Member nations should do everything they can to inform interested parties of the work of the Commission.

20. DATE AND PLACE OF NEXT ANNUAL MEETING

The Finance and Administration Committee had been unable to make a firm recommendation to the Commission since it was not known whether a member country would be able to offer to host the 31st Meeting. There were also uncertainties about the extra costs involved in holding a Technical Committee meeting after the Scientific Committee but before the Commission meeting itself. After much discussion it was decided that the date and place of the 31st Meeting would be provisionally fixed as the week commencing 25 June 1979 in London, subject to any invitations being received from member governments and to review in the light of new information on costings and venues which would be available at the Special Meeting in December.

21. AMENDMENTS TO THE SCHEDULE

(All the amendments adopted by the Commission at the 30th Annual Meeting are given in Appendix 6).

(i) Revision in the light of legal opinion

Professional advice had indicated that a complete review and revision of the Schedule from a legal standpoint would be a lengthy and costly process. The Commission therefore endorsed the Finance and Administration Committee's recommendation that a working group of lawyers from member nations be convened by the Chairman, Vice-Chairman and Secretary of the Commission to rewrite the IWC Schedule. Member nations should cover the cost of this group's work.

(ii) Revision of Interpretation section

The Scientific Committee had proposed a number of revisions to the wording of the Interpretation section of the Schedule, paragraph 1. Substantive changes were the separate identification of bowhead, right and pygmy right whales, and the recognition of the pygmy blue whale. A general change was the substitution of 'any whale known as' for 'any whale known by the name of'. The taxonomic name of the sperm whale is also updated.

The Commission adopted the amended format of paragraph 1 of the Schedule and the Secretary was instructed to carry out any editorial changes required to bring Table 1 of the Schedule into the line with the geographical distribution of the various whales now defined.

(iii) Review of Information Required section

The Scientific Committee had stressed the increasing need for sightings data to be collected, especially systematic sightings, and the use of experienced observers on research vessels.

The Commission accepted the recommendation endorsed by the Technical Committee that a standard log book recording data on the time budget of catching operations be used in future, and noted the *pro-forma* developed by the Scientific Committee. It agreed to consider the inclusion of a requirement to provide such data in the Schedule, at its next Meeting.

The Commission also agreed to the proposal by the Scientific Committee that in Schedule paragraph 26a(1) the words 'or tissue samples from one testis' be deleted, to bring the biological data to be collected into line with the current requirements of the scientists.

22. ADHERENCE OF NON-MEMBER COUNTRIES TO THE CONVENTION

Following the 29th Annual Meeting the Chairman sent copies of the relevant resolutions adopted at that meeting to non-member whaling nations, requesting their co-operation with regard to the conservation of the various whale stocks concerned.

At the present meeting the Commission welcomed statements by the Observers representing Chile, the Republic of Korea, Spain and Peru indicating that their Governments were taking the appropriate steps to adhere to the International Convention for the Regulation of Whaling, 1946. All four nations expected to become members of the Commission before the next Annual Meeting.

The Commission adopted a Resolution (Appendix 7) put forward by the USA concerning whaling by non-member nations.

Members of the Commission including Brazil, Canada, Denmark, Japan, the Netherlands, South Africa and the UK all made statements concerning their current or proposed actions in compliance with the two resolutions adopted last year dealing with the prohibition of importation of whale products from non-member countries and the prohibition of the transfer of whaling vessels and equipment and other types of assistance to non-member countries.

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

Following the decision of the 1977 Tokyo Special Meeting, the Secretary distributed copies of the agreed negotiating text adopted at the 29th Annual Meeting to the 17 IWC member nations and 10 other whaling nations.

The Commissioner for Denmark outlined the arrangements made by his Government for the Preparatory Conference to be held in Copenhagen, 4–7 July 1978. Participants from 21 countries and 5 international organisations were expected to attend.

24. CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES)

The Observer from the CITES made a statement welcoming the mutual granting of observer status agreed between the CITES and the IWC. The CITES now has 46 member states including 10 IWC members, and he appealed to those not in the CITES to join. The Second Meeting of the Conference of Contracting Parties will be held in Costa Rica, 19–30 March 1979. There is growing co-operation between the two Conventions, and the IWC is invited to be represented at the Costa Rica meeting.

25. CO-OPERATION WITH OTHER ORGANISATIONS

The Commission received reports from its Observers at meetings of the International Council for the Exploration of the Sea, Inter-American Tropical Tuna Commission, International Commission for the Conservation of Atlantic Tunas and International Commission for Southeast Atlantic Fisheries and also had reports on the meeting to renegotiate the International North Pacific Fisheries Convention and the Special Meeting on Antarctic Marine Living Resources. In connection with the proposed Antarctic Treaty the Commission agreed that the Secretary should contact the UK Government to explore ways in which co-operation can be developed between the two organisations.

The Commission was also informed that the United Nations Food and Agriculture Organisation Advisory Committee on Marine Resources Research working party on marine mammals has set up a working group on scientific aspects of management in multi-species fisheries situations to which the IWC Scientific Committee will be invited to send a representative. A similar invitation will also be extended for the working group formed to examine the scientific basis for Southern Ocean management.

26. TWENTY-NINTH ANNUAL REPORT

The draft Annual Report circulated in advance of the meeting was adopted.

27. ELECTION OF CHAIRMAN AND VICE-CHAIRMAN

Mr A. G. Bollen (Australia) retired as Chairman of the Commission at the end of the meeting, having completed his three year term of office. On the proposal of Norway, seconded by Denmark, Mr T. Asgeirsson (Iceland) was unanimously elected as Chairman.

This left the position of Vice-Chairman vacant and Brazil, seconded by Iceland, proposed Mr K. Yonezawa (Japan). He, however, declined the post because of his other commitments, and Mr M. C. Mercer (Canada) was then proposed by Denmark, seconded by the USA and elected unanimously as Vice-Chairman.

A. G. Bollen
Chairman

Appendix 1

ADMISSION OF ACCREDITED OBSERVERS TO MEETINGS

At its 30th Annual Meeting held in London, 26–30 June 1978, the Commission amended Rule III of its Rules of Procedure to read:

'(a) Any Government not a party to the Convention or any intergovernmental organisation may be represented at meetings of the Commission by an observer or observers, if such non-party government or intergovernmental organisation has previously attended any meeting of the Commission, or if it submits its request in writing to the Commission 30 days prior to the start of the meeting, or if the Commission issues an invitation to attend.

(b) Any international organisation with offices in more than three countries may be represented at meetings of the Commission by an observer, if such international organisation has previously attended any meeting of the Commission, or if it submits its request in writing to the Commission 30 days prior to the start of the meeting and the Commission issues an invitation with respect to such request.

Appendix 2

RULES OF PROCEDURE OF THE TECHNICAL COMMITTEE

Participation

Membership shall consist of those member nations that elect to be represented on the Technical Committee. Delegations shall consist of Commissioners, or their nominees, who may be accompanied by technical experts.

The Secretary of the Commission or a deputy shall be an *ex-officio* non-voting member of the Committee.

Observers may attend Committee meetings in accordance with the rules of the Commission.

Organisation

The Chairman and Vice-Chairman shall be elected for the following year by the Technical Committee at the end of each Annual Meeting. Normally the Vice-Chairman of the Commission would be the Chairman of the Technical Committee.

Sub-committees may be designated by the Committee to consider technical issues as appropriate.

The initial agenda for the next Annual Meeting and work programme for the Committee during the forthcoming year shall be developed by the Committee prior to adjournment each year. A provisional agenda shall be prepared by the Committee Chairman with the assistance of the Secretary and shall be distributed to Commissioners 30 days in advance of the Committee meeting.

Meetings

The Annual Meeting shall be held between Scientific and Commission meetings with reasonable overlap of meetings as appropriate to agenda requirements. Special meetings may be held as agreed by the Commission or the Chairman of the Commission.

Rules of conduct for observers shall conform with rules established by the Commission for meetings of all committees and plenary sessions.

Reports

Committee reports and recommendations shall, as far as possible, be developed on the basis of concensus. However, if a consensus is not achievable, the Committee shall report to the Commission the different views expressed. The Chairman or any national delegation may request a vote on any issue. Resulting recommendations to the Commission shall be based on a simple majority of those nations casting an affirmative or negative vote.

Documents on which recommendations are based should be available on demand immediately following each Committee meeting.

Technical papers produced for the Commission may be reviewed by the Committee for publication by the Commission.

Appendix 3

Capture of Humpback Whales in Greenland Waters

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 30TH ANNUAL MEETING

WHEREAS the Scientific Committee of the International Whaling Commission has recommended removal of the exemption to the protected stock status of humpback whales which provides that the taking of 10 humpback whales per year is permitted in Greenland waters;

AND WHEREAS the same Committee has noted that other than biological considerations (e.g. subsistence needs) may be taken into account by the Commission;

AND WHEREAS the same Committee has recommended that fin whales be taken instead of humpbacks in Greenland waters,

THE COMMISSION REQUESTS the Danish Government to attempt to substitute fin whales for humpback whales in meeting the provisions of the International Whaling Commission Schedule, in so far as they apply to fin and humpback whales in West Greenland waters.

Appendix 4

Reporting Data Relative to Humane Killing

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 30TH ANNUAL MEETING

WHEREAS little data on the humaneness of methods currently used to kill whales are available; and

WHEREAS the Contracting Governments of the International Whaling Commission desire whales to be killed by the most humane method possible,

BE IT HEREBY RESOLVED BY THE INTERNATIONAL WHALING COMMISSION that all whale catchers operating in conjunction with factory ships, land stations, and small-type whaling operations, and native operations taking species listed in paragraph 1 of the Schedule should report the following information on each whale taken, whenever possible:

(1) Time to death from the time struck,

(2) Information relating to the reliability of the killing device.

Appendix 5

RULES OF DEBATE

Rule 1 – Right to Speak

(1) The Chairman shall call upon speakers in the order in which they signify their desire to speak.

(2) A Commissioner or Observer may speak only if called upon by the Chairman, who may call a speaker to order if his remarks are not relevant to the subject under discussion.

(3) A speaker shall not be interrupted except on a point of order. He may, however, with the permission of the Chairman, give way during his speech to allow any other Commissioner to request elucidation on a particular point in that speech.

(4) The Chairman of a committee or working group may be accorded precedence for the purpose of explaining the conclusion arrived at by his committee or group.

Rule 2 – Submission of Motions

(1) Proposals and amendments shall normally be introduced in writing in the working language of the meeting and shall be submitted to the Secretariat which shall circulate copies to all delegations in the session. As a general rule, no proposal shall be discussed at any plenary session unless copies of it have been circulated to all delegations no later than the day preceding the plenary session. The presiding officer may, however, permit the discussion and consideration of amendments, or motions as to procedure, even though such amendments, or motions have not been circulated previously.

Rule 3 – Procedural Motions

(1) During the discussion of any matter, a Commissioner may rise to a point of order, and the point of order

shall be immediately decided by the Chairman in accordance with these rules of procedure. A Commissioner may appeal against any ruling of the Chairman. The appeal shall be immediately put to the vote and the Chairman's ruling shall stand unless a majority of the Commissioners present and voting otherwise decide. A Commissioner rising to a point of order may not speak on the substance of the matter under discussion.

(2) The following motions shall have precedence in the following order over all other proposals or motions before the Commission:

(a) to adjourn the session;
(b) to adjourn the debate on the particular subject or question under discussion;
(c) to close the debate on the particular subject or question under discussion.

Rule 4 – Arrangements for Debate

(1) The Commission may, on a proposal by the Chairman or by a Commissioner, limit the time to be allowed to each speaker and the number of times the members of a delegation may speak on any question. When the debate is subject to such limits, and a speaker has spoken for his allotted time, the Chairman shall call him to order without delay.

(2) During the course of a debate the Chairman may announce the list of speakers, and with the consent of the Commission, declare the list closed. He may, however, accord the right of reply to any Commissioner if a speech delivered after he has declared the list closed makes this desirable.

(3) During the discussion of any matter, a Commissioner may move the adjournment of the debate on the particular subject or question under discussion. In addition to the proposer of the motion, a Commissioner may speak in favour of, and two Commissioners may speak against the motion, after which the motion shall immediately be put to the vote. The Chairman may limit the time to be allowed to speakers under this rule.

(4) A Commissioner may at any time move the closure of the debate on the particular subject or question under discussion, whether or not any other Commissioner has signified the wish to speak. Permission to speak on the motion for the closure of the debate shall be accorded only to two Commissioners wishing to speak against the motion, after which the motion shall immediately be put to the vote. The Chairman may limit the time to be allowed to speakers under this rule.

Rule 5 – Procedure for Voting on Motions and Amendments

(1) A Commissioner may move that parts of a proposal or of an amendment shall be voted on separately. If objection is made to the request of such division, the motion for division shall be voted upon. Permission to speak on the motion for division shall be accorded only to two Commissioners wishing to speak in favour of and two Commissioners wishing to speak against, the motion. If the motion for division is carried, those parts of the proposal or amendments which are subsequently approved shall be put to the vote as a whole. If all operative parts of the proposal or of the amendment have been rejected, the proposal or the amendment shall be considered to have been rejected as a whole.

(2) When the amendment is moved to a proposal, the amendment shall be voted on first. When two or more amendments are moved to a proposal, the Commission shall first vote on the last amendment moved and then on the next to last, and so on until all amendments have been put to the vote. When, however, the adoption of one amendment necessarily implies the rejection of another amendment, the latter amendment shall not be put to the vote. If one or more amendments are adopted, the amended proposal shall then be voted upon. A motion is considered an amendment to a proposal if it merely adds to, deletes from or revises part of that proposal.

(3) If two or more proposals relate to the same question, the Commission shall, unless it otherwise decides, vote on the proposals in the order in which they have been submitted. The Commission may, after voting on a proposal, decide whether to vote on the next proposal.

Appendix 6

AMENDMENTS TO THE SCHEDULE

A. Substantive amendments

Paragraph 1.

Amend to read:

1. The following expressions have the meanings respectively assigned to them, that is to say:

'baleen whale' means any whale which has baleen or whale bone in the mouth, i.e. any whale other than a toothed whale.

'beaked whale' means any whale belonging to the genus *Mesoplodon*, or any whale known as Cuvier's beaked whale (*Ziphius cavirostris*), or Shepherd's beaked whale (*Tasmacetus shepherdi*).

'blue whale' (*Balaenoptera musculus*) means any whale known as blue whale, Sibbald's rorqual, or sulphur bottom, and including pygmy blue whale.

'bottlenose whale' means any whale known as Baird's beaked whale (*Berardius bairdii*), Arnoux's whale (*Berardius arnuxii*), southern bottlenose whale (*Hyperoodon planifrons*), or northern bottlenose whale (*Hyperoodon ampullatus*).

'bowhead whale' (*Balaena mysticetus*) means any whale known as bowhead, Arctic right whale, great polar whale, Greenland right whale, Greenland whale.

'Bryde's whale' (*Balaenoptera edeni, B. brydei*) means any whale known as Bryde's whale.

'dauhval' means any unclaimed dead whale found floating.

'fin whale' (*Balaenoptera physalus*) means any whale known as common finback, common rorqual, fin whale, herring whale, or true fin whale.

'gray whale' (*Eschrichtius robustus*) means any whale known as gray whale, California gray, devil fish, hard head, mussel digger, gray back, or rip sack.

'humpback whale' (*Megaptera novaeangliae*) means any whale known as bunch, humpback, humpback whale, humpbacked whale, hump whale or hunchbacked whale.

'killer whale' (*Orcinus orca*) means any whale known as killer whale or orca.

'minke whale' (*Balaenoptera acutorostrata, B. bonaerensis*) means any whale known as lesser rorqual, little piked whale, minke whale, pike-headed whale or sharp headed finner.

'pilot whale' means any whale known as long-finned pilot whale (*Globicephala melaena*) or short-finned pilot whale (*G. macrorhynchus*).

'right whale' (*Eubalaena glacialis, E. australis*) means any whale known as Atlantic right whale, Biscayan right whale, Nordkaper, North Atlantic right whale, North Cape whale, Pacific right whale, Southern right whale.

'pygmy right whale' (*Caperea marginata*) means any whale known as southern pygmy right whale, pygmy right whale.

'sei whale' (*Balaenoptera borealis*) means any whale known as sei whale, Rudolphi's rorqual, pollack whale, or coalfish whale.

'sperm whale' (*Physeter macrocephalus*) means any whale known as sperm whale, spermacet whale, cachalot or pot whale.

'toothed whale' means any whale which has teeth in the jaws.

'lost whale' means any whale that has been taken but not delivered to the factory ship or land station.

'whales taken' means whales that have been killed and either flagged or made fast to catchers.

'lactating whale' means (a) with respect to baleen whales – a female which has any milk present in a mammary gland, (b) with respect to sperm whales – a female which has milk present in a mammary gland the maximum thickness (depth) of which is 10 cm or more. This measurement shall be at the mid ventral point of the mammary gland perpendicular to the body axis, and shall be logged to the nearest centimetre: that is to say, any gland between 9.5 cm and 10.5 cm shall be logged as 10 cm. The measurement of any gland which falls on an exact 0.5 centimetre shall be logged at the next 0.5 centimetre, e.g. 10.5 cm shall be logged as 11.0 cm.

However, notwithstanding these criteria, a whale shall not be considered a lactating whale if scientific (histological or other biological) evidence a is presented to the appropriate national authority establishing that the whale could not at that point in its physical cycle have had a calf dependent on it for milk.

'small-type whaling' means catching operations using powered vessels with mounted harpoon guns hunting exclusively for minke, bottlenose, beaked, pilot or killer whales.

Paragraph 7(d).

Amend to read:

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

Sperm whale stocks

1. Western Division
West of a line from the ice edge south along the 180° meridian of longitude to 180°, 50° N, then east along the 50° N parallel of latitude to 160° W, 50° N, then south along the 160° W meridian of longitude to 160° W, 40° N, then east along the 40° N parallel of latitude to 150° W, 40° N, then south along the 150° W meridian of longitude to the equator.

2. Eastern Division
East of the line described in 1.

Bryde's whale stocks

1. Western Stock
West of the 160° W meridian of longitude

2. Eastern Stock
East of the 160° W meridian of longitude'

Paragraph 9.

Amend to read:

'The number of baleen whales taken during the open season in the Southern Hemisphere by factory ships, land stations or whale catchers attached thereto under the jurisdiction of the Contracting Governments shall not exceed 6,221 minke whales and 0 Bryde's whales (pending a satisfactory estimate of stock size), in the 1978/79 pelagic season and the 1979 coastal season. The total catches taken in any of the Areas I to VI shall not exceed the limits shown in Table 1. However, in no circumstances shall the sum of the Area catches exceed the total quotas for each species.'

Paragraph 10.

Amend to read:

'The number of baleen whales taken in the North Pacific Ocean and dependent waters in 1979 and in the North Atlantic Ocean in 1979 shall not exceed the limits shown in Table 1.'

Table 1.

Amend to read as shown.

Paragraph 11.

Amend to read:

'. . . with respect to the Bering Sea stock of bowhead whales that:

(a) in 1978, hunting shall cease when either 20 have been struck or 14 landed,
(b) in 1979, hunting shall cease when either 27 have been struck or 18 landed,
(c) it is forbidden to strike, take or kill calves or any bowhead whale accompanied by a calf.'

Table 1

Baleen whale stock classification and catch limits.

SOUTHERN HEMISPHERE – 1978/79 pelagic season and 1979 coastal season.

Area	Longitudes	Sei Classi-fication	Sei Catch limit	Minke Classi-fication	Minke Catch limit	Bryde's Classi-fication	Bryde's Catch limit	Fin Classi-fication	Fin Catch limit	Blue Classi-fication	Humpback Classi-fication	Right, Bowhead, Pygmy Right Classi-fication	Gray Classi-fication	Gray Catch limit	Bottlenose Classi-fication
I	120° W – 60° W	PS	0	–	738	IMS	0	PS	0	PS	PS	PS	–	–	–
II	60° W – 0°	PS	0	–	1,272	IMS	0	PS	0	PS	PS	PS	–	–	–
III	0° – 70° E	PS	0	–	2,510	IMS	0	PS	0	PS	PS	PS	–	–	–
IV	70° E – 130° E	PS	0	–	1,389	IMS	0	PS	0	PS	PS	PS	–	–	–
V	130° E – 170° W	PS	0	–	563	IMS	0	PS	0	PS	PS	PS	–	–	–
VI	170° W – 120° W	PS	0	–	371	IMS	0	PS	0	PS	PS	PS	–	–	–
Total catch not to exceed			0		6,221		0*		0	0	0	0	–	–	–
NORTHERN HEMISPHERE – 1979 season															
ARCTIC		–	–	–	–	–	–	–	–	–	–	PS	–	–	–
NORTH PACIFIC															
Whole region		PS	0	–	–	–	–	PS	0	PS	PS	PS	–	–	–
Okhotsk Sea–West Pacific Stock		–	–	SMS	400	–	–	–	–	–	–	–	–	–	–
Sea of Japan Stock		–	–	SMS	–	–	–	–	–	–	–	–	–	–	–
Remainder		–	–	IMS	0*	–	–	–	–	–	–	–	–	–	–
Eastern Stock		–	–	–	–	IMS	0*	–	–	–	–	–	SMS	178+++	–
Western Stock		–	–	–	–	IMS	454	–	–	–	–	–	PS	0	–
NORTH ATLANTIC															
Whole region		–	–	–	–	IMS	0*	–	–	PS	PS	PS	–	–	PS++
West Greenland Stock		–	–	SMS***	394	–	–	SMS***	15[1]	–	–	–	–	–	–
Newfoundland–Labrador Stock		–	–	–	–	–	–	IMS	90	–	–	–	–	–	–
Canadian East Coast Stock		–	–	SMS	48	–	–	–	–	–	–	–	–	–	–
Nova Scotia Stock		PS	0	–	–	–	–	PS	0	–	–	–	–	–	–
East Greenland–Iceland–Jan Mayen Stock		–	–	SMS	320	–	–	–	–	–	–	–	–	–	–
East Greenland–Iceland Stock		–	–	–	–	–	–	SMS	304**	–	–	–	–	–	–
Iceland–Denmark Strait Stock		SMS	84	–	–	–	–	–	–	–	–	–	–	–	–
Spain–Portugal–British Isles Stock		–	–	–	–	–	–	SMS+	–	–	–	–	–	–	–
Svalbard–Norway–British Isles Stock		–	–	SMS	1,790	–	–	–	–	–	–	–	–	–	–
West Norway–Faroe Islands Stock		–	–	–	–	–	–	PS	0	–	–	–	–	–	–
North Norway Stock		–	–	–	–	–	–	SMS***	61	–	–	–	–	–	–

* Pending a satisfactory estimate of stock size.
** The total catch of fin whales shall not exceed 1,524 in the six years 1977 to 1982 inclusive.
*** Provisionally listed as SMS for 1979, pending the accumulation of sufficient information for classification.
+ Provisionally listed as SMS for 1979, catches, not to exceed present catch levels.
++ Provisionally listed as PS for 1979, pending the accumulation of sufficient information for classification.
+++ Available to be taken by aborigines or a Contracting Government on behalf of aborigines pursuant to paragraph 11, but not for commercial purposes.
1 The combined catch limit of fin and humpback whales in West Greenland waters shall not exceed 15 whales.

Paragraph 14.

Amend to read:

'The number of sperm whales taken in the Southern Hemisphere in the 1978/79 pelagic season and the 1979 coastal season shall not exceed 4,222 males and 1,214 females. The total catch in any of the Divisions 1 to 9 shall not exceed the limits shown in Table 2.'

Paragraph 15.

Amend to read:

'The number of sperm whales taken in the North Pacific Ocean and dependent waters in 1979 and in the North Atlantic Ocean in 1979 shall not exceed the limits shown in Table 2.'

Table 2.

Amend to read as shown.

New paragraph to follow the present paragraph 23, all subsequent paragraphs to be renumbered.

'24(a) All whale catchers operating in conjunction with factory ships and land stations shall report the following information on each whale taken:

(1) Methods used to kill a whale, other than a harpoon, and in particular compressed air.
(2) Number of whales struck but lost.

(b) A record similar to that described in sub-paragraph (a) of this paragraph shall be maintained by vessels engaged in 'small-type whaling' operations and by native peoples taking species listed in paragraph 1, and all the information mentioned in the said sub-paragraph shall be entered therein as soon as available.'

Paragraph 26(a)(1) [old numbering, new paragraph 27(a)(1)].

Amend to read:

'both ovaries or the combined weight of both testes'.

B. Consequential changes

Paragraph 8(a).

Amend the fourth paragraph to read:

'For the 1978/79 pelagic season and the 1979 coastal season in the Southern Hemisphere and for the 1979 season in all other areas . . .'.

Paragraph 24(a) [old numbering, new paragraph 25(a)].

Amend third line to read:

'. . . of data on the number of Bryde's and minke whales taken . . .'.

[Note that the Schedule dated April 1978 contains a misprint in this line – the word 'fin' should have been deleted following the 29th Annual Meeting.]

Table 2

Sperm whale stock classifications and catch limits

		Males		Females	
Divisions	Longitudes	Classification	Catch limit	Classification	Catch limit
SOUTHERN HEMISPHERE – 1978/79 pelagic season and 1979 coastal season					
1	60° W– 30° W	SMS	273	SMS	91
2	30° W– 20° E	IMS	808	IMS	241
3	20° E– 60° E	SMS	847	SMS	281
4	60° E– 90° E	IMS	566	PS	0
5	90° E–130° E	SMS	402	IMS	159
6	130° E–160° E	IMS	276	IMS	83
7	160° E–170° W	SMS	176	SMS	98
8	170° W–100° W	IMS	874	IMS	261
9	100° W– 60° W	PS	0	PS	0
NORTHERN HEMISPHERE – 1979 season					
NORTH PACIFIC					
Western Division		SMS	–[2]	SMS	–[2]
Eastern Division		IMS	–[2]	IMS	–[2]

	Total Classification	Total Catch limit
NORTH ATLANTIC	SMS	685

[2] Catch limits for 1979 are to be set later by decision of the Commission before operations start.

Appendix 7

Non-member Whaling Countries

RESOLUTION OF THE INTERNATIONAL WHALING COMMISSION 30TH ANNUAL MEETING

WHEREAS it is the purpose of the International Whaling Commission to provide for the effective conservation and management of whale stocks worldwide,

WHEREAS the Commission welcomes the intention of the Governments of Peru and Republic of Korea to become members of the Commission by the time of the 31st Meeting of the International Whaling Commission,

WHEREAS the Commission welcomes the intention of the Government of Chile to become a member of the Commission by the end of 1978,

WHEREAS the Commission welcomes information that the Government of Spain expects to become a member of the Commission in the near future,

WHEREAS the Commission is concerned about the taking of species listed in the Annex when the catches by non member nations exceed the Commission's conservation measures,

BE IT HEREBY RESOLVED by the International Whaling Commission that the Secretary of the Commission shall:

(1) indicate to Peru, Republic of Korea, Spain and Chile that the Commission is pleased to hear that they plan to join the Commission,

(2) encourage other countries listed in the Annex to become members of the International Whaling Commission,

(3) communicate with nations listed in the Annex, to provide them with information on International Whaling Commission actions on stocks of interest to them as given in the Annex, and

(4) request catch data, biological data and any other specific information particularly needed in the case of a particular stock or requested by the International Whaling Commission with respect to a certain country.

Annex

NON-MEMBER WHALING COUNTRIES

Country	Species	Area/Division	IWC classification	IWC catch limits
Bequia	Humpback	NA	Protection Stock	0
People's Republic of China	Minke?	NP (Sea of Japan)	Sustained Management Stock	No increase in total effort
Democratic People's Republic of Korea	Minke?	NP (Sea of Japan)	Sustained Management Stock	No increase in total effort
People's Republic of China	Bryde's	NP (Western)	Initial Management Stock	454
Portugal (Azores and Madeira)	Sperm	NA	Sustained Management Stock	685
Tonga	Humpback	SH	Protection Stock	0
NATIONS EXPECTING TO BECOME MEMBERS OF IWC				
Peru	Sperm	SH (9)	Protection Stock	0
Peru	Sei	SH (1)	Protection Stock	0
Peru	Bryde's	SH 'Peruvian Stock'	Initial Management Stock	0
Republic of Korea	Bryde's	NP (Western)	Initial Management Stock	454
Republic of Korea	Minke	NP (Sea of Japan)	Sustained Management Stock	No increase in total effort
Spain	Fin	NA	Sustained Management Stock	Not to exceed present catch levels
Spain	Sperm	NA	Sustained Management Stock	685
Spain	Humpback	NA	Protection Stock	0
Chile	Sperm	SH (9)	Protection Stock	0
Chile	Sei	SH (1)	Protection Stock	0

Note: The relevant parts of this resolution shall be communicated to the appropriate authorities in relation to the *Sierra* and another factory ship believed to be taking baleen whales in the Atlantic from an operational base probably in Las Palmas, Canary Islands, but not under Spanish flag.
NA = North Atlantic; NP = North Pacific; SH = Southern Hemisphere.

Report of the Scientific Committee

The Committee met at 9.30 a.m. on 12 June 1978 and following days, at the Cambridgeshire Hotel, Bar Hill, Cambridge, under the Chairmanship of K. R. Allen.

There were present:

K. R. Allen	
G. R. V. Anderson J. L. Bannister A. E. Caton S. T. Frost G. P. Kirkwood G. W. Smith	Australia
A. Struik	
W. G. Doubleday E. D. Mitchell	Canada
F. O. Kapel	Denmark
J. Jónsson	Iceland
T. Doi Y. Fukuda S. Kimura S. Ohsumi Y. Shimadzu K. Yamamura	Japan
P. J. H. van Bree	Netherlands
M. W. Cawthorn	New Zealand
I. Christensen A. Jonsgård C. J. Rørvik	Norway
J. P. Fortom-Gouin P. Morgane G. Pilleri	Panama
P. B. Best	South Africa
R. G. Borodin M. V. Ivashin L. G. Nazarova G. V. Weiner	U.S.S.R.
S. G. Brown	
D. J. Garrod J. Harwood J. W. Horwood M. Klinowska R. M. Laws C. Lockyer	United Kingdom
J. Rudge	
E. D. Asper J. M. Breiwick R. L. Brownell D. G. Chapman W. F. Perrin M. F. Tillman	U.S.A.
S. J. Holt	FAO
M. Bjorkland S. Kuwabura	UNEP
J. R. Beddington	IUCN
J. Berney	CITES (Observer)
J. Valdivia	Peru (Observer)
J. Gordon Clark	Friends of the Earth (Observer)
P. Spong	Greenpeace (Observer)
R. Storro-Patterson	Whale Centre International (Observer)
G. P. Donovan R. Gambell	IWC

1. CHAIRMAN'S REMARKS

The Chairman welcomed the participants and expressed special pleasure that for the first time, an observer from Peru was attending a regular meeting of the Committee.

2. APPOINTMENT OF RAPPORTEURS

Duties were shared between Donovan, Cawthorn and Lockyer. Chairmen of sub-committees appointed rapporteurs for their meetings.

3. ADOPTION OF AGENDA

The Agenda adopted is shown in Annex A.

4. ARRANGEMENTS FOR THE MEETING

4.1 Establishment of sub-committees
In accordance with its Rules of Procedure, the Committee established a number of *ad hoc* sub-committees which met during the meeting. Reports arising are dealt with under the relevant Agenda items, and as Annexes:

Annex C Report of the sub-committee on sei and Bryde's whales
Annex D Report of the sub-committee on North Atlantic whales
Annex E Report of the sub-committee on sperm whales
Annex F Report of the sub-committee on minke whales
Annex G Report of the sub-committee on protected stocks
Annex H Report of the sub-committee on small cetaceans
Annex J Report of the sub-committee on humane killing techniques
Annex K Report of the sub-committee on cetacean behaviour and management
Annex L Report of the sub-committee on requirements for data on catching effort

4.2 Computer arrangements
Computer facilities were arranged at the Cambridge University Computer Centre.

5. REVIEW OF DOCUMENTS AND REPORTS

5.1–5.5
Lists of documents, progress and other reports available are appended as Annexes B1, B2 and B3.

5.6 Scientific permits
The Committee recommends the following data and measurements be obtained for each animal taken under special scientific permit (based on *J. Fish. Res. Bd Can.* 32 (7): 973–5).

Field no ....
Species .... Sex .... Length ....
Observer .... Date, time of death ....
Locality ....
....
Tooth or baleen counts: Upper l. .... r. ....
Lower l. .... r. ....
Length longest baleen plate ....
Width longest baleen plate ....
Colour of baleen ....
Number of throat or ventral grooves (count latter between flippers) ....
Snout to centre of eye ....
Snout to anterior insertion of flipper ....
Snout to centre of umbilicus ....
Snout to end of ventral grooves ....
Snout to genital slit (centre) ....
Snout to anus ....
Total length, snout to notch ....
Girth at umbilicus ....
Flipper length, anterior, insertion to tip ....
Flipper length, axilla to tip ....
Flipper width, maximum ....
Fluke width ....
Fluke depth[1] ....
Dorsal fin height ....

[1] Defined as bottom of notch to nearest point on anterior margin.

5.6.1 Permits for 1977/78
In accordance with a permit issued in 1977 to take no more than 120 Bryde's whales in the Southern Hemisphere in 1977/78, Japan took 114 Bryde's whales. A provisional report on the whales taken is given in SC/30/Doc 30.

At the 1977 meeting, the Scientific Committee adopted a new Rule of Procedure concerning the review of scientific permits (Rule F, *Rep. int. Whal. Commn* 28: 41–2). Due to misunderstanding when this Rule was to take effect, the USSR issued a permit in November 1977 to take Southern Hemisphere Bryde's whales without previously submitting the proposals to the Scientific Committee for review. When this mistake was brought to their attention, the USSR immediately cancelled the permit, although by this time 5 Bryde's whales had been taken. A preliminary report of these whales is given in SC/30/Doc 55.

5.6.2 Advance review of permits
Japan proposes to continue its investigation of Southern Hemisphere Bryde's whales in 1978/79 and a possible research programme is attached to SC/30/Doc 30. The matter was referred to the sei and Bryde's whale subcommittee and is dealt with in Annex C and Item 11.2.

5.7 Previous seasons' catches and other statistical material
Statistical data prepared at the Bureau of International Whaling Statistics under the direction of E. Vangstein were presented to the Meeting.

5.8 Progress of whale marking and whale mark recoveries. Commission's contribution to whale marking
Brown presented SC/30/Rep 7 (Annex I) which contained a summary of whale marking during 1977 and 1978; the Committee received the report. Bearing in mind the value of short term, concentrated marking programmes for age data or stock determination, the Committee proposes that a stock of marks be built up and be available for immediate use in specified projects such as IDCR programmes, etc., and proposes that the Commission provide £5,000 for this purpose.

The Committee strongly recommends that all marking of minke whales should be with 0.410 marks and not 12-bore marks.

5.9 Sighting programme. Data reports from 1977/78 season and analyses of data
Sightings data were detailed in the progress reports, and SC/30/Rep 6. Analyses of sightings data were given in SC/30/Docs 26 and 27. Data on particular species are dealt with where relevant in the reports of sub-committees.

5.10 Stock handbook
The Committee noted with appreciation the draft document prepared by Brownell on catches on marine mammals, 1966–75 giving details of catcher country, area caught, numbers caught, estimates of numbers lost and a description of the fisheries. There is a possibility that this data may be stored in computer form in the USA.

5.11 Indexed list of Scientific Committee documents
In accordance with the Committee's recommendation, the Secretariat prepared a list by meeting of papers presented to the Committee since 1960. An edge punch file card index by author and subject has been compiled.

6. RULES OF PROCEDURE

6.1 Admission of observers
The Committee discussed the possibility of granting IUCN adviser status in the same way as FAO and UNEP, as had been proposed at the Special Meeting on Minke Whales held in Seattle in May. In Rule A2 of the Rules of Procedure (*Rep. int. Whal. Commn* 28: 38–9) it is stated that "The representatives of other international organisations of similar scientific standing [to FAO and UNEP] may also be given the same status [adviser] in the Scientific Committee, subject to the agreement of the Chairman of the Committee acting according to such policy as the Commission may decide."

While the majority of the Committee re-affirmed the wording of the above Rule, some members of the Committee believed that the above Rule refers only to representatives of intergovernmental organisations and that although some members of IUCN are governments others are not and therefore felt that IUCN should not be granted adviser status. The Committee was also unable to agree on the scientific standing of IUCN although the majority of the Committee thought that IUCN was of a similar standing to FAO and UNEP. The Committee decided to seek guidance from the Commission.[1]

The Committee notes that CITES has a reciprocal arrangement with the IWC for the exchange of observers and that CITES may give the Commission advice on trade matters.

6.2 Submission of documents

It was pointed out that the Rules of Procedure as they stood allowed people with no connection with the IWC to submit papers to the Committee but did not allow observers to do the same. It was agreed to amend the fourth sentence of Rule A3 to read:

> 'An observer admitted under this Rule shall not participate in discussions but the papers and the documents of the Scientific Committee shall be made available at the same time as to members of the Committee.'

It was also agreed to insert a new Rule E5 (d). These amendments are shown in full in Annex R (pp. 103–5).

6.3 Consideration of *ad hoc* questions during Plenary Sessions

A new Rule D3 was adopted by the Committee and is shown in full on p. 104.

6.4 Completion of report prior to opening of Plenary Sessions

A new Rule E6 was adopted by the Committee and is shown in full on p. 104.

7. REPORTS FROM INTERNATIONAL AGENCIES

7.1 FAO/ACMRR Working Party on Marine Mammals

Holt reported that the FAO/ACMRR met recently in Rome and considered the report of its Working Party on Marine Mammals and the results of the Bergen consultation. It had submitted advice to the Director-General of FAO, including support of FAO's continued interests in whales and whaling and the need to co-operate with other organisations, especially IWC, UNEP and IUCN.

The ACMRR is increasingly concerned with the scientific aspects of management in multi-species fisheries situations, particularly with respect to the exploitation of the food supply of target species as well as the competition with man by predators such as the marine mammals for resources of common foods which have been reduced by inadequately managed fisheries. A working group has been set up in which the IWC Scientific Committee will be invited to be represented.

ACMRR has also joined with SCAR and SCOR in sponsoring the BIOMASS programme of research and evaluation of Southern Ocean living resources. A joint working group has been formed and will meet later this year to examine the scientific basis on Southern Ocean management and, again, the Scientific Committee will be invited and asked to designate a participant.

The Chairman expressed his appreciation of the recognition of the nature of the contribution the Committee could make, and was joined by others in agreeing that the Committee should respond positively to these invitations. The Committee would review this item at the 1979 meeting when it expected to be able to examine the proposals from FAO and UNEP for implementation of the ACMRR recommendations.

7.2 IUCN Interim Committee on Marine Mammals

Holt reported that the Interim Committee had met early in 1978. It had established two working groups: one was interdisciplinary, examining the proposal for revising the whaling convention, especially in relation to the drafting of a convention for conservation of the living resources of the southern ocean; the other to discuss multispecies modelling and problems concerning the definition of management objectives on a scientific basis. The Committee noted that IUCN intends convening a workshop on cetacean sanctuaries later this year, and that the Interim Committee will hold its second meeting at about the same time. Holt indicated that he understood that it was intended that the reports of the Interim Committee and of its working groups would be available for consideration by the Scientific Committee at its next meeting.

8. INTERNATIONAL DECADE OF CETACEAN RESEARCH – RESEARCH PROPOSALS

Last year the Scientific Committee identified 12 research programmes which should receive priority in 1977–78 (*Rep. int. Whal. Commn* 28: 40). The following information is available on these programmes:

1. Computer facilities.
   - (a) At the present meeting.
     These were arranged in conjunction with the Australian Government who paid for Dr G. P. Kirkwood to travel to Cambridge. The IWC supported him during his 4 week preparation for the meeting.
   - (b) Other.
     Work is being continued by Breiwick on storing detailed information from BIWS on computer tapes and arranging programmes to extract these data ($10,000).
2. North Pacific sperm whale age data analysis.

   This project has been undertaken by the US National Marine Fisheries Service in co-operation with the Far Seas Fisheries Research Laboratory. $25,000 has been made available for this project in 1978 and equipment has been bought and personnel are being hired. An additional $25,000 will be made available to continue the project in 1979.
3. Southern Hemisphere minke whales, marking and sightings programme.

   The Committee noted with appreciation that the Japanese government has set aside 300,000 yen for marking and sightings and that part of this is for Southern Hemisphere minke whales.
4. North Atlantic minke whale age data analysis.

   This project has been undertaken by Norway at a cost of about $15,000. Six vessels (each with one biologist) will be collecting biological material

[1] At its 30th Annual Meeting the Commission agreed to replace the word "international" by "intergovernmental" in Rule A2, and insert a new Rule A3: "Further to Paragraph 2 above, the International Union for the Conservation of Nature and Natural Resources shall have *ad hoc* adviser status in the Scientific Committee." This means that Rule A3 cited in Item 6.2 becomes A4 in the new Rules of Procedure shown on p. 103.

especially ear plugs. The material will be examined by Canadian, British and Norwegian biologists. (Norway is also making available $90,000 for an intensive markings cruise of North Atlantic minke whales.)

5. Southeast Indian Ocean sperm and other whales, marking and sightings programme.

   The Indian Ocean marking and sightings programme has not been pursued because the cost of chartering the Soviet whale catcher originally offered for this project has increased beyond the figure quoted the year before, which itself was more than could be found by prospective contributions. The Soviet scientists indicated that negotiations with the Secretary over the hire of this vessel would be re-opened. The Soviet scientists also stated that the USSR would be funding a research vessel in 1978/79 in the Southern Hemisphere, probably in the Indian Ocean.

6. Southern Hemisphere Bryde's whales, collection of biological data, marking and sightings programme.

   A scientific permit programme has been carried out by Japan (SC/30/Doc 30).

7. North Atlantic sei whales (Iceland–Denmark Strait Stock), marking and sightings programme.

8. North Atlantic bottlenose whales, collection of biological data, marking and sightings programme.

   Although neither of the North Atlantic programmes has been undertaken to date because of lack of funding, a contribution of $5,000 Can. from the Government of Canada has been received which could be used in the North Atlantic area.

   The American scientists indicated that it is expected that the USA will make available $25,000 for high priority North Atlantic projects.

   The Commission has purchased two 12-bore marking guns and a supply of standard, increased charge and 0.410 whale marks in the expectation that some whale marking projects will be undertaken in the near future. These supplies are in addition to the regular order of marks provided under the international whale marking scheme.

9. North Atlantic sperm whales, collection and analysis of biological material.

   Biological collections are being carried out by an independent worker.

10. North Atlantic fin whales, analysis of present collections and future collections and analysis.

    Icelandic/British collections are being analysed by the Sea Mammal Research Unit (UK) and further collections are being arranged by these national authorities.

11. North Atlantic sperm whales, analysis of Icelandic biological material (especially age data).

    Analysis is being carried out by the Sea Mammal Research Unit.

12. North Pacific gray whales, expansion of sightings research, possible marking.

    The USA are funding a comparative aerial–ground survey of gray whales in San Ignacio Lagoon, Baja, California (SC/30/Prog Rep 11).

Apart from these programmes, the IWC made £1,356 available to cosponsor the International Workshop on Historical Whaling Records (convenor M. F. Tillman) with NOAA, the US Marine Mammal Commission and the Kendall Whaling Museum (who hosted the workshop), in September 1977 (SC/30/Rep 1). Three projects arose out of this meeting: an analysis of bowhead logbooks by J. R. Bockstoce ($10,000); a world census of logbooks by S. C. Sherman ($6,000) (both sponsored by the USA); pilot extraction of data from logbooks by J. L. Bannister ($14,000) (sponsored by the People's Trust for Endangered Species).

The IWC is also providing £1,000 to cosponsor the International Workshop Conference on Age Determination of Odontocetes along with £2,937 donated by Australia to the Research Fund. The other sponsors are the US Marine Mammal Commission and the US NMFS. The meeting will be held at the NMFS Southwest Fisheries Center, La Jolla, California, 5–19 September 1978.

9. CLASSIFICATION OF WHALE STOCKS AND DETERMINATION OF QUOTAS – GENERAL PRINCIPLES

9.1 Effects of environmental variability

SC/30/Docs 7, 18 and 25 were available to the Committee on this subject. All of the papers examined the time taken to reach protection status as a measure of the risks of environmental variability. It was agreed that the frequency distributions of the values of this time meant that the mean time was a poor measure of the risks involved and that the probability of reaching protection after a certain number of years was a more appropriate measure. Kirkwood stressed that under the current management strategy the quotas are reduced if a decline in stocks is observed and that any assumption of a constant catch *ad infinitum* was unrealistic. Thus the important question is whether a population may be reduced to the protection level before the decline is observed. It was noted that a period of 10 years may be necessary to make such an observation and therefore that the probability of a stock reaching protection within 10 years is a good measure of risk.

An important difference in the assumptions behind the three analyses was that although all three included variability in recruitment rates which was probably an overestimation of the likely range, only SC/30/Doc 18 incorporated variable mortality rates. The result showed that variability in adult mortality rate would have a much greater effect on population survival than a similar degree of variability in recruitment rate. Doubleday suggested that one possibility of obtaining upper estimates for variability in adult mortality would be examining the time taken to extinction in an unexploited stock model. Best thought that variation in the mortality of mature animals would be reflected in recruitment. Some members of the Committee thought that age distribution data available from fin, sei and sperm whales suggested that variation in natural mortality rates was small, although the method by which the age distributions are obtained may affect the degree of variability.

9.2 Effects of changes in carrying capacity

The Committee reviewed the problem of the use of single species models in situations where important interspecies interactions occur. It recognised that this was raised in a particularly acute form by the New Management Procedure and hoped that this might be resolved by any revision of this procedure. The Committee did not believe that these problems could be dealt with at present by complex multi-species models. It considered, however, that an effective approach could be made using single species models which provided for a changing environment.

9.3 Provision for errors of estimation

The Committee discussed this problem in the light of SC/30/Doc 8 and it was generally agreed that the errors in assessment of yields and of population levels arising from model structure and parameter values are of greater significance than stochastic environmental effects for most large cetaceans. It was noted that with the reduction in fleets there is a considerable decrease in the sampling area with the result that it becomes more difficult to detect changes in population size. The Committee stressed the importance of increased and more systematic sightings effort.

The view was expressed that in a new fishery it is possible to obtain good estimates of pregnancy and mortality rates relatively quickly and hence as soon as age at maturity is determined recruitment can be also estimated. On the other hand, total population levels are more difficult to estimate. It may be easier to estimate the current stock size but this does not resolve the question of quotas particularly under the present management plan.

9.4 Need for new classification categories

This item was deferred pending discussion on alternative management procedures.

9.5 Quotas for male sperm whale Initial Management Stocks

The Committee had before it no new material on this issue and therefore cannot add anything to the discussion given last year (*Rep. int. Whal. Commn* 28: 46). This item could be included for further study if the Commission decides to have a special meeting to discuss an alternative management procedure (Item 9.7 below).

9.6 Step procedures in changing quotas

At the 29th Meeting the Scientific Committee was asked to consider further the question of step procedures and especially to consider the possibility of block quotas or maintaining quotas at the same level for a number of years, in order to minimise the economic confusion resulting from sudden changes in quota.

Fukuda had presented a paper at Cronulla (SP/SPC/5) which showed that theoretically step procedures could be implemented which would not alter the recovery time expected under the present management scheme. Beddington pointed out that this proposal assumed perfect knowledge of stock sizes and replacement yields. Further consideration was deferred pending discussion on alternative management procedures.

9.7 Alternative Management Procedure

The Committee had three documents before it: SC/40/Docs 1, 24 and 51. These were discussed. The Committee believes that the time appears appropriate to develop improvements in management procedure and recommends that if the Commission wishes to examine the question then a special meeting would be appropriate. The Chairman agreed to write a report summarising the documents and the points raised in the discussion (Annex O).

9.8 Moratoria on pelagic and on non-pelagic whaling

The Convention has as its objective the safeguarding of all stocks of whales for future generations in order to achieve their optimal levels by directing exploitation to those stocks best able to sustain it. Quota regulations to achieve this have in recent years changed from a basis expressed in "Blue Whale Units" to a species and increasingly, to a stock specific regime to secure appropriate discrimination. This policy has been pursued with increasing vigour since the introduction of the New Management Procedure in 1975. The procedure improved the direction of exploitation toward stocks best able to sustain it by establishing management criteria which, for example, instead of protecting species solely on a threat of extinction, introduced a protected threshold related to the capacity of the stock to recover, and in the Initial Management Stock category prohibited exploitation of stocks where there are insufficient data to permit stock assessment. Introduction of the New Management Procedure has been followed by improvements in the data and in the precision of assessments although gaps remain, e.g. the precise definition of the identity of some stocks. The system is still evolving and could be further improved as is clear from Item 9.7.

The reduced level of whaling is increasing the difficulty in interpretation of information from those operations which can only be compensated by increased detail in that information and supplemented by other programmes.

The Scientific Committee notes that some stocks depleted to very low levels in earlier decades have re-established themselves from below levels envisaged by the Protection Stock category. There are others that have not yet recovered, although they are not extinct. It is not yet possible to estimate exact recovery times of depleted stocks and further information must be sought on critical population sizes by research on protected stocks. But these and other depleted stocks are, or can be, completely protected by implementation of scientific recommendations. Having said that, the possibilities that a stock classified as a Sustained Management Stock should have been protected, or, where correctly classified, that the quota has exceeded the sustainable yield, cannot be excluded. The Committee believes, however, that although critical minimum population sizes have not yet been identified, a stock is very unlikely to be threatened with extinction before the need to reclassify it becomes evident.

The small risk from continued whaling operations could naturally be eliminated if *all* deliberate removals from populations cease under a moratorium. Such a moratorium would, however, be a broad, non-specific regulation which would make it impossible to distinguish between the requirements of different stocks in achieving the Commission's ultimate objective of allowing exploitation of those stocks which are able to sustain it.

They will not all recover at the same rate, nor would their relative numbers necessarily be re-established in the proportions of former years. Whale populations may become subject to a variety of other risks (e.g. effects of pollution or commercial harvesting of their food).

The surveillance necessary to monitor both the consequences of a possible moratorium, and the redevelopment of stocks, in a manner which provides quantitative measures necessary to management in future generations, would continue to require the provision of adequate data. This implies a system equivalent to the main sources of data on currently exploited stocks, and increased effort in respect of protected species.

It is the opinion of the Scientific Committee that the present management procedure does safeguard whale species and identified major stocks for future generations at a very small risk, whilst enabling a continued yield to be taken. Notwithstanding the difficulties, the implementation of the New Management Procedure is leading to a better knowledge of whale population dynamics. This would be lost under a moratorium unless there were a very considerable increase in monitoring and research activity.

The representative of Panama presented a minority statement which appears as Annex P.

9.9 Criteria for management

9.9.1 The choice between yield by weight and yield by number for sperm whales

If the aim of the exploitation is to maximise weight of product regardless of cost then clearly regulations should be set so as to maximise weight. Such regulations could themselves be expressed in terms of a quota by number. On the other hand, if costs are to be considered and the criterion to be used is something else, for example maximum net revenue, then the choice is much more complex. Since the Committee has no information on such costs there is no way it can make any statement on which is the most rational choice. The same consideration applies, of course, to the present policy of seeking to maximise yield in numbers.

As a separate consideration, it is true that if the regulations were set so as to maximise catch by weight rather than by number, then the exploitation of females would be reduced. Moreover, the MSY stock level for MSY (weight) is higher than for MSY (number). In the presence of uncertainty over population levels and population responses the higher population levels involve less risk of overexploitation.

Annex J, Table 1 of the report of the Canberra meeting (*Rep. int. Whal. Commn* 28: 88) shows the difference between the maximum yield by weight and the level at which this is attained according to the 1977 assessment for the Southern Hemisphere. The combined totals give some indication of the effects involved.

For males, maximising total yield by weight results in an increase of 6,964 tonnes (5%). For females, maximising total yield by weight leads to a decrease of 4,591 tonnes (21%). The combined weight of both sexes is increased by 2,373 tonnes (1.3%) if the weight criterion is chosen. Thus it is seen that the gain in weight using the MSY by weight criterion is quite small and at the present time much less than the variability of the estimates. On the other hand the estimated effect on the MSY level is larger. For all Divisions combined in the Southern Hemisphere, the male MSY level is increased from 77,400 (33.6% of initial numbers) to 84,000 (36.5% of initial numbers), a 7.9% increase. For females it is increased from 274,200 (76.0% of initial) to 299,500 (83.0% of initial), an 8.4% increase. This represents a decrease of risk of overexploitation through incorrect assessment, but one which is difficult to quantify. In taking MSY (weight) 4% more males would be taken but 16% fewer females than in taking MSY (number). The quotas given by the New Management Procedure applied to an MSY (weight) objective rather than MSY (number) would, in 1977, have been 7% fewer males and 19% fewer females and implied a loss in the 1977/78 season of 9% of the weight yield.

9.9.2 The choice of optimum minimum size to maximise yield by weight

It is well known that if the weight of an exploited animal is to be maximised, then the theoretical age of recruitment to exploitation is chosen at that age where the growth rate equals the mortality rate. This carries with it the implication that the exploitation rate on older ages is infinitely large and it is usual in practice to choose the minimum limit at less than the exact point of equality of growth and mortality rates. To find this value requires an age–weight model. Such a model has been given by Lockyer (Estimates of growth and energy budget for the sperm whale, *Physeter catodon*, ACMRR/MM/SC/38, 1976). Actually this paper gives two growth curves for male sperm whales. Fitting quadratic equations to the curved upper section as a rough approximation procedure yields an estimate of the age at which growth rate equals mortality rate as 41–47 years. Thus it would appear that if one were to choose a minimum age to get maximum weight it should be somewhat below the above ages and could be calculated for any given rate of exploitation. It is not clear without further analysis that such a minimum length limit is consistent with the catch quota determined from the model. If the lower limit does not permit the required catches the length limit would need to be lowered.

If any females are to be taken, the length limit would be immaterial since there is almost no relationship between length and age above 10 m in length, which includes essentially all of the female catches.

9.9.3 The choice of protecting from exploitation all female sperm whales

A full evaluation of the loss that would be expected from the MSY if females were protected from exploitation will depend in part on the parameter responses expected because of exploitation. An evaluation could be made through runs of the program SPVAP with different parameter values and response functions. This could not, however, reveal any changes in effects on disturbance of nursery groups of catching or not catching females from them which cannot be predicted at the present time. It is apparent that the numerical loss would be tiny since according to the present model the Southern Hemisphere MSY catch of females is 0.7% of the MSY female stock level (*Rep. int. Whal. Commn* 28: 88). Present quotas permit a take of less than 0.5% of the total stock of females.

The SPVAP output tabulated in *Rep. int. Whal. Commn* 27: 247–8 permits an approximate evaluation of changes in product weight from protecting females and taking males in the appropriate numbers. The loss in number would be 9–10% with respect to the MSY (number) but under such a regime there would be a gain in catch by weight of 3–4% because the increase in the number of males that could be caught more than offsets the reduced number of females. If a regime of maximising catch by weight was being pursued, the percentage loss in number by not catching females would be of the order of 4%, and in this case the loss in weight would be less than 0.5%. If there is no female catch, either commercially or under scientific permit, certain types of data required for population estimates will not be available.

Technical considerations as well as scientific ones also affect the relative significance of various choices discussed in the above paragraphs.

10. MAJOR EXPLOITED STOCKS, STATUS AND REGULATORY MEASURES

10.1 Sei whales, Southern Hemisphere (also see Annex C)
For Areas III–V a least squares method utilising sightings and CPUE data gave the results shown in Table 1.

Table 1

Exploitable stock size (000s) of Southern Hemisphere sei whales

	1910	1930	1960	1979
Area III CPUE	24.2	22.1	21.3	3.0
Area III sightings	23.2	21.1	20.1	1.4
Area IV sightings	–	17.6	18.0	6.1
Area V CPUE	–	13.3	13.9	3.8
Area V sightings	–	13.7	14.3	4.4

The Committee noted the good agreement between CPUE and sightings estimates in Areas III and V. A similar analysis for Area II failed to provide useful results. Comparison with Areas III–V indicated a reduction from an average stock size of about 11,400 over the period 1965–67, to 5,100 in 1976. This information, plus the fact that considerable catches were taken before the 1965–67 period, suggests a substantially depleted stock.

Sightings data from Area IV show a 76% reduction over the period 1967–78 with average catches of about 500 per year throughout the previous decade.

For Area I the Committee examined three sets of estimates provided by the sub-committee (p. 57). Two of these (the modified DeLury and least squares estimates) were less independent of each other than the third (based on sightings data). The first two methods were based upon a series of CPUE indices corrected to allow for handling time (Annex C, Table 3). The results indicate a reduction to between 30% and 40% of the pre-1951 stock figure. Ohsumi provided a revised series of CPUE data using a different correction for handling time which indicated a somewhat lower decline in CPUE over the period, but the majority of the Committee agreed that utilising these data would make little difference to the overall result although it might be slightly higher than the 41% result obtained by the sub-committee. The majority of the Committee believed that the Area I stock should be reclassified as a Protection Stock.

Recommendations
The majority of the Committee recommends that Area I and Area IV be reclassified as Protection Stocks and therefore that the catch limits in all Areas be zero.

Ohsumi stated that in his opinion the results obtained at this meeting were premature and that for Area I and Area IV the same recommendations should be made as in 1977, i.e. that Area I be a Sustained Management Stock with a catch limit of 353 and Area IV an Initial Management Stock with catch limit of 418.

The Japanese scientists were very disappointed at these results, although they appreciated an attempt to resolve some ambiguities in the last report of the Committee. In their opinion:
"The report presented is simply based on a model with a single set-up of input parameters except for some Areas. Evidence is not presented on the reliability of this single set of input parameters. For instance, the actual age at recruitment was not constant over the years as assumed. The correlation between the calculated and the observed exploitable stock sizes may be fairly good, but in the light of the fleet operations it seems unrealistic that the fishing mortality (F) value exceeds 0.6 in the outputs, and the high variability of catchability (Q) values in the outputs indicate that the efforts themselves have not yet been fully corrected in spite of many corrections applied to the raw effort data.

Generally speaking, the population estimates for some given years are further reduced to incredible levels against the sightings data by species, and are greatly changed from those given at the last meeting.

Unfortunately, limited time precluded detailed study of the estimates. Further, the report could not give any clear definition of the target reference level. The Japanese scientists believe that it is still open to discussion this year. It will exclude any possibility of stock classification and at the same time, the Japanese scientists have been wondering why the Scientific Committee could not act in the same way as in the case of the southern minke whale.

They strongly request that the current replacement yields should be given in the report along with the difficulties of classification.

Classification and quotas of the southern sei whale have been violently changed over the last four years; not because of the actual changes in stock size but because of modifications in the process of analysis of the stock size estimate and of the target level, damaging the industry, willingly or not.

The Japanese scientists urge that more careful analyses and discussions are required before another dramatic change, such as is indicated by these results, is recommended to the Commission."

10.2 Minke whales, Southern Hemisphere (also see Annex F)
Given that the Southern Hemisphere minke whale population was increasing prior to the beginning of exploitation, the Committee was not able to recommend an appropriate classification of stocks under the present management procedure. The Commission may in future wish to consider an appropriate management strategy for this circumstance but, in the meantime and as a holding measure, catch limits for 1978/79 might be established at the level of the present replacement yields.

The Committee examined alternative population models on which to base calculations of replacement yield (RY). It agreed that it would use on this occasion a procedure based on the following steps:

(a) An estimate of the mean population of Area IV over 1971/72–1977/78 derived from the ZMK analysis.
(b) Extrapolating this to other Areas by means of estimates of relative population density derived from CPUE and sightings data.
(c) Constructing for each Area and each sex a series of population estimates for the beginning of each year using actual catches, and values of $M = 0.095$ and $r_{II} = 0.152$ in the equation

$$N_{t+1} = (N_t - C_t)\, e - M + r_{II}\bar{N}$$

Table 2

Stock estimates and current replacement yields of Southern Hemisphere minke whales

	Sex	Area I	II	III	IV	V	VI	Total
No. at beginning of season: 1971/72	♂	4,693	9,863	20,260	11,844	3,166	2,096	51,922
	♀	4,714	11,854	22,370	13,578	3,480	2,161	58,157
	♂ + ♀	9,407	21,717	42,630	25,422	6,646	4,257	110,079
1978/79	♂	3,910	11,783	26,120	8,332	3,168	2,727	56,040
	♀	3,843	10,806	25,061	8,072	2,914	2,939	53,635
	♂ + ♀	7,753	22,589	51,181	16,404	6,082	5,666	109,675
Replacement yield, 1978/79	♂	311	637	1,234	627	253	151	3,213
	♀	345	789	1,493	713	301	147	3,788
	♂ + ♀	656	1,426	2,727	1,340	554	298	7,001

where $\bar{N}$ is the mean population obtained in step (b).

(d) Calculating a replacement yield for 1978/79 by solving the equation below for RY.

$$N_{79} = (N_{78} - RY)\, e^{-M} + r_{II} \bar{N} \quad \text{with} \quad N_{79} = N_{78}.$$

Most members of the Committee agreed that on account of the lack of statistically significant difference between the estimates of r_{II} for the two sexes and the absence of sex-specific values for the parameters it was proper to use the mean value of r_{II} for the two sexes (0.152).

This procedure gave the estimates of population at the beginning of 1971/72 and 1978/79 and of the 1978/79 replacement yield set out in Table 2 (data from Annex F, Appendix 2).

One alternative would be for the Commission to use the total replacement yield for each Area as the quotas for 1978/79. However, concern has been expressed by the Committee on a number of occasions about the continuing high, although variable, proportion of females in the catches. There is a likelihood that adoption of the above quotas would lead, at least in some Areas, to the taking of a female catch greater than the replacement yield. Continuation in the coming season of such catches could have an adverse effect on the population.

The Committee therefore suggests that unless it is possible for the industry to regulate catches so as to maintain catches of each sex within the respective replacement yields, the Commission should consider ways of reducing the risk of taking an excessive catch of females.

One way of doing this would be for catching of minke whales to cease when the replacement yield for that Area of either sex had been taken. Another way would be to set a total quota for each Area equal to the female RY plus a proportion of the female RY equal to the expected proportion of males to females in the catch.

Possible bases for such a calculation would be the proportion of males to females in each Area in the season 1977/78 or the average proportion for the seasons 1971/72–1977/78. Another possibility would be to use an overall ratio of 1.5 females to males which is the approximate average for all Areas in all years. The results of these alternative calculations are given in Table 3.

Some members believe that of these three alternatives the Commission should take the safest course which is to take alternatives (1) or (2).

Ohsumi and Shimadzu insisted that management by sex of the minke whale was premature for immediate practical application. It would be the first occasion in the case of the baleen whales and probably the whaling strategies would be obliged to change, successfully or not. Direct implementation without any trial may result in the male catch always being short of the replacement yield, resulting in an adverse effect on successful reproduction. More essentially, the effect of the excess catch of females becomes apparent 7 or 8 years later, so that the situation is not so urgent that this hypothesis must be immediately adopted.

Table 3

Alternative catch limits for Southern Hemisphere minke whales

	I	II	III	IV	V	VI	Total
(1) 1977/78 ratio in each Area	506	1,179	2,117	964	505	384	5,655
(2) 1971/72–1977/78 ratio in each Area	671	1,156	2,282	1,263	512	337	6,221
(3) 1.5 : 1 ratio in all Areas	575	1,333	2,487	1,189	501	245	6,330

10.3 Sperm whales (also see Annex E)

10.3.1 Sperm whales, Southern Hemisphere

The Committee noted that there had been insufficient time available to carry out updated stock and yield estimations for all the series of CPUE data available for the Southern Hemisphere Divisions which had been used in obtaining estimates at La Jolla. The Committee was able to examine only a single estimate, undertaken for Division 6, based on Japanese Antarctic pelagic operations outside the baleen season, for which a consistent time series of CPUE data was available. This indicated that using the modified POPDYN programme, estimates of initial and current stock size would be likely to be lower than in earlier assessments. The Committee was not able, however, to predict by how much the recommended catch limit might decrease with the new parameters used.

In the absence of information on which to base recommendations for catch limits for the Southern Hemisphere, the Committee believes that there are two alternative courses of action open, as follows:

(1) To reconvene the meeting at the earliest opportunity to consider estimations based on all available Southern Hemisphere data sets using the current model and values for effort and population parameter agreed to at this meeting and to recommend catch limits; the necessary computing work could be carried out to be available after 5–6 weeks.

(2) For the Commission to adopt at this meeting a series of interim catch limits for the 1978/79 pelagic season and the 1979 land station season, pending a full reassessment at a special meeting to be held during the year at which recommendations would be made for the 1979/80 season.

The Committee is unable to recommend on scientific grounds any specific values for such catch limits; however, the Committee suggested that:

(a) no 10% allowance by Division should be permitted for any stocks;
(b) for Initial Management Stocks of males, the catch limits should be held at the 1977/78 recommended catch limits;
(c) for Initial Management Stocks of females, all of which are less than 10% above the boundary between IMS level and SMS level, most members believed that the catch limits should be 90% of the 1977/78 recommended catch limits;
(d) for all Sustained Management Stocks except males in Division 5 and both sexes in Division 7 the interim catch limit should be 90% of the 1977/78 recommended catch limit;
(e) for males in Division 5 and both sexes in Division 7, the stocks were assessed in 1977 to be close to their MSY levels and additional protection is desirable. Some members believed that these catch limits should be reduced to zero.

Beddington and Holt felt that it was important to draw to the attention of the Commissioners that analysis of the pregnancy rate in the Australian catches in Division 5 indicated a statistically significant decrease with time. A possible explanation for this phenomenon would be similar to that noted for the western North Pacific Stock. In that stock the analysis indicated that there had been a sufficient reduction in the socially mature male population to produce a decrease in the pregnancy rate. Accordingly, if this possibility is recognised, an interim catch limit of zero for both male and female stocks might be the appropriate response.

The Committee agreed that Protection Stocks as previously assessed should remain in that category.

The suggestion outlined above would result in the catch limits given in Table 4.

10.3.2 Sperm whales, North Pacific

The Committee reviewed results of assessments carried out by the sub-committee (p. 70).

It notes that under the New Management Procedure the recommended catch levels would be as follows:

	Western Division		Eastern Division	
	Males	Females	Males	Females
Catch limit	782	231	3014	667
Classification	SMS	SMS	IMS	IMS

The current estimations have been undertaken for two divisions separately (Eastern and Western). A major effort modification has been introduced to provide an estimate of searching hours rather than CDW as the unit of effort, with mature natural mortality rate set at 0.055 and an age of recruitment of 16, updated to 13 to allow for the change in size limit after 1972.

At the same time the effect of catches prior to 1946 has been taken into account. The current estimates cannot therefore be compared directly with those obtained at Cronulla.

While under the New Management Procedure there would be an allowable catch in the Western Division, the Committee does not wish to recommend catch limits for either sex without drawing the Commission's attention to the fact that analysis of the behaviour of the western North Pacific stock over time indicated that during the period 1970–78 the ratio of socially mature males to sexually mature females fell below that determined by a reserve male ratio of 0.3. Accordingly the analysis indicated that

Table 4

Southern Hemisphere sperm whales – suggested catch limits by Division, 1978/79 and 1979

Division		1977/78 + 1978 classification	1977/78 + 1978 catch limit[1]	Adjustment (% of previous catch limit)	Suggested 1978/79 + 1979 catch limits[2]
1	Males	SMS	303	90	273
	Females	SMS	101	90	91
2	Males	IMS	808	Nil	808
	Females	IMS	268	90	241
3	Males	SMS	941	90	847
	Females	SMS	312	90	281
4	Males	IMS	566	Nil	566
	Females	PS	0	Nil	0
5	Males	SMS	536	(90)	(482)
	Females	IMS	177	90	159
6	Males	IMS	276	Nil	276
	Females	IMS	92	90	83
7	Males	SMS	234	(90)	(211)[3]
	Females	SMS	130	(90)	(117)[3]
8	Males	IMS	874	Nil	874
	Females	IMS	290	90	261
9	Males	PS	0	Nil	0
	Females	PS	0	Nil	0

[1] 10% allowance between divisions not included.
[2] No allowance between divisions suggested.
[3] The Committee believes additional protection is desirable – see Item 10.3, Southern Hemisphere, 2(3).

there would be a reduction in recruitment in later years and that such a reduction would occur even if no further catches were to be taken. (Table 5, p. 70, gives the predicted change in the level of recruited population of both sexes for the period 1979–89 on the assumption that no catches would be taken). Due to the difference in the age of recruitment between the sexes, the decrease in the female mature stock occurs before that of the male recruited stock. Hence the analysis indicated that even if no catch is taken the stock will decline. The Japanese scientists stated that they wished to register reservations with respect to the computer outputs. First, there is too wide a difference in abundance between the Eastern and Western Divisions, especially when the enormous difference in area is taken into account. The Japanese scientists regret that time did not permit them to review annual changes in stock size in both regions as estimated in the outputs, but they felt that those changes would probably not be in agreement with the postwar development of sperm whaling in the North Pacific. Secondly, the efforts of the Japanese coastal whaling have not been incorporated into the analysis in question. The apparent CPUE in these operations indicate that the stock size has not changed over the years. The result of the output seems to be inconsistent with the trend in the abundance of the stock in the coastal waters. Such computer outputs would never be persuasive to the Japanese scientists unless and until the efforts of coastal whaling were duly incorporated into the process of analysis.

The Japanese scientists consider that the recommendations of the Scientific Committee fluctuated violently during the last 12 months and that more careful analysis is required before another drastic change, such as this, is recommended to the Commission.

The Committee agreed that improvements in the assessments could be made by including Japanese coastal effort data, further analysis of age and length data, pregnancy rate information, and use of time budget data from the Soviet operation. It urges that these matters should be investigated before any future assessments are carried out.

11. OTHER NON-PROTECTED STOCKS, STATUS AND REGULATORY MEASURES

11.1 Minke whales

11.1.1 Minke whales, North Pacific (also see Annex F)

A. *Okhotsk Sea/West Pacific Stock.* The Committee recommends that this stock remains classified as a Sustained Management Stock with a catch limit of 400 whales.

B. *Sea of Japan Stock (Sea of Japan, Yellow Sea and East China Sea).* The Committee recommends that this stock remains classified as a Sustained Management Stock with Japanese catching effort not to be increased.

C. *"Other" North Pacific Stock.* The Committee recommends that this stock remains classified as an Initial Management Stock with a zero catch limit pending satisfactory estimates of stock size.

The Committee recommends that a full analysis of the fishery on the Okhotsk Sea/West Pacific Stock with an examination of the effect upon efficiency of introducing motorboats be submitted next year.

The Committee, noting the doubling of the Republic of Korea catch from the Sea of Japan Stock recommends that the Commission urge the Republic of Korea not to increase their fishing effort on this stock in 1979 and to provide CPUE and the biological data normally required by the Commission from member nations from their whaling activities.

11.1.2 Minke whales, North Atlantic (also see Annex D)

A. *Canadian East Coast Stock.* The Committee recommends that this stock remains classified as a Sustained Management Stock with a catch limit of 48 whales.

B. *West Greenland Stock.* The Committee noted that females constituted more than two-thirds of the catch for this stock and that preliminary evidence suggested that the extension of the season will not alter the proportion of females in the catch. The Committee therefore recommends that the effect on the population of this high take of females should be investigated.

The Committee also recommends that this stock remains provisionally classified as a Sustained Management Stock with a catch limit of 394 whales.

C. *East Greenland–Iceland–Jan Mayen Stock.* The Committee recommends that this stock remains classified as a Sustained Management Stock with a catch limit of 320 whales.

D. *Svalbard–Norway–British Isles Stock.* The Committee noted that in all seasons from 1970 to 1977 more females than males were taken, basically as a result of segregation by sex in area and time. The 1977 catch contained 56.0% females, compared with 67.5% females in the 1976 catch. The Committee recommends that some way be found to reduce the high proportion of females in the catch.

The Committee recommends that this stock remains classified as a Sustained Management Stock with a catch limit of 1,790 whales.

E. *Proportion of females in the catch.* Most members of the Committee observed that essentially the same recommendation regarding examination of the effect on the population of the high proportion of females in the catch, had been made in previous years. They expressed their view that the continued relatively higher catches of females within the overall quotas for the West Greenland and for the Svalbard–Norway–British Isles Stocks could lead to reduction of quotas for these stocks unless operational means can quickly be found to correct the imbalance in both areas.

11.2 Bryde's whales (also see Annex C)

11.2.1 Bryde's whales, Southern Hemisphere

The Committee notes the need for further population estimates and biological data on this stock and recommends that it remains classified as an Initial Management Stock with a zero quota.

The Committee notes that Peru takes Bryde's whales and recommends the Commission to urge that there be no increase in catch pending further studies.

SC/30/Doc 30 presented a research proposal from Japan including a suggestion to take no more than 120 Bryde's whales from the Indian Ocean as part of the final year of a 3-year programme. The relative advantages of concentrating research effort in one area or dividing it between two areas were discussed and the Committee felt that this should be considered in any future proposals for research programmes.

11.2.2 Bryde's whales, North Pacific
The Committee agreed as a temporary measure to divide the area into two stocks separated at 160°W.

A. *Western Stock.* The Committee recommends that this stock be classified as an Initial Management Stock with a catch limit of 454 whales.

B. *Eastern Stock.* The Committee notes that at present this stock is unexploited and recommends that it be classified as an Initial Management Stock with a zero quota pending further information in accordance with the Schedule. The Committee also notes that the greater part of this area where Bryde's whales are found is closed to pelagic whaling.

11.2.3 Bryde's whales, North Atlantic
No new information was available on the status, number of stocks, or distribution of Bryde's whales in the North Atlantic. Stock units in this region are unknown. The Committee noted that the stock(s) were essentially unexploited and that data were inadequate to provide any estimates of stock sizes. Therefore, the Committee recommends that stocks in this region should be classified as Initial Management Stocks with zero quota pending satisfactory estimates of stock size.

11.3 Fin whales, North Atlantic (also see Annex D)

A. *Nova Scotia Stock.* The Committee recommends that this stock remains classified as Protection Stock.

B. *Newfoundland – Labrador Stock.* The Committee recommends that this stock remains classified as an Initial Management Stock with a catch limit of 90 whales.

C. *West Greenland Stock.* The Committee recommends the development of a marking scheme for this population, possibly using a boat from the Norwegian small whale fishery, to try to determine the size of this stock and its relation to other stocks.

The Committee recommends that this stock remains classified as a Sustained Management Stock (provisional) with a catch limit for 1979 of five whales, the average catch for 1973–77. If the exemption for the humpback whale catch off West Greenland is removed by the Commission, then the fin whale catch limit could be increased to 15.

D. *East Greenland–Iceland Stock.* The Committee noted that Icelandic catcher log book data from 1962–73 had been worked up and recommended that log book data from 1974 onwards should be examined with a view to using searching time as an indicator of population size.

The Committee recommends that this stock remains classified as a Sustained Management Stock with the existing catch limits. These are 1,524 whales in the six years 1977–82 with a total catch of not more than 304 in one year.

E. *North Norway Stock.* The Committee recommends that this stock remains classified as a Sustained Management Stock (provisional) and that if whaling should recommence, catches should not exceed the average catch over the period 1948–71 of 61 annually.

F. *West Norway and Faroe Islands Stock.* The Committee recommends that this stock remains classified as a Protection Stock.

G. *Spain–Portugal–British Isles Stock.* The Committee notes that all catches on this stock are by non-member countries. It is awaiting information from Spain on the 1976 and 1977 catches. Best reported that although the combined catcher/factory vessel *Sierra* and a second factory vessel, which are based in the Canary Islands, have catch data, they are under orders from their owners to withhold this information. They are believed to be operating, at least in part, on North Atlantic stocks.

The Committee recommends that this stock remains classified as a Sustained Management Stock (provisional) and that there be no increase in present catch levels. The Committee also recommends that the Commission make renewed efforts to obtain catch and effort data for the *Sierra*'s operations.

11.4 Sei whales, North Atlantic (also see Annex D)
The Committee noted the difficulty in using the Icelandic station's catcher vessels for a marking programme because sei whales are only found on Icelandic whaling grounds during the whaling season, but stresses the need for such a programme and recommends that this be carried out as soon as possible.

A. *Nova Scotia Stock.* The Committee recommends that this stock remains classified as a Protection Stock.

B. *Iceland–Denmark Strait Stock.* The Committee recommends that this stock remains classified as a Sustained Management Stock with a catch limit of 84 whales (the average catch for the five years 1973–77). The Committee notes that under the present system, due to the erratic nature of this fishery, the averaging policy will result in a gradual decline in the catch limit. However, the present policy is intended only as an interim measure until adequate information is available to classify the stock.

11.5 Sperm whales, North Atlantic (also see Annex D)
The Committee recommends the collection of biological material from catches at Spanish land stations.

The Committee also recommends that this stock remains classified as a Sustained Management Stock with a catch limit of 685 whales.

11.6 Bottlenose whales (also see Annex H)
The Committee recommends that this stock remains classified as a Protection Stock (provisional).

12. PROTECTION STOCKS, REVIEW OF STATUS (also see Annex G)

12.1 Bowhead whales
The Committee reconfirms its recommendations at Canberra and Cronulla that from a biological point of view the only safe course is to reduce the kill of bowhead whales from the Bering Sea stock to zero. It also notes and repeats the recognition made in Cronulla that the Commission may wish to discuss other considerations (subsistence and cultural needs, etc.). These are beyond the expertise of the Scientific Committee.

No new information was available on any other stocks.

12.2 Right whales
The Committee recommends to the Commission that it urgently request non-member countries, including those that have only an aboriginal or subsistence kill, that they join the Commission in protecting this species completely.

The Committee looks forward to receiving estimates of stocks and stock increases of right whales off Argentina from Payne and requests that Argentina continues such studies on current stock levels.

12.3 Gray whales

The Committee recommends that the Soviet aboriginal fishery for gray whales should be managed to achieve a more balanced sex ratio – in recent years the average percentage of females in the catch has been 68% although it was 54% in 1977.

The Committee repeated its request to Mexico to provide full details of the research being carried out on the breeding grounds.

The Committee recommends that the Eastern Stock should be reclassified as a Sustained Management Stock with a catch limit of 178 whales (the average known catch over years 1968–77). It is recommended that the Western Stock should remain classified as a Protection Stock and that non-member nations should be urged not to kill any whales from this stock.

12.4 Blue whales

The Committee recommends that all stocks of this species continue to be classified as Protection Stocks. The Committee also urges all countries having material that might help clarify the taxonomic and population status of the pigmy blue whale to analyse it and publish the results.

12.5 Humpback whales

The Committee noted that the Commission intends to review the exemption in the Schedule allowing Greenland to take 10 humpbacks per year. Based upon the concerns expressed in Annex G, the Committee recommends that the exemption be removed and that Greenland be urged to take fin whales instead. It also notes that the Commission may wish to discuss other considerations (e.g. subsistence). These are beyond the expertise of the Scientific Committee.

The Committee recommends that Spain takes steps to prohibit catches from the very depleted eastern Atlantic stock.

The Committee recommends that the Tongan government and FAO provide statistics on the aboriginal kill of this species.

The Committee notes that the coastal migration paths of humpbacks (and some other species) make systematic sightings quite feasible and therefore recommends that the Commission asks countries to undertake such systematic sightings including providing data on effort and if possible the fraction of the migrating group included.

12.6 Fin whales, Southern Hemisphere, North Pacific

A. *Southern Hemisphere.* The Committee recommends that a reanalysis of fin whale stocks, taking into account new effort modifiers, consideration of species interdependence, marking data and sightings data, be undertaken as soon as possible. The concerns expressed in SC/30/Doc 6 are noted.

B. *North Pacific.*. The Committee recommends that this stock remains classified as a Protection Stock.

12.7 Sei whales, North Pacific

The Committee recommends that this stock remains classified as a Protection Stock.

13. REVIEW OF PROTECTION STOCKS APPROACHING SUSTAINED MANAGEMENT CATEGORY

The Committee recommends the need for a thorough reanalysis of the pigmy blue whales and Area VI fin whales (see also Items 12.4 and 12.6) which are two stocks that appear to be in this category, and repeats the need for consideration of the points raised in SC/30/Doc 6. The Committee recommends that a systematic sightings programme should precede any exploitation of these stocks.

14. REVIEW OF ABORIGINAL AND SUBSISTENCE FISHERIES

The Committee did not believe that it could usefully undertake a review of the aboriginal and subsistence fisheries question at this time. If the Commission decides to hold a special meeting on alternative management procedures then this subject could appropriately be on the agenda. If such a meeting is held then specialists from other disciplines than those available in the Committee should be invited.

15. SPERM WHALES, NEED FOR CLOSED SEASON

The Committee examined the report of the sub-committee (Annex E) and agreed that the present closed seasons for socially mature males (those over 45 ft in length) in both the North Pacific and Southern Hemisphere should be retained, i.e. October to January inclusive in the Southern Hemisphere north of 40°S; and March to June inclusive in the North Pacific and dependent waters south of 40°N.

16. AMENDMENTS TO THE SCHEDULE

16.1 Opening and closing dates for the Antarctic baleen whale season

The Committee reaffirmed its statement of last year that it noted that the duration of the seasons for sperm and minke whales throughout the world is limited to eight and six months respectively in any period of 12 months. There appear to be no biological reasons for restricting the Antarctic baleen whaling season by precise dates now that there are catch limits set by Areas based upon the Commission's management policy, and in view of the present arrangements with regard to national quotas.

The Committee therefore recommends to the Commission that a four-month season for baleen whales should be declared by Contracting Governments, and suggests the following amendment to the Schedule paragraph 2(a) to read:

> "Each Contracting Government shall declare for all factory ships and whale catchers attached thereto under its jurisdiction one continuous open season not to exceed four months out of any period of 12 months during which the taking or killing of baleen whales except minke whales by the whale catchers may be permitted."

16.2 Amendments to paragraph 1 of the Schedule

The Committee agreed to recommend the amendment of paragraph 1 of the Schedule as shown in Annex M.

17. SMALL CETACEANS

17.1 Status of stocks

The small cetaceans sub-committee presented its report (Annex H); the report was received by the Committee.

17.2 Recommendations for management and conservation

The Committee considered the recommendations of the sub-committee and recommends as follows:

(a) The northern bottlenose whale, *Hyperoodon ampullatus*, should remain classified as a Protection Stock (provisional) for the entire North Atlantic.
(b) The Committee continues to recommend that the bottlenose whale research programme as recommended at the 1977 meeting (*Rep. int. Whal. Commn* 28: 66) should be carried out with emphasis on sightings and marking.
(c) Catch statistics on the incidental kill of small cetaceans in the international purse seine fishery by vessels of IWC member nations (Panama, Mexico, Canada and France) should again be requested.
(d) That the Commission should encourage research by member nations into competition between small cetaceans and fishermen.
(e) The Commission's attention should be drawn to the Committee's recommendation on the management of small cetaceans at its 1976 meeting (*Rep. int. Whal. Commn* 27: 49, 480) that there is an urgent need for an international body to effectively manage stocks of all cetaceans not covered by the present IWC Schedule.
(f) Statistics and data (as outlined in *Rep. int. Whal. Commn* 27: 480–1) on all types of small cetacean fisheries (including direct, incidental and live capture) should be submitted to the IWC as part of the national progress reports, to be reviewed by the small cetaceans sub-committee and forwarded to BIWS.

18. DATA COLLECTION, STORAGE AND MANIPULATION

18.1 Arrangements for exchange of data, for collection storage by a central agency, and for provision of computing facilities

The Scientific Committee noted that its operations are becoming more dependent on efficient computer facilities and the ability to cope with very large data bases and computations of ever-increasing complexity.

The Committee also noted that attempts to complete analyses at annual meetings have been frustrated by occasional computer unavailability and the sheer size of the task of carrying out full assessments of each major stock.

The Committee agreed on the need to establish a permanent data bank and agreed to recommend that the Commission appoint a suitably qualified person to its permanent staff to maintain this data bank and to ensure that programmes developed by members of the Committee are implemented on locally available computers.

The Committee also agreed to establish a sub-committee, with Kirkwood as convenor, whose function would be to examine the types of data available for inclusion in the permanent data bank. The sub-committee was also charged with the responsibility of recommending upon a practical operating procedure for the analysis of new data and for undertaking future stock assessments.

Such procedures should permit in-depth revisions and analyses of biological parameter estimates, stock limits and population models, possibly at special meetings, with assessments carried out subsequently. Under such a programme, results of assessments would be reported to the Annual Meeting, at which updating might be possible but major reassessments would probably not be feasible. The sub-committee should take into account the effect of such procedures upon the Commission (particularly in regard to financial provisions), national groups (in providing appropriate personnel) and the timing and frequency of special meetings.

Recommendations

The Scientific Committee recommends the urgent establishment of a permanent computer data bank, the data management system for which could possibly be done by contract, and the appointment of a suitably qualified person to the permanent staff of the Commission to manage this data bank and to ensure that programmes developed by members of the Committee are implemented on locally available computers.

18.2 Collection of additional statistics

18.2.1 On large cetaceans

The Committee agreed that as the number and size of pelagic fleets and coastal operations decrease it will become increasingly difficult to monitor trends in stock abundance through traditional CPUE measurements. Alternative indices of abundance such as sightings should therefore become more important. The Committee commended the continued support afforded by the Japanese Government to sightings cruises but noted that their usefulness as an additional source of information would be increased if they were conducted in a more systematic manner.

The Committee agreed that serious considerations should be given to placing experienced observers on oceanographic research vessels particularly fisheries vessels to undertake whale sightings, although recognising that such sightings programmes may be limited by the research priorities on such vessels.

One potentially important avenue for such sightings was afforded by the increase in experimental krill fishery expeditions in Antarctic waters and the Committee agreed that cooperation should be sought with those nations involved through the BIOMASS programme.

The Committee also considered a proposal that experimental whaling and sightings expeditions could be carried out, the proceeds of the catches taken by such expeditions to be used to cover some of the costs. The Committee agreed that more information on the design, likely cost and profitability of such experimental expeditions would have to be examined in detail at a later date but agreed that any catch taken on such expeditions could only be considered within the catch limits set by the Commission.

A sub-committee was set up to examine data requirements for catching effort and how such data may best be obtained. The Committee received the report (Annex L).

The Committee recommends that a requirement to provide the data set out in the specimen forms of Annex L be included in the Schedule but recognises the practical difficulties involved and suggests that the requirement be preceded by the words "where possible". However, the importance of collecting data of an equivalent quality is stressed, even if it can only be obtained from a small sample of each fleet or operation.

The Committee also recommended that the Commission considers producing and circulating log books of the format given in Annex L to all member nations, as perhaps the only way in which the required data can be collected in a standardised way.

18.2.2 On small cetaceans
The matter was referred to the small cetaceans sub-committee and is dealt with in Annex H.

18.3 Collection of biological data
In 1977 the Committee recommended amendments to the Schedule requiring the collection of certain biological data from each whale captured, while agreeing to consider them further in 1978.

The practical problems of the histological preparation and examination of testis tissue were discussed. The Committee recommended that in the Schedule (Paragraph 26a(i)) the words "and tissue samples from one testis" be deleted so that it reads:

"(i) both ovaries or the combined weight of both testes."

It was also suggested that biological samples collected (e.g. teeth) could be sent to laboratories in countries other than the catcher country in order to obtain the relevant information as quickly as possible and to utilise existing expertise more fully.

It was suggested that member countries should list in their progress reports details of the amount of biological material collected.

19. EFFECTS OF POLLUTION ON WHALE STOCKS, INCLUDING SMALL CETACEANS

The Committee repeats the request of last year that the Commission urges all countries to make studies of levels of pollutants on all species of cetaceans, both those taken in commercial catches and those found stranded. It notes that many studies, particularly tissue collections, have been initiated, but that many of these are being held up by lack of funds for analysis. The Committee urges governments to undertake these analyses.

The Committee notes that some Canadian studies have been undertaken on the effects of oil exploration and development on beluga whales and asks that such information be made available to the Committee.

20. HUMANE KILLING OF WHALES

The Committee received the extensive review in SC/30/Doc 38 and understood that further unpublished material was available.

20.1 Specific research proposals
A working group was set up to formulate research proposals (Annex J). The Committee received its report and makes the following recommendations to the Commission:

1. A systematic investigation and evaluation of the efficiency of present methods of killing whales is needed, in particular observations by suitably qualified veterinarians and other personnel, of the rapidity of unconsciousness and death and of the nature of the injuries caused.

   Such observations should cover examples of at least one large whale pelagic or coastal operation and one small-type whaling operation.
2. Following these field observations, and depending on the nature of the conclusions reached, a report-back meeting should be held between the research personnel and the IWC representatives to decide on future action.
3. Further research by qualified personnel into electrical, pharmacological and explosive methods should be urged on whaling nations in an effort to achieve the most humane methods of killing whales as quickly as possible.
4. In order to compare results from different fisheries standard criteria for unconsciousness and death should be formulated.
5. The information requested in 1977 should continue to be collected and forwarded to the Secretary for analysis.

20.2 Ethics of killing cetacea
The Committee was charged with considering ethics, "particularly but not exclusively as related to cetacean neuroanatomy, cetacean intelligence potential and cetacean social bonds". The Committee received no specific documents relating to the ethics of killing cetacea, but related information was contained in SC/30/Rep 5.

Some members felt that the Committee was no more qualified than any other body to comment on the general ethics of killing animals; the general opinion of the Committee was that more relevant items for discussion under the general heading (Item 20. Humane Killing of Whales) would be in relating cetacean intelligence and behaviour to the management of whaling.

A sub-committee was formed to provide guidelines for discussion. The sub-committee report contained in Annex K was accepted by the Committee. The Committee recognised that the sub-committee was limited by constraints of time, limited behavioural expertise and reference material available.

Pilleri and Morgane presented a minority report to the Committee (Annex N).

The Committee noted the relevance for future investigations of items mentioned in the report, especially the importance of certain behavioural studies to assessment and management techniques. The Committee recommends that the Secretariat continues to seek information on this subject, enquires into the possibilities of a co-sponsored meeting and encourages outside specialists to provide documents for discussion at the next Annual Meeting.

21. EDITORIAL POLICY RELATIVE TO PUBLICATION OF THE SCIENTIFIC COMMITTEE'S REPORTS AND ASSOCIATED DOCUMENTS

The Committee discussed various ways in which the present financial burden on the Commission of duplication of Committee documents could be relieved. The Commission's Secretary strongly expressed the view that a 2,000 word limit (as followed by ICES) for such documents would greatly relieve the financial and handling problems. However, Committee members generally felt that whereas a length limit on papers was desirable, it was not always possible and that the more practicable solution was to turn the onus and responsibility of duplication of papers directly to the authors. The Committee agreed that for all primary scientific papers for consideration at the meeting sufficient copies of such documents should be supplied to the Secretary in advance of or on the first day of the meeting for distribution to all members. Only in exceptional circumstances should copying of documents be undertaken by the

Secretariat and in that case a top copy must be received by the Secretary at least 2 weeks before the meeting.

The Committee agreed that all documents should include an abstract, and that authors should be urged to have their papers refereed by professional colleagues prior to publication. Authors should attach to their papers a statement whether the paper has been revised and/or refereed since the meeting. Papers for publication should be received by the Secretary in final form within 3 months of the close of the meeting at which they were presented.

The Committee agreed that the Secretary should be asked to investigate the possibility of further special issues on appropriate subjects. Papers for such issues could be subjected to more rigorous refereeing.

The Secretary is requested to publish annually in the Report maps showing the full system of statistical subdivisions.

The Secretary informed the Committee that future plans were for published Scientific Committee documents to be recorded in *Zoological Record*, and that it was also intended that abstracts be published in *Biological Abstracts.* FAO was also being approached to include IWC papers in their appropriate title and abstract series.

The Secretary requested the Committee members to forward reprints of papers related to cetacean studies and more especially reprints of Committee documents published outside the Commission within the last 10 years, to the Secretariat for the archives.

The present situation regarding rapporteurs for the Committee meetings was regarded as unacceptable owing to the pressure of other duties within the Committee on these persons. The Committee requests the Chairman and the Secretary of the Commission to examine ways in which this problem might be alleviated and suggests that the country where the meeting is being held might consider providing persons to the Scientific Committee solely for duties as rapporteurs.

22. FUTURE MEETINGS AND SPECIAL STUDIES

The Committee agreed that a period of about 2 weeks would be required to carry out a thorough review of the sperm whale model and parameters and to undertake a reassessment of North Pacific stocks. Southern Hemisphere stocks would not be reassessed at that meeting. Monday, 27 November, was chosen as a possible starting date.

The Committee noted that its proposals for special studies on humane killing and on the influence of behaviour on management would be arranged by the Secretary.

It also noted that the Technical Committee had set up a special working group on alternative management procedures, and that this would report to the Scientific Committee at the next annual meeting.

The special committee on data requirements and computing and on operating procedures would work by correspondence and report at the 1979 meeting.

23. ELECTION OF OFFICERS AND COMMITTEES

K. R. Allen and J. L. Bannister were elected Chairman and Vice-Chairman respectively for 1978/79.

It was agreed that a standing sub-committee on Small Cetaceans was required for 1978/79. W. Perrin was elected Convenor of this sub-committee.

J. L. Bannister undertook to convene the Special Meeting on sperm whales.

24. INITIAL AGENDA FOR 1979 MEETING

Committee members were asked to advise the Chairman of any special items which should be included in the 1979 agenda, but which had not been noted in the Report.

Annex A

AGENDA

1. Chairman's remarks
2. Appointment of rapporteurs
3. Adoption of agenda
4. Arrangements for meeting
   - 4.1 Establishment of sub-committees
   - 4.2 Computer arrangements
   - 4.3 General
5. Review of documents and reports
   - 5.1 Documents
   - 5.2 Progress reports
   - 5.3 Reports of special meetings
     - 5.3.1 Sperm whales
     - 5.3.2 Minke whales
     - 5.3.3 Historical studies
   - 5.4 Other reports
   - 5.5 Reports of standing sub-committees
     - 5.5.1 Sperm whales
     - 5.5.2 Small cetaceans
   - 5.6 Scientific permits
     - 5.6.1 Permits for 1977/78
     - 5.6.2 Advance review of permits
   - 5.7 Previous season's catches and other statistical material
   - 5.8 Progress of whale marking and whale mark recoveries. Commission's contribution to whale marking
   - 5.9 Sighting programme. Data reports from 1977/78 season and analyses of data
   - 5.10 Stock handbook
   - 5.11 Indexed list of Scientific Committtee publications
6. Rules of procedure
   - 6.1 Admission of observers
   - 6.2 Submission of documents
   - 6.3 Consideration of *ad hoc* questions during plenary sessions
   - 6.4 Completion of report prior to opening of plenary sessions
7. Reports from international agencies
   - 7.1 FAO/ACMRR Working Party on Marine Mammals
   - 7.2 IUCN Interim Committee on Marine Mammals
8. International Decade of Cetacean Research – Research Proposals
9. Classification of whale stocks and determination of quotas – general principles
   - 9.1 Effects of environmental variability
   - 9.2 Effects of changes in carrying capacity
   - 9.3 Provision for errors of estimation
   - 9.4 Need for new classification categories
   - 9.5 Quotas for male sperm whale Initial Management Stocks

9.6 Step procedures in changing quotas
9.7 Alternative management procedure
9.8 Moratoria on pelagic and on non-pelagic whaling
9.9 Criteria for management

10. Major exploited stocks, status and regulatory measures
    10.1 Sei whales, Southern Hemisphere
    10.2 Minke whales, Southern Hemisphere
    10.3 Sperm whales
        10.3.1 Southern Hemisphere
        10.3.2 North Pacific
11. Other non-protected stocks, status and regulatory measures
    11.1 Minke whales
        11.1.1 North Pacific
        11.1.2 North Atlantic
    11.2 Bryde's whales
        11.2.1 Southern Hemisphere
        11.2.2 North Pacific
    11.3 Fin whales, North Atlantic
    11.4 Sei whales, North Atlantic
    11.5 Sperm whales, North Atlantic
    11.6 Bottlenose whales, North Atlantic
12. Protection stocks, review of status
    12.1 Bowhead whales
    12.2 Right whales
    12.3 Gray whales
    12.4 Blue whales
    12.5 Humpback whales
    12.6 Fin whales, Southern Hemisphere, North Pacific
    12.7 Sei whales, North Pacific
13. Review of protection stocks approaching sustained management category
14. Review of aboriginal and subsistence fisheries
15. Sperm whales, need for closed season
16. Amendments to the Schedule
    16.1 Opening and closing dates for the Antarctic baleen season
    16.2 Amendments to paragraph 1 of the Schedule
17. Small cetaceans
    17.1 Status of stocks
    17.2 Recommendations for management and conservation
18. Data collection, storage and manipulation
    18.1 Arrangements for exchange of data, for collection and storage by a central agency, and for provision of computing facilities
    18.2 Collection of additional statistics
        18.2.1 On large whales
        18.2.2 On small cetaceans
    18.3 Collection of biological data
19. Effects of pollution on whale stocks, including small cetaceans
20. Humane killing of whales
    20.1 Specific research proposals
    20.2 Ethics of killing cetacea
21. Editorial policy relative to publication of Scientific Committee's reports and associated documents
22. Future meetings and need for special studies
23. Election of officers and committees
24. Initial agenda for 1979 meeting

Annex B1

LIST OF SCIENTIFIC COMMITTEE DOCUMENTS

SC/30/Doc

1 ALLEN, K. R. Towards an improved whale management procedure.
2 BROWN, S. G. International co-operation in Antarctic whale marking 1971 to 1977.
3 BEDDINGTON, J. R. On some problems of estimating population abundance from catch data.
4 BEDDINGTON, J. R. and MAY, R. M. A possible model for the effect of adult sex ratio and density on the fecundity of sperm whales.
5 HOLT, S. J. A simple model of pelagic whaling.
6 HOLT, S. J. and GORDON CLARK, J. Reclassification of protected baleen whale stocks.
7 KIRKWOOD, G. P. Accounting for risks in whale management – 1. Risks associated with fluctuating environments.
8 KIRKWOOD, G. P. Accounting for risks in whale management – 2. Risks associated with estimation errors.
9 KIRKWOOD, G. P. The net catcher day as a measure of effort.
10 MAZANOV, A. and KIRKWOOD, G. P. A simulation approach to estimating pregnancy rates in sperm whale populations.
11 KIRKWOOD, G. P. A note on the assessment of North Pacific sperm whales.
12 KIRKWOOD, G. P. Maximum likelihood estimation of population sizes using catch and effort data.
13 HARWOOD, J. The effects of inter-specific competition on the choice of management policies for fin and sei whales.
14 KIRKWOOD, G. P. A note on the modelling of sperm whale pregnancy rates.
15 KIRKWOOD, G. P. Sensitivity tests for the sperm whale model.
16 WINN, H. E. and SCOTT, G. P. A model for stock structuring of humpback whales (*Megaptera novaeangliae*) in the western North Atlantic.
17 BOTKIN, D. B., SCHIMEL, D. S., WU, L. S. and LITTLE, W. S. Some comments on density dependent factors in sperm whale populations.
18 BEDDINGTON, J. R. and GRENFELL. B. Risk and stability in whale harvesting.
19 PERRIN, W. F., SLOAN, P. A. and MENDERSON, J. P. Taxonomic status of the "south-western stocks of spinner dolphin *Stenella longirostris* and spotted dolphin *S. attenuata*".
20 LOCKYER, C. and BROWN, S. G. A review of recent biological data for the fin whale population off Iceland.
21 LOCKYER, C. Changes in a growth parameter associated with exploitation of southern fin and sei whales.
22 KIRKWOOD, G. P. and BANNISTER, J. L. Revised abundance indices for sperm whales off Albany, Western Australia.

23 KAPEL, F. O. Exploitation of large whales in West Greenland in the twentieth century.
24 GARROD, J. and HORWOOD, J. W. Whale management: strategy and risks – a comment.
25 HORWOOD, J. W., KNIGHT, P. J. and OVERY, R. W. Harvesting of whale populations subject to stochastic variability.
26 MASAKI, Y. Japanese pelagic whaling and whale sighting in the 1977/78 Antarctic season.
27 WADA, S. Indices of abundance of large sized whales in the North Pacific in the 1977 whaling season.
28 OHSUMI, S. Bryde's whales in the North Pacific in 1977.
29 OHSUMI, S. Further examination on population assessment of Southern minke whales in Area IV.
30 OHSUMI, S. Provisional report on the Bryde's whales caught under special permit in the Southern Hemisphere in 1977/78 and a Research Programme for 1978/79.
31 DOI, T. Theoretical aspects analysed by introducing age-specific maturity and age-specific availability into population analysis of minke whales in the Antarctic.
32 SHIMADZU, Y. The effect of meteorological factors on the catch of the minke whale in the Antarctic.
33 BEST, P. B. Pregnancy rates in sperm whales, Durban.
34 WOLMAN, A. A. and RICE, D. W. Current status of the gray whale.
35 MARQUETTE, W. M. The 1977 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos.
36 BRAHAM, H., KROGMAN, B., LEATHERWOOD, S., MARQUETTE, W., RUGH, D., TILLMAN, M. and JOHNSON, J. Preliminary report of the 1978 spring bowhead whale research programme results.
37 DARLING, J. Abundance and behaviour of gray whales which spend the summer off the west coast of Vancouver Island.
38 MITCHELL, E. and STAWSKI, M. A bibliography of whale killing techniques especially "humane" methods.
39 MITCHELL, E. and KOZICKI, V. M. Example of daily activity log for shore-based whale catcher vessels.
40 MITCHELL, E., BLAYLOCK, G. and KOZICKI, V. M. Modifiers of effort in whaling operations: with a survey of anecdotal sources on searching tactics and use of Asdic in the chase.
41 MITCHELL, E. Magnitude of early catch of east Pacific gray whale (*Eschrichtius robustus*).
42 MITCHELL, E. Collection of scientific data from "aboriginal" whale fisheries.
43 BREIWICK, J., MITCHELL, E. and CHAPMAN, D. Initial population size of Bering Sea stock of bowhead whale (*Balaena mysticetus*): An iterative method.
44 ALLEN, K. R. The status of currently protected whale stocks.
45 BRAHAM, H. W. & LEATHERWOOD, S. Ingutuk: Preliminary remarks on morphological variation of the bowhead whale (*Balaena mysticetus*).
46 RUGH, D. J. and BRAHAM, H. W. California gray whale (*Eschrichtius robustus*) fall migration through Unimak Pass, Alaska, 1977: A preliminary report.
47 BOCKSTOCE, J. A preliminary estimate of the reduction of the western Arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry: 1848–1915.
48 RICE, D. W. Bryde's whales in the equatorial eastern Pacific.
49 BAXTER, B. A., WHITEHEAD, H. P. and NICHOLS, G. Preliminary report on the population of humpback whales on Silver, Navidad and Mouchoir Banks during the winter 1977–78.
50 HOLT, S. J. A note on the method of estimated net rate of increase from age-compositions.
51 HOLT, S. J. Proposal for a modified management policy.
52 FOWLER, C. W. A rationale for modifying effort by catch, using the sperm whale of the North Pacific as an example.
53 HOLT, S. J. Further considerations on the assessments of Southern Hemisphere minke whales.
54 BLOKHIN, S. A. On the status of the gray whale stocks in the coastal waters of Chuckotka Peninsula.
55 KUZNIN, M. V., IVASHIN, M. V. and VLADIMIROV, V. V. Preliminary report on Bryde's whale catch taken by special permit in the Southern Hemisphere during the 1977/78 whaling season.
56 ANON. Distribution of whales in the North Pacific on expeditional data of 1965/66, 1969/70 and 1975.
57 MICHALEV, Ju. A. Revealing of differences in the Antarctic baleen whale stocks on the basis of the analysis of the "Jacobson's Organ" position.
58 VEINGER, G. N. Intraspecies structural data of sperm whales in the North Pacific.
59 CHRISTENSEN, I. The killer whale (*Orcinus orca*) in the north-east Atlantic.
60 CHRISTENSEN, I. and RØRVIK, C. J. Stock estimate of minke whales in the Svalbard–Norway–British Isles area from markings and recoveries 1974–77.
61 CHRISTENSEN, I., JONSGÅRD, A., and RØRVIK, C. J. Preliminary catch statistics for minke whales (*B. acutorostrata*) caught by Norway in 1977.
62 CHRISTENSEN, I. Norwegian minke whales fishery in 1976 and 1977.
63 FORTOM-GOUIN, J. P. and SPONG, P. On the efficiency of sonar in sperm whaling.
64* FORTOM-GOUIN, J. P. On the ethics of sperm whaling.
65 ANON. Sperm whales: Pregnancy data (USSR).
66 ANON. Sperm whales: USSR data.
67 ANON. USSR data.
68 VALDIVIA, J. The status of cetacean stocks in northern coastal waters of Peru (1968–77).

* Not received.

Annex B2

LIST OF PROGRESS REPORTS

SC/30/Prog Rep
1 Australia
2 Canada
3 Iceland
4 Japan
5 Denmark
6 New Zealand
7 Norway
8 South Africa
9 USSR
10 United Kingdom
11 USA

Annex B3

LIST OF REPORTS

SC/30/Rep
1 Report on the International Workshop on Historical Whaling Records – Kendal – September 1977.
2 Report of the Scientific Committee special meeting: North Pacific Sperm Whale Assessment Cronulla – November 1977.
3 Report of the Workshop on the Status of Dall Porpoise in the North Pacific – Seattle – January 1978.
4 Report of the Scientific Committee Special meeting: Southern Hemisphere Minke Whales – Seattle – May 1978.
5 Humane Killing and Cetacean Intelligence.
6 Sightings Reports of Prohibited Species.
7 Whale Marking – Progress Report 1978.

Annex C

REPORT OF THE SUB-COMMITTEE ON SEI AND BRYDE'S WHALES

Members: Borodin, Brownell, Chapman, Fukuda, Garrod, Harwood, Horwood (Convenor), Ivashin, Kirkwood, Lockyer, Ohsumi, Tillman, Valdivia, Yamamura.

Documentation available:
SC/30/Docs 3, 5, 9, 12, 21, 26, 27, 28, 30, 40, 48, 55, 56, 58.
SC/30/Prog Rep 5

Stocks considered (numbers refer to the Scientific Committee Agenda Item):
10.1 Southern Hemisphere sei whales
11.2.1 Southern Hemisphere Bryde's whales
11.2.2 North Pacific Bryde's whales
11.2.3 North Atlantic Bryde's whales

The North Pacific sei whales were considered by the sub-committee on Protected Stocks (Annex G). The North Atlantic sei whales were considered by the sub-committee on North Atlantic Stocks (Annex D).

10.1 Southern Hemisphere sei whales

The catch in the 1977/78 season was restricted to Areas I and IV. The catches are shown below:

	Catch limit (including allowance)	USSR	Japan	Total
Area I	388	311	0	311
Area IV	460	0	254	254
	⩽771	311	254	565

It was noted that the Japanese catch has a shortfall of 206: 42 from Area I and 164 from Area IV. The Japanese scientists explained that this was due to a seamen's strike delaying the start of the expedition by about 10 days so that the fleet arrived at the sei whale grounds (40°–45°S) around the end of December. Bad weather and the late start meant that the fleet missed the main sei whale concentrations which had started to move south judging from the scarcity of the food species observed.

In addition to documents listed above, the sub-committee had available the Report of the Sei Whale Meeting, Tokyo, 1977 (*Rep. int. Whal. Commn* 28: 335–43), and the Report of the Scientific Committee, 1977 (*ibid.*, pp. 47–54). These reports dealt in detail with analyses of population estimates. Those analyses involving age–population structure gave very low recruitment rates, eg. Table 12 (*Rep. int. Whal. Commn* 28: 53) and those estimations of numbers using pregnancy rate data and age at sexual maturity data (SEI programme, *Rep. int. Whal. Commn* 28: 337–8; also SC/30/Doc 12) gave poor correlations.

The sub-committee reassessed pregnancy rates, considering that the 1930 rates were actually higher than those originally calculated from the data in the Bureau of International Whaling Statistics. The new rates were based on data of Matthews (1938, *Discovery Rep.* 17: 248–9) and Gambell (1968, *Discovery Rep.* 35: 125–6).

Analyses using the new pregnancy rates and ages at maturity listed below were undertaken. The analyses were based on the model described in SC/30/Doc 12 but utilised a least-squares technique rather than the maximum likelihood estimation.

1. Pregnancy rates. These were increased linearly with time from p = 0.47 (pre-1930) to 0.57 (1970) (Masaki, 1978, *Rep. int. Whal. Commn* 28: 421–9). This is a slightly different procedure than used in SEI programme by Allen and Kirkwood (*ibid.*, pp. 151–7) and the Committee (*ibid.*, p. 50) where actual pregnancy rates were used. As pointed out the rate determined from BIWS

are dubious and in addition require a correction of undetermined amount depending on the time within the season when the whales are caught.

2. New ages at first parturition data by Area were based on data on age at sexual maturity (SC/30/Doc 21) adjusted with the addition of one year for the gestation period.

Ages at recruitment were taken as averages by Area from Table 3 (*Rep. int. Whal. Commn* 28: 340), mortality rate was M = 0.07. The value of M was taken from p. 49 of the same volume based on the Allen and Kirkwood paper noted above.

The analyses were carried out with different CPUE data from last year as follows:

1. CHW was adjusted by subtracting one hour for each whale caught, and by applying the same weather and distributional modifiers as previously used by Ohsumi and Yawamura (1978, *Rep. int. Whal. Commn* 28: 459–67) to produce CPUE – II′. The subtraction of one hour was based on handling times for sperm and minke whales with the assumption that a similar time would be applicable to fin and sei whales to give a better estimate of searching time.
2. The SEI analyses were also undertaken with CPUE uncorrected for weather and distributional effects but with the same correction for handling time applied (CPUE′).
3. Analyses were also undertaken using sightings data as an index of abundance from Series D and E (Masaki, SC/30/Doc 26).

The sightings and CPUE data are given in Table 1.

A priori CPUE II′ was considered a better index than CPUE′ and lack of time meant that a CPUE′ run was not attempted for Areas III and IV. For Areas II and V CPUE′ gave no useful answers along with CPUE II′ in Area IV. Area II gave no useful answers, for any data set. The 'no useful answers' are estimated stock sizes of millions, or going to zero during the time series.

The population estimates and correlation coefficients for Areas III to V are given in Table 3.

The correlation coefficients were obtained from linear regression of the stock size calculated from the model, against the index of density, either CPUE II′ or sightings. The regression was between stock size at the beginning of the season with the index during the season. 'n' is the number of values used in the regression.

Area VI

According to the model, the Area VI stock was reduced to zero in 1976 and thus does not give a useful result. The several analyses of the stock last year gave fairly consistent results, with the average of ratios of the 1977/78 level to the 1959/60 level equal to 0.48.

Sightings data of Table 1 indicate that the 1975–78 levels are about 24% of the 1967–69 levels when the stock had already been reduced by a decade of catches averaging about 500 per year. This stock was classified as a Protection Stock last year.

Area II

The SEI analyses of Area II gave no useful results. The CHPOP and COHORT analyses used last year indicated a high stock size compared with other areas but at 52% of MSYL. However, the recruitment rates, used in some of

Table 2

Results: Areas II to V, run summary

	CPUE II′	CPUE′	Sightings
II data	√	√	√
Run	√	√	√
Good result	x	x	x
III data	√	√	√
Run	√	x	√
Good result	√		√
IV data	√	√	√
Run	√	x	√
Good result	x		√
V data	√	√	√
Run	√	√	√
Good result	√	x	√
VI data	x	x	√
Run			√
Good result			x

Table 1

CPUE and sightings data used in the SEI analysis

	Area II			Area III			Area IV			Area V			Area VI	
	CPUE II′	CPUE′	Si	CPUE II′	CPUE′	Si	CPUE II′	CPUE′	Si	CPUE II′	CPUE′	Si	Si	
1960										0.0639	0.0312			
1961										0.0395	0.0018			
1962														
1963														
1964										0.0277	0.0504			
1965	0.1032	0.1114												
1966	0.0548	0.1932	0.0479	0.0843	0.1172	0.0335								
1967			0.0157	0.0718	0.1695	0.0570	0.1294	0.1952	0.0369			0.1309	0.0056	
1968				0.0552	0.1552	0.0515	0.0668	0.0936	0.0324		0.0350	0.1382	0.0335	0.1104
1969				0.0315	0.0562	0.0198	0.0394	0.0514	0.0205	0.0239	0.1498	0.0360	0.0177	
1970	0.0401	0.1060	0.0113	0.0282	0.0446	0.0103	0.0412	0.1180	0.0616					
1971				0.0189	0.0303	0.0106	0.0469	0.1378	0.0424			0.0235	0.0042	
1972				0.0261	0.0375	0.0079	C.0455	0.1307	0.0209	0.0302	0.2025	0.0700		
1973				0.0255	0.0451	0.0134	0.0417	0.1029	0.0205	0.0310	0.1747	0.0366	0.0047	
1974				0.0224	0.0319	0.0064	0.0572	0.1018	0.0130	0.0149	0.1063	0.0226	0.0444	
1975			0	0.0077	0.0132	0.0023	0.0282	0.0803	0.0101	0.0302	0.1289	0.0104	0.0145	
1976	0.0286	0.0508	0.0176				0.0427	0.1492	0.0101	0.0097	0.0535	0.0096	0.0029	
1977			0			0.0040			0.0100			0.0128	0.0073	
1978			0			0.0116			0.0049			0.0165	0.0204	

Table 3

Sei whale exploitable population sizes (000s)

	1910	1930	1960	1979	r^2	n
III						
CPUE II′	24.2	22.1	21.3	3.0	+0.93	10
Sightings	23.2	21.1	20.1	1.4	+0.61	12
IV						
Sightings	–	17.6	18.0	6.1	+0.55	12
V						
CPUE II′	–	13.3	13.9	3.8	+0.56	10
Sightings	–	13.7	14.3	4.4	+0.51	11

Notes:

1. The comparisons between the results from CPUE and sightings data in both Areas III and V show a remarkable agreement.
2. All Areas show substantial depletion relative to pre-exploitation levels.
3. Sightings data gave useful results in each Area. The reduction in fishing effort and associated problems (SC/30/Doc 24) suggest that sightings may become the most useful data base.
4. Sightings densities relative to Area VI for the approximate period 1967–69 are Area III = 1.00, Area IV = 0.76, Area V = 1.50, whereas relative numbers from the simulation show approximately Area III = 2.2, Area IV = 2.2, and Area VI = 2.6. This may indicate that the absolute numbers predicted for Area VI may be low by a factor of 2 (assuming Areas to be the same area).
5. Area III and V results for 1930 are about the same as last year. Area IV estimates are a little lower (c.f. Table 8a, *Rep. int. Whal. Commn* 28: 52).

those analyses, were less than the assumed natural mortality rate (Table 12, *Rep. int. Whal. Commn* 28: 53).

The sightings data show a drop to 50% between 1966/67 and 1975–78. CPUE II′ and CPUE′ between 1965/66 and 1977 show a drop to 33–36% respectively. The average catch during the period 1955 to 1965 was about 2,000 whales with over 16,000 being taken in the season 1964/65. Since neither the sightings nor the CPUE data show present densities much larger than in the other Areas (Table 1) where stock sizes are of the order of 2,000–6,000, it is clear that the Area II stock level is a small percentage of pre-exploitation levels.

From Table 1, density indices from the period 1965 to 1967 can be related to similar indices for the other areas at about that time. Using the successful model runs to give absolute values in Areas III–V, an estimate of numbers over the period 1965–67 can be obtained. A similar comparison can be made using the 1976 indices. This technique resulted in average values of:

$N_{65-67} = 11.4$ and $N_{76} = 5.1$

These factors and especially the average catch of 2,000 whales between 1955 and 1965 indicate that this stock should continue to be protected.

Area I

Last year highly variable estimates of current and initial stock sizes were averaged to produce an estimate of initial and current (1978) stock sizes of 14,200 and 11,300. This gave a Sustained Management Stock with a catch limit of 353.

This year three analyses were attempted.

(1) A modified DeLury analysis which is described below. This Area has had a very erratic history of sei whale catches: almost 1,000 in total in 1924/25–1928/29, then zero or negligible exploitation until 1956/57. Two seasons of medium catches were followed by three of much smaller catches, then two of high catches (2,451 in total). After eight seasons of variable but generally low catches there have been six seasons of higher catches. This latter series is shown in Table 4 together with CPUE calculated as indicated in the Table footnote.

It is difficult to know what recent recruitment may have been either as a result of earlier catches of sei whales themselves or in response to reductions of other baleen species. For this reason it has been more reasonable to estimate recruitment based on pregnancy rate and age of first parturition data. As in other Areas, pregnancy rates have been assumed to increase from 0.47 in 1930 linearly to 0.57 in 1970, with age of first parturition decreasing linearly over the same period from 13 to 9 years.

With this recruitment, for any given initial N_0, it is straightforward to calculate the 1972/73 population level. N_0 has been selected as 1950/51 and this level has been assumed to be approximately constant for the previous nine years. With the forward calculated population levels available it is possible to calculate recruitments for 1972/73 to 1977/78 and then carry out a modified DeLury to estimate the initial 1972/73 stock, taking into account both catches, natural mortality and recruitment. By successive iteration that N_0 (1950/51 level) has been chosen for which the forward calculated 1972/73 level is equal to the modified DeLury estimate based on the above input and CPUE's for 1972/73 to 1977/78. To the nearest 10 the results so obtained are:

$N_{1951} = 5{,}320$; $N_{1960} = 4{,}950$;
$N_{1973} = 3{,}840$; $N_{1979} = 1{,}670$

On the basis of this analysis the present stock level is 31% of the 1951 stock level. The populations referred to here are the animals 9 years and over which are recruited during the later exploitation and also coincide with the mature population after 1970. The mortality rate used is M = 0.07.

(2) An estimation similar to that for the other Areas and age of first parturition data. As in other Areas, rate trend was used and the ages at maturity described in (1). The estimation used the CPUE data given in Table 4.

Table 4

CPUE based on corrected CDW

Season	CDW	Sei catch	Total catch of all whales	Corrected CDW	CPUE
1972/73	364	460	551	318.1	1.45
1973/74	1,749	1,126	1,959	1,585.8	0.71
1974/75	1,845	1,027	3,388	1,562.7	0.66
1975/76	905	198	1,050	817.5	0.24
1976/77	444	298	1,251	339.8	0.88
1977/78	552	311	927	474.8	0.66

Corrected CDW = CDW – 1/12 (total catch). This is an approximation to searching time assuming that handling time of each whale caught equals one hour approximately 1/12 of a working day.

The results give:

$N_{51} = 7{,}400$; $N_{60} = 7{,}000$; $N_{79} = 3{,}000$

($N_{79}/N_{51} = 0.41$ modified DeLury (1): $N_{79}/N_{51} = 0.31$.)

(3) Between 1966 and 1975 there was only a total of

231 miles of scouting boat sightings in D and E of Area I. In 1977 and 1978 there was a total of only 379. However, in 1976 there were 3,364 miles searched in Zones D and E. This gave 0.0116 whales seen/mile.

This index of density can be compared with similar indices for Areas III, IV and V for which there were successful estimates.

Area III had sightings in 1975, 1977 and 1978 which gave an average Area I estimate of 0.6 in 1976.

Area IV had sightings in 1975–77 which gave an average Area I estimate of 4.6 in 1976.

Area V had sightings in 1975–77 which gave an average Area I estimate of 4.6 in 1976 also.

The average of these three figures is 3.3.

Summary

	1951	1976	1979	'79/'51
Modified DeLury	5.3	–	1.7	0.31
Least-squares	7.4	3.2	3.0	0.41
Relative sightings and least-squares estimates from III–V	–	3.3	–	–

The relative sightings corroborate the low estimates of stock abundance in Area I and suggest that the trends observed in the CPUE series are real and that the stock is probably between 30% and 40% of the 1951 level. The stock should be classified as a Protected Stock.

SC/30/Doc 68 indicates that about 60 sei whales per year have been taken recently by Peru.

Recommendations
Areas I and IV – Reclassify as Protected Stock.
Areas II, III, V and VI – Remain as Protected Stock.
Areas I to VI – Catch limit zero.

11.2 Bryde's whales

11.2.1 Southern Hemisphere
The sub-committee welcomed Valdivia's report SC/30/Doc 68 on statistical and biometrical data of Bryde's whales (and other whales) from the Paita Land Station in Peru for a period of 10 years.

The catches of Bryde's whale have averaged about 400 per year with a small proportion of sei whales included in the catch. Very little is known about the South Pacific Bryde's whale stocks and it is not possible to comment at this stage as to what effect this take of 400 has had. However, length data presented to the sub-committee by Dr Valdivia indicated a decline in the average length of females in the catches over the past 10 years of about 2 feet. By contrast in the North Pacific Japanese coastal statistics show a smaller decline and the Soviet and Japanese pelagic fleets no decline in average length at capture, thus the decline observed may be a cause for some concern and the sub-committee would be pleased to receive further biological data on this stock and would prefer that there would be no increase in catches pending further studies.

Japanese research in the Southern Hemisphere
SC/30/Doc 30 presented the preliminary results of the Japanese research on Bryde's whales in the Southern Hemisphere in 1977/78. Under a special permit, 114 whales were taken from the western South Pacific Ocean, and in the Indian and Pacific Oceans 75 Bryde's whales and 97 other whales were marked. 29,000 miles of searching were undertaken by scouting boats and 133 Bryde's whales seen. Analyses of the data are still being undertaken.

SC/30/Doc 30 also presented a research proposal including a suggestion of a take of not more than 120 Bryde's whales from the Indian Ocean (1976/77 research catch was 120 from the South Pacific and 105 from the Indian Ocean, 1977/78 was 114 from the South Pacific). The 120 in 1978/79 would be from the eastern Indian Ocean.

The sub-committee noted that if the stock was to be exploited, more information is needed through sightings, markings and age parameters. It is of particular importance that, as outlined in SC/30/Doc 30, the catch should be taken at least randomly to avoid bias in favour of taking older animals. The younger animals are needed: (1) to aid in the understanding and interpretation of ear plug growth layers, (2) to avoid bias in the construction of age–length keys at the younger ages.

A comparison of sightings data of 1977 and 1977/78 between the Indian Ocean and Series L and M in the North Pacific (SC/30/Doc 27) gave a ratio of density of 1.6 in favour of the North Pacific. This will give a very approximate current Indian Ocean stock size of 10,000. SC/30/Doc 30 points out that a sustained take of 120 could be taken from a population of 5,000. Continued catches of 156 from the Japanese coastal station have not seriously affected the North Pacific stock but a catch of 400 per year over 10 years off Peru may be having an effect. Consequently the sub-committee felt that a take of 120 in one year was acceptable.

Finally, it is noted that this is the third special permit and it was considered desirable to request a review of the future strategy of this work from the Japanese scientists at the next meeting.

11.2.2 North Pacific

11.2.2.1 North Pacific (Eastern)
SC/30/Doc 48 provided a total population estimate for this species in the equatorial eastern Pacific (between 10°N and 07°S, and from 90°W to 110°W) of about 10,000 with 9 calves per 100 adults. This indicates a calving season that corresponds with the Northern Hemisphere winter and that these whales are probably part of a migratory North Pacific stock on their winter grounds. Rice noted that most of the whales referred to as *Balaenoptera edeni* in his report were reported as *B. borealis* and *B. physalus* by Berzin, 1978 (*Rep. int. Whal. Commn* 28: 173–7).

11.2.2.2 North Pacific (Western)
In last year's report of the Scientific Committee (*Rep. int. Whal. Commn* 28: 64), the stock was classified as an Initial Management Stock with an estimated current population size of 17,840 and with a recommended catch limit of 524 whales, 90% of MSY.

The sub-committee reviewed marking, sightings, catch, mean catch length and catch effort data from the Japanese coastal and Japanese and Soviet pelagic operations.

To date there have been only nine usable tag recaptures from a total of 140 marked whales since 1972 (SC/30/Doc 28), from which a population estimate of 40,800 had been calculated for the period 1975–77.

The tag returns in 1977 suggested that coastal and oceanic populations may well be one intermingling stock.

Sightings data were given in SC/30/Doc 27. However, these were largely for areas outside Zones L and M, and hence were not suitable for stock analysis in the whaling grounds.

The mean lengths of the catches of Bryde's whales by sex in the Japanese coastal operations appeared to show a decline from 1968 to 1976 of approximately one foot. The same trend was observed in both males and females, which may indicate a shift in area of operations.

The mean lengths of the catches taken in the Japanese pelagic operations between 1974 and 1977 showed little variability and the Soviet mean length data between 1973 and 1977 appeared to be very stable.

The CPUE data for the Japanese coastal operations were very variable from year to year and this was explained as the result of fluctuations in abundance of the Bryde's whales with oceanographic conditions prevailing.

Japanese pelagic CPUE data showed no change from the 1976 figure, although in both 1976 and 1977 the CPUE data are higher than in 1974 and 1975. The Soviet CPUE data for Zones L21–25, however, showed a drop from the 1976 figure, and a suggestion of a decline since 1973. It was noted by the sub-committee that in 1977 the Soviet pelagic catch was only 275 of a potential catch limit of 500 Bryde's whales, although the number of CDW in Zones L21–25 was as high as some earlier seasons when the catch was higher (Ohsumi, SC/30/Doc 28).

Following Tillman (*Rep. int. Whal. Commn* 28: 315–7) the updated Soviet CPUE gave the following table:

Year	Total N. Pacific catch	USSR CPUE
1971	919	0.480
1972	201	0.111
1973	724	0.302
1974	1,363	0.295
1975	1,433	0.275
1976	1,340	0.255
1977	775	0.206

As much of the Soviet effort is devoted to sperm whales, the effort in May and June for Zones L and M (exclusive of 28, 29, 30), when and where over 70% of Bryde's whales are taken, might be a more appropriate measure and gave the following CPUE. Actual searching time may be approximated by assuming a 12 hour day and 1 hour subtracted for each sperm and Bryde's whale caught. This is given as CPUE′

	Soviet CPUE (CDW)	Soviet CPUE′ (CSW)
1973	0.895	873
1974	0.699	674
1975	0.904	963
1976	0.844	817
1977	0.293	269

These data show no statistically significant trends.

Veinger explained that three factors were responsible for the low Soviet catch and the large drop in CPUE: (1) that a special request for sperm whales meant that they were preferentially taken, (2) that in searching for sperm whales much time was lost through bad weather north of 40°S and (3) that the 200 mile exclusive Zones had posed difficulties for the fleet. Also the fleet arrived a little later than normal due to the factory ships being used for fish processing.

A modified DeLury analysis (Chapman SC/25/Doc 2) was attempted with the CPUE data and gave the following results.

The update of Tillman's analysis gave $N_{70} = 13,072$. Excluding the 1972 and 1977 data gave $N_{71} = 10,616$. The L and M series in May and June gave $N_{73} = 11,092$ and the modified CPUE′ gave $N_{73} = 10,424$. Taking these values back to 1970 with the catch equation gave an average $N_{70} = 11,476$.

It should be noted that the exclusion of the 1977 value in the May and June data sets gave very high values with no trend and that the Japanese pelagic CPUE shows a rise. These, the invariant length data and the Soviet explanation of the low 1977 value would suggest that 11,476 is an underestimate.

The mark and recaptures provide a second independent set of data. SC/30/Doc 28 gives 9 returns and an estimate of 40,800. It was noted that 7 came from Japanese vessels and 2 from Soviet vessels. The catch over the period 1973–77 was about the same for both fleets and although the 2:7 ratio may be due to chance, low Soviet returns in the past suggested that the Soviet catch should be reduced to 2/7th to compensate. This gave a revised weighted estimate of 24,416 over the period 1973–77. Relating this to the 1970 base level using the catch equation gave an estimate of $N_{70} = 28,000$.

An average of these two independent estimates was $N_{70} = 19,738$ which was regarded as acceptable as the CPUE data were thought to underestimate the stock size.

A further complication is that over the past 30 years the Japanese coastal fishery has taken a small catch of 156.5 per year. The sub-committee therefore assumed that the DeLury analysis gave not N_0 but an N equivalent to that commensurate with an equilibrium stock level of a take of 156.5. If it is assumed that MSYL is at 0.6 N_0 and that MSY = 0.04 × MSYL then a catch of 156.5 gives $N/N_0 = 0.939$ and so $N_0 = N_{70}/0.939 = 21,020$.

Consequently the current level (N_{79}) derived from the catch equation was $N_{79} = 15,561$ and it is at 123% of the MSYL (21,020 × 0.6) and the stock can be classified as an Initial Management Stock.

The recommended catch limit is 454.

11.2.3 Bryde's whales North Atlantic

No new information was available on the status, number of stocks, or distribution of Bryde's whales in the North Atlantic. Stock units in this region are unknown. The sub-committee noted that the stock(s) were essentially unexploited and that data were inadequate to provide any estimates of stock sizes. Therefore, the sub-committee recommended that stocks in this region should be classifed as Initial Management Stocks with zero quota pending satisfactory estimates of stock size.

Recommendations on stock classification and catch limits

11.2.1 Southern Hemisphere Bryde's whales – IMS, zero quota pending satisfactory estimates of stock size.
"Peruvian stock" – no increase in catches.

11.2.2 North Pacific Bryde's whales – The area should be divided into two stocks, separated at 160° W.
A. Western Stock – IMS, catch limit 454 whales.
B. Eastern Stock – IMS, zero quota pending satisfactory estimates of stock size.

11.2.3 North Atlantic Bryde's whales – IMS, zero quota pending satisfactory estimates of stock size.

Other recommendations

The sub-committee recommends that the Japanese research effort on Bryde's whales continues in the Southern Hemisphere as proposed in SC/30/Doc 30 which includes a catch of no more than 120 whales from the Indian Ocean under Special Permit.

Annex D

REPORT OF THE SUB-COMMITTEE ON NORTH ATLANTIC WHALES

Members: Brown (Convenor), Brownell, Christensen, Harwood, Jonsgård, Jónsson, Kapel, Lockyer, Mitchell, Rørvik, van Bree (part-time).

The sub-committee noted that information on protected species in the North Atlantic would be considered by the protected species sub-committee, and that bottlenose whales would be considered by the small cetaceans sub-committee.

Documentation available

SC/30/Docs 13, 20, 23, 60, 61, 62.
SC/30/Prog Reps 2, 3, 4, 7, 10, 11.

Geographical boundaries of stocks

As noted in *Rep. int. Whal. Commn* 28: 77, the co-ordinates for the boundaries of some stocks as defined last year by the Scientific Committee might need slight correction. These have now been compared with a large scale chart by Kapel and the necessary small corrections made (Appendix I). At the same time it was proposed that a small change be made in the northern boundary of stocks off East Greenland to bring it into line with the ICES Statistical Areas boundary. It will be necessary to examine the distribution of catches to determine the effect of this change and the sub-committee recommends that the adoption of all the proposed corrections and changes be considered again at the 1979 meeting.

11.3 Fin whales

Status and regulatory measures

A. *Nova Scotia Stock* – No new information was available for this stock and it is recommended that it continue to be classified as a Protection Stock.

B. *Newfoundland–Labrador Stock* – In the absence of new information, this stock should continue to be classified as an Initial Management Stock with a catch limit of 90 whales. No catches have been taken from this stock since 1972 (*Rep. int. Whal. Commn* 27: 48).

C. *West Greenland Stock* – The sub-committee agreed that there is no biological evidence that this is a discrete stock, but agreed that the distinction was useful for statistical purposes. Kapel (SC/30/Doc 23) provided some evidence that fin whales from this area were larger than those from other areas, but he felt that the measurements were not particularly reliable. The sub-committee recommended the development of a marking scheme for this population, possibly using a boat from the Norwegian small whale fishery, in an attempt to determine its size and relation to other stocks. Historical information on the fishery is provided in SC/30/Doc 23; an average of 22–23 animals was taken in the period 1924–39, and 1946–58; the document suggests that this level of exploitation was determined by factors other than the abundance of whales. Since 1958 only a very few fin whales have been taken, and Kapel believes that available information indicates that fin whales are more abundant off West Greenland than recent catches suggest. In the absence of firm evidence on the size of the population the sub-committee continues to classify it as a Sustained Management Stock (provisional) with a catch limit for 1979 of 5 animals, the average catch for the five years 1973–77. Kapel pointed out that most, if not all, of the animals described as "sei" whales in the period 1959–76 (SC/30/Doc 23, Table 1C) were fin whales. Incorporation of these animals would raise the mean of catches 1973–77 to 7.

D. *East Greenland–Iceland Stock* – The present position on the biological collections being made at the Icelandic whaling station was discussed. Collections are being made by a British biologist during the 1978 season and these will be continued in future seasons, by Icelandic or British biologists. Jónsson reported that it was intended to set up a Marine Mammal Section in the Marine Research Institute, and that the Icelandic biologist now being trained in Norway is expected to work in this Section.

Icelandic/British collections for seasons 1975, 1976 and 1977 are reported in SC/30/Doc 20. The newly calculated population estimate of 10,500 with a 95% confidence interval of 6,995–21,812 using this data is higher than the previous estimate of 8,300 (SC/25/Doc 5) but is no more reliable because of the assumptions made for the natural mortality of 0.040 ± 0.005 and of insignificant differences in Z values (SC/30/Doc 20). One new whale mark was recovered in 1977. Using the 1975, 1976 and 1977 catch data Rørvik updated the previous stock estimate based on marking (Rørvik, Jónsson, Mathison and Jonsgård, 1976 *Rit. Fisk* 5(5): 1–30). The new best estimate is 8,148 with a 95% confidence interval of 4,033–17,682. The exploitation rate is 2.7% with a 95% confidence interval of 1.4–6.2%. Rørvik has also re-calculated the increase in effort from 1948 to 1977 using data on total catch (27%) and whale units (26%). These two alternative calculations are in close agreement with the previous estimate of a 29% increase in effort using the fin whale catch (Rørvik *et al.*, 1976).

The sub-committee noted that catcher log book data from 1962–73 had been worked up (Rørvik *et al.*, 1976) and recommended that log book data from 1974 onwards should be examined with a view to the use of searching time as an indicator of population size. The sub-committee considers that this stock should continue to be classified as a Sustained Management Stock, with the existing catch limits. These are 1,524 whales in the six years 1977–82, with a total catch of no more than 304 in one year (*Rep. int. Whal. Commn* 27: 47). The Icelandic catch in 1977 was 144 (275 in 1976).

E. *North Norway Stock* – No new information was available on this stock, and it should remain provisionally classified as a Sustained Management Stock. Should whaling recommence, catches should not exceed the average catch over the period 1948–71 of 61 annually.

Catches have not been taken from this stock since 1971.

F. *West Norway and Faroe Island Stock* – In the absence of any new data, this should continue to be classified as a Protection Stock.

G. *Spain–Portugal–British Isles Stock* – The sub-committee is awaiting information from Spain on the 1976 and 1977 catches. If this is not available, the sub-committee recommends that the stock continue to be provisionally classified as a Sustained Management Stock for 1979, and that there be no increase in present catch levels. Best reported (pers. comm.) that the combined catcher/factory vessel *Sierra*, and a second vessel, are now based in the Canary Islands. Baleen whales are being caught and it seems likely that these include fin whales.

Sei whales

No new information was available on the identity of the different stocks. The sub-committee believes that marking data would provide much useful information, but because animals are seen only during the whaling season on the Icelandic whaling grounds, Jónsson reported that it is difficult to mount a marking programme using the station's catcher vessels.

Status and regulatory measures

A. *Nova Scotia Stock* – No new data were provided for the sub-committee and it is recommended that this should remain classified as a Protection Stock.

B. *Iceland–Denmark Strait Stock* – Biological material was collected by a British biologist during the 1977 season but the results of this work are not yet available. Collections are being made in 1978. An Icelandic or British biologist will be available to make further collections in future seasons. No marking was carried out in 1977 and none will be done in 1978 for the reason noted above. In the absence of any estimates of the size of the stock the sub-committee considers that the stock should continue to be classified as a Sustained Management Stock and that the current catch limit system should continue, although it is recognised that because of the erratic occurrence of the species on the whaling grounds, the present averaging process will result in a gradual decline in the size of the catch limit. For the five years 1973–77 the average catch is again 84 whales. The Icelandic catch in 1977 was 132 (3 in 1976).

Minke whales

Sex ratio

Because of the differential distribution by sex of minke whales, catches have tended to show a large proportion of females (SC/30/Doc 23; SC/30/Doc 62). The sub-committee expressed its concern about this biased ratio. Possible measures to counteract this effect are discussed for some stocks.

Stocks and regulatory measures

No new information was available on stock identity.

A. *Canadian East Coast Stock* – No new information was available and the sub-committee recommends that the stock should remain classified as a Sustained Management Stock with a catch limit of 48 whales. Catches have not been taken from this stock since 1972.

B. *West Greenland Stock* – Kapel reported that because of fine weather the Greenland based catch was approximately 250 animals (SC/30/Prog Rep 3), Christensen reported that 75 animals were taken by one Norwegian boat (SC/30/Doc 61). Kapel reported that a little biological material, including ear plugs, has been collected from the Greenlandic catch in 1977. In the absence of further information on the status of the stock, the sub-committee recommended that it remains classified as a Sustained Management Stock with a catch limit of 394 animals (the average catch for the period 1968–77). The sub-committee noted that females constituted more than two-thirds of the catch. Kapel provided preliminary evidence that the extension of the season had not altered the proportion of females in the catch (Appendix II). The sub-committee recommended that the effect on the population of this high take of females should be investigated.

C. *East Greenland–Iceland–Jan Mayen Stock* – The Icelandic season closed early in 1977; as a result 194 animals were taken instead of the quota of 200 (SC/30/Prog Rep 4). Due to the early closing of the Norwegian season (detailed in SC/30/Doc 61) no animals were taken by Norway. No new information on stock identity and size was available but 7 whales were marked in 1977 and marking will continue. Information from historical and biological studies of this stock is being compiled by an Icelandic biologist and should be available for the next meeting of the Scientific Committee. It was noted that statistics on effort and catch distribution are being collected for this stock. The sub-committee recommended that there should be no change in the present classification as a Sustained Management Stock with a catch limit of 320 whales (the average catch over the years 1961–75).

D. *Svalbard–Norway–British Isles Stock* – The Norwegian Government closed the season on 1 July due to marketing problems, but 1,697 whales were taken (SC/30/Doc 61). Christensen and Rørvik presented an analysis of mark returns (SC/30/Doc 60) which updated their previous analysis (*Rep. int. Whal. Commn* 28: 183–4) and provided an estimate of stock size of 50,592 animals with a 95% confidence interval ranging from 26,895 to 100,172. A yearly quota of 1,790 gives an exploitation rate of 3.5% with a 95% confidence interval ranging from 1.8% to 6.7%. The average distance moved by animals marked in 1975 and captured in 1977 was only 30 nautical miles; however, this was probably due to a very high catch in the marking area. Rørvik pointed out that the average distance moved by animals marked in 1975 and captured in1976 was 273 nautical miles, suggesting an adequate mixing of the marked animals. Two catching boats will be used to continue the marking programme in 1978. Christensen is continuing a study of the effects of weather conditions to refine the relationship between catch and effort (SC/30/Doc 62). It was noted that more females than males were taken in all seasons from 1970 to 1977; this is basically a result of segregation by sex in area and time. In particular, there is a high proportion of females in the Barents Sea and Svalbard areas early in the season, and no animals are taken in these areas after 1 July.

The 1977 catch contained 56.4% females; a decrease of 10.3% from the 1976 values (SC/30/Doc 62). However, the sub-committee recommends that some way be found to reduce the high proportion of females in the catch.

A programme of biological collections is being carried out in the 1978 season. Until more data are available on this stock, the sub-committee agreed that this stock should continue to be classified as a Sustained Management Stock with a catch limit of 1,790 animals (the average catch in the ten years 1966–75).

Sperm whales

No new information was available for any stock. Rørvik drew attention to the fact that the average length of sperm whales caught off Iceland has declined since 1957. Some of these variations are probably caused by segregation of animals by size (Rørvik, pers. comm.). He intends to prepare a paper on this subject. Collections of teeth and other biological material are being made from the Icelandic catch. There have been practical difficulties in working up the material but it is hoped to present an analysis of the results at the next meeting. Collections are also being made by an independent research worker at Madeira. Catch data are incomplete from 1976 from the Azores and Madeira, and from 1974 from Spain. The Icelandic catch in 1977 was 110 (111 in 1976).

In the absence of further information the sub-committee recommends that the North Atlantic sperm whale stock should remain classified as a Sustained Management Stock and that the catch remain at current levels, i.e. an average of 685 animals per year. The greater part of the catch is taken by non-member nations.

Processing of biological collections made in the North Atlantic area

The sub-committee understands that at present there are no problems relating to the processing of biological collections which are being made in the North Atlantic area, except for those made by non-member nations. The sub-committee believes that it is important to obtain biological material from the whales taken by Spanish land stations. Arrangements will be made for collections of ear plugs from minke whales made in the 1978 season to be examined by different laboratories to study possible variations in readability and the application of techniques to reduce this.

Competition effects between fin and sei whales

The possible consequences of competition between fin and sei whales were discussed in the light of SC/30/Doc 13. Mitchell noted that, historically, right whales also competed with sei whales. It is possible that an increase in the North Atlantic blue whale population would also affect sei whale stocks. SC/30/Doc 13 points out that if there is competition, both the potential yield from a stock and the size of the equilibrium population will be reduced. However, competition can increase the stability of stocks from which fixed quotas are taken. In reply to a question from Jónsson about the practical applications of this sort of analysis, Harwood admitted that it could only make qualitative predictions but that it did suggest that if catch was regulated on the basis of effort the effects of competition would be slight and this might be the safest policy to pursue. The sub-committee believes that research on the effects of competition should be continued.

IDCR – research proposals in the North Atlantic area

The 1977 meeting of the Scientific Committee agreed a list of research programmes (*Rep. int. Whal. Commn* 28: 40). Members of the sub-committee reported on the progress of the programmes relating to the North Atlantic region.

No. 4. Minke whales – collection and analysis of age data from the Norwegian fishery.

This programme will start in the 1978 whaling season.

No. 7. Sei whales – marking and sighting cruises.

No progress.

No. 8. Bottlenose whales – marking, sighting and collection of biological materials.

No money was available for this project in the 1978 season. This project will be reviewed again for the 1979 season.

No. 9. Sperm whales – collection and analysis of biological material from Madeira.

Collections are being made in the 1978 season.

No. 10. Fin whales – analysis of existing Icelandic/British biological collections and further collections.

Collections for 1975, 1976 and 1977 have been analysed and reported on. Additional collections are being made in 1978.

No. 11. Sperm whales – analysis of biological collections

In progress.

Recommendations

1. Stock classifications and catch limits for the 1979 season

FIN WHALE STOCKS

1. Nova Scotia: Protection Stock: Zero.
2. Newfoundland–Labrador: Initial Management Stock: 90.
3. West Greenland: Sustained Management Stock (provisional): 5.
4. East Greenland–Iceland: Sustained Management Stock: Total catch not to exceed 1,524 in the six years 1977 to 1982 inclusive, and no more than 304 in one year.
5. North Norway: Sustained Management Stock (provisional): 61.
6. West Norway–Faroe Islands: Protection Stock: Zero.
7. Spain–Portugal–British Isles: Sustained Management Stock (provisional): Catches not to exceed present levels.

SEI WHALE STOCKS

1. Nova Scotia: Protection Stock: Zero.
2. Iceland–Denmark Strait: Sustained Management Stock: 84.

MINKE WHALE STOCKS

1. Canadian East Coast: Sustained Management Stock: 48.
2. West Greenland: Sustained Management Stock (provisional): 394.
3. East Greenland–Iceland–Jan Mayen: Sustained Management Stock: 320.
4. Svalbard–Norway–British Isles: Sustained Management Stock: 1,790.

SPERM WHALE STOCKS

Sustained Management Stock: 685.

2. Other recommendations

1. Marking of fin whales off West Greenland.
2. Examination of catcher log book data from 1974 onwards for Icelandic fin whale catches.
3. Investigation of the effect of the high proportion of females in minke whale catches off West Greenland, and in the Svalbard–Norway–British Isles stock.
4. Collection of biological material from catches at Spanish Land Stations.

Appendix 1

GEOGRAPHICAL BOUNDARIES FOR FIN, MINKE AND SEI WHALE STOCKS IN THE NORTH ATLANTIC

The following changes should be made (*Rep. int. Whal. Commn* 28: 34, and Annex C, p. 77).

Fin whale stocks

1. *Nova Scotia*
   South and West of a line through:
   46°49′N 54°07′W (Cape St Mary's), ... (unchanged).
2. *Newfoundland–Labrador*
   West of a line through:
   ... (unchanged) ... 52°15′N 42°W, ... and
   North of a line through:
   ... (unchanged) ... 46°49′N 54°07′W (Cape St Mary's)
3. *West Greenland*
   East of a line through:
   ... (unchanged) ... 52°15′N 42°W
   and West of a line through:
   52°15′N 42°W, ... (unchanged).
4. *East Greenland–Iceland*
   East of a line through:
   ... (unchanged) ... and
   West of a line through:
   ... (unchanged) ... 73°30′N 3°E, and South of 73°30′N latitude.
5. *North Norway*
   North and East of a line through:
   73°30′N 20°30′W, 73°30′N 3°E, ... (unchanged) ...
6. *West Norway and Faroe Islands*
   South of a line through:
   ... (unchanged) ... and
   North of a line through ...
   (unchanged) 56°43′N, 8°13′E (Thyborøn).
7. *British Isles – Spain and Portugal*
   South of a line through:
   56°43′N, 8°13′E (Thyborøn), ... (unchanged).

Corresponding changes should, of course, be made for minke whale stocks 1, 2, 3 and 4, and sei whale stocks 1 and 2.

These adjustments bring the stock boundaries in better accordance with the ICNAF/ICES Divisions.

Appendix 2

Table 1

Information on sex ratios of minke whales caught by the Greenlanders
(Preliminary Analysis)

Region		1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964
NW	♂		2	–	–	2	1	4	3	1	–	–	–	–	–
	♀		20	14	24	27	30	18	13	14	13	–	–	–	–
	?		16	21	7	7	5	6	3	6	13	25	17	17	7
CWe	♂		–	–	–	–	–	–	–	1	–	–	5	2	1
	♀		–	–	–	–	–	–	–	5	–	–	5	2	3
	[		21	4	21	22	18	31	22	38	38	41	35	15	–
CWw	♂		–	–	–	–	–	1	–	4	10	5	14	3	4
	♀		–	–	–	–	–	6	–	7	18	17	29	5	15
	?		33	66	70	95	38	36	47	76	47	19	22	44	20
SWn	♂		–	–	–	–	–	–	–	–	–	–	–	12	2
	♀		–	–	–	–	–	–	–	–	–	–	–	5	1
	?		49	31	50	59	27	34	53	69	130	97	55	49	42
SWs	♂		–	–	6	6	5	1	9	8	–	2	5	3	19
	♀		–	–	9	12	10	1	7	17	16	25	15	17	18
	?		28	20	17	22	8	58	55	20	30	11	15	17	24
S	♂		–	1	–	–	–	–	–	–	-	–	–	–	2
	♀		–	5	–	–	–	–	–	–	–	–	–	–	2
	?		16	17	13	16	14	4	–	3	1	2	5	5	4

Table 2

Monthly distribution of catches of mink whales, by region in West Greenland, 1963–74
(from Kapel, 1977, *Rep. int. Whal. Commn* 27: 459)

Region	Jan.–Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
NW + CWe	3 (?)	1	4	64	126	147	127	63	23	–
CWw	8 (?)	1	20	94	139	172	116	94	23	8
SWn	–	1	11	36	84	73	29	18	6	1
SWs	15 (?)	142	199	163	107	113	81	142	64	13
S	2 (?)	4	5	5	8	2	13	11	14	2

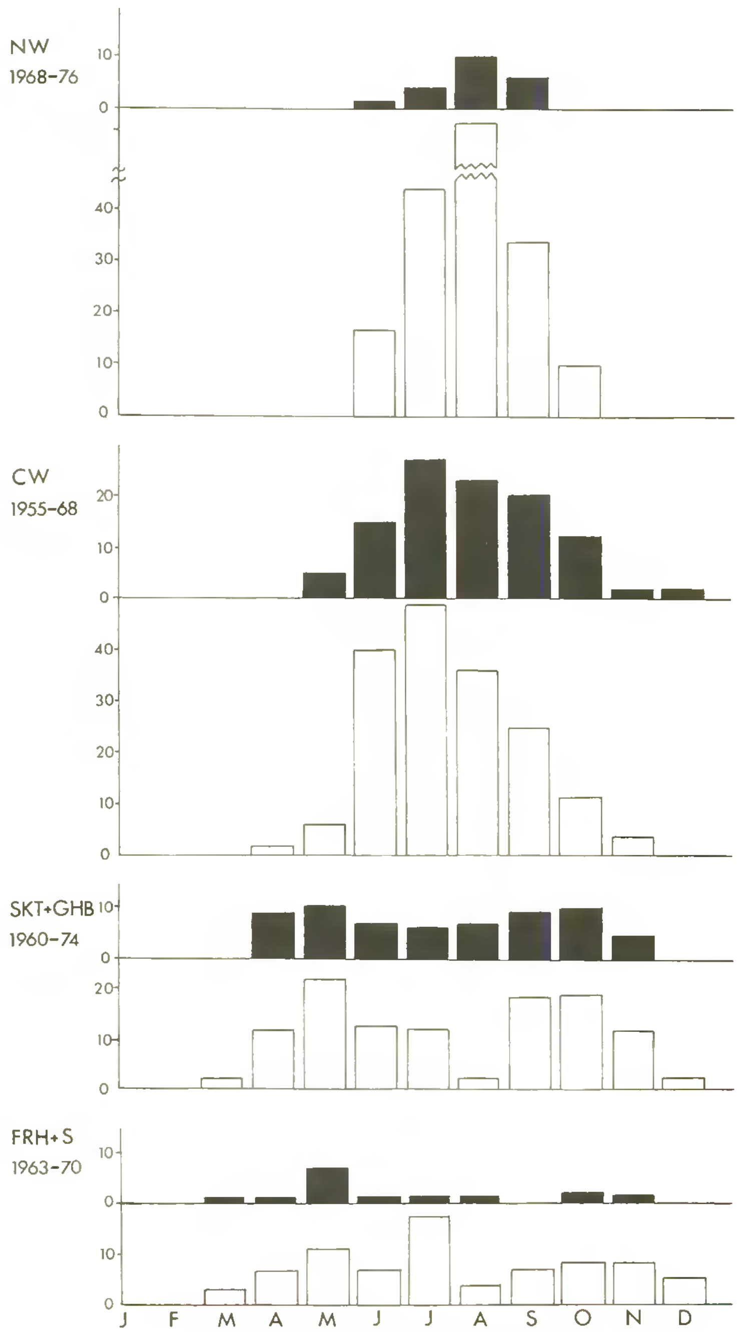

Fig. 1. Catch, by sex and month, of minke whales caught by Greenlanders.
■ males, □ females.

Table 3

Sex ratios for minke whales caught by Greenlanders

Region		Jan.–Mar. Sum.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
NW	♂	–	–	–	6	9	10	15	–	–	–
(1968–76)	♀	–	–	–	94	91	90	85	100	–	–
CW	♂	–	–	(45)	27	35	38	43	52	(20)	(100)
(1955–68)	♀	–	(100)	(55)	72	65	62	57	48	(80)	–
SKT + GHB	♂	–	45	32	37	35	(78)	35	36	31	–
(1960–74)	♀	(100)	55	68	63	65	(22)	65	64	65	(100)
FRH + S	♂	(33)	(13)	39	(13)	6	(20)	–	(20)	(11)	–
(1963–70)	♀	(66)	(87)	61	(87)	94	(80)	(100)	(80)	(89)	(100)

Annex E

REPORT OF THE SUB-COMMITTEE ON SPERM WHALES

Scientific Committee Agenda Item 10.3 – Sperm Whales

1. APPOINTMENT OF RAPPORTEURS

Duties were shared by Best, Cawthorn and Anderson.

2. ADOPTION OF AGENDA

The sub-committee adopted the agenda used at the special meeting in Cronulla, 1977 (*Rep. int. Whal. Comm* (special issue 2))

3. REVIEW OF DOCUMENTS AND STATISTICAL MATERIAL

SC/30/Docs 4, 10, 11, 14, 15, 17, 22, 33, 52, 58, 63, 64, 65, 66 on sperm whales were available to the sub-committee. Catch data for 1977/78 seasons were available from BIWS, provided by Vangstein. Peruvian data for catches by sex and length were provided in SC/30/Doc 68. Kirkwood had ensured that available catch data from 1946/47 to the present were accessible on the Cambridge University Computing Laboratory facilities.

4. EFFORT MODIFIERS

4.1 It was pointed out that at the Cronulla meeting the effort modifiers developed had been applied to catcher days rather than searching hours. Beddington (SC/30/Doc 3) proposed a new model for sperm whale fishing effort based on a breakdown of a Catcher Day's Work into time wasted, time handling and time searching. It was agreed that these factors would vary over time, i.e.

1. In the early years of the North Pacific pelagic fishery in in the 1950's, operations were carried out in high latitudes but in later years they had shifted to lower latitudes, so that the effective day-length had changed over time.
2. Industrial conditions had changed with more resting time allowed for catcher crews now than in the past.
3. With the shift in the latitude of operations, the object of the chase had changed from large males to herds of females and small males; chasing and handling times for these smaller animals would differ.
4. This change in the object of the chase would also have produced changes in the searching time, because the chasing time expended per whale would not be the same both for groups of animals and large solitary bulls. These changes would all affect the length of components of the working day and hence available searching time per day.

It was agreed that a small sub-committee would draw up a time budget for a Catcher Day's Work for the North Pacific sperm whale fishery with estimates of likely change over time.

The initial group reached broad agreement on the qualitative nature of changes in the Catcher Day's Work time budget and after further discussion in the sub-committee an expanded group (consisting of Beddington, Allen, Kirkwood, Ohsumi, Bannister, Doubleday and Best) were asked to quantify the components where possible with the following results, where CDW = $T_r + T_s + T_c + T_h + T_t + T_w$

4.2 Time resting (T_r) = 24 hour day length correction
In the North Pacific areas of operation have changed with current areas further south than previously. There is thus a correction to be applied for changes in day length. In addition there have been changes in working conditions, with crews requiring increased resting times. However, these two changes are correlated and as a single correction factor, an integer value for the mean of three mid-season months was used, with mid-season taken as 5 July. Day lengths used are the period between civil sunrise and civil sunset for the various latitudes (Table 1).

Table 1

Day length, civil sunrise to civil sunset, Northern Hemisphere (6° below horizon)

Series	Mean latitude	Day length at 5 July (hrs)	Mean day length at 5 June, 5 July, 5 August	Integer value used (hrs)
Q	62°N	24.0	24.0	24
P	55°N	18.0	17.3	18
N	45°N	16.1	15.8	16
M	35°N	14.9	14.5	15
L	25°N	14.1	13.9	14

4.3 Time handling (T_h) = handling time per whale
Time handling is defined as the period between a whale being struck and the catcher resuming a search. The major effect with changing operations in recent years is probably tonnage-dependent, with an effect only evident when vessels over 600 t entered the fishery. There is little information on handling times for smaller vessels. After 1957, however, most vessels catching sperm whales were over 600 t and despite the advantages of such larger vessels in their increased seaworthiness in bad weather, that effect may have been offset by increased handling times resulting in part from the increased height of the deck above sea level.

Handling time for the smaller males and females in current catches may be less than in the catches of earlier operations. However, the effects are likely to counteract each other with any net change small and difficult to quantify. The sub-committee agreed to accept the values for handling time given by Ohsumi in SC/SPC/Doc 2: pelagic 20 minutes; coastal 32 minutes.

4.4 Time wasted (T_w)
CPUE estimations have tended to deal with male catches only. Where female sperm whales are taken as part of a catch, the T_w component will have to be modified to compensate for time spent in catching and handling females. At the Cronulla meeting, a correction factor was applied to CDW for the proportion of female sperm whales in the catch, where:

$$\text{CDW (adjusted)} = \text{Total CDW} - (\text{female catch} \times 1.20)/11.83$$

With the change to the current procedure for CPUE estimation based on the catch/unit searching time, a modified form of the correction factor was applied (see Appendix C).

4.5 Time towing (T_t)

Towing time, which includes picking up time, can be expected to increase with decreasing stock numbers, an increase which may be balanced by changes in efficiency in more recent operations. In earlier operations a specific catcher was designated as tow boat within a pelagic fleet. As soon as sufficient whales had been taken, the designated tow boat would return to the factory ship with the whales taken. In current operations, no particular catcher is designated as a tow boat when sufficient whales are taken. However, there are documented values for T_t only for recent operations and the sub-committee agreed to adopt those given by Ohsumi in SC/SPC/Doc 2: pelagic 0.2217 hours per catcher per whale; coastal 2.13 hours per catcher per whale.

It was recognised that with a probable increase in the distance offshore of the whaling grounds in the coastal operations, towing time would also have increased; however, much of the increase would have taken place after dark and the figure given by Ohsumi was adopted for the whole period.

4.6 Chasing time (T_c)

The sub-committee agreed that it was necessary to obtain measures of chasing time for as many operations as possible. Ohsumi (SC/SPC/Doc 2) gave data on time budgets for pelagic and coastal whaling operations in the North Pacific during the 1977 and 1976/77 seasons respectively. The sub-committee adopted values of 0.5682 hours for current pelagic operations and 0.22 hours for current coastal operations.

It was noted that some of the technological changes that have occurred in the Japanese fleets have not been adopted by other fleets. The Soviet scientists reported that they had requested that information on chasing times in Soviet operations be collected and that the data would be made available as soon as it was obtained.

The sub-committee agreed that the effect of Asdic was on chasing time, which includes time spent on unsuccessful chases.

The effectiveness of Asdic is dependent to a very great extent on the skill of the operator, the type of Asdic in use, local ocean conditions and the species being hunted. Two main types of Asdic equipment are available – a fixed beam, shallow deflection type best suited to baleen whaling, and a variable or deeper-deflection type more suited to sperm whaling operations. Consequently Asdic factors should be calculated for individual operations.

Best stated that operations off Durban had used Asdic sets which were more effective in sperm whaling than the sets used by Japanese operations in the North Pacific and Antarctic. It also appeared likely that the effectiveness of Asdic at Durban was enhanced by co-operation between catches during the chase, particularly of female schools. After some discussion it was considered that such co-operation did not occur in higher latitudes, where schools of bulls were the object of the chase or when large solitary bulls were being chased.

The Soviet scientists stated that the North Pacific Soviet fleet only had 3–5 vessels with Asdic, that it had been introduced only for 3–4 seasons for experimental use in both the North Pacific and the Antarctic and was of the sort most useful for baleen whales.

The Peruvian fleet of three catchers has been fitted with Asdic since 1968 and has used the equipment consistently since then.

The Western Australian fleet has been fitted with Asdic since 1971, one set being of the Durban "sperm whale" type.

Data presented by Mitchell (SC/30/Doc 39) on chasing times for a Nova Scotia operation in 1970–72 gave a mean time to capture for successful chases of 1.86 hours ± 19 hours 00 minutes. Ohsumi (SC/SPC/Doc 2) gave values for average chasing time for pelagic operations of 0.59 hr (35 minutes), including unsuccessful chases. He estimated that chasing times varied from about 22 minutes for 30–35 ft whales to 35 minutes for 50–55 ft whales. In coastal operations, again including unsuccessful chases, an average time of 13 minutes per whale is given by Ohsumi. The sub-committee agreed that more detailed information on time budgets for all operations was essential and recognised that the values given by Mitchell are indicative of the long chasing times likely in areas where large solitary males are taken. (Asdic was sometimes used in the Canadian operation.)

The only available detailed CDW time budgets were those prepared by Ohsumi *loc. cit.* and the sub-committee asked Beddington, Kirkwood and Doubleday to investigate methods of assessment of the effects of Asdic on catch per searching hour, in particular to provide a modifying factor for pre-Asdic operations. Values for the Asdic correction factor of 0.26 hours per whale caught and 1.57 hours per whale caught for North Pacific pelagic and coastal operations respectively and 4.54 hours per whale caught for Southern Hemisphere pelagic operations were adopted (Appendices I and II).

The sub-committee noted the considerable difference between the correction factors (4.54 hours per whale caught in the Southern Hemisphere and 0.26 in the North Pacific pelagic operations). It was agreed that the high value for the Southern Ocean accords with an operation dealing with a high proportion of single adult males, widely dispersed. It was suggested that the much lower correction factor for North Pacific pelagic operations may result from differences in water depth and different distributions and densities of stocks.

The sub-committee agreed that it was not reasonable to pool the obtained values, and after considerable discussion agreed to adopt the values calculated for each operation.

4.7 Time searching (T_s)

Time available for searching is derived by difference once the other components of CDW are estimated. It was noted that with the increase in fuel oil prices after the oil crisis in 1973, catcher boat speeds have been reduced from 14.5 knots to 12 knots, a change of 17%. This should be taken into account in the calculation of post-1973 effort for both the North Pacific and the Southern Ocean.

5. STOCK IDENTITY

5.1 Northern Hemisphere

North Pacific

The proposal in SC/30/Doc 58 for three stock divisions, based on distributions of different fluke notch shapes, was examined by the sub-committee. It was recognised that the report was preliminary and required additional data.

The sub-committee again discussed briefly the paper submitted by Mitchell to the Cronulla meeting (SC/SPC/Doc 20). While noting Mitchell's view that biological evidence for three separate stocks was growing, the sub-committee agreed to the boundary as shown in Fig. 1. The boundary agreed to at the Cronulla meeting was retained north of 50°N.

The change was considered by the Scientific Committee to be a conservative one in that the zone of mixing recognised by Ohsumi and Masaki (1977, *Rep. int. Whal. Commn* 27: 173) was excluded from the Eastern Division stock, the earlier boundary having run through the Hawaiian group.

The sub-committee recognised that in recommending yields for the Western Division, it might be necessary to further divide the Western Division into two statistical areas to ensure that catch effort was more evenly distributed.

Mitchell believed that a more conservative approach is to include the 10° square P26 in an eastern stock on the basis of distribution of catches and general trends in the migration of sperm whales and anecdotal information on their movement through the eastern Aleutians (cf. Cronulla document SC/SPC/20).

Ohsumi believed that marking results showed that a significant amount of mixing of stocks of large males occurred between 160°E and 160°W, north of 50°N and that consideration should be given to delineation of a discrete mixing zone in that region which should also be treated as a separate statistical area.

5.2 Southern Hemisphere

In the absence of any additional information, the nine current Southern Hemisphere sperm whale management Divisions were accepted by the sub-committee.

6. BIOLOGICAL PARAMETERS

6.1 Pregnancy rate

The sub-committee agreed that a likely range of pregnancy rates in a stock which contained an adequate number of mature males was from 20% when the females were essentially unexploited, to 25% when the female stock was close to zero. Some evidence of an increase in pregnancy rate with increased exploitation of females was given in SC/30/Doc 33 for the Durban stock – this response appeared to occur mainly in older females.

A model of pregnancy rate change based on the assumption that there was essentially a random search of males for females (SC/30/Doc 17) was considered by the Committee to produce biologically unrealistic results, in that there was essentially no response in pregnancy rate to a reduction in population until stocks of females had been reduced to nearly 50% of their initial size.

The sub-committee agreed that for the present, a density dependent exponent of 1.4 should continue to be used for changes in this parameter: the degree of change shown by the Durban stock to a relatively small degree of reduction tended to support this assumption rather than that of a linear response.

Allen noted that, under the modified logistic model, the MSY for a given value of $(r_0 - m)$ increases as the density dependent exponent, and therefore the MSYL, is increased. Thus if the value of $(r_0 - m)$ used in any model has been estimated directly, as from the considered maximum reproductive potential of the species, there is a risk that use of an over-estimate of the MSYL will lead to an over-estimate of MSY, and under the New Management Procedure, a reduction of the population. The cut-off applied in the New Management Procedure to the quota for populations estimated to be below MSYL would, however, operate from the estimated and not the true MSYL, thereby preventing further population reduction, provided the true population level relative to unexploited is known. The potential risk associated in this way with an over-estimate of MSYL will also not apply where the value of $(r_0 - m)$ is deduced from an estimate of current recruitment rate, and not estimated directly.

6.2 Reserve male ratio

The Committee had before it two alternative models of the effect of a reduction in the ratio of males to females. The first of these was the assumption in the existing model that

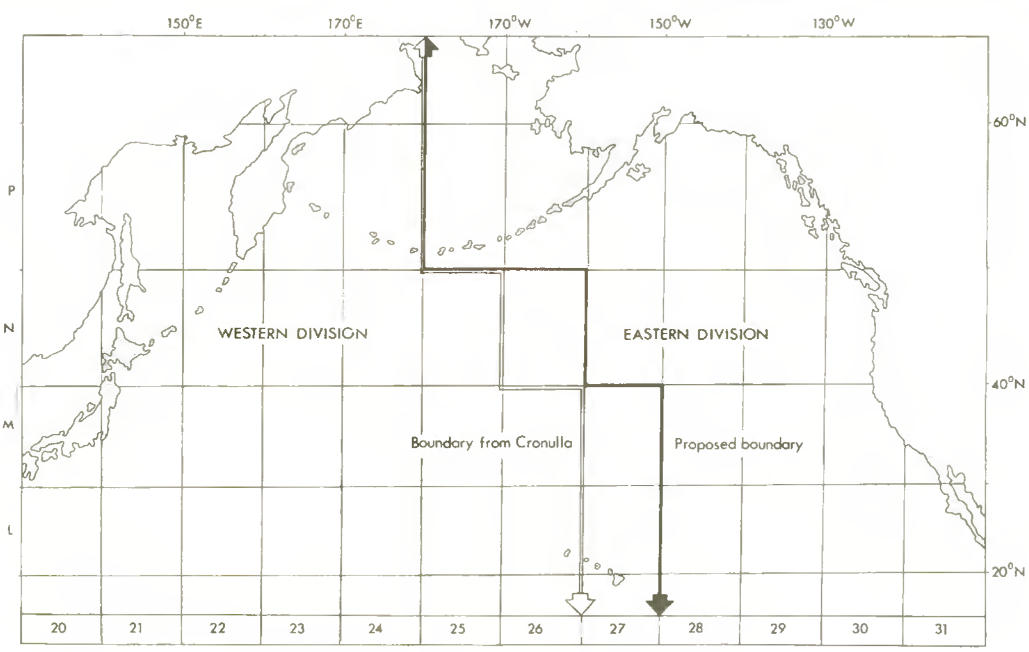

Fig. 1. North Pacific sperm whale stock Divisions.

Table 2a

Sperm whale population parameters – North Pacific

		1976 (a)	1977 (b)			1978 (c)		Notes
			pre-1960	61–72	73–77	60–72	72–78	
Average age at recruitment	♂	15	13	15	13	16	13	By inspection of length frequency data pre-1972
	♀	15	10	15	13	10	10	stock figures corrected for 13–16 year classes.
Average age at maturity	♂*	25		25		25		Both values are for both exploited and
(*Social maturity.)	♀	10		10		10		unexploited stocks. *Rep. int. Whal. Commn* 27: 241.
Natural mortality rate	Juvenile	0.05		0.0589		0.055		More conservative figure agreed to by sub-committee.
	Mature	0.33–0.05		0.0589		0.0926		From balance equation.
Mean number of mature females available to a school master		10		10		10		Mean school size 15 with 1.5 mature males. *Rep. int. Whal. Comm* 27: 241.
Reserve male ratio		0.3		0.3		0.3		To give 2 males per school of 15 females. *Rep. int. Whal. Commn* 27: 42.
Pregnancy rate	Unexploited	19		20		20		Theoretical minimum 4-year calving interval.
(theoretical values)	Exploited	25		25		25		*Rep. int. Whal. Commn* 27: 42.
Density-dependent exponent		1.4		1.4		1.4		Representing an MSY level of 60%. *Rep. int. Whal. Commn* 28: 61.

(a) Canberra 1977 (values except for mean age at recruitment as at La Jolla, *Rep. int. Whal. Commn* 27: 42).
(b) Cronulla 1977 (see *Rep. int. Whal. Commn* 28: 60–62 and SC/30/Rep 2). 42.)
(c) Cambridge, 1978.

there was no change in the pregnancy rate until the mature male stock had fallen to a critically low level (taken to be a ratio of two mature males to each school of mature females). The pregnancy rate would then fall in a linear fashion to zero as the male : female ratio declined to zero.

The alternative model made no assumptions about the reserve male ratio, but assumed that the limiting factor to fertilisation was the probability of adequate mixing of males and females (SC/30/Doc 4). Assuming the probability of 100% mixing at the initial ratio of males to females in the unexploited stocks, the model indicated that if the females remained unexploited the slow initial decline in pregnancy rate would accelerate as male stocks were progressively depleted.

The Committee had much discussion about the validity of these two models. Some members considered that the second model was a more reasonable representation of the likely response given the dispersed nature of female schools on the breeding grounds, and they considered that an assumption of perfect mixing between the sexes at all levels down to a highly disturbed sex-ratio and reduced density was unrealistic. They also considered that it is more conservative to adopt this model.

Other members felt that because of the nature of the

Table 2b

Sperm whale population parameters – Southern Hemisphere

		1976 (a)	1977 (b)	1978 (c)	Notes
		(Div. 9)			
Average age at recruitment	♂	20 (15)		20	To be refined by reference to length frequency analysis
	♀	13 (13)		13	of Divisional catches.
Average age at maturity	♂*	25	25	25	As for Northern Hemisphere.
(*Social maturity.)	♀	8.5–10	10	10	
Natural mortality	Juvenile – 1	0.133	0.133		Juvenile mortality derived from balance equation in
rate	Mature – 1	0.05 (2 yrs+)	0.05	0.055	analysis.
Mean number of mature females available to a school master		10	10	10	As for Northern Hemisphere.
Reserve male ratio		0.3	0.3	0.3	As for Northern Hemisphere.
Pregnancy rate	Unexploited	0.19	0.19	20	Theoretical values, as for Northern Hemisphere.
	Exploited	0.25	25	25	
Density-dependent exponent		–	1.4	1.4	As for Northern Hemisphere.

(a) *Rep. int. Whal. Commn* 27 (1977): 42.
(b) *Rep. int. Whal. Commn* 28 (1978): 57.
(c) Cambridge, 1978.

sperm whale's social organisation it was reasonable to assume that effective pregnancy rates would be maintained until the ratio of mature males to females dropped very considerably. They pointed out that the critical reserve ratio used inferred that at this level mature males fertilised only three females annually, i.e. 1.5 per mature male per year. They also indicated that the model was conservative in that it assumed that all males below 25 years of age played no part in breeding (despite the fact that males 10 years and older are capable of producing spermatozoa), and that it assumed that school masters remained with the school for the duration of the breeding season and did not move between schools after fertilising the females present. These members of the sub-committee also felt that it was unrealistic to assume that there would be a problem of adequate mixing of sexes in such a mobile and apparently highly evolved mammal.

It was felt that the suitability of either model might be judged from the correlation between trends in apparent pregnancy rates and the relative degree of reduction of male and female stocks.

Chapman, Best, Breiwick and Bannister undertook analysis of apparent pregnancy rates for Albany (Western Australia), Peru, Southern Hemisphere Divisions 4 and 5 and the Western stock of the North Pacific (Appendix IV). Significant trends with time could only be detected for the Australian data (adjusted to account for missed foetuses) and the Western stock of the North Pacific (by comparing the summed 1966–69 data with those summed for 1974–76). In both regions a statistically significant decline was observed.

The sub-committee agreed that a reserve male value of 0.3 males per 10 mature females would be adopted prior to the assessments being available. While many members of the sub-committee considered that a value of 0.3 was sufficiently conservative, others did not and would have preferred a higher value.

Mitchell and Fortom-Gouin believed that either the reserve breeding male ratio be increased or that protection of both breeding bulls and cows should be extended to cover more of the breeding season (see Table 1 and recommendation 2, Mitchell and Kozicki, 1978, *Rep. int. Whal. Commn* 28: 195–8).

6.3 Age at recruitment

North Pacific

A sub-group (Allen, Beddington and Kirkwood) examined length distributions for Areas III + IV and V (representative of catches in current Eastern and Western Divisions) and age distributions of the total North Pacific as provided at the Cronulla meeting (SC/SPC/9 and 3). By inspection of those data and Ohsumi's raw age-length key (1977, *Rep. int. Whal. Commn* 27: 298) they agreed that the average age of recruitment in both Divisions should be taken as 16 years, corresponding to an average length of 39 feet. However, they recognised that in the years 1966–69 inclusive, in the Western Division, there was a much higher proportion of small animals in catches and those years were omitted from CPUE estimations for the Western Division.

The sub-committee agreed to adopt the value of 16 years as the average age at recruitment for males in both Divisions, and that a value of 10 years would be used for the average age of recruitment for females in both areas.

7. STOCK ESTIMATION

7.1 Stock estimation programs

The sub-committee had available programs used at the Cronulla meeting for stock estimations, with the new alternative outlined in SC/30/Doc 12 in which a maximum likelihood estimation technique is used rather than the least squares fitting approach previously employed.

In addition, the sub-committee discussed at length the applicability of the approach in SC/30/Doc 4 (see Sections 7.1, 7.2) and agreed that it could be incorporated into both the stock estimation procedure POPDYN and SPVAP, the MSYL and yield estimating procedure. During the course of the meeting, however, it became apparent that there would be insufficient time to incorporate the necessary changes in POPDYN and SPVAP and the sub-committee agreed to use the procedures adopted at Cronulla with subsequent modifications for maximum likelihood estimation.

7.2 Stock estimates

The Committee agreed that stock estimates should be obtained from Japanese pelagic data for both Western and Eastern Divisions. The Soviet data did not give adequate time series showing a decline in CPUE which could be used in the estimations. The time series used for Japanese and Soviet data are given in Appendix V.

The years 1966–69 were omitted from the Japanese Western Division estimation following inspection of length frequencies in the catches, where the sub-committee noted that a different component of the stock was being exploited over that period.

The sub-committee noted that in estimating the 1979 catches, it had been assumed that catch limits set by the Special Meeting of the Commission in Tokyo represented the actual catch in 1978.

The sub-committee agreed that although information on catches in the early years of the North Pacific fishery were not complete, those available should be included and therefore estimates of initial population size are for the year 1910. The data available are given in SC/30/Doc 11.

The results of the assessments are shown in Table 3.

The POPDYN model predicted that pregnancy rates in the Western stock would remain fairly constant (at around 21.5%) prior to 1970, but would decline thereafter as a result of the reserve male ratio falling below 0.3 from 1970 onwards.

The pregnancy rate predicted in 1975 was 11.5%, representing a decrease of 46.5% from 1968. The decline in

Table 3

North Pacific stock sizes ($\times 10^3$)
(Average age at recruitment shown in parentheses)

	Western Division	Eastern Division
	Males	
1910	104.7 (16)	121.0 (16)
1979	35.1 (16)	89.8 (16)
	Females	
1910	145.6 (10)	168.3 (10)
1979	110.2 (10)	162.6 (10)

observed pregnancy rates between 1966–69 and 1974–76 (and which apparently referred to the Western stock – see Appendix IV) was 38%. The sub-committee noted that this agreed with predictions from the current model and that proposed in SC/30/Doc 4, but did not provide an adequate basis for determining which pregnancy rate model was the more appropriate. The matching of the observed decline with that predicted by the POPDYN model, however, did provide some confirmation of the population trends produced by this method.

Classifications and catch limits – North Pacific

Using the population estimates obtained above the SPVAP programme was employed, with population parameters as already defined to give MSY levels and yield. The results are shown in Table 4.

Table 4

Estimated stock sizes and MSY and recommended catch limits North Pacific (Average age at recruitment shown in parentheses)

	Western Division		Eastern Division	
	Males	Females	Males	Females
1910 stock ($\times 10^3$)	123.4 (13)	145.6 (mature)	142.7 (13)	168.3 (mature)
1979 stock ($\times 10^3$)	52.7 (13)	110.2 (mature)	111.4 (13)	162.6 (mature)
1979/1910	42.7%	75.7%	78.1%	96.6%
MSY level/ 1910 stock	45.9%	80.4%	45.9%	80.4%
MSY	2897	641	3349	741
1979 MSY level	93%	94%	170%	120%
Classification	SMS	SMS	IMS	IMS
Catch limits	782	231	3014	667
Total catch males 3796				
females 898				

The sub-committee noted that the decline in observed pregnancy rates since 1966–69 was in the same order as the changes in pregnancy rate predicted for a drop in reserve male ratio and noted with some concern that current yields were based on a declining stock. Extrapolations from the 1979 stock level, made with an assumption of zero catches in the period 1979–89, are given in Table 5.

8. NEED FOR CLOSED SEASON FOR MALES

The sub-committee referred to the decision at Cronulla (IWC/SPEC 77/02) and Canberra (*Rep. int. Whal. Commn* 28: 70) and confirmed its view that the present closed seasons for socially mature males in both the North Pacific and Southern Hemisphere should be retained.

The sub-committee also considered the effects of taking females from breeding schools. It was noted that information available indicated more cohesion in female schools than in all male or mixed schools, and that school masters appeared to spend only a short period with the breeding schools (see 6.2). While some members recognised that protection of females during the breeding season would be a more conservative measure, others considered current management procedures allow a sufficient margin of safety.

Table 5

North Pacific sperm whales – Western Division stock
Extrapolation from 1979 to 1989 based on zero catches from 1979 onwards

Year	Exploitable females	Exploitable males 16–24	Exploitable males over 25	Total exploitable males	Ratio females: males
1979	110,200	28,500	6,600	35,100	16.7:1
1980	110,700	31,200	7,200	38,400	15.4:1
1981	109,900	33,500	8,100	41,600	13.6:1
1982	108,100	35,300	9,300	44,600	11.6:1
1983	106,100	36,800	10,700	47,500	9.8:1
1984	104,100	37,900	12,100	50,000	8.6:1
1985	102,000	38,800	13,600	52,400	7.5:1
1986	99,700	38,800	15,300	54,100	6.5:1
1987	97,500	37,800	17,200	55,000	5.7:1
1988	95,400	35,800	19,200	55,000	5.0:1
1989	93,400	33,400	21,300	54,700	4.4:1

Ages at recruitment to exploitable stocks are 10 years for mature females, 16 years for immature males and 25 years for socially mature males. The decline in pregnancy rates which is estimated to have begun in 1970 will thus not be reflected in a decline in exploitable female stocks until 1980, in exploitable immature male stocks until 1986 and socially mature male stock until 1995.

The sub-committee recognised that the peak conception period off western South America, particularly off Peru, may well occur earlier in the year than in other parts of the southern ocean. It urges analyses of available data for previous Division 9 catches so that an appropriate regulation can be framed for that area.

While the sub-committee therefore recognises a possible latitudinal shift in the timing of the peak of conception in the Southern Hemisphere the information available for the North Pacific indicate no such changes over the latitudinal zones covered by the present fishery.

Appendix I

ESTIMATION OF CHASING TIME PRIOR TO THE INTRODUCTION OF ASDIC IN SPERM WHALING

J. R. Beddington, G. P. Kirkwood and W. G. Doubleday

Introduction

At the Cronulla meeting of the Scientific Committee, data were presented on the effect of Asdic on the catch per catcher day of both the pelagic and coastal whaling of the Japanese whaling operations (Ohsumi SPC/SC/Doc 3). In the same document the present state of the components of the time budget of both operations were presented. In discussion it was claimed that the main effect of Asdic was to alter the chasing time of the catcher boat. This paper presents a method of calculating the necessary change in chasing time that would be produced by the observed changes in catch per catcher day, on the assumption that this is truly the main effect.

Model structure
Assume each catcher day worked (CDW) has the following components:

$$CDW = 24 \text{ hours}$$

where T_0 is the total number of daylight hours, and T_r the resting time.

Then

$$T_0 = T_s + hW + T_cW = T_0 + T_r$$

where: T_s = No. searching hours/day; h = No. handling hours/whale; T_c = No. chasing hours/whale/day; and W = total catch of whales per day.

If C is the catch of males per CDW, the previously used catch per unit effort, then the corresponding catch per searching hour is

$$\frac{C}{T_0 - hW - T_cW}$$

Assuming vessels with and without Asdic were fishing the same whale stocks, and were identical in all respects except for Asdic, the catches per searching hour of the different vessels in the same year should be equal.

Then for a male only catch:

$$\frac{C}{T_0 - hC - T_c} = \frac{C'}{T_0 - hC' - xC'}$$

where the dashes denote vessels without Asdic, and x is the unknown chasing time per whale caught without Asdic. Then:

$$x = T_c + T_0 \;\frac{1}{C'} - \frac{1}{C} \quad \text{hours/whales caught/day.}$$

If $C = (1 + \alpha)C'$, so that α is the previous "Asdic factor",

$$x = T_c + T_0 \frac{\alpha}{C'(1+\alpha)} \text{ hours/whale caught/day}$$

and the change in chasing time per whale caught per day is thus:

$$\frac{T_0\,\alpha}{C'(1+\alpha)}$$

Results
Table 1 presents the decrease in catching time per whale in hours that would be necessary for some specified improvement in the catch per catcher day. Two other factors influence this decrease: the duration of the working day T_0 and the pre-Asdic level of catch per catcher day. Data are tabulated for three levels of the working day, five levels of pre-Asdic catch per catcher day and six levels of percentage of increase in the catch per catcher day.

Table 1

Decreases in chasing time in hours following the introduction of Asdic

		Pre-Asdic CPUE				
	Alpha	0.5	1	2	3	4
	0.05	1.5	0.7	0.3	0.2	0.1
	0.1	2.9	1.4	0.7	0.4	0.3
T_0 = 16 hours	0.2	5.3	2.6	1.3	0.8	0.6
	0.3	7.3	3.6	1.8	1.2	0.9
	0.4	9.1	4.5	2.2	1.5	1.1
	0.5	10.6	5.3	2.6	1.7	1.3
	0.05	1.7	0.8	0.4	0.2	0.2
	0.1	3.2	1.6	0.8	0.5	0.4
T_0 = 18 hours	0.2	6.0	3.0	1.5	1.0	0.7
	0.3	8.3	4.1	2.0	1.3	1.0
	0.4	10.2	5.1	2.5	1.7	1.2
	0.5	12.0	6.0	3.0	2.0	1.5
	0.05	1.9	0.9	0.4	0.3	0.2
	0.1	3.6	1.8	0.9	0.6	0.4
T_0 = 20 hours	0.2	6.6	3.3	1.6	1.1	0.8
	0.3	9.2	4.6	2.3	1.5	1.1
	0.4	11.4	5.7	2.8	1.9	1.4
	0.5	13.3	6.6	3.3	2.2	1.6

We comment only that the values of the chasing time change include time spent unsuccessfully chasing whales.

For catching operations using Asdic, we have available estimates of T_0, h and T_c. We may now obtain an estimate of the chasing time before the introduction of Asdic.

Catches of males per CDW are available for Japanese pelagic whaling operations in the North Pacific for vessels with and without Asdic between 1958 and 1961. During that period the catch of females was extremely small, so that we may assume that in the above notation W = C.

In both the Southern Ocean and Japanese coastal fisheries a substantial female catch occurred during the period for which comparative information is available. It is a straightforward process to adjust this estimation procedure to allow for this catch.

In concluding we note that such estimates of the change in chasing time would be made for within season comparisons of catch per catcher day. They are thus likely to be underestimates of the true change.

Appendix II

ESTIMATES OF THE EFFECT OF ASDIC ON CHASING TIME FOR JAPANESE WHALING OPERATIONS

J. R. Beddington and G. P. Kirkwood

Using the procedure outlined in Appendix I, the following results were obtained for the effect of Asdic on the chasing times of catcher boats.

Pelagic North Pacific (data source Ohsumi SC/SPC/Doc 2)
Mean value of chasing time change for various expeditions = 0.26 hours/whale caught.

Standard error = 0.116.
d.f. = 6.

Individual estimates of change in chasing time were obtained and averaged to produce mean.

Mean daylength: Pelagic (P zone) 18 hr; Coastal 11.6–15.5 hr.

Coastal North Pacific
Mean values of male CPUE for males = 0.805.
Mean value for Asdic factor = 0.254.
(Data source Ohsumi SC/SPC/Doc 2)
Mean value of female CPUE obtained from Tillman, 1977 (*Rep. int. Whal. Commn* 27: 343–50) = 1.188.
Estimate of chasing time change = 1.57 hours/whale caught.

Southern Ocean – Mean daylength 19 hr.
Value of CPUE per year obtained from Gambell (*Rep. int. Whal. Commn* 27: 280–6).
Values of Asdic factor obtained from Ohsumi (SC/SPC/Doc 2).
Mean value of CPUE = 0.863.
Mean value of Asdic factor = 0.26.
Estimate of change in chasing time = 4.54 hours/whale caught.

Appendix III
CALCULATION OF EFFORT AND CPUE
G. P. Kirkwood and J. R. Beddington

If T_s = searching time in hours, T_h = handling time in hours, T_c = chasing time in hours then:

T_s = Catcher days x Day length correction – Male catch ($T_h + T_t + T_c$) – Female catch x Total female time

T_c = (1 – Proportion of fleet with Asdic) x Asdic correction + Basic chasing time + r (mean length – mean length$_{1977}$) where r is derived from length : chasing time regression line.

$$\text{Effort} = \frac{\text{No. hours searched x proportion of fleet less than 600 t x Speed in knots}}{\text{Pre-1973 speed (= 14.5 knots)}}$$

$$\text{CPUE} = \frac{\text{Male catch}}{\text{Effort}}$$

The following values were used:

	North Pacific		Southern Hemisphere
	Coastal	Pelagic	
Handling time (hr): T_h	0.53	0.33	0.33
Towing time (hr): T_t	2.13	0.2213	0.2213
Chasing time (hr): T_c	0.22	0.5682	0.5682
Chasing time correction (hr/whale)	+1.57	+0.26	+4.54
Total time/female (hr)	1.2	1.137	1.13
Mean length (1977) (ft)	41.9	41.9	–
Length/T_c (min/ft)	–	0.4656	–

The proportion of the Japanese fleets equipped with Asdic was as follows:

	North Pacific[1]		Antarctic Expeditions[2]	
	Pelagic	Coastal		
1954	0	–		
1955	0	–	1955/56	0.0
1956	0	–	1956/57	0.038
1957	0	0	1957/58	0.091
1958	0.30	0	1958/59	0.176
1959	0.40	0	1959/60	0.256
1960	0.60	0.15	1960/61	0.357
1961	0.85	0.18	1961/62	0.547
1962	1.00	0.25	1962/63	0.633
1963	1.00	0.33	1963/64	0.628
1964	1.00	0.30	1964/65	0.653
1965	1.00	0.32	1965/66	0.750

	North Pacific[1]		Antarctic Expeditions[2]	
	Pelagic	Coastal		
1966	1.00	0.40	1966/67	0.800
1967	1.00	0.50	1967/68	0.857
1968	1.00	0.90	1968/69	0.974
1969	1.00	0.90	1969/70	0.971
1970	1.00	1.00	1970/71	0.971
1971	1.00	1.00	1971/72	0.973
1972	1.00	0.95	1972/73	0.971
1973	1.00	0.95	1973/74	0.967
1974	1.00	0.94	1974/75	0.964
1975	1.00	0.94	1975/76	–
1976	1.00	0.93		

[1] Ohsumi, S. (SC/SPC/Doc 2, approximate values from Fig. 5).
[2] Ohsumi, S. Sperm whale catch efficiency by Japanese whaling catcher boats in the Antarctic. (*Rep. int. Whal. Commn* 27: 305–7.)

Appendix IV

D. G. Chapman, P. B. Best and J. M. Breiwick

Table 1

Grouped pregnancy rate data for North Pacific sperm whales (presumed Western Pacific stock) – biological records SC/SPC/19

Month	1966–69 No. of mature females (% current preg.) (% previous preg.)	1974–76 No. of mature females (% current preg.) (% previous preg.)	Diff. (% of 1966–69 value)
May	118	78	
	(12.7)	(5.1)	–60
	(35.6)	(21.8)	–39
June	348	482	
	(23.0)	(10.8)	–53
	(26.1)	(18.3)	–30
July	173	305	
	(31.2)	(23.0)	–26
	(20.8)	(16.4)	–21
August	175	232	
	(32.6)	(25.4)	–22
	(17.7)	(7.8)	–56
September	–	213	
		(24.4)	
		(2.3)	
Mean			–38

Chi-square value (current preg.) = 13.32, $p < 0.05$.
(previous preg.) = 14.49, $p < 0.05$.

There is thus a significant decline in the 1974–76 rate of about 38% of the 1966–69 pregnancy rate.

Table 2

Australia (from SC/30/Prog Rep 1)

Year	No. exam.	% Preg.[1]	% Doubtful	Adjusted preg.[2] 37%	% Preg. (adjusted)
1964	65	30.8[3]	18.5	6.8	37.6
1965	46	26.1[3]	8.7	3.2	29.3
1973	101	23.8[4]	11.9	4.4	28.2
1974	156	12.2[5]	26.9	10.0	22.2
1976	153	9.8[5]	7.2	2.7	12.5
1977	43	14.0[5]	23.3	8.6	22.6

[1] All current pairing season.
[2] Based on sizes of corpora lutea.
[3] Biologists.
[4] Technician.
[5] Inspectors.

Table 3

USSR data[1] (Southern Hemisphere) from SC/30/Doc 65

	1964/65–1971/72			1972/73–1967/77		
Div. 4	n	% early	% late	n	% early	% late
Nov.	117	11.1	30.8	341	7.6	15.5
Dec.	54	3.7	31.5	0	–	–
Jan.	10	20.0	10.0	28	10.7	14.3
Feb.	2	0	0	0	–	–
March	9	44.4	0	0	–	–
April	4	25.0	0	0	–	–
	196			369		
Div. 5						
Oct.	54	0	33.3	0	–	–
Nov.	11	9.1	27.3	9	0	22.2
Dec.	35	14.3	45.7	0	–	–
Jan.	4	0	50.0	20	10.0	40.0
Feb.	0	–	–	0	–	–
March	1	0	100.0	0	–	–
April	12	16.7	8.3	0	–	–
	117			29		

[1] Partly biologists' records.

Table 4

Apparent pregnancy rates: Peru (Division 9) from Valdivia (pers. comm.)

	1975				1976				1977				Total			
	N	% Preg.	% R.O.[1]	Total	N	% Preg.	% R.O.[1]	Total	N	% Preg.	% R.O.[1]	Total	N	% Preg.	% R.O.[1]	Total
January	–	–	–	–	–	–	–	–	5	0	40.0	40.0	5	0	40.0	40.0
February	–	–	–	–	–	–	–	–	5	0	20.0	20.0	5	0	20.0	20.0
March	–	–	–	–	–	–	–	–	2	0	0	0	2	0	0	0
April	–	–	–	–	5	0	0	0	22	9.1	22.7	31.8	27	7.4	18.5	25.9
May	–	–	–	–	14	0	42.9	42.9	23	0	8.7	8.7	37	0	21.6	21.6
June	–	–	–	–	25	4.0	32.0	36.0	–	–	–	–	25	4.0	32.0	36.0
July	–	–	–	–	–	–	–	–	–	–	–	–	0	–	–	–
August	–	–	–	–	4	25.0	0	25.0	–	–	–	–	4	25.0	0	25.0
September	–	–	–	–	12	8.3	50.0	58.3	–	–	–	–	12	8.3	50.0	58.3
October	12	8.3	33.3	41.6	18	5.6	27.8	33.3	–	–	–	–	30	6.7	30.0	36.7
November	5	20.0	80.0	100	–	–	–	–	23	4.3	17.4	21.7	28	7.1	28.6	35.7
December	–	–	–	–	–	–	–	–	27	14.8	18.5	33.3	27	14.8	18.5	33.3

[1] All carcases opened at sea and foetuses frequently lost. Hence all animals with corpora lutea but no foetus have been classed as "recently ovulated" (R.O.), but many of these may have been pregnant.

Appendix V

NORTH PACIFIC CPUE DATA

Year	Western Division ♂	♂ CPUE	♀	♀ CPUE	Eastern Division ♂	♂ CPUE	♀	♀ CPUE
(a) Japanese pelagic								
1954	0	0.0	0	0.0	479	0.1584	0	0.0
1955	229	0.1456	0	0.0	847	0.1448	0	0.0
1956	808	0.3135	0	0.0	781	0.2008	0	0.0
1957	604	0.1799	0	0.0	1007	0.2876	0	0.0
1958	960	0.2605	0	0.0	397	0.1997	0	0.0
1959	687	0.2250	1	0.0003	1080	0.2156	1	0.0002
1960	439	0.2486	0	0.0	1258	0.2099	1	0.0002
1961	497	0.2876	10	0.0058	1206	0.2065	1	0.0002
1962	600	0.1638	0	0.0	1893	0.1469	9	0.0007
1963	1094	0.1796	1	0.0002	1510	0.1100	0	0.0
1964	698	0.1732	0	0.0	1710	0.1217	17	0.0012
1965	667	0.1940	3	0.0009	1670	0.1328	23	0.0018
1966	1449	0.1816	71	0.0089	1307	0.1080	64	0.0053
1967	1716	0.1672	173	0.0169	940	0.1459	162	0.0252
1968	1398	0.1393	376	0.0375	916	0.2011	202	0.0444
1969	763	0.0650	378	0.0322	1251	0.1330	607	0.0645
1970	1558	0.1602	197	0.0203	719	0.1247	137	0.0238
1971	869	0.0748	140	0.0120	640	0.1159	146	0.0264
1972	610	0.0750	65	0.0080	732	0.1529	160	0.0334
1973	464	0.0944	90	0.0183	965	0.2041	270	0.0571
1974	711	0.1413	370	0.0735	609	0.2222	80	0.0292
1975	695	0.1323	467	0.0889	295	0.1954	49	0.0325
1976	466	0.0743	570	0.0909	17	0.0251	0	0.0
1977	0	0.07	0	0.0	0	0.0251	0	0.0
(b) Soviet								
1961	0	0.0	0	0.0	0	0.0	0	0.0
1962	534	0.1191	32	0.0071	1080	0.0726	305	0.0205
1963	972	0.1030	212	0.0225	3321	0.0368	334	0.0037
1964	1953	0.0765	403	0.0158	2446	0.0399	445	0.0073
1965	3400	0.0689	180	0.0036	4252	0.0782	339	0.0062
1966	5821	0.0838	314	0.0045	3146	0.1000	155	0.0049
1967	5273	0.1079	273	0.0056	3663	0.1150	175	0.0055
1968	4572	0.1016	303	0.0067	4459	0.1440	192	0.0062
1969	4233	0.1001	399	0.0094	3192	0.0861	374	0.0101
1970	5369	0.1081	831	0.0167	1869	0.0851	498	0.0227
1971	5052	0.1138	460	0.0104	0	–	0	–
1972	830	0.0361	423	0.0184	481	0.0306	2	0.0001
1973	1241	0.0316	1809	0.0461	734	0.0482	474	0.0311
1974	1195	0.0301	1585	0.0399	688	0.0401	495	0.0288
1975	1355	0.0382	1639	0.0463	413	0.0444	343	0.0369
1976	1727	0.0400	1567	0.0363	253	0.0426	124	0.0209
1977	0	0.0400	0	0.0363	0	0.0	0	0.0

Annex F

REPORT OF THE SUB-COMMITTEE ON MINKE WHALES

10.2 Southern Hemisphere minke whales

The sub-committee (Tillman, convenor) had available the following documents pertaining to the Southern Hemisphere stocks of minke whales: SC/30/Doc 26, 29, 31, 32, 50, 53. Also available were SC/30/Rep 4 and the results of work requested in that report from Best (indices of relative abundance) and Beddington (Area IV abundance estimates)

The sub-committee reviewed the catch data provided in SC/30/Doc 26 and compared these with catch limits in the current schedule (Table 1).

The southern fishery essentially achieved its allotted catch limits of 5,000 whales, leaving 690 minke whales for the 1978 season of the Brazilian Land Station which operates in Area II.

Table 1

Area	Limit	Limit + 10%	Actual catch Total	Japan	USSR
I	640	704	463	–	463
II	1,045	1,150	362	–	362
III	1,660	1,826	1,801	1,012	789
IV	875	963	963	481	482
V	845	930	884	668	216
VI	625	688	527	239	288
	5,690		5,000	2,400	2,600

Effort modifiers

The sub-committee reviewed SC/30/Doc 29 and Doc 32 which dealt, respectively, with the within-season correction for changing female abundance and with corrections for wind and visibility. SC/30/Doc 29 also dealt with the decision in SC/30/Rep 4 to exclude the 1977/78 CPUE data point due to the unusual doubling of processing time per whale in that season.

Regarding within-season corrections, the sub-committee noted that the CPUE data of Paper S.14 conflicted with the sightings data provided in SC/30/Doc 29, giving different patterns of seasonality in different Areas, particularly in Areas III and IV. After reviewing all pertinent data available, the sub-committee agreed that, although it was biologically reasonable to expect within-season changes in female abundance, there was no basis on which to quantify the pattern of change at this time. The sub-committee recommends that further research be undertaken with the aims of resolving the conflicting sources of evidence and of quantifying an appropriate adjustment factor. In particular, a more thorough analysis of sightings data was suggested, to examine the within-year variability of the trend of Fig. 2, SC/30/Doc 29.

In the interim, the sub-committee agreed to adjust for seasonality as recommended in SC/30/Rep 4 by removing the first and second ten-day periods in November from the pooled CSW for the season.

Regarding corrections for meteorological factors, the sub-committee welcomed the analysis given in SC/30/Doc 32 which utilised an additive regression model as recommended in SC/30/Rep 4. It was noted that the analysis failed to examine the possibility of significant interaction between wind and visibility. This possibility was examined, and it was found that inclusion of an interaction term resulted in an even more significant relationship than was reported in SC/30/Doc 32. However, an extremely high correlation ($R^2 = 0.976$) was found between the 100 correction factors from this additive model with those from the multiplicative model used in Paper S.14. Consequently, the sub-committee agreed to adopt the meteorological correction factors provided in Paper S.14 and hence to use CSW_2, as defined in SC/30/Rep 4, as the appropriate measure of effort in its assessments.

Concerning the 1977/78 CPUE data point, SC/30/Doc 29 reported that a new item of operation, the confirming time, had been added to processing records in 1977/78. Confirming time is defined as the time required to confirm the species, the condition (whether or not a cow with calf) and size of the whale. This time had inappropriately been included in processing time in 1977/78, resulting in a high figure being reported in 1977/78. The sub-committee agreed that confirming time must be added to searching time in 1977/78 to be comparable with effort data from previous years.

Relative abundance

As noted in SC/30/Rep 4, stock estimates for Areas I, II, III, V and VI could be obtained by prorating the Area IV estimate utilising measures of abundance relative to Area IV. These measures could be obtained from sightings data or from CPUE data. Table 2 summarises the results provided by Best for sightings data. The abundance index for each Area was calculated as the sum of the products for each Zone of the average density within a 5° square, the number of 5° squares comprising the whaling ground in that Zone, and the average surface area within a 5° square (average surface areas are given in Table 3).

The results for CPUE data are given in Table 4, utilising C/CSW_2 data from SC/30/Rep 4 and the total area of each whaling ground from Table 2.

The sub-committee considered the above results to be independent estimates of the relative abundance and agreed to combine them utilising weighted averages to account for the precision of each estimate (Table 5).

Stock estimates

Since the data were evidently as a whole internally more coherent for Area IV (SC/30/Rep 4), the sub-committee agreed to prorate estimates of abundance from that Area to

Table 2

Relative abundance based upon average sightings density (whales sighted/10^2 miles) observed by 5° square within statistical Zones

Zone	I	II	III	IV	V	VI
50–55°S						
Average density	0.31	0.52	0.25	0.59	0.20	0.17
No. 5° squares[1]	12	12	14	12	12	10
Abundance index	7.024	11.782	6.609	13.368	4.532	3.210
55–60°S						
Average density	0.17	10.49	1.75	3.06	0.96	0.86
No. squares	12	12	14	12	12	10
Abundance index	3.403	210.010	40.874	61.261	19.219	14.348
60–65°S						
Average density	1.41	10.94	12.03	12.49	3.33	2.15
No. squares	12	12	14	12	12	10
Abundance index	24.283	188.405	241.706	215.098	57.348	30.855
65–70°S						
Average density	9.66	26.89	75.31	22.69	5.31	1.75
No. squares	11	8	14	4	8	10
Abundance index	126.508	256.112	1,255.250	108.055	50.575	62.626
Total area ($10^5 km^2$) of ground	72.993	69.420	86.548	64.656	69.420	61.820
Abundance index for area	161.218	666.309	1,544.438	397.783	131.674	111.039
Relative abundance	0.41	1.68	3.88	1.00	0.33	0.28

[1] Those comprising the whaling ground within a Zone.

Table 3

Average area within a 5° statistical square by Zone in the Southern Hemisphere

Zone	Average area ($10^5 km^2$)
50–55° S	1.888
55–60° S	1.668
60–65° S	1.435
65–70° S	1.191

obtain estimates for the other Areas. A number of procedures and data bases were utilised to obtain independent verification of estimates for Area IV.

(a) Table 7 from SC/30/Rep 4, based upon an estimate of Z from Area IV C/CSW_2 data for year classes in succeeding years, excluding the 1977/78 data point, where $F = Z - M$ and $P = \bar{C}/F$.

(b) Paper S.14, assuming N_{IV} constant during the period of exploitation, solved the equation

$$N_{IV} = (N_{IV} - \bar{C})\, e^{-M} + (1 - e^{-i})\, N_{IV}$$

where $M = 0.094$ and $i = 0.159$, 0.142 for females and males respectively.

Table 4

Relative abundance based upon average C/CSW_2 and area of distribution for Area IV

Area	Relative density	Relative area	Relative abundance
I	0.660	1.129	0.745
II	0.828	1.074	0.889
III	1.492	1.339	1.998
IV	1.000	1.000	1.000
V	0.776	1.074	0.883
VI	0.463	0.956	0.443

(c) Beddington's results based on F derived from the equation $Z' = F + M - i$ where Z' is obtained from the linear regression of $\ln(C/CSW_2)$ for Area IV versus time, or from an assumed slope of zero.

Additionally, $M = 0.095$ and the following values are used:

		Males	Females	Total
Average catch	1971/72–76/77	1,226	1,523	2,749
	1971/72–77/78	1,086	1,407	2,493
	r	0.140	0.164	0.152
	i	0.131	0.152	0.141

			Slope	95% upper	95% lower	Zero
♂	1976/77	Z' =	+0.045	−0.268	+0.359	0
		P =	15,136	–	3,104	34,056
	1977/78	Z' =	+0.005	−0.206	+0.219	0
		P =	26,488	–	4,259	38,017
♀	1976/77	Z' =	+0.127	−0.206	+0.460	0
		P =	8,277	–	2,946	26,719
	1977/78	Z' =	−0.030	−0.348	+0.288	0
		P =	52,111	–	4,078	24,684
Total	1976/77	Z' =	+0.094	−0.209	+0.398	0
		P =	19,636	–	6,191	59,118
	1977/78	Z' =	−0.018	−0.278	+0.241	0
		P =	89,035	–	8,686	53,613

Table 5

Comparison of relative abundance results using C/CSW_2 data and sightings data and weighted average of results

	C/CSW_2		Sightings		
Area	Relative abundance	Variance	Relative abundance	Variance	Weighted average[1]
I	0.75	0.03450	0.41	0.00931	0.48
II	0.89	0.10498	1.68	0.13570	1.23
III	2.00	0.20073	3.88	0.40075	2.63
IV	1.00	–	1.00	–	1.00
V	0.83	0.03352	0.33	0.00422	0.39
VI	0.44	0.04004	0.28	0.00172	0.29

[1] Weights = 1/Variance.

(d) CHPOP procedure which uses the method of Allen (1966, *J. Fish. Res. Bd Can.* 23: 1553–74) for estimating stock sizes by minimising the sums of squares of differences between actual and expected catches, assuming $M = 0.095$ and $r_{II} = 0.152$ for sexes combined.

CHPOPR (SC/30/Doc 12), which uses a maximum likelihood procedure to compare actual with expected catches, indicated that no estimates having statistically significant likelihood would result from the currently available C/CSW_2 data. The sub-committee agreed that this result did not imply that we had less confidence in the CHPOP and CHPOPR methods than with other procedures utilised, but rather that a means was now available for judging the precision of these two methods. The results of CHPOPR may be compared with the very wide confidence limits given by the method in paragraph (c) above.

(e) "ZMK" method which obtains an estimate of Z which is not contaminated with recruitment by following the changes in relative abundance of a year-class or group of year-classes.

The relative abundance of a cohort or group with relative abundance $N_{a,t}$, where a is the age of the youngest age-class in the group in year t is given by

$$N_{a,t} = CPUE_t \times P_{a,t}$$

where the CPUE is that for the whole catch of either or both sexes, as appropriate, and $P_{a,t}$ is the proportion of group, a, in the catch.

An estimate of Z is then obtained by regressing $\ln(N_{a,t})$ against time, weighting the points by the size of the age sample. This is an estimate of the mean Z for the period of the data, and the estimate of corresponding mean population obtained by dividing the mean catch by the mean F ($F = Z - M$).

In the present case the effort used in calculating CPUE is CSW_2 and the resulting Zs for each sex separately are shown in Fig. 1. Z has been calculated for the groups of year-classes including all older than each age from 12 to 17 years in 1971/72. It is apparent that the estimate of Z increases with initial age at first, but that it stabilises at about age 16. The mean values of Z for this age are therefore an appropriate measure of the average total mortality rates of the fully recruited component of the population. These values are:

Males	0.22
Females	0.25
Combined	0.235

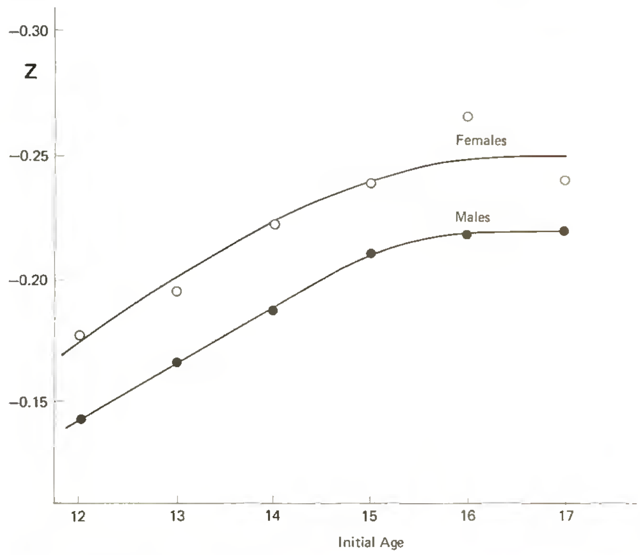

Fig. 1. Estimates of Z by sex.

The corresponding estimates of the mean population from 1971/72 to 1977/78, taking M = 0.095, are:

$$\text{Males} \quad \frac{1086}{0.22 - 0.095} = 8{,}688$$

$$\text{Females} \quad \frac{1407}{0.25 - 0.095} = 9{,}077 \quad \Big\} \; 17{,}765$$

$$\text{Combined} \quad \frac{2493}{0.235 - 0.095} = 17{,}807$$

Taking the combined mean-season population as 17,800 and constructing a time series with the actual catches using:

$$N_2 = (N_1 - C)\, e^{(0.15-0.095)}$$

and mid-season = N − C/2, we obtain a population at the beginning of 1971/72 of 25,500 and at the beginning of 1978/79 of 14,400.

(f) DOIPOP (SC/30/Doc 31) simulated an estimate of the population, taking into account the possible changes in the age at sexual maturity. The driving functions are given in time series, based on observations of biomass change and of ages at sexual maturity (Masaki, S.10). After discussion, an assumption of a linearly changing pregnancy rate was replaced by a constant pregnancy rate (0.75).

The simulation results are checked *a posteriori* by a comparison of the simulated age composition with the actual in the recent catch and a comparison of the simulated abundance trend with the actual C/CSW_2 trend over these eight years. Based upon a Chi-square test, the goodness of fit is extremely high between the simulated and the actual age composition ($P > 0.90$), and the correlation ($r = 0.543$) between the recent trends, both simulated and actual, is better than in the case of ZMK, although it is still insignificant.

Although there are some problems remaining in establishing the driving functions of the model in time series and in selecting the simulation results as most probable, DOIPOP has promise for future application because the method is free from problematical use of effort data.

Some members of the sub-committee believed that DOIPOP was not an adequate estimation procedure since it did not incorporate an internal statistical procedure for comparing simulated results with observed data. For example, actual and expected age distributions or actual and expected CPUEs in each season could be compared utilising either least squares or maximum likelihood procedures. It was also noted that the driving function of the model was a time series beginning in 1904 of assumed changes in the age at sexual maturity. It was felt that a better model would be achieved if changes in age at maturity were related to baleen whale biomass, considered to be a more appropriate measure of environmental change for Southern Hemisphere minke whales. It was further noted that the assumption that the transition layer is formed at sexual maturity has still yet to be confirmed (SC/30/Rep 4). Consequently, the data base for deriving the driving function of the model has not yet been validated. If validated, it was felt that it would be a better procedure to start the simulation in the 1920s when the actual changes in transition layer were observed.

As a consequence of the above problems, some members of the sub-committee believed that it was inappropriate to use the results from DOIPOP. Others believed that, based on the *a posteriori* tests made, the results were reasonable and should be included in the synthesis of results.

A summary of estimates is given in Table 6.

Upon considering the synthesis of results in Table 6, the sub-committee agreed to reject a number of procedures. Table 7, SC/30/Rep 4 did not utilise the 1977/78 data point and, moreover, was determined to be a much simplified version of ZMK which did not take into account the results from the middle years of age distributions as did ZMK. Paper S.14 did not utilise the 1977/78 data point, and the Regression Procedure with assumed slope zero (Slope Zero) represents an update of that analysis. The Regression Slope Procedure assumes unrealistically that the value of F is constant throughout the period of exploitation, and estimates from the two data series used show contradicting results. The assumption of constant F is also unrealistic for the Zero Slope Procedure.

CHPOP projected that population changes would occur down to 59% of initial values; these projections were felt to be inconsistent with the underlying C/CSW_2 data.

For the reasons previously noted, some members believed that the results of DOIPOP should not be included in the synthesis, whereas others believed that it was appropriate to do so.

Some members concluded that ZMK was the most appropriate estimation procedure since it attempts to remove the recruitment effect on an annual basis rather than utilising an assumed constant rate to adjust a calculated or assumed slope as do the two Regression Procedures. Moreover, ZMK makes no explicit assumption concerning the state of change within the stock during the period of exploitation.

Stock sizes were also calculated on the explicit assumption that the regression slope was zero (Slope Zero), i.e. that the stock had neither increased nor decreased over the period of pelagic whaling. This gave population estimates in the range 54,000–63,000 whales. However, the assumption of zero slope in this case does not imply that whaling had not detectably affected the stock size, but rather that it had had exactly the same, but opposite, effect on the

Table 6

Average stock sizes for Area IV derived by various procedures and data bases

Procedure	Data series	Method	Average exploitable stock size for series
Table 7, SC/30/Rep 4	1971/2–1976/7	Sexes separate	16,099
		Sexes combined	14,170
Paper S.14	1971/2–1976/7	Sexes separate	50,600
Regression slope	1971/2–1976/7	Sexes separate	23,413
		Sexes combined	19,636
	1971/2–1977/8	Sexes separate	78,599
		Sexes combined	89,035
Slope Zero	1971/2–1976/7	Sexes separate	60,775
		Sexes combined	59,118
	1971/2–1977/8	Sexes separate	62,701
		Sexes combined	53,613
CHPOP	1971/2–1977/8	Sexes combined	10,682
ZMK	1971/2–1977/8	Sexes separate	17,765
		Sexes combined	17,807
DOIPOP	1971/2–1977/8	2 x females	38,948

stock as had the environmental change which led to the stock having a positive natural rate of increase up to the time that whaling began. Some members of the sub-committee therefore felt that there was no special reason in this case for preferring the zero slope over any other null hypothesis.

Other members of the sub-committee concluded that the Zero Slope Method was the most appropriate estimation procedure since it utilised the conservative assumption that the stock had neither increased nor decreased over the period of pelagic whaling. This assumption was consistent with the C/CSW_2 data and conservative if one took into account the increasing trend observed in seasonally adjusted CPUE (Ohsumi, S.14).

Consequently, the sub-committee agreed to prepare stock estimates utilising the results from ZMK, DOIPOP and Slope Zero.

The Area IV stock sizes for each method were prorated to the other Areas using the measures of relative abundance. These values were assumed to be the average stock size during the 1971/72–1977/78 seasons. For each method, the 1971/72 (initial) and 1978/79 (current) stock levels were calculated by comparing these average stock sizes with an average stock size calculated for each Method and Area as:

$$\left(\sum_{t=1}^{7} N_t - \sum_{t=1}^{7} C_t/2\right)/7$$

where:

$$N_{t+1} = (N_t - C_t)\, e^{-M} + rN_1 \quad (1)$$

$$M = 0.095$$

$$r = 0.152$$

and N_1 is the stock size at the start of the 1971/72 season.

The stock estimates resulting from this process are given in Table 7.

After reviewing these results, the sub-committee agreed that ZMK provided the best estimates of initial and current stock sizes. Particularly notable were the projections of a slight downward change in Area IV and of a slight upward change in Area III which were consistent with the observed trends in the available CPUE data. This contrasted with the results for the other procedures which consistently predicted increases in all stock Areas, which in some cases were substantial. Since ZMK was free of inherent assumptions about the state of change in the population, the value of i, and the constancy of F, and thus made the best and fullest use of the available data, the sub-committee agreed that it provided the best and most prudent basis for calculating catch limits.

Despite the undertaking of a vigorous analysis of effort data in SC/30/Rep 4, and above, the great dichotomy of the above estimates continues to raise questions about the adequacy of assessments based solely upon CPUE data. Moreover, the only independent evidence currently available, sightings, is also too variable to place any confidence in its being able to detect any but major changes in abundance. These circumstances point out the need for a properly organised and scientifically supervised census (based upon sightings and marking) which is conducted independently of whaling operations.

Although both sightings and marking of minke whales are being carried out at present, these are either inadequate (Southern Hemisphere to date – Annex I) or not executed systematically (no estimates of effective track-width, no attempt to arrange grid search). The sub-committee noted that the research programme outlined in Appendix 1 rectifies these past inadequacies by concentrating efforts upon Area IV which probably has been most heavily affected by catches.

The sub-committee strongly recommends that this research be undertaken next year, if at all possible, so that a proper basis for assessment is developed.

Classification and catch limits

SC/30/Rep 4 summarised evidence indicating that the minke whale population was increasing prior to the beginning of exploitation. Under this circumstance, it is not possible to determine reliably what the "initial" population was, or what the present changing capacity of the minke whale environment (and hence its MSY level and MSY) might be. Under the present management procedure of the IWC, the sub-committee could therefore not recommend an appropriate classification of Southern Hemisphere minke whale stocks even if the calculations were available. This is basically a consequence of the multispecies interdependence of the Antarctic baleen whales and other species, and

Table 7

Season	Method	Area I	II[1]	III	IV	V	VI	Total
1971/72	DOIPOP	17,873	44,164	92,029	41,088	13,863	9,856	218,873
	ZMK	9,106	21,700	43,996	22,825	6,741	4,560	108,928
	Slope zero	25,829	64,555	135,630	57,667	20,328	14,664	318,673
1978/79	DOIPOP	19,705	52,278	113,416	43,433	15,430	12,368	256,630
	ZMK	8,054	22,425	49,583	19,162	5,965	5,330	110,519
	Slope zero	30,278	79,376	171,359	65,465	24,021	18,757	389,256

[1] Assuming a Brazilian land station catch of 690 in 1978.

requires a decision by the Committee on an appropriate management strategy.

In the meantime, and as a holding measure, the Commission might wish to set catch limits at the level of the present replacement yield, i.e. that catch which will maintain the population at the same level for one year. Replacement yields are calculated for each Area by solving equation (1) when $N_{78/9} = N_{77/8}$ and $M = 0.095$, $r = 0.152$ (SC/30/Rep 4), and the ZMK estimates of current and initial sizes are used:

	Area I	II	III	IV	V	VI	Total
Replacement yields	719	1,392	2,412	1,905	532	231	7,191

It should be noted that it would be more appropriate to base calculations of sustainable and replacement yields on estimates of the numbers of females than of both sexes combined. The difference may be important when the removals of the two sexes have differed greatly: in Area IV the average catch of females has exceeded that of males by nearly 40% and there have also been unbalanced ratios in other Areas. The Committee has not, however, been able to make such calculations in the time available.

Size limits

The sub-committee reviewed SC/30/Rep 4 which indicated that the mean size at sexual maturity for both sexes combined is 25 ft at which stage about 70% of growth in body weight has been completed.

The report adequately states the arguments for and against imposition of a size limit for Southern Hemisphere minke whales. After reviewing these arguments the sub-committee reiterated its conclusions that there are no compelling reasons to advocate the need of any particular length for a minimum size limit and that it should be possible to maintain an adequate level of recruitment through the adoption of a suitable catch limit.

11.1.1 North Pacific minke whales

No new assessment data were available to the sub-committee. However, Ohsumi provided the 1977 landing statistics (Table 8) from all whaling grounds around Japan to update Table 1 in SC/29/Doc 36 (*Rep. int. Whal. Commn* 28: 272). The reduced catches from the Okhotsk Sea and Hokkaido, Japan Sea grounds were reported to be due to the imposition of the Soviet 200-mile fisheries zone which reduced the effective size of those areas. Moreover, oceanographic conditions reportedly were not suitable for whaling off Sanriku.

Catches from the Republic of Korea were also reported for 1976 and 1977 by Brownell.

The sub-committee welcomed Ohsumi's report that systematic collection of catch, effort, and biological data from small-type whaling had begun in 1977, and that a report would be submitted regarding this effort at the next annual meeting.

No new evidence was received which would change the sub-committee's recognition of two stocks in the western North Pacific.

Ohhotsk Sea/West Pacific stock

Ohsumi reported that, as in recent years, only seven vessels operated in 1977, resulting in a catch per vessel-ton of 0.94. Comparison of this value with Fig. 2 (*Rep. int. Whal. Commn* 28: 271) indicated that an obvious change in the status of the stock was not yet apparent. It was noted that the trend, begun in the late 1960s, of using motor boats to chase minke whales may help explain the increased CPUEs observed in that figure. Noting the intent of the Japanese scientists to report on their systematic data collection program, the sub-committee recommended that a full analysis of the fishery be undertaken with a report to be submitted at the next annual meeting; this report should include an examination of the problem of how the introduction of motor boats affected efficiency.

Table 8

Catch of minke whales by small-type whaling along the coast of Japan in 1977

Ground	Male	Female	Total
Okhotsk Sea	56	47	103
Hokkaido, Pacific	69	15	84
Sanriku	31	29	60
Japan Sea	0	0	0
Hokkaido, Japan Sea	0	1	1
Total	156	92	248

Pending this analysis, the sub-committee recommends that the stock continue to be classified as a Sustained Management Stock and that the quota agreed upon last year, 400 whales, be applied in the interim. This level represents the mean annual catch for the period 1965–76 with an allowance for the variation apparently inherent in the fishery.

Sea of Japan stock

This stock is exploited by the Republic of Korea, minimally by Japan, and possibly by the People's Republic of China and the Democratic People's Republic of Korea. As in past years no catch data were available from the latter two non-member nations. However, the following catches were reported for the Republic of Korea, another non-member nation:

1976	447
1977	1,033

The sub-committee was particularly concerned about the increasing Korean catch which in 1977 more than doubled the previous 15 years' (1962–76) average of 473. It strongly recommended that the Commission undertake the actions noted below since increasing catches by this country may adversely affect the stock.

Lacking further information, the sub-committee was not able to make a more comprehensive assessment. It recommends that the Commission urge non-member whaling nations currently exploiting the stock to provide CPUE and biological data from their whaling activities. Until this information becomes available, the sub-committee recommends that the stock be classified as a Sustained Management Stock and that the Japanese catching effort on this stock should not be increased. It further strongly recommends that the Commission urge non-member whaling nations currently exploiting this stock to apply similar restraint.

Other North Pacific stocks
Other stocks in the North Pacific should be classified as Initial Management Stocks with zero quota pending satisfactory estimates of stock size.

Recommendations

10.2 Minke whales, Southern Hemisphere

Recommendations for stock classifications and catch limits for 1979
Given that the Southern Hemisphere minke whale population was increasing prior to the beginning of exploitation the sub-committee was not able to recommend an appropriate classification of stocks under the present management procedure. The Commission may in future wish to consider an appropriate management strategy for this circumstance but, in the meantime and as a holding measure, catch limits might be established at the level of the present replacement yields:

	Area						
	I	II	III	IV	V	VI	Total
Replacement yields	719	1,392	2,412	1,905	532	231	7,191

Other recommendations
Recommend that further research be undertaken with aims of resolving the conflicting sources of evidence and of quantifying an appropriate factor to adjust effort for within-season changes in female abundance.

Recommend that there are no compelling reasons to advocate the need of any particular length for a minimum size limit.

Strongly recommend that a properly organised and scientifically supervised census (based upon sightings and marking) be concentrated in Area IV (see Appendix I) next year, if possible.

11.1 Minke whales

11.1.1 North Pacific

Recommendations for stock classifications and catch limits for 1979

Okhotsk Sea/West Pacific Stock – Sustained Management Stock with a catch limit of 400 whales.

Sea of Japan Stock – Sustained Management Stock with Japanese catching effort not to be increased.

Other North Pacific Stocks – Initial Management Stocks with zero catch limit pending satisfactory estimates of stock size.

Other recommendations
Recommend that a full analysis of the fishery on the Okhotsk Sea/West Pacific Stock with an examination of the effect upon efficiency of introducing motorboats be submitted next year.

Noting the doubling of the Korean catch, recommend that the Commission urge non-member whaling nations currently fishing the Sea of Japan stock not to increase their fishing effort in 1979 and to provide CPUE and biological data from their whaling activities.

Appendix I
PROPOSED RESEARCH PROGRAMME ON MINKE WHALE POPULATION ESTIMATION

Best proposed that the present diffused sightings and marking efforts should be concentrated in one statistical Area, enabling a higher probability of obtaining a more statistically robust estimate of population size. It is proposed that such a programme should initially concentrate in Area IV, as this region has proved to be the key one for all the most recent population estimates, and is the one which so far shows the most evidence of having been affected by catches.

In order to obtain a population estimate from marking with a reasonable degree of accuracy, a substantial number of animals must be marked. To obtain an estimate with 95% confidence limits within 50% of the mean, it can be calculated that if the population size is approximately 20,000 and the expected take about 700 animals, then about 600 animals need to be marked. Given current mean catch rates of 7 to 10 minke whales per day, it should be possible to mark this number of animals in about 100 catcher-days. Three scouting vessels operating for one month should be sufficient for this purpose.

It is proposed that this marking should precede any catching attempt in Area IV by as substantial a period as possible, in order to allow adequate mixing of tagged and untagged animals. Simultaneous marking and catching operations within the Area should not be permitted.

The marking programme should be undertaken simultaneously with a systematic sightings cruise organised on a grid basis between 55°S and 65°S, from which independent estimates of stock size might be obtained through a strip-census technique. This will require particular emphasis on the accurate measurement of the effective track-width. Both the marking and sightings programme should be carried out on a grid basis to avoid an uneven distribution of marks and to achieve a proper evaluation of density distribution.

Certain other precautions must be taken in order to ensure that the marking experiment is successful. A certain proportion of the whales should be double-tagged in order to test the accuracy of recording. As the rate of mark recovery will be crucial to the accuracy of the population estimate it is also essential that either experiments on the efficiency of tag recovery are carried out, or metal detectors are installed in factory equipment, or both.

Details of the proposed survey cannot be finalised at this stage (23 June), as the strategy of the Antarctic whaling fleets is not yet known. However, the proposals will involve the following special arrangements:

1. Provision of 1,500 .410 whale marks and at least three .410 marking guns.
2. Provision of scientific personnnel on all survey vessels to supervise operations.
3. Provision of adequate monitoring or measuring of the rate of recovery of marks on board the factory vessels concerned.

Member governments may wish to assist with items 1 and 2 above.

Appendix II

NOTE ON SOUTHERN HEMISPHERE MINKE WHALE STOCKS AND QUOTAS

S. Holt and B. Grenfell
24 June

We have worked since the Committee adjourned, on 21 June in consultation with Allen, Beddington and Kirkwood.

Correct determination of a replacement catch as an interim measure should, as the Scientific Committee has agreed, be such as to avoid the likelihood of further decline in the number of female whales. With the exception of Area VI, where catches have in any case been small so far, females have very considerably exceeded males in catches; the overall ratio females/males for all Areas throughout the period of pelagic whaling was 1.52. The corresponding ratio in Area IV was 1.30 while the ratio of the numbers in the average population as calculated by the ZMK procedure was 1.045, i.e. close to unity, as would be expected unless there were considerable differences, by sex, in the natural mortality rates and/or ages at recruitment. In fact if the female/male ratio at birth was unity and the pre- and post-recruitment mortality rates were the same for each sex, the one year difference in mean age at recruitment (six for females, seven for males) would give a female/male sex ratio in the stock of 0.950. Clearly, whaling has been having a much greater relative impact on the females than on the stocks as a whole.

We have calculated, by the same procedure as that used by the minke whale sub-committee,[1] the number of females at the beginning of the 1971/72 season and of the 1978/79 seasons; the natural mortality rate was taken as 0.095 and the recruitment rate $r_{II} = 0.152$.

The results are tabulated in Table 1, with the corresponding replacement catch for the 1978/79 season. It should be noted that it is not appropriate to use the female $r_{II} = 0.164$ given for Ohsumi because use of the corresponding value of male $r_{II} = 0.140$ together with a common M value would lead to a rapidly changing sex ratio in the recruited population which is quite unrealistic; the female and male values, while differing, would need to be much closer to each other to give the calculated sex ratio which is unbalanced only by the fact that males recruit one year later than females.

Since it is not practicable to set quotas for minke whales by sex the expected sex ratio in the 1978/79 catches must be used to determine the combined quota in each Area. The overall sex ratio (all Areas) in catches has varied from year to year, with a tendency to increase, values in the last two seasons, 1.770 and 1.905 respectively, being substantially higher than in earlier years. This general pattern holds in most Areas although there are Area to Area variations; for example in Area IV exceptionally few females were taken in 1972/73 and 1976/77. It seems clear that by selection of appropriate whaling grounds within Areas and/or periods within seasons, whalers can rather substantially determine the sex ratio in their catches. Thus, if it were known in advance that future quotas would be affected by the state of the population of females, and particularly by the proportion of females in the previous season's catch, whalers could be expected to act accordingly and hold down the sex ratio as far as was operationally practicable.

In accordance with this argument we have calculated the 1978/79 quotas on the basis that the sex ratio would be the same as in the 1977/78 catches. This clearly gives relatively conservative quotas because the sex ratio in 1977/78 was higher than in previous years. If one wishes to be less conservative one could use other formulas, such as the average sex ratio over the period of whaling in each Area. These two sets of results are given in the last two rows of the table.

The method used by the minke whale sub-committee assumes that the number of recruits was and still is constant: it actually implies that the Area IV stock would, if not exploited, eventually stabilize at 29,900 whales. If however the stock was, before exploitation, increasing exponentially, as implied by the analysis of catch curves, then the recruitment should be a constant fraction of the parent stock. In this case the number of recruits should have been increasing prior to whaling, and this should be taken into account in the simulation of post-whaling stock sizes of mean of which is tuned to the estimated mid-season mean size to calculate the number at the beginning

[1] There is a small arithmetic difference; we applied the 0.152 recruitment factor to the mean stock size at mid-season rather than at the beginning of the 1971/72 season. The overall differences thereby generated do not exceed 20 in total replacement yield estimates.

Table 1

Starting and current stock sizes, and replacement yields. Constant number of recruits

	I	II	III	IV	V	VI	Total
No. ♀♀ at beginning of season:							
1971/72	4,714	11,854	22,370	13,578	3,480	2,161	58,157
1977/78	3,843	10.806	25,061	8,072	2,914	2,939	53,635
Replacement yield	345	800	1,493	713	301	147	3,799
Quota from sex ratio:							
1977/78	506	1,179	2,117	964	505	384	5,655
1971/72–1977/78	671	1,156	2,282	1,263	512	337	6,221

The total quota obtained by applying the sex ratio for all Areas in 1977/78 to the total number of females at the beginning of the 1978/79 season is 5,729; the corresponding figure by applying the overall sex ratio in catches in all years, all Areas, is 6,269.

of the 1971/72 season. Furthermore, the effect of whaling on stock size in the first years of whaling will now determine the recruitment in recent years and the replacement catch calculations, so an appropriate time lag must be included in the estimation procedure and in the subsequent simulation of stock sizes. This has been done, using six years as the age of recruitment, and the results are given in Table 2. In this case it is appropriate to apply the recruitment rate derived from the analysis of catch curves, the mean for both sexes being 0.149 from Ohsumi's Table 2.[2]

Furthermore the difference between the value for females of 0.154 and that for males of 0.144 given in this Table is very close to what would be expected from the difference of about one year in the estimated ages at recruitment. Thus in the calculation of female stock and replacement catches we have used $r = 0.154$.

Since the recruitment in the next few years will be affected by the whaling carried out in the early 1970's, it is instructive to calculate the consequences of continuing a replacement yield policy for more than one year; these are shown, for both sexes combined, in Table 3. It will be seen that the quotas would decline for several years.

When this is recognised, an alternative calculation may be considered: to determine those catches, not more than the 1978/79 replacement yields, which if taken in 1978/79 would not necessarily be followed by lower quotas in 1979/80 or subsequent years. The last row of Table 3 shows appropriate values, resulting in a total of 7,244, which can be compared with a slightly less conservative procedure of setting a quota at the mean replacement level for 1978/79 to the stabilisation season 1985/86. This latter would however lead to some decreases in stocks in intermediate years. Such a procedure would not only tend to stabilise the stock, but could also result in a somewhat higher average catch of minke whales over the period, during which more knowledge may become available on which to base a better dynamic model.

It is more difficult to carry forward the estimates for females, unless we suppose that the result of a correct determination of the total quota is that the replacement yield of females is actually taken. The results of these calculations are shown in Table 4. The total quota based on lowest female replacement yield in each Area over the stabilisation period, compared with 7,244 in Table 3 and applying to 1977/78 sex ratios is 6,032.

It would seem reasonable therefore to establish a reasonably conservative total interim quota for the 1977/78 season in the range 5,655 (from Table 1) to 6,032. It may be noted that the 1977/78 quota was within that range.

Whatever total were chosen we suggest that an allocation based on the constant recruitment rate model rather than the model assuming a constant number of recruits would be preferable since this would tend to divert effort somewhat from the Areas in which whaling has already had a sub-

[2] Successive female stock sizes were calculated by the formula

$$N_{t+1} = (N_t - C_t)\, e^{-M} + (N_{t-6} - C_{t-6})(e^r)$$

where r is now the instantaneous recruitment rate.

Table 2

Starting and current stock sizes, and replacement yields. Constant recruitment rate, 6 year time lag

	I	II	III	IV	V	VI	Total
			Both sexes				
No. at beginning of season:							
1971/72	9,624	23,026	46,518	24,113	7,125	4,820	115,226
1978/79	8,137	22,736	49,993	19,354	6,026	5,372	111,618
Replacement yield	933	1,762	3,357	2,014	691	338	9,095
			Females				
No. at beginning of season:							
1971/72	4,827	11,855	24,048	12,667	3,679	2,439	59,515
1978/79	4,067	10,806	24,982	9,956	2,964	2,815	55,590
Replacement yield	502	800	1,987	1,100	396	178	4,963
Quota from sex ratio:							
1977/78	735	1,179	2,817	1,488	664	464	7,760
1971/72–1977/78	974	1.156	3,038	1,949	673	408	8,603

Table 3

Replacement yields in successive years. Both sexes. Model for constant recruitment rate = 0.149

	I	II	III	IV	V	VI	Total
Season							
1978/79	933	1,762	3,357	2,014	691	338	9,095
1979/80	984	1,783	3,397	1,447	728	363	8,702
1980/81	839	1,810	3,409	948	770	390	8,176
1981/82	622	1,745	3,535	920	700	422	7,944
1982/83	569	1,614	3,584	1,135	663	433	7,898
1983/84	551	1,619	3,597	1,249	504	451	7.971
1984/85	627	1,751	3,851	1,491	464	414	8,598
Mean	732	1,726	3,533	1,316	646	402	8,355
Lowest	551	1,614	3,357	920	464	338	7,244

stantial impact, to those that are apparently still relatively little affected.

It may be noted that the distribution of the 1977/78 quota among Areas was somewhat closer to the results of the present constant recruitment model, but both of these lead to considerably bigger quotas for Area III than in 1977/78, with somewhat lower quotas in the other Areas.

Examination of predicted time series of stock sizes

The constant recruitment model applied to both sexes combined predicts that in Area IV the stock declined, by the beginning of the 1975/76 season, to 62.0% of the number it had reached at the beginning of the 1971/72 season (hereafter referred to as "starting number") and then, with reduced whaling increased to 64.5% of the starting number by the beginning of the 1978/79 season. In other Areas various patterns of change are seen; the catch significantly exceeded the replacement yield in one or more years in all Areas except III. By this calculation the 1977/78 quota was 1,926 whales less than the replacement yield at that time.

The constant recruitment model applied only to females showed in Area IV a decline by the beginning of the 1975/76 season to 57% of the reproductive potential (i.e. number of recruited females) compared with the starting value. Again, there is some recovery, to 59% by the beginning of the 1978/79 season. In other Areas again there are various patterns of change; in all Areas – including Area III – the catch of females exceeded the replacement yield of females in one or more years.

With the constant rate of recruitment model the pattern is slightly different: the overall population changes tending to be somewhat damped as a consequence of the particular patterns of whaling over time. For example, the lowest Area IV stock, both sexes combined, reached was at the beginning of the 1975/76 season when it was 63% of the starting number. Thus, by any model this stock should, viewed retrospectively, have been classified as "sustained management" stock at that time. It would be desirable to compare the correlation coefficients with CPUE values for the two models but there has not been time to do this. We have however calculated for Area IV the time it would take the stock to recover to the size and yielding potential that it had in 1971 if no catches were taken from that Area from now on; the time is about 10–12 years. For the constant number of recruits model this is 12 years, and for the constant recruitment rate model it is 6 years: in both cases the recovery time is the same, to within a year, if the recovery of females is estimated, or of both sexes combined.

Table 4

Female replacement yields in successive years. Model for constant recruitment rate = 0.154

	I	II	III	IV	V	VI	Total
1978/79	502	1,081	1,987	1,100	396	178	5,244
1979/80	529	1,081	2,004	840	417	192	5,063
1980/81	479	1,079	1,958	512	441	207	4,676
1981/82	365	985	2,027	479	389	225	4,470
1982/83	347	884	2,038	613	374	234	4,490
1983/84	310	866	1,966	718	274	241	4,375
1984/85	339	940	2,084	831	247	235	4,676
Mean	410	988	2,009	728	363	216	4,714
Lowest	310	866	1,958	479	247	178	4,038
1977/78 Quotas							
(a) Mean 1977/78 sex ratio	601	1,455	2,849	985	609	564	7,063
1971/72–1977/78 sex ratio	796	1,428	3,072	1,290	617	495	8,698
(b) Lowest 1977/78 sex ratio	454	1,276	2,776	648	414	464	6,032
1971/72–1977/78 sex ratio	602	1,251	2,994	849	420	408	6,524

Annex G

REPORT OF THE SUB-COMMITTEE ON PROTECTED STOCKS

12.1 Bowhead Whales

Bering Sea Stock

The sub-committee had available to it a complete review of recent research in SC/30/Doc 36 together with additional information in SC/30/Docs 35, 43, 45 and 47. The sub-committee expressed appreciation of the substantial US research programme which the Committee had requested for a number of years. This led to a much improved population estimate of 2,260. Attention was drawn to the low number of calves sighted leading to an estimated total number of calves equal to 29 in the population.

It is possible that this component of the population is underrepresented because of sighting difficulty or because they are segregated from the rest of the migration but until there is positive evidence on these points the sub-committee expressed concern that the normal recovery process for this stock may have been altered.

In the circumstances the sub-committee urges the Committee to reconfirm its recommendations at Canberra and Cronulla that from a biological point of view the only safe course is to reduce the kill to zero. The sub-committee notes and repeats the statement made in Cronulla that the Commission may wish to discuss other considerations (subsistence and cultural needs, etc.). These are beyond the expertise of the Scientific Committee.

The sub-committee noted that the USA is committed to its research program for at least three years and expressed its appreciation of this. It was noted that researchers in Canada have carried out some research on this stock and it requests that this information be made available to the Committee. It also noted that part of this stock spends some time in waters under USSR jurisdiction and it suggests that the Commission recommend that the USSR carry out or permit research on this component. In particular such research should include sightings surveys and collections and analyses of earplugs and ovaries from any aboriginal kills.

Finally it was noted that the analysis and the research are still in preliminary stages and further information might lead to new recommendations.

Other stocks

No new information was available. No catches were reported from any other stocks (SC/30/Prog Reps 2 and 3) but all remain seriously depleted.

12.2 Right whales

Sightings data on this species are given in SC/30/Docs 26 and 27, SC/30/Rep 6 and SC/30/Prog Reps 1, 6 and 8. In all areas where comparative data are available these are the least abundant of the protected species. Only the small stock off South Africa shows evidence of significant increase. In view of the continued seriously low level in almost all areas, it is suggested that the Committee recommend to the Commission that it urgently request non-member countries, including those that have only an aboriginal or subsistence kill, that they join the Commission in protecting this species completely.

In response to a reiteration of the request by Mitchell (1977) on the compilation of sightings data on right whales off Cape Cod (*Rep. int. Whal. Commn* 27: 45), American scientists informed the sub-committee that the matter had been explored and they concluded that the data referred to have no value. The sub-committee looks forward to receiving estimates of stocks and stock increases of right whales off Argentina from Payne and requests that Argentina conduct additional studies.

12.3 Gray whales

The sub-committee had information on this stock in SC/30/Docs 34, 37, 41, 46 and 54 and in SC/30/Prog Rep 9. These documents include data on kills at various times together with census estimates at different locations in California and one in the Aleutians, and an aerial survey in the lagoons of Baja California. The best series of data based on shore counts near Monterey show a stable population of about 11,000 over the past eleven years. The Aleutian estimate is higher (about 15,000); the aerial lagoon survey, which took place in one short period of the season and missed one area, and hence was incomplete in respect to the total population, gave an estimate of 7,000. The shore counts at Point Loma have been more erratic than the series from locations near Monterey but it was noted that the three most recent counts at Point Loma have shown an increasing trend to a new high value in 1977/78. American scientists indicated that further analysis is being undertaken which may provide more information to explain the variations, but in the meantime it seems reasonable to assume that the population is stable at the level of exploitation that results from the Soviet kill on behalf of its aboriginals. The sub-committee noted and agrees with the recommendation in SC/30/Doc 54 to the effect that this kill might be managed to achieve a more balanced sex ratio – in recent years the average percentage of females in the catch has been 68% although it was 54% in 1977 (SC/30/Prog Rep 9).

In discussing the status of the stock the sub-committee considered some of the points made in SC/30/Doc 41 where it was suggested that gray whales were subject to a considerable aboriginal exploitation prior to the onset of commercial operations. This makes it more difficult to determine what the "original" level of the population should be, even if it is assumed that the carrying capacity of the habitat (i.e. the lagoons and offshore area of Baja California) has not been altered by activities of man. If Ohsumi's (1976) model (*Rep. int. Whal. Commn* 26: 340–9) is accepted, the gray whale stock should be classified as an Initial Management Stock with a zero quota for females and with a quota of approximately 50 for males in addition to the whales taken in the Soviet aboriginal catch, assuming that this aboriginal catch remains constant with respect to recent levels and sex composition.

The sub-committee noted that in response to the committee's request of last year the USSR had provided some information on gray whale catches but expressed the hope that the remaining information requested, analysis of earplugs and ovaries, would be forthcoming in the near future. Some of the information requested from the USA and Canada in 1977 was provided in SC/30/Docs 34 and 37 but it is requested that the remaining information sought (carcass examination results, sightings documentation), be provided by 1979. The sub-committee had no information in response to the committee's request to Mexico to provide full details of the research being carried out on the breeding grounds and therefore suggests this request be repeated.

12.4 Blue whales

Sightings data on this species are shown in SC/30/Docs 23, 26, and 27, SC/30/Rep 6 and SC/30/Prog Reps 1, 10 and 11. In addition SC/30/Doc 23 contains some historic catch data of this species off Greenland. Blue whale sightings off Iceland increased in 1977 over the previous years with approximately the same sightings effort. In the southern oceans after seven years of below average sightings the number sighted increased considerably, notably in Area II Sector D and Area V Sector E. In other ocean areas any changes observed were minor.

The situation in the Antarctic will be analysed as future observations become available; possibly some local concentrations of this species are beginning to rebuild. Even if this were true and not an artifact of sampling, the species as a whole remains at low levels and should receive continued protection in all oceans.

The sub-committee noted that the Special Meeting on Southern Hemisphere Minke Whales (SC/30/Rep 4) made calculations on other species and showed original and present levels of pigmy blue whales (p. 357). These are clearly very preliminary calculations and need to be reconsidered in greater depth, perhaps as part of the fin whale reanalysis suggested below (Item 12.6).

Again if any exploitation were to be considered it is recommended that it be preceded by an intensive marking and sighting programme reviewed and approved by the Scientific Committee. All countries having material that might help to clarify the taxonomic status of the pigmy blue whale are urged to analyse it and publish the results.

12.5 Humpback whales

In addition to the sightings data given in SC/30/Docs 23 and 49, SC/30/Rep 6 and SC/30/Prog Reps 1, 2, 6, 7, 9, 10 and 11, there are data on kill of this species in Greenland (SC/30/Doc 23), in the Caribbean (SC/30/Doc 16) and in Tonga (SC/30/Prog Rep 6) and censuses of local stocks in SC/30/Docs 16 and 49 and SC/30/Prog Rep 11. Casual observations of this species in 1977 off Greenland appear to show more humpbacks than in previous years although the information on effort is uncertain.

Baxter *et al.* (SC/30/Doc 49) estimate the Caribbean breeding stock, which may be the total western Atlantic stock, to be 2,300. Some members feel that some of the assumptions are not well founded and the resulting estimate is high. Winn and Scott (SC/30/Doc 16) argue for three separate breeding stocks in this area, but the sub-committee found their argument unconvincing and in the absence of other data accepts the previous hypothesis of one western Atlantic stock.

The sub-committee noted the Commission's request to collect data on all sources of mortality to western North Atlantic humpbacks. Kills in the decade 1967-76 averaged 7.5 per year (25% in the Caribbean, 75% in Greenland). Strandings data are being collected including information as to the cause of mortality where possible and will be provided by American and Canadian scientists in the near future. The sub-committee noted that the Commission intends to review the exemption in the Schedule permitting Greenland to take 10 humpbacks per year. It was noted from SC/30/Doc 49 that 22 calves were counted in a total of 1,609 whales sighted in the Caribbean and this leads the sub-committee to recommend that this exemption be removed and that Greenland be urged to take fin whales instead. This was based on the fact that western Atlantic fin whale stocks are believed to be larger and in better condition than the humpback whale stock and fin whale catches could add to the knowledge of their distribution if additional marking were carried out in West Greenland. Kapel suggested that humpback whales were not in small numbers near Greenland and that there might be some difficulties with a switch to fin whales. The Commission may wish to take into account other considerations as in the case of bowhead whales.

The sub-committee noted that three humpback whales have been taken in Spanish whaling operations in recent years and recommends that the Commission asks Spain to take steps to prohibit catches from this very depleted eastern Atlantic stock. Stocks in other areas of the world, as ascertained from sightings, remain at low levels, generally between blue and right whales in abundance. The sub-committee recommends that the Tongan government collects statistics on its aboriginal kill of this species.

The sub-committee notes that the coastal migration paths of humpback whales in particular, but also of some other species, make systematic sightings quite feasible. It suggests the Commission asks countries to undertake such systematic sightings including providing data on effort, and if possible the fraction of the migrating group included.

12.6 Fin whales
Southern Hemisphere

In addition to the updated estimates given by Chapman and Breiwick (Appendix 1) the Committee considered the sightings data in SC/30/Doc 26 (in particular in Table 40). No clear trends were indicated in these data. The sub-committee recommends that at the earliest opportunity there should be a reanalysis of fin whale stocks taking into account new effort modifiers, consideration of species interdependence, marking data, etc. In this connection the concerns expressed in SC/30/Doc 6 were noted. Also any such reanalysis should take into account the sightings data in a systematic manner. It was suggested that an experimental harvest might be appropriate in one Area but members of the sub-committee emphasised that this should only be carried out if it had been preceded by intensive marking and accompanied by more intensive sighting studies. While such studies might be conducted in Area VI where the stock, according to the model update, is closest to Sustained Management status, other considerations, such as earlier marking efforts might also be important.

12.6 Fin whales
North Pacific

According to SC/30/Doc 44 this stock was, in 1975, 37% below MSY level (and 39% of initial level). Thus there is little reason to expect that this stock has recovered to Sustained Management level. The only data available are in SC/30/Doc 27 based on Japanese sightings. In particular Fig. 4d, (p. 255) supports the conclusion based upon the model that this stock should remain classified as a Protection Stock.

12.7 Sei whales – North Pacific

SC/30/Doc 44 notes that, in 1975, this stock was estimated to be at 21% of initial level. This stock, even with the most optimistic model, must still be at a relatively small fraction of the initial stock level. The Japanese sightings data shown in SC/30/Doc 27 (cf. particularly Fig. 4e, p. 256), are in agreement with the model in suggesting that the decline of the stock has ceased but it remains at 20-30% of initial level. This stock should remain in the Protection Stock category.

13 Review of protection stocks approaching Sustained Management Category

The only stocks that appear to be in this category are the pigmy blue whales and Area VI fin whales. These were discussed above and the need for thorough reanalysis emphasised. We repeat that the points raised in SC/30/Doc 6 need consideration in such a reanalysis.

14 Review of aboriginal and subsistence fisheries

The sub-committee had available to it SC/30/Doc 42 and it considered the status of the bowhead stock (Item 12.1) as well as the Greenland exemption for humpback whales (Item 12.5). It did not believe that it could usefully undertake a review of the aboriginal and subsistence fisheries question at this time. If the Commission decides to open up the question of management procedure either through a special meeting or otherwise this subject could very appropriately be on the agenda of any such meeting. If such a meeting is held, specialists from other disciplines than those available in the Committee should be invited.

19 Effects of pollution on whale stocks, including small cetaceans

The sub-committee repeats the request of last year that the Commission urge all countries to make studies of levels of pollutants on all species of cetaceans, both those taken in commercial catches and those found stranded. These are particularly important for species taken in catches of coastal operations in areas where industrial or agricultural activities have involved heavy use of chlorinated hydrocarbons, polychlorinated biphenyls or heavy metals. The sub-committee was informed that many studies have been initiated, particularly tissue collections but many are being held up by lack of funds for analysis. It is hoped that such studies can be completed and either final or preliminary results published in the near future. The critical situation in respect to pollution off Corsica was noted again and reference made to the papers of Viale. The sub-committee notes that some Canadian studies have been conducted on the effects of oil exploration and development on beluga whales and asks that such information be made available to the Committee.

Appendix I

UPDATED ESTIMATES OF FIN WHALE STOCKS IN SOUTHERN OCEANS

D. G. Chapman and J. Breiwick

Allen (1977) (*Rep. int. Whal. Commn* 27: 221) updated the 1975 estimates of fin whale stocks in several areas using the model that had been adopted at the special meeting of the Committee on classification of stocks in La Jolla. Using the same procedure estimates of the fin whale stocks in Areas II-VI of the Southern Hemisphere are shown in Table 1 below. These require, in addition to the values given in Allen, estimates of 1971 and 1972 (i.e. parent stock) populations. These have been calculated assuming equal average increase before catch between 1970 and 1975 populations and of course subtracting the appropriate catches. The estimated populations for 1971 to 1975 found in this way are given in Table 1. It should be noted that only the last three estimates are based on the model update.

Finally, Table 1 shows the estimated percentage of the MSY population level as a basis of classification. All remain in the Protection Stock category according to this model.

Table 1

Estimates of Southern fin whale stocks 1970–78 (000s)

	Area I	II	III	IV	V	VI
1970/71	2.9	13.5	30.2	7.4	2.4	9.7
1971/72	2.9	14.2	30.3	7.1	2.4	10.1
1972/73	2.9	14.9	30.6	6.8	2.6	10.6
1973/74	3.0	15.8	31.6	6.9	2.6	10.8
1974/75	2.9	16.6	33.0	7.2	2.7	10.9
1975/76	2.8	17.5	34.7	7.4	2.7	11.2
1976/77	2.7	18.1	36.1	7.8	2.9	11.6
1977/78	2.9	18.7	37.4	8.1	3.0	12.0
1978/79	3.1	19.4	38.8	8.4	3.1	12.4
1978/79 population as % MSY population		28	45	25	19	89

Annex H

REPORT OF THE SUB-COMMITTEE ON SMALL CETACEANS

1. The sub-committee had available a number of documents and progress reports dealing with small cetaceans. These were SC/30/Docs 19, 23 and 59; SC/30/Prog Reps 2, 3, 6, 7, 8, 9, 10 and 11; SC/30/Reps 3 and 5; IWS LXXIX and LXXXI (Provisional issue); and Small Cetaceans Doc 1 ("Porpoise mortality status report no. 78-7").

2. Management of Small Cetaceans

At the 28th Annual Meeting of the International Whaling Commission, it was agreed that all cetaceans taken for their own value be subject to consideration by the Scientific Committee and that the following species in the following areas should be considered for immediate action:

(1) Northern bottlenose whale (*Hyperoodon ampullatus*), North Atlantic;
(2) Striped dolphin (*Stenella coeruleoalba*), North West Pacific;
(3) Dall's porpoise (*Phocoenoides dalli*), North West Pacific; and
(4) Harbour porpoise (*Phocoena phocoena*), North Atlantic.

Progress on the management of these species over the past two years is outlined below:

Northern bottlenose whale

This species was provisionally listed as a Protection Stock for the entire North Atlantic in 1978, pending the accumulation of sufficient information for classification. No new data were available, and the sub-committee recommends that the provisional classification as a Protection Stock should remain.

Striped dolphins

No management actions have been taken.

Dall's porpoise

The USA and Japan have agreed to a research plan on Dall's porpoise taken in the Japanese salmon gill-net fishery. This programme includes collection of statistics on the number of porpoises incidentally caught and the collection of biological samples.

Harbour porpoises

No management actions have been taken.

The sub-committee again recommends that all cetaceans taken deliberately for their own value should be subject to consideration by the Scientific Committee for future management.

3. Research

It is again recommended that the Secretariat and governments of member nations be urged to initiate or augment research on species involved in direct fisheries. These include recommendations on northern bottlenose whale, striped dolphin, Dall's porpoise, and harbour porpoise outlined in the sub-committee's 1976 report (*Rep. int. Whal. Commn* 27: 481). The sub-committee noted that the recommended bottlenose whale research programme from 1977 was not carried out this year for financial reasons. The sub-committee still recommends that this programme be carried out as recommended at the 1977 meeting (*Rep. int. Whal. Commn* 28: 66).

4. Regional Fisheries Accounts and Catch Statistics

Arctic

Provisional small cetacean catch statistics for Canada and Greenland for 1977 are presented in the Progress Reports from Canada and Denmark. Catches are of the same order of size as previous years.

Temperate North Atlantic

Norway has begun a programme of research on the killer whale because of concern by fishermen that killer whales are increasing in number and competing with them for herring. The programme includes marking for identification (three have been marked to date) and studies of behaviour, feeding habits and life history (SC/30/Doc 59).

Black Sea

Berkes (1977, *Oryx* 14(2): 163–7) presents the first available information on the Turkish fishery for dolphins (bottlenose dolphin, common dolphin and harbour porpoise). The dolphins are taken by purse seine and by shooting. The only restriction on the fishery is a seasonal prohibition from 10 June to 30 September, coinciding with the breeding season. Estimates of catches are available for 1965–73 (numbers obtained by conversion of weight, at 50 kg per animal):

1965	52,000
1966	236,000
1967	8,000
1968	88,000
1969	332,000
1970	136,000
1971	176,000
1972	176,000
1973	176,000[1]

No explanation is given of the wide year-to-year variation in the catch. The report recommends that efforts be made to document fishing effort and catch by species. The sub-committee endorses these recommendations.

Eastern Tropical Pacific

Annual estimated numbers of dolphins killed (of all species in the aggregate) by fishermen in the international purse seine fishery in the eastern tropical Pacific Ocean, 1970–77,

[1] Estimated by FAO (FAO, 1974. Catches and landings 1973. *Yb. Fish. Statist.* 36).

are presented in IWS LXXXI (Provisional Issue). The kills are broken down into two categories: by US fishermen and by fishermen of other nations. In 1977 for the first time, the estimated US kill was less than that of other nations (27,000 *vs.* 44,000). US kills for the period 1 January through 2 May total an estimated 3,321 (SC/30/Small Cetaceans Doc 1). Statistics on incidental kill in the fishery by vessels of IWC member nations Panama, Mexico, Canada and France were last year recommended by the sub-committee to be submitted (*Rep. int. Whal. Commn* 28: 81), but the data have not been forthcoming. The sub-committee again recommends that the Committee request that catch statistics be solicited from member nations.

Perrin informed the sub-committee that an additional species has been added to the list of species involved in the fishery, the false killer whale (*Pseudorca crassidens*).

North Pacific

Research has begun on the problem of incidental mortality of Dall's porpoise in the Japanese gillnet fishery for salmon in the far northern Pacific. SC/30/Rep 3 is the report of an assessment workshop conducted in Seattle, Washington, USA in January this year. A planning meeting for joint research by the USA and Japan was held in April, and research has begun, including collection of sightings data and life history specimens and data by US scientific observers aboard Japanese salmon motherships and salmon research vessels (SC/30/Prog Rep 11). A progress report will be presented to the next meeting of the sub-committee.

M. A. Bigg at Nanaimo, BC, has begun a study of feeding habits of killer whales off British Columbia (SC/30/Prog Rep 2). During 1977, the USA collected sightings data for killer whales in inside waters of Washington State (SC/30/Prog Rep 11).

Temperate South Pacific

The sub-committee was pleased to note that studies recommended last year on Hector's dolphin (*Cephalorhynchus hectori*) are underway. The programme includes ship surveys and the marking of fourteen dolphins (SC/30/Prog Rep 6) by A. N. Baker at the National Museum of New Zealand.

Indian Ocean

New data were available on the incidental catch of dolphins in shark nets off Natal (SC/30/Prog Rep 8). Four of the 20 animals examined were *Tursiops aduncus* (*T. truncatus* in IWC list of recommended names).

Antarctic

An increase in the number of killer whales taken by the USSR was reported (SC/30/Prog Rep 9). Seventy-seven whales were taken during the 1977/78 season, compared with a mean of 22 taken over the past eight seasons.

5. The problem of competitive interactions between fisheries and small cetaceans

The sub-committee recognised that much attention in the popular press has recently been focused on putative direct competition for fish between fishermen and small cetaceans. The recent "Iki Island Incident", in which large numbers of false killer whales (*Pseudorca crassidens*) and bottlenose dolphins (*Tursiops truncatus*) were authorised to be killed by Japanese local governmental authorities, provoked extensive press coverage and unfavourable comment worldwide. Christensen and Jonsgard reported to the sub-committee on great concern by Norwegian fishermen that killer whales (*Orcinus orca*) may be preventing recovery of the depleted coastal herring stock in Norwegian waters through predation. Many other situations of similar nature exist around the world, some involving fish and/or marine mammal populations that traverse international fisheries boundaries. The members of the sub-committee agreed that, while the potential for significant competition between fishermen and marine mammals exists and such competition has been demonstrated in some cases, in nearly all such situations the relationship is only asserted to exist, rather than demonstrated to exist.

Recognising the potentially serious nature of these situations, both in terms of fishery resources and in terms of danger to small cetaceans, the sub-committee urges the Committee to recommend that the Commission foster and support research by member nations into general and specific competitive relationships between small cetacean populations and fish populations, as well as providing data on kills to IWS.

In both of the examples discussed above, the member governments have initiated relevant programmes of research. Christensen described current effort, including a reward system, to collect life history and diet data from killer whales authorised to be taken in Norwegian coastal waters. Ohsumi briefly described a new programme of biological and technological research aimed at assessing and relieving the situation around Iki Island. Both will provide progress reports on the new programmes at the next meeting of the sub-committee.

6. Live-capture fisheries

The sub-committee recognised that live-capture fisheries are expanding from some of the traditional areas in the United States and Canada to Mexico, northern South America, the Baltic Sea, Japan, Bahama Islands and Iceland. Species involved are: *Sotalia fluviatilis, Pseudorca crassidens, Lagenorhynchus acutus, Tursiops truncatus* and *Orcinus orca.* Needs of new aquariums in Asia and Europe have caused the live-capture fisheries to develop in new areas. An additional reason for these new fisheries is the strict regulation of exports from the USA since 1972.

7. Recommendations to the Scientific Committee

a. Continued provisional classification as a Protection Stock, of the northern bottlenose whale, *Hyperoodon ampullatus* should remain for the entire North Atlantic.
b. The sub-committee still recommends that the bottlenose whale research programme be carried out as recommended at the 1977 meeting (see *Rep. int. Whal. Commn* 28: 66).
c. Catch statistics on incidental kill of small cetaceans in the international purse seine fishery by vessels of IWC member nations (Panama, Mexico, Canada and France) should again be requested.
d. The sub-committee urges the Committee to recommend that the Commission foster and support research by member nations into general and specific competitive relationships between small cetacean populations and fish populations.

e. The sub-committee again calls the Committee's attention to its recommendation on the management of small cetaceans at its 1976 meeting (see *Rep. int. Whal. Commn* 27: 480) that there is an urgent need for an international body to effectively manage stocks of all cetaceans not covered by the present IWC Schedule.
f. Statistics and data should be collected by the IWC on a mandatory or optional basis for small cetaceans as outlined in the sub-committee's 1977 Report (see *Rep. int. Whal. Commn* 27: 480).

Annex I

WHALE MARKING – PROGRESS REPORT 1978

S. G. Brown

Sea Mammal Research Unit, Natural Environment Research Council

Information on the progress of whale marking is available in the following progress reports, SC/30/Prog Reps 2, 4, 5, 6, 7, 9 and 11, and recent marking is also referred to in SC/30/Docs 28, 30, 59 and 60. Progress in Antarctic marking under the international scheme during the whaling seasons 1971/72 to 1976/77 is reported in SC/30/Doc 2.

A total of 561 large whales was marked in the Southern Hemisphere during the 1977/78 Antarctic season. The total includes 4 blue, 57 fin, 98 sei, 75 Bryde's, 3 humpback, 123 minke and 201 sperm whales, all marked with Discovery-type marks (Table 1).

Seventeen whales were marked in the North Atlantic Ocean in 1977 and early 1978; 6 humpback, 7 minke and 4 sperm whales. Five of the humpback whales were marked with modified Discovery-marks (Visual streamer/flag and Quinacrine). 81 whales were marked in the North Pacific Ocean in 1977 and early 1978, including 9 fin, 30 sei, 32 Bryde's, 5 humpback and 5 sperm whales.

Some small cetaceans were marked including four belugas in the Canadian Arctic and one killer whale off Svalbard in 1977, and 14 Hector's dolphins were freeze branded and tagged off New Zealand.

Information on a new design of a visible tag, suitable for both large and small cetaceans, is given in SC/30/Prog Rep 6. Experiments are continuing with the implantation of radio-tags in humpback whales in Alaskan waters.

Discovery-type marks were recovered from 4 Bryde's whales and 2 sperm whales in the North Pacific Ocean, and from 5 minke whales in the Arctic North Atlantic in 1977. Details of marks recovered in the Antarctic season 1976/77 are given below. Full details of recoveries in the 1977/78 season are not yet available.

WHALE MARKS RECOVERED IN THE ANTARCTIC WHALING SEASON 1976/77

Four whale marks from two sei whales and two minke whales found during the Antarctic whaling season 1976/77 have been reported to the Sea Mammal Research Unit (Table 2). Three of the marks are in the USSR series. Additional marks in the series were also recovered from five sperm whales but full details are not available.

The one mark in the international scheme series, No. 32344, was a .410 mark fired into a minke whale, estimated

Table 1

Large whales marked during 1977 and 1978, and in the Antarctic season 1977/78

	Blue	Fin	Sei	Bryde's	Humpback	Minke	Sperm	Total
Southern Hemisphere								
South of 40° S								
International Scheme–								
Japan	–	56	89	–	–	63	95	303
USSR	1	–	8	–	–	33	14	56
North of 40° S								
International Scheme –								
Japan (including *Taka Maru*)	3	1	1	75	3	27	69	179
USSR	–	–	–	–	–	–	23	23
Total	4	57	98	75	3	123	201	561
Northern Hemisphere								
North Atlantic								
Canada 3/78	–	–	–	–	5*	–	–	5
Iceland 1977	–	–	–	–	–	7	–	7
Norway 1977	–	–	–	–	1	–	–	1
USSR 1977/78	–	–	–	–	–	–	4	4
Total	–	–	–	–	6	7	4	17
North Pacific								
Japan (*Taka Maru* 1/78–3/78)	–	–	–	31	–	–	4	35
Japan 1977 (Scouting boats)	–	9	30	1	–	–	1	41
USA 7/77	–	–	–	–	5*	–	–	5
Total	–	9	30	32	5	–	5	81

* Includes whales marked with modified Discovery-type marks, radio tags, etc.

Table 2

Marks recovered in the Antarctic season 1976/77

Mark No.	Date marked	Date recovered	Time elapsed (years, months)	Position marked	Position recovered	Sex	Length in feet
				Minke whales			
32344	17.ii.77	18.ii.77 (from refrigerator vessel)	0.0	67° 02′ S, 61° 06′ E	66° 48′ S, 59° 41′ E (approx.)	–	–
				USSR series			
B537 (Sei)		24.xii.76			43° 59′ S, 152° 28′ E	Male	47
690709 (Sei)		24.iii.77 (from flushing tank)			Area III–V	–	–
680102 (Minke)		23.ii.77			66° 29′ S, 49° 58′ E	Female	29

length 28 feet, on 17 February 1977 in position 67° 02′ S, 61° 06′ E. It was recovered on a refrigerator vessel on the following day and no details of the sex or length of the animal are available. This mark and No. 680102 in the USSR series are the first marks to be recovered from minke whales in the Southern Hemisphere.

Annex J

REPORT OF THE SUB-COMMITTEE ON HUMANE KILLING TECHNIQUES

Committee Members

Best, Cawthorn (convenor), Donovan, Yamamura.

Documentation available

The sub-committee had available two documents dealing with whale killing techniques and humane killing. These were SC/30/Doc 38 and SC/30/Doc 38 Appendix 1.

Data available

In response to a request by the Scientific Committee in 1976 for data from nations taking minke and other species of whales, data were submitted by Japan and South Africa detailing kill times and number and type of harpoon used for sperm, fin, sei and minke whales.

Current whaling techniques

Most large whale catching operations, both coastal and pelagic, use 90 mm harpoon cannons firing a 60 kg, 4 fluked harpoon, armed with a flat-topped, cast iron explosive grenade of approximately 8 kg weight, charged with 400 gm of black powder.

During the mid-1960s the Japanese whaling industry changed to 75 mm cannons firing a 45 kg harpoon. This was motivated by

(a) change in exploited species from large fin and blue whales to smaller species such as sei and minke whales, and
(b) the need to conserve meat for human consumption.

Vessels involved in coastal small whaling operations in the Northern Hemisphere use 40-60 mm harpoon cannons firing 2 or 4 fluked harpoons topped with a cold (non-explosive) grenade.

The Japanese, although using either 75 mm or 50 mm harpoons and cold grenades in their minke whale fisheries, despatch harpooned animals swiftly using an electric lance which has a maximum output of 100 V 25 amps.

Minke whales are taken in the Southern Ocean by Soviet vessels using 90 mm harpoons with cold grenades, the harpoons propelled by a reduced charge.

Open boat, hand harpooning methods are still practised in three areas, the Azores for sperm whales, Tonga, and Bequia in the West Indies, for humpbacks.

Bowhead whales are killed from open boats by Alaskan Eskimos using bomb lances and shoulder guns designed during the 19th century.

Death times

Best (1975, *Rep. int. Whal. Commn* 25: 208–14) and Ohsumi (1977, *Rep. int. Whal. Commn* 27: 204–5) have recorded death times for harpooned sperm, fin, sei and minke whales.

The most serious problem in obtaining and comparing such data is the degree of subjectivity involved in deciding the moment of death.

Best recorded median death times for 140 sperm whales killed off South Africa by three different gunners (Fig. 1). They ranged from 2 min 10 sec to 4 min. The maximum death time recorded in 140 observations was 19½ min (a result of detonator malfunctions). There was no significant difference in the death times for small (<40′), medium (40′–45′) or large (>45′) sperm whales. A geometric mean of 1.6 harpoons per sperm whale killed was reported.

Ohsumi (Table 1) collected mean kill times (in brackets) from 244 fin whales (5.52 min), 564 sei whales (3.91 min) and 946 minke whales (3.72 min).

The death times for 10 minke whales taken off South Africa averaged 5 min 20 sec. A possible reason for this time being somewhat greater than the Japanese average is

Table 1

Death times for fin, sei and minke whales taken by Japan (from Ohsumi, 1977)

Fin whales

Time (min)	Kyo-maru No. 1 Whales	%	Kyo-maru No. 11 Whales	%	Total Whales	%
0- 5	58	73.4	8	18.6	66	54.1
5-10	19	24.1	20	46.5	39	32.0
10-15	2	2.5	8	18.6	10	8.2
15-20	–	–	5	11.6	5	4.1
20-25	–	–	2	4.7	2	1.6
Total	79		43		122	
Average time (min)	3.35		9.51		5.52	

Sei whales

Time (min)	Kyo-maru No. 1 Whales	%	Kyo-maru No. 11 Whales	%	Total Whales	%
0- 5	129	81.7	56	45.2	185	65.6
5-10	28	17.7	60	48.4	88	31.2
10-15	1	0.6	8	6.4	9	3.2
Total	158		124		282	
Average time (min)	2.72		5.44		3.91	

Minke whales

Time (min)	Fumi-maru No. 5 Whales	%
0- 5	818	86.5
5-10	101	10.7
10-15	18	1.9
15-20	6	0.6
20-25	2	0.2
25-30	1	0.1
Total	946	
Average time (min)	3.72	

that although both use a cold (non-explosive) harpoon, the Japanese employ a two-point electrical lance to kill the animal after having made fast.

Preliminary data from the Australian sperm whale fishery (Table 2) suggests a similar range of death times to those from South Africa, and a slightly higher geometric mean of number of harpoons used (1.9).

Alternatives

The use of drugs to kill or anaesthetise whales would undoubtedly be effective but the problems of calculating dose rates, delivery methods, drug residues in meat destined for human consumption, and the possible dangers to gunners and crew involved in handling equipment render this method impractical for the present, although if some of these problems can be overcome the technique is promising.

Electrical harpooning has been researched by whaling companies and others since the mid-19th century. Recent Japanese reports showed electrical harpooning to be 50% less effective than explosive harpooning. Some disadvantages encountered in this method are lowered meat quality through localised burning, danger to gunners of electrocution, and the problems of reduced flexibility and added weight to forerunners and other equipment.

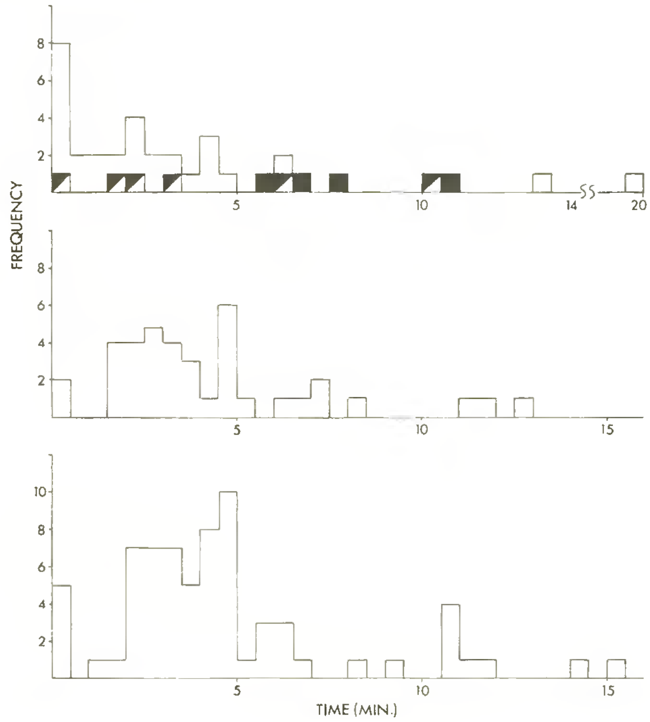

Fig. 1. Death times of whales – data for three different gunners □ sperm, ■ minke, ▨ sperm + minke (after Best, 1975)

When electrical equipment functions satisfactorily the average time from impact to signs of death, as recorded by Wall (1961, *Rep. int. Whal. Commn* 12: 32-5) was 2-5 min. But this time varies with individual whales' resistance to electric shock, the location of the harpoon and a number of other factors. The relative degree of suffering induced by this technique is unknown.

Table 2

Samples of 61 sperm whales taken at Albany (Australia)

% Died instantly	% Died within 5 min	% Died over 5 min
20.6	55.1	24.3

Advances in the design and techniques in explosive harpooning have led to this form of killing being as efficient as electrical techniques. Norwegian type grenades attached to 90 mm and smaller harpoons are made of cast iron, designed to fragment on detonation and sever major organs and vessels in the whale's body speeding death. However, the Japanese have introduced a more efficient steel grenade which breaks into two sections concentrating considerably greater explosive force into a smaller area killing by shock rather than fragmentation.

Conclusions

It would appear from available data that explosive harpooning is still the most reliable and efficient method of killing whales practised today. The use of tethered or untethered "killer" harpoons to administer a rapid *coup de grace* to whales made fast, but not killed by the first harpoon is a commendable humane practice.

Other methods such as electrical harpooning and the use of drugs to kill whales should not be overlooked; further assessment and research into these methods should proceed in an effort to ensure that while whaling is being practised every effort is made to kill the animals as humanely as is practicably possible.

The hand harpooning methods and those employed by Alaskan Eskimos are both inefficient and undeniably prolong death times.

Loss of whales struck but not landed is inevitable. This problem in Alaska has diminished in 1978 under a new management regime.

Recommendations for future research

1. A systematic investigation and evaluation of the efficiency of present methods of killing whales is needed, in particular observations by suitably qualified veterinarians and other personnel of the rapidity of unconsciousness and death and of the nature of the injuries caused.

   Such observations should cover examples of at least one large whale pelagic or coastal operation and one small-type whaling operation.
2. Following these field observations, and depending on the nature of the conclusions reached, a report-back meeting should be held between the research personnel and the IWC representatives to decide on future action.
3. Further research by qualified personnel into electrical, pharmacological and explosive methods should be urged on whaling nations in an effort to achieve the most humane methods of killing whales as quickly as possible.
4. In order to compare results from different fisheries standard criteria for unconsciousness and death should be formulated.

Annex K

REPORT ON THE SUB-COMMITTEE ON CETACEAN BEHAVIOUR AND MANAGEMENT

MEMBERS

Brown, Brownell, Cawthorn, Christensen, Fortom-Gouin, Harwood, Kapel, Lockyer, Mitchell (Convenor), Morgane, Pilleri, Van Bree and others.

TERMS OF REFERENCE

To set out draft guidelines for discussion of cetacean neuroanatomy, intelligence potential, "social bonds" and other scientific matters as they may relate to assessment and management of whale stocks.

The sub-committee emphasizes that it does not include any behavioural scientists, and that in view of this lack of expertise and lack of access to relevant literature at this meeting, the following points are not intended to be more than notes for discussion. A list of literature cited is given as Appendix II.

EVIDENCE

1. Definitions of intelligence

Intelligence is difficult to define, and interspecies comparisons are also difficult. No working definition of intelligence was satisfactory to the sub-committee, especially in view of the subjectivity involved in judging cetacean abilities.

2. Structure of cetaceans

a. Neuroanatomy

Evidence of the amount and quality of neocortex is important:

(i) topographic differentiation (the relatively great number of neocortical areas)

(ii) the amount of the neocortex, especially association neocortex, and

(iii) the lamination of the cortex and the numerous synapses and processes associated with each nerve cell indicate neuroanatomical complexity in all cetaceans (summary in Morgane and Jacobs, 1972). This degree of complexity has been compared with that of man.

b. Neuroanatomical correlates and their relation to potential for intelligence

Specialisation for enhanced acoustic sense does not alone explain the increased size of the cetacean brain. The enhanced acoustic sense may be no more sophisticated than the comparable visual system in a mammal such as man, relative to the processing and interpretation of input by the brain.

> "The communication systems of delphinids appear to be of approximately the same size and complexity as those of most other species of birds and mammals" (Wilson, 1975, p. 478).

However, the total amount of brain association neocortex may relate to complex mental functions (the processing of higher nervous activity on the basis of multiple sources of nervous input, or cortical integration), and learning capacity.

Two viewpoints are now current:

> "While the matter is one needing further studies (particularly of a physiological and behavioural nature) before any definitive conclusions are drawn, the enormous surface of the whale cortex and its luxuriant and highly convoluted appearance . . . still appear to be sound arguments for considering the cetaceans as potentially intelligent and highly developed fellow beings" (Morgane, 1974, p. 89).

Also:

> "It is important to emphasize that there is no evidence whatever that delphinids are more advanced in intelli-

gence and social behaviour than other animals. In intelligence the bottle-nosed dolphin probably lies somewhere between the dog and rhesus monkey (Andrew, 1962). The communication and social organization of delphinids generally appear to be of a conventional mammalian type" (Wilson, 1975, p. 474).

There has been no comparable evaluation and conclusion for mysticetes.

3. Observed behaviour

a. Social behaviour (can be discussed under the following categories)

Sexual behaviour, size/age-related behaviour (including groups pair behaviour) and co-operative behaviour (including courtship, feeding, migration and defence/attack behaviour). Lockyer prepared notes for discussion on these points (Appendix I).

b. Tool using and/or manipulation

Consideration of the ability to use tools would of necessity be confined to such manipulation of objects as is possible given the physical structure of cetaceans. Limited published observations include: the manipulation of objects by small cetaceans with their mouths and tongues, in captivity, and Brown and Norris (1956) described the use of a scorpion fish by porpoise in captivity to capture a moray eel.

c. Vocal communications

An example is the humpback whale. The humpback whale vocalises long sequences of varied sounds during the calving season which have been called "songs" (Payne, 1977 and other works). Within a season there is apparently exact repetition of a sequence, which may last up to 25 min, but the "songs" change from year to year making them more complex than bird songs (Payne, in preparation). The function of this behaviour is presently unknown.

d. Abstract concepts

One paper is suggestive of problem-solving, and communication of resulting information, by delphinids (Evans and Dreher, 1962, encounter of net in wild). The little published data (e.g. Lilly, Miller and Truby, 1968: experiment on sonic pulse count matching) on abstract concepts is inconclusive: a more conclusive experiment on shape matching was reported by Kellogg and Rice (1966), and the novel behaviour of a captive porpoise is also relevant (Pryor, Haag and O'Reilly, 1969).

e. Interspecies interactions

(i) Interaction with man. Busnel (1973) and Bryden (1978) give the evidence for symbiotic relationships between man and porpoises in the Mediterranean, off Africa and off Australia. Mead (1962) described co-operation between killer whales and men in hunting humpback whales.

(ii) Interaction with non-cetacean species other than man. The nature of the bond between porpoise and tuna (Perrin, 1968) is not well understood.

4. Significance of complex behaviour to assessments and management

a. Assessment

The following behavioural parameters may affect estimation of population abundance and status, from the gathering of data in the field to injecting biases in calculations if not recognised and taken into account.

(i) Catch-per-Unit-Effort analyses. Diving patterns and their change with experience and in the chase (Lockyer, 1977), evasive or seeking behaviour (e.g. Mitchell, 1978), social factors such as strength of pair-bonding, pod formation and epimeletic behaviour that affect the catchability of the second whale taken from a group, the long term cohesion and biological efficiency of groups after removal of whales, the learning ability of whales upon being chased, the nature of association between adult males and schools of mature female sperm whales, the constriction of breeding or feeding range as populations are reduced in number, the possible tendencies to form groups of the same sizes as when they existed at higher, total densities.

(ii) Sightings analyses. Some items from (i) apply here, as do: diving patterns and changes with experience and in the chase, habit of breaching and lobtailing, evasive or seeking behaviour, stereo-typical behaviour relating to migration routes, calving and breeding activity and areas, and relative to oceanographic features and feeding areas.

(iii) Tag - recapture analysis. Some of the items relating to (ii) are also pertinent here, as well as: learning, e.g. whether whales, once tagged, might then always avoid ships (with resulting low recovery levels).

b. Management

Biological results of harvesting regimes are important in evaluating different management procedures. Unanswered questions remain on the biological consequences of: removing a few animals from pods (especially breeding animals, e.g. dominant sperm bulls, Mitchell, 1977), or instead, of taking the entire pod, effects of selection in fisheries for large animals, local depletion of a population in part of its range, and removal of large numbers of socially mature animals as it relates to survival of young and their later success as parents.

Appendix I
SOCIAL BEHAVIOUR

A number of aspects of social behaviour were recognised and are discussed below:

1. Sexual behaviour

Cetacea, more specifically members of the Delphinidae, have been observed to exhibit a wide range of sexual behaviour both in captivity (Caldwell and Caldwell, 1972) and in the wild (Lockyer *et al.*, 1978). Factors influencing such behaviour are difficult to assess, involving both interaction of hormonal stimulation (Hutchinson, 1978) and environmental factors (Hinde, 1970). At the present time the interpretation of the significance of observations on variable sexual behaviour is uncertain.

2. Size related behaviour

a. Group behaviour

There is much information concerning cetacean social groupings and patterns of behaviour. For example, sperm whales are known to have a complex social organisation with separate schools of juvenile, male and female whales and solitary bulls (Ohsumi, 1971; Gambell, 1972 and Lockyer, 1977). Mysticetes are well known to exhibit differential behaviour in juveniles and adults, and also temporary segregation by sex (e.g. minke whales, see Annex D, this volume). The migration and feeding timings are noticeably different (Mackintosh and Wheeler, 1929; Gambell, 1968 and Lockyer, 1976). Dolphins are known to form coherent groupings of different sized animals (Wuersig, 1978; Wuersig and Wuersig, 1977). Close association of animals can be recognised from surfacing/br s performed in unison (Wuersig and Wuersig, 1977). Mass strandings also reflect social cohesiveness (e.g. Van Heel, 1962).

b. Pair behaviour

Mysticetes are frequently found in pairs (male/female) and usually in small groups. This is probably a reflection of monogamy orientated mating, unlike the polygamous groupings of the sperm whale. The most common pair bond is that of cow and calf in most Cetacea up until weaning. The weaning stage is not well known for the sperm whale, for which it may be very protracted (Best, 1968). The cow is known to exhibit variable degrees of protectiveness to the calf, dependent on species and age of the calf.

3. Co-operative behaviour

a. Courtship

This is well documented for delphinids in captivity (Caldwell and Caldwell, 1972), and involves postural displays on the part of both male and female. The courtship behaviour in *Tursiops* is apparently learnt from the mother at an early age by the calf, as the mother frequently encourages the juvenile to attempt mating in response to postural displays (Caldwell and Caldwell, 1972).

Courtship behaviour in the wild is not so well documented, but in baleen whales (e.g. right whales) this may sometimes involve more than two whales (Donnelly, 1967; Payne, 1972, 1976). The courtship behaviour in sperm whales is probably analogous to that in other animals with harem social structures, where only one bull (or only a few) are permitted status to mate with mature females. The complex maturation of the testis tissue in sperm whales (Best, 1969) may be a reflection of this behavioural pattern.

b. Feeding

The strategies and mechanics of feeding in baleen whales are published in several sources (e.g. Nemoto, 1959; Kawamura, 1974; Gaskin, 1976; Gill and Hughes, 1971), although detailed hunting behaviour is not documented for most odontocetes. The seasonality of feeding (Lockyer, 1976) in many Cetacea (baleen whales) is an important factor in their survival in an otherwise perhaps unfavourable environment.

c. Defence/attack behaviour

Most Cetacea are not known to be aggressive. However, killer whales have been observed to effect well co-ordinated group attacks on larger whales (Baldridge, 1972) and also seals (Condy *et al.*, 1978).

Defensive behaviour is most frequently observed in cow/calf relationships and by the male, if the female of a pair is injured.

d. Migrations

Annual migrations between breeding grounds in warm temperate and sub-tropical waters, and feeding grounds in polar or cold temperate waters are well documented in many mysticete species. Migrations are also documented in some odontocetes (e.g. sperm whales, bottlenose whales) but they are not so well defined as in mysticetes and more information is needed for many species. The breeding grounds of many stocks of balaenopterid species are unknown, and it is likely that they do not form concentrations of animals in the breeding areas. Other species (e.g. humpback, gray and black right whales) form concentrations on breeding grounds in coastal waters. The migration routes of some species and stocks of balaenopterids may bring part but not all of the stock into coastal waters (Mackintosh, 1965).

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Annex L

SUB-COMMITTEE ON REQUIREMENTS FOR DATA ON CATCHING EFFORT

Members

Best, Yamamura, Ivashin, Valdivia, Bannister, Mitchell and Jónsson.

The sub-committee compiled examples of existing catcher log books from different whaling operations. A draft form for collecting data on the time budget of catching operations was drawn up by Best and circulated amongst members of the sub-committee for their comments. This is considered to be the ideal format for collecting such data, and although some members considered it unlikely that they could obtain such data on a routine basis it was considered important that every effort should be made to collect data of an equivalent quality, even if it could only be achieved from a small sample of each fleet or operation.

The proposed formats of the title page and daily record sheet are attached. Consideration should be given carefully to the suggestion that the IWC should produce and circulate log books of this nature to all member nations for recording effort data. This might be the only way in which the data needed would be collected in a standardised way.

Title page (one logbook per catcher per season)

CATCHER NAME .... YEAR BUILT ....

ATTACHED TO EXPEDITION/LAND STATION ....

SEASON ....

OVERALL LENGTH .... WOODEN/STEEL HULL

GROSS TONNAGE ....

TYPE OF ENGINE .... H.P. ....

MAXIMUM SPEED .... AVE. SEARCHING SPEED ....

ASDIC SET, MAKE AND MODEL NO. ....

DATE OF INSTALLATION ....

MAKE AND SIZE OF CANNON ....

TYPE OF FIRST HARPOON USED (EXPLOSIVE, ELECTRIC, NON-EXPLOSIVE) ....

TYPE OF KILLER HARPOON USED ....

LENGTH AND TYPE OF FORERUNNER ....

TYPE OF WHALELINE ....

HEIGHT OF BARREL ABOVE SEA LEVEL ....

SPEEDBOAT USED, YES/NO

NAME OF CAPTAIN ....

NUMBER OF YEARS EXPERIENCE ....

NAME OF GUNNER ....

NUMBER OF YEARS EXPERIENCE ....

NUMBER OF CREW ....

Daily record sheet

DATE....................................... CATCHER NAME....................................... SHEET NO. ....

SEARCHING:	TIME STARTED (OR RESUMED) SEARCHING					
	TIME WHALES SEEN					
	WHALE SPECIES					
	NUMBER SEEN and NO. OF GROUPS					
	POSITION FOUND					
	NAME OF CATCHER THAT FOUND WHALES					
CHASING:	TIME STARTED CHASING (OR CONFIRMED WHALES)					
	TIME WHALE SHOT or CHASING DISCONTINUED					
	ASDIC USED (YES/NO)					
HANDLING:	TIME WHALE FLAGGED or ALONGSIDE FOR TOWING					
	SERIAL NO. OF CATCH					
TOWING:	TIME STARTED PICKING UP					
	TIME FINISHED PICKING UP or STARTING TOWING					
	DATE AND TIME DELIVERED TO FACTORY					
RESTING:	TIME STOPPED (FOR DRIFTING OR RESTING)					
	TIME FINISHED DRIFTING/RESTING					
	TIME CEASED OPERATIONS					

TOTAL SEARCHING TIME............................
TOTAL CHASING TIME.................................
TOTAL HANDLING TIME..............................
TOTAL TOWING TIME..................................
TOTAL RESTING TIME.................................
OTHER TIME
(e.g. bunkering, in port)..................................

WEATHER CONDITIONS

TIME	SEA STATE	WIND FORCE & DIRECTION	VISIBILITY

WHALES SEEN (No. and No. of schools)

BLUE..
FIN ....
HUMPBACK...
RIGHT...
SEI ....
BRYDE ....
MINKE...
SPERM...
OTHERS ....
(specify) ....

SIGNED..

Annex M

REVISED PARAGRAPH I OF THE SCHEDULE
(new wording in bold)

1. The following expressions have the meanings respectively assigned to them, that is to say:

"baleen whale" means any whale which has baleen or whale bone in the mouth, i.e. any whale other than a toothed whale.

"beaked whale" means any whale belonging to the genus *Mesoplodon*, or any whale known as Cuvier's beaked whale (*Ziphius cavirostris*), or Shepherd's beaked whale (*Tasmacetus shepherdi*).

"blue whale" (*Balaenoptera musculus*) means any whale known as blue whale, Sibbald's rorqual, or sulphur bottom, **and including pygmy blue whale.**

"bottlenose whale" means any whale known as Baird's beaked whale (*Berardius bairdii*), Arnoux's whale (*Berardius arnuxii*), southern bottlenose whale (*Hyperoodon planifrons*), or northern bottlenose whale (*Hyperoodon ampullatus*).

"bowhead" (*Balaena mysticetus*) means any whale known as bowhead, Arctic right whale, great polar whale, Greenland right whale, Greenland whale.

"Bryde's whale" (*Balaenoptera edeni, B. brydei*) means any whale known as Bryde's whale.

"dauhval" means any unclaimed dead whale found floating.

"fin whale" (*Balaenoptera physalus*) means any whale known as common finback, common rorqual, fin whale, herring whale, or true fin whale.

"gray whale" (***Eschrichtius robustus***) means any whale known as gray whale, California gray, devil fish, hard head, mussel digger, gray back, or rip sack.

"humpback whale" (*Megaptera novaeangliae*) means any whale known as bunch, humpback, humpback whale, humpbacked whale, hump whale or hunchbacked whale.

"killer whale" (*Orcinus orca*) means any whale known as killer whale or orca.

"minke whale" (*Balaenoptera acutorostrata, B. bonaerensis*) means any whale known as lesser rorqual, little piked whale, minke whale, pike-headed whale or sharp headed finner.

"pilot whale" means any whale known as long-finned pilot whale (*Globicephala melaena*) or short-finned pilot whale (*G. macrorhynchus*).

"right whale" (*Eubalaena glacialis, E. australis*) means any whale known as Atlantic right whale, Biscayan right whale, Nordkaper, North Atlantic right whale, North Cape whale, Pacific right whale, Southern right whale.

"pygmy right whale" (*Caperea marginata*) means any whale known as southern pygmy right whale, pygmy right whale.

"sei whale" (*Balaenoptera borealis*) means any whale known as sei whale, Rudolphi's rorqual, pollack whale, or coalfish whale.

"sperm whale" (*Physeter macrocephalus*) means any whale known as sperm whale, spermacet whale, cachalot or pot whale.

"toothed whale" means any whale which has teeth in the jaws.

"lost whale" means any whale that has been taken but not delivered to the factory or land station.

"whales taken" means whales that have been killed and either flagged or made fast to catchers.

"lactating whale" means (a) with respect to baleen whales – a female which has any milk present in a mammary gland, (b) with respect to sperm whales – a female which has milk present in a mammary gland the maximum thickness (depth) of which is 10 cm or more. This measurement shall be at the mid ventral point of the mammary gland perpendicular to the body axis, and shall be logged to the nearest centimetre: that is to say, any gland between 9.5 cm and 10.5 cm shall be logged as 10 cm. The measurement of any gland which falls on an exact 0.5 centimetre shall be logged at the next 0.5 centimetre, e.g. 10.5 cm shall be logged as 11.0 cm.

However, notwithstanding these criteria, a whale shall not be considered a lactating whale if scientific (histological or other biological) evidence is presented to the appropriate national authority establishing that the whale could not at that point in its physical cycle have had a calf dependent on it for milk.

"small-type whaling" means catching operations using powered vessels with mounted harpoon guns hunting exclusively for minke, bottlenose, beaked, pilot or killer whales.

Annex N

MINORITY STATEMENT ON THE ETHICS OF WHALING

The scientists in the Panamanian delegation at the Scientific Committee meeting (Pilleri and Morgane) were disappointed that the Scientific Committee did not attempt to identify as it was requested the ethical problems of whaling, which is quite different from taking any particular stand on the problems.

They considered that their combined professional expertise enabled them to identify at least one grave ethical problem.

They considered, on the basis of their scientific knowledge, that there exist sufficiently compelling neuroanatomical and neurophysiological reasons to assume a high intelligence potential in the great whales presently hunted. This opinion is shared by a number of their colleagues specialised in cetacean neuroanatomy and neurophysiology, including Dr Myron Jacobs, Dr Carola Kraus, Dr Margarethe Gihr and Dr Willard McFarland.

They believed that it was their duty to state, as individuals, their ethical position on this problem.

They believe that it is very wrong to kill for commercial profit peaceful beings with a high intelligence potential.

They further believe that moratorium is the only ethical solution to this problem until satisfactory experiments permit them to confirm or reject the assumption of a high intelligence potential in the species of great whales presently hunted.

Annex O

ALTERNATIVE WHALE MANAGEMENT PROCEDURES

CHAIRMAN'S REVIEW

The current management procedure was adopted by the Commission in 1975. It replaced a system under which there was no clearly defined policy and the Commission made individual decisions on each case before it. Over the 10 years preceding 1975 a series of important steps had however, been taken in the direction of better conservation of the whale stocks although very much still remained to be done. The seriously depleted species such as blue and humpback whales had been protected, the quota system had been extended from the Antarctic to the North Pacific, the blue whale unit had been replaced by individual species quotas, and a start had been made on sub-dividing these by stock units, and in the case of the sperm whales, by sexes. A guideline of setting quotas at below sustainable yields had also been adopted.

The so-called "new management procedure" was however a major leap forward in providing a set of rules under which decisions on the protection of stocks and on the levels of quotas, if any, were largely removed from the political arena and based on the advice given to the Commission by the Scientific Committee. The requirement to give this advice in explicit quantitative detail has in turn greatly stimulated the activities of the Scientific Committee, and its analyses are now carried out in much greater depth and with much greater examination of the detailed data than in the previous period. To achieve this it has become necessary to provide the Committee with an increasing level of computer support to store the extensive data in retrievable form and to carry out the computations. The work of the Committee has also been stimulated by increasing participation of appropriate scientists who are not drawn from national delegations.

The scheme has now been in operation for three full years, and although this may seem a fairly short time it has been sufficient to gain some experience of its strengths and weaknesses. It has become evident that operation of this scheme in its present form is giving rise to a number of problems. Some of those arise from its effect on the operations of the Commission and of the industry. Others come from the difficulties, and indeed the doubtful appropriateness in some cases of trying to define catch limits in terms of the present criteria.

The Scientific Committee therefore considered that it would now be useful to review the possibilities of developing an improved system. The Committee had before it four documents (SC/30/Doc 1 by Allen, SC/30/Doc 24 by Garrod and Horwood, SC/30/Doc 51 by Holt and a working paper by Doubleday). The Committee discussed some of the problems in a preliminary manner and the present paper summarises some of the points which emerged in the papers and in the discussion. A detailed summary of the four documents is appended.

1. Problems arising under the present procedure

A number of these are summarised in SC/30/Doc 1. They include:

a) The lack of a generally acceptable definition of optimum stock level.
b) The lack of evidence as to the relation of the MSY level to the unexploited population level.
c) The requirement on the Scientific Committee to make recommendations with a precision far in excess of the accuracy of the assessments on which they are based.
d) The frequent changes in assessments which have generally resulted from changes in the models and in the methods of analysis and not from real changes in stock sizes.
e) Large quota changes may result from quite small changes in the stock assessments due to the sensitivity of the quota-calculating procedure for stocks near MSY level.
f) The heavy load on the Scientific Committee caused by the need to assess all stocks every year makes it difficult to devote sufficient time to critical analyses.
g) The system is designed to bring stocks to optimum levels as quickly as possible and therefore provides minimal opportunities to observe density dependent effects as stocks move from one level to another over a substantial range.
h) There is no specific provision for adjustments to quotas on basis of level of uncertainty of estimates.

In addition there are further difficulties in applying the present scheme, both conceptually and in practice, which arise directly from the close linkage of the decisions to the status of the stock relative to the MSY level. These include:

a) Even in a stable situation the MSY level is almost impossible to define. Even where we can get reasonably good estimates of current and unexploited stock levels, the level of MSY relative to the latter can only be based on judgement and not on observation.
b) In practice stocks are in a dynamic situation in which they are being influenced by past events, due particularly to the fact that recruitment comes from a stock some years earlier. Thus the actual replacement yield at a given time from a stock at the MSYL may be above, or, more seriously, below the MSY. In such circumstances it becomes possible for a catch of 90% MSY to reduce the stock even if all estimates are made correctly. This situation seems to exist at present in the western North Pacific sperm whales.
c) Where a stock is naturally expanding due to an increase in carrying capacity, following perhaps a reduction of competitors, e.g. Southern Hemisphere sei and minke whales, the concept of an MSYL becomes almost meaningless. In theory it exists but it has not been experienced in the past and may not be in the future, even without exploitation, since one cannot foretell what will happen to the competitors and to other factors (e.g. a krill fishery) which may influence the food supply.

2. Multi-species and single species models

In an ideal world the entire ecosystem would be managed with full knowledge of the interactions of all its components so as to maximise the combined benefits from all of them. Clearly this is impossible at present. Indeed, we lack the knowledge to manage comprehensively the particular components of the ecosystem which are of special interest to us here, e.g. krill and its predators, baleen

	Allen Doc 1	Garrod and Horwood Doc 26	Holt Doc 51	Doubleday
Target population level	None implicit – adjust quota by observation to maximise yield or benefit	Specifically not to be defined. Objective only to keep stock in a sustained management range	None implicit, stable level will result from population response	Required but not defined
Protection stock level	33% (example only) of initial stock size	75% of initial management threshold – or numerical level set on present knowledge	Minimum MSYL, i.e. 50% of initial, which is not defined	–
Reference population level	Initial, defined as at beginning of current phase of whaling on particular stock	Some experienced stock level	Initial – not defined	Target level
Reference yield level for quota	Current replacement yield (RY)	Current replacement yield (RY)	Current biological production (BP)	Current surplus yield (? = replacement yield)
Provision for changing environment or inter-specific relations	Current RY will respond to changes. Use of initial population level gives fixed reference point	None explicit	Current (BP) will respond to changes. Initial level is fixed reference point	Current surplus yield responds to changes. Target level unspecified
Relation of quota to stock size relative to reference level	Increase on linear or stepped scale from 0 at protection level to maximum – example 90% at optimum. Constant above this level. Basis for newly exploited stocks undefined	Not specified	Linear increase of proportion of biological production from zero at protection level to 1 at MSP level, ? and above this level	Add (or subtract) proportion of difference between current and target stock level to fixed proportion of current surplus yield
Provision for errors of assessment in fixing quotas	Uncertainty factor applied to quotas on arbitrary stepped scale. No procedure for estimating uncertainty suggested	None	None	Fixed quotas on basis of lower confidence limits of assessments – level undefined
Duration of quotas	Stabilisation for about 5 years	Not stated, annual review implied?	Not stated, annual review implied?	–

whales, seals, birds, fish, squid. Even overall management of the baleen whales as a group is still impossible. We do not know how changes in the numbers of the still numerous species (e.g. sei and minke whales) would affect the rate of recovery of the depleted species (e.g. blue and fin whales) or, in fact, whether the latter would ultimately return to their original numbers if all exploitation ceased.

We can however allow for these effects in the short term by using single species models which incorporate the observed changes in population characteristics and thus the observed tendencies to increase and decrease. Such models can describe the past and relate present to past population levels. They cannot foretell the future.

3. Optimum or target population levels

Even if agreement on a definition of the optimum population level could be achieved it would still be impossible to identify precisely the population level at which it would occur. This is evident even for the simplest of all possible definitions, the MSY level. While we can devise models which will give MSY at any desired level, we have not got, and have little prospect of getting, sufficient accurate data as to how the parameter values really change with population size to enable us to define the true MSY level.

It is therefore not possible to set up a sound management procedure using the stock position relative to MSY level as a key factor in determining classifications and quotas. However, it is possible to devise schemes which will cause stocks to stabilise close to the desired level even without prior identification of the target. This has been done in slightly different ways in SC/30/Docs 1 and 51. Both of these would cause stocks ultimately to stabilise somewhere above the MSY level, without previously defining where this level occurred. The precise point at which stability would be reached would depend on the control parameters used in the management procedure.

4. Reference level for quotas

The present procedure sets quotas as a certain proportion of the MSY, and this in turn has to be extrapolated from information about the current and past condition of the stock by using a population model. Both SC/30/Doc 1 and Doc 51 point out that use of a characteristic of the existing population as the basic quantity from which the quota is calculated would be more direct and reduce the dependence upon models. They suggest respectively the current replacement yield (RY) and current gross biological production (BP) as the quantity from which an appropriate fraction could be taken as the quota. Both merit further study and each has advantages and disadvantages. Both could be estimated for many whale populations in several fairly direct ways with comparatively little dependence on sophisticated population models.

5. Relation of quota to stock level

The essential general principle should be that the proportion of RY or BP which could be taken as quota should increase as the stock level increases, being zero at the threshold of the Protection category. This would ensure maximum rate of increase to stocks at the lowest levels. If the proportion of RY or BP which may be taken is increased gradually over a wide range of stock sizes this would help to avoid large abrupt changes in quotas as a result of changes in assessments. Either a smooth graduation or a series of steps could be employed as was technically desirable. Under this scheme changes in MSYL associated with changes in population models would not produce changes in quotas. The wider the range over which the proportion of the RY available is graduated the less will be the effect on quotas of either real changes in stock size or of changes in assessments.

6. Protection Stock levels

Complete protection of stocks below a certain critical level would continue to be an essential feature of any new scheme, and is included in all the present proposals. All of these schemes could simply be adjusted to provide for whatever protection stock level is considered desirable, the method of calculating quotas applying only to stocks above this level. The use of the RY as the basis from which to calculate quotas has the advantage that the RY is also a direct measure of the rate at which the stock is automatically protected. This feature conveys a higher degree of protection than calculating quotas from a problematical MSY and may make the precise level at which protection is imposed less critical.

7. Allowances for the uncertainties in assessments

The present procedure and practice, is based on the use of "best estimates" within a framework designed to provide margins for error by limiting the maximum quota to 90% of MSY and by cutting off quotas very rapidly for stocks falling below MSYL.

In practice, there is and always will be, a great range in the accuracy with which stock assessments can be made.

It would be possible, as SC/30/Doc 1 suggests, to include in the determination of quotas, a factor based on the adjudged accuracy of assessment. Development of both appropriate means of judging the level of uncertainty, and a suitable formula for applying it to the quotas, would be difficult but the Scientific Committee could examine the matter.

8. Duration of quotas

The large number of stocks which have to be examined (now over 50), and the rapidly increasing depth of analysis, are throwing a heavy burden on the Scientific Committee which is now generally holding two special meetings a year in addition to that in June. If the frequency with which each stock was examined was reduced somewhat it would allow more time for detailed study of the most critical problems. It would be essential to ensure, however, that examination was not delayed in cases where important new information was available or a stock showed signs of unexpected decline.

Annex P

MINORITY STATEMENT ON ITEM 9.8

by J. P. Fortom Gouin

Some reasons why a Moratorium fulfills the stated objective of the Convention to safeguard the whale stocks.

A moratorium is the only policy which eliminates the risks of depletion and even disappearance of some local stocks, risks which exist with present quotas because: the boundaries of the stocks are poorly known (especially in the case of the sperm whales); the critical population sizes (below which the trend toward disappearance is irreversible) are not known at all while they should be known for each local stock; economic logic dictates that the whaling fleets catch their quotas in as small an area as possible taking into consideration quota areas and preference for larger individuals (there exist risks of gross overexploitation of some local stocks if the quota areas include several local stocks); there exist large uncertainties about the values of the parameters used, the assumptions made on the models used (the consequence is that there exist large margins of errors on the estimates of populations and yields, and consequently there exist significant risks that some stocks are exploited which should be protected, or that the quotas exceed the sustainable yields).

A moratorium allows the fastest possible rate of growth for the present stocks; will give the Commission's Scientific Committee an opportunity to improve their estimations. The data base available to the Scientific Committee is insufficient to reach accurate estimates. If the end of the moratorium was tied to a planned scientific programme designed to obtain sufficient data to reach accurate estimates, it is likely that the whaling companies would provide a quantity of new data, some of which have been requested for years unsuccessfully by the Scientific Committee. A moratorium does not imply any reduction in scientific research. A moratorium is the ethical policy, if one accepts the ethical rule stated by Drs Pilleri and Morgane in Annex N that it is wrong to kill for commercial profit peaceful beings with a high intelligence potential.

Annex Q

MINORITY STATEMENT ON SPERM WHALE STOCK ASSESSMENTS

J. P. Fortom-Gouin

The author who has participated in the sperm whale stock assessments of the Scientific Committee at the IWC 30th meeting was encouraged that a certain amount of progress has been made: the dangerous situation in the western North Pacific has been recognised. Even with zero quotas, this population is expected to decline in the years to come; the decline in the pregnancy rate in the North Pacific, and at least off Australia in the Southern Hemisphere, has also been recognised. However, the author has several other reasons for his deep concern about the situation of the sperm whale populations which has led him to recommend a 10-year moratorium as the best policy at present for the preservation of the populations of this species. Some of these reasons are as follows: the reduction in size of the males caught; the decrease in the pregnancy rates; the fact that for the past several years, the pelagic whaling fleets have failed to catch their quotas; the fact that the critical population sizes below which no recovery is possible are not known; the fact that the boundaries of the stocks are practically unknown, so that local stocks can be depleted even if overall quotas were satisfactory.

Also, there appear to be a number of reasons why the population estimates reached by the Scientific Committee are overestimations, and why the quotas recommended are consequently too high. These reasons can be grouped in three categories:

The biological parameters used.
The assumptions used in the mathematical model.
The effort modifiers used to correct the catches-per-catcher-day data.

1. Biological Parameters

a. Juvenile mortality rate. The precise value used hides the fact that there exists absolutely no evidence on the juvenile mortality rate. However, this rate is higher than the adult mortality rate in every mammal species for which there is evidence. The model used by the Scientific Committee has the same value for juvenile and adult mortality rate (5.5%), well below the rates observed for other mammal species.

b. Pregnancy rate. No consideration has been given to the effect of social dislocation created by the increased hunting of females in nursery groups since 1972. This author believes that it is one of the reasons why the observed pregnancy rates are generally below the theoretical rates calculated with the model.

c. Birth rate. It is assumed to be equal to the pregnancy rate, which ignores abortions and still births.

d. Male reserve ratio. It is a fundamental methodological error to say that because only one mature male has been observed inside the nursery groups for every 10 mature females, all the others are unnecessary to the reproductive process. Considering that the adult males separate from the nursery groups to undertake polar migrations, it is evident that there must be a number of males searching unsuccessfully for a nursery group in order to be successful. The author agrees with Mitchell and Bertrand that the reserve male ratio of 0.3 appears insufficient to cover the above consideration. The result that can be expected from the choice of an insufficient male reserve ratio is a decrease in the pregnancy rate.

e. Age at recruitment. Although it has been changed a lot over the years, the model uses only one age at recruitment for males, and only one for females.

2. Assumptions of the Model

(i) The stocks were stable at their maximum level in 1910 – while it is difficult to estimate at what level the stocks were in 1910, it would be extremely surprising if after over a century of continuous world-wide sperm whaling the stocks were still at their maximum unexploited level. If wrong, the assumption leads to an overestimation of present populations in relation to their unexploited level, and leads consequently to quotas too high.

(ii) The fluctuations of the environment have no effect on the stocks. Neither do pollution or natural catastrophes; squid fisheries or interference by other human activities.

3. Effort Modifiers

Catches-per-catcher-day reflect two different things: the abundance of the whales and the efficiency of the whaling operation – in order to obtain an estimate of the abundance, CPUE (catch per unit of effort) must be corrected for the "effort modifiers" which changed the efficiency of the whaling operations. The author thinks that the calculations of the Scientific Committee have underestimated these effort modifiers.

a. Asdic

The effect of Asdic (sonar) on the efficiency of a whaling operation has been best documented in Durban, South Africa. The ratio of the catches-per-day of the boats with Asdic has been calculated separately by Best and Gambell and found to be 2.30. The results of five whale marking cruises out of Durban with and without Asdic confirms this result: the ratio of the whales sighted which were successfully marked by the boats with Asdic against the boats without was 2.36. This appears to indicate an increase in efficiency between 130% and 136%.

Taking the above results in consideration it is hard to understand how in the North Pacific the apparent increase in efficiency was only 5.5%. The ratio of the catches-per-day of the boats with and without Asdic was proposed by Ohsumi at the Cronulla special meeting to be only 1.055 in North Pacific Japanese pelagic whaling. This was an average for the ratios of several fleets, some of which were inferior to 1, which appears to indicate that in some fleets the boats with Asdic are less efficient than the boats without.

It is true that the operation of a coastal station and a pelagic fleet are different, but not that different as for the operation of the catcher boats. In a coastal station, these travel at night in order to reach the whaling grounds at dawn and tow back the whales caught at night, which approximates the operation of the catcher boats in a pelagic fleet as for their daylight whaling effort.

In conclusion, it does not appear reasonable to the author to accept the undocumented figure of 1.055 proposed by Ohsumi in the North Pacific, when there exists a well documented figure of 2.30 for the Durban operation, and when no reason has been given why Asdic would be so much less efficient in a pelagic operation than in a coastal one. Accepting the Durban figure could mean a downward revision of population estimates of over 50%.

b. Effort modifiers other than Asdic and tonnage

It is evident that the catches-per-catcher-day are influenced not only by the operation of the catcher's boats, but also by the efficiency of the whole whaling fleets. Better oceanographic knowledge (underwater relief, water temperature and turbidity, location of food concentrations, location of whale concentrations by scouting boats, etc.) allows the pelagic fleets to find the whale concentrations every year more efficiently.

A pelagic whaling fleet is a high technology operation which must have been improved by experience and technological progress (better navigation equipment, better radio equipment, better design of catcher boats and factory ships, better co-ordination between the different elements of the fleet, etc.).

Because there is no quantitative data on the increase of efficiency of the fleet as a whole, the Scientific Committee has ignored it. But this has the same effect on the model as assuming that the efficiency increase was zero.

The author cannot believe that zero was the total increase in efficiency in the operation of the whaling fleets as a whole (as distinct from the operation of the catcher boats themselves). In particular the Japanese industry has been successfully reaching increases in efficiency and productivity of up to several per cent per year in many sectors and there is no reason why the whaling industry would be completely different.

c. Effort modifiers: shift in whaling grounds and concentration of depleted populations

The assumption that catches-per-catcher's-day are proportional to the population level may be invalid. Artificially high CPUE are probably created by two factors: the whaling fleets have been shifting their whaling grounds as they became depleted – steady or higher catches recorded, they do not reflect a stable population but only a change of whaling ground; sperm whales are a social species which may be contracting its feeding and breeding grounds as a stock becomes depleted. The catches will reflect the stable density, but not necessarily the shrinking territory.

Conclusion

In conclusion, there are a number of reasons to believe that the estimates of sperm whale populations by the Scientific Committee are overestimated.

Furthermore, these calculations are to a large degree arbitrary and they reach different results according to the models used, but the validity of not one of these models has every been tested by observation or experiment, which is the fundamental rule of scientific reasoning.

Consequently, management decisions must be extremely conservative and prudent in order to counterbalance the incertitude and large possible errors in the quotas recommendations made, and the built-in bias towards overestimation which has been partially analysed above.

Annex R

SCIENTIFIC COMMITTEE RULES OF PROCEDURE

(as amended at the 30th Annual Meeting of the Commission)

A. Membership and Observers

1. The Scientific Committee shall be composed of scientists nominated by the Commissioner of each nation which elects, at the Annual Meeting of the Commission, to be represented on that Committee. The Secretary of the Commission shall be an *ex-officio* non-voting member of the Scientific Committee.
2. The Scientific Committee recognises that while FAO and UNEP are represented at the Commission's meeting by observers their representatives attend the Scientific Committee as scientists with the status of advisers to the Committee. The representatives of other intergovernmental organisations of similar scientific standing may also be given the same status in the Scientific Committee, subject to the agreement of the Chairman of the Committee acting according to such policy as the Commission may decide.
3. Further to Paragraph 2 above the International Union for the Conservation of Nature and Natural Resources shall have *ad hoc* adviser status in the Scientific Committee.
4. Any other international organisation sending an accredited observer to a meeting of the Commission may nominate a scientifically qualified observer to be present at meetings of the Scientific Committee. Any such nomination must reach the Secretary not less than 60 days before the start of the meeting in question and must specify the scientific qualifications and relevant experience of the nominee. The Chairman of the Scientific Committee shall decide upon the acceptability of any nomination but may reject it only after consultation with the Chairman and Vice-Chairman of the Commission. Observers admitted under this rule shall not participate in discussions but the papers and documents of the Scientific Committee shall be made available to them at the same time as to members of the Committee. The number of places for observers admitted under this Rule at any meeting and the observers to whom they are to be allocated shall be determined by the Chairman of the Scientific Committee having regard to the accommodation available but the number shall not normally be less than five.
5. The Chairman of the Committee, acting according to such policy as the Commission or the Scientific Committee may decide, may invite qualified scientists not nominated by a Commissioner to participate by invitation or otherwise in Committee meetings as non-voting contributors. They may present and discuss documents and papers for consideration by the Scientific Committee, participate on subcommittees, and they shall receive all Committee documents and papers.

B. Agenda

1. The initial agenda for the Committee meeting of the following year shall be developed by the Committee prior to adjournment each year. The agenda should identify as

far as possible key issues to be discussed at the next meeting and specific papers on issues should be requested by the Committee as appropriate.
2. The provisional agenda for the Committee meeting shall be circulated for approval sixty days prior to the Annual Meeting of the Committee and comments will be considered only if received by the Chairman 21 days prior to the beginning of the Annual Meeting.

C. Organisation

1. The Scientific Committee shall include standing sub-committees by area or species, or other subject, and a standing sub-committee on small cetaceans. The Committee shall decide at each meeting on sub-committees for the coming year.
2. The sub-committees shall prepare the basic documents on the identification and classification of stocks, including biological parameters, initial and present stock size and catch limits using catch records supplied by the Secretariat, and related matters as necessary, for the early consideration of the full Committee.
3. The sub-committees, except for the sub-committee on small cetaceans, shall concentrate their efforts on stocks of large cetaceans particularly those which are currently exploited or for which exploitation is under consideration, but they may examine fishery matters in which both large and small cetaceans are taken or refer those matters as appropriate to the sub-committee on small cetaceans.
4. The Chairman may appoint other sub-committees as appropriate.
5. The Committee shall annually elect from amongst its members a Chairman and Vice-Chairman at the conclusion of the Annual Meeting of the Commission. The Vice-Chairman shall act for the Chairman in his absence.

D. Meetings

1. The Scientific Committee shall meet during the 10 days beginning on Monday of the two weeks prior to the Annual Commission Meetings. The Thursday and Friday of the second week shall be available to the Secretariat for final preparation of the report of the Committee.
2. The sub-committees should meet during the first few days of the full Committee meeting; their progress should be reviewed at regular intervals at plenary sessions of the full Committee. During those days there should be opportunity for generating ideas, production of papers by individuals and other reviews of data. It should be the aim of the sub-committees to complete their work and prepare reports for the full Committee by the end of the first week. Sub-committees, including sub-committees consisting of the full Committee, may meet on other occasions as necessary.
3. The Scientific Committee will consider *ad hoc* questions during the week of the Plenary Session only if they are referred to it by the Chairman of the Technical Committee or of the Commission.

E. Scientific Papers and Reports

The following documents and papers will be considered by the Scientific Committee for discussion and inclusion in its report to the Commission:

1. 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.
2. Special Reports. The Committee may request special reports, including special national reports, as necessary on matters to be considered by the Committee for the following year.
3. Sub-committee Reports. Reports of the standing sub-committees or of special sub-committees appointed by the Chairman shall be considered by the Committee for inclusion in its Report to the Commission. These reports shall be considered as working documents and the recommendations contained therein be subject to modification by the full Committee before inclusion in its Report.
4. The above reports should be distributed to Committee and sub-committee members as early as possible.
5. Scientific Papers.
   (a) Any scientist may submit a scientific paper for consideration by the Committee. The Secretary may, with the concurrence of the Committee, set technical guidelines for the preparation and presentation of such papers. Scientific papers shall be of two types, primary papers presenting new data or analysis, and secondary papers expanding or analysing data and concepts in the primary papers or reports to the Committee.
   (b) Primary scientific papers will be considered for discussion and inclusion in the papers of the Committee only if the paper is received by the Secretariat on or by the first day of the annual Committee meeting. Exceptions to this Rule can be granted by the Committee only in the case of exceptional extenuating circumstances.
   (c) Secondary papers will be considered for discussion and inclusion in the papers of the Committee only if:
      1. The paper is received by the Secretariat before the end of the first week of the Committee meeting, or
      2. Preparation of the paper is specifically requested by the Scientific Committee through its Chairman.
   (d) The Scientific Committee may receive and consider unpublished scientific documents from non-members of the Committee (including observers) and may invite them to introduce their documents at a meeting of the Committee provided that they are received under the same conditions (with regard to timing, etc.) that apply to members.
6. The preliminary report of the Scientific Committee shall be available to all Commissioners by the opening date of the Commission meeting.
7. Publication of Scientific Papers and Reports.

Scientific papers and reports shall be included in the Commission's archives in the form in which they were considered by the Committee or its sub-committees.

Documents on which management recommendations are based should be available on demand immediately after the meeting of the Committee at which the recommendations were made. Scientific papers and reports (revised as necessary) will be selectively included in the Committee Report published by the Commission. The Secretariat, with the concurrence of the Scientific Committee shall issue guidelines for the technical revision of the papers or reports. Scientific papers which are original contributions and deserve a broad dissemination in the primary literature may be considered for publication at the request of the author in a new scientific journal, published by the Commission, with the possible title "Journal of Cetacean Management". Papers will be subject to outside review before acceptance; the Secretary shall be the Editor.

F. Review of Scientific Permits

1. When proposed Scientific Permits are sent to the Secretariat before they are issued by national governments the Scientific Committee shall review and comment on them.
2. The proposed permits and supporting documents should include specifics as to the objectives of the research, number, sex, size and stock of the animals to be taken; opportunities for participation in the research by scientists of other nations, and the possible effect on conservation of the stock resulting from granting the permits.
3. The Scientific Committee shall review the scientific aspects of the proposed permits at its annual meeting and comment on such proposed permits to the Commission, the national government concerned, and any scientist designated by that government.
4. In the event that the proposed permits would be granted prior to the next annual meeting of the Scientific Committee, members shall review and comment on the scientific aspects of the proposed permits by mail.
5. The proposed permits and the preliminary results of any research resulting from the permits should be made available for the next meeting of the Scientific Committee as part of the national progress report or as a special report.

SC/30/Prog Rep 1

Australia
Progress Report on Cetacean Research
June 1977 – May 1978

This report refers to work carried out at the Western Australian Museum and at CSIRO Division of Fisheries and Oceanography, Cronulla, New South Wales.

SPECIES AND STOCKS STUDIED

Data have continued to be obtained from the single company operating on sperm whales off Albany, southern Western Australia. Aerial observation programmes on humpback and southern right whales off Western Australia have also continued.

FIELD OBSERVATIONS AND COLLECTIONS

Collections of 416 teeth and 66 ovary pairs were obtained from the Albany commercial catch during the 1977 season. Combined testis weights for the first 30 males caught in each month of operation were recorded. The work was undertaken by Inspectors appointed by the State Department of Fisheries and Wildlife. Similar work is being carried out during 1978.

Aerial sightings programmes for humpback whales off Carnarvon, Western Australia (in July) and for southern right whales off the southern coast of Western Australia (from July to December) were undertaken in 1977. Funds are available for the programmes to be repeated during 1978.

MARKING

No marking was carried out, and there were no recoveries reported from the Albany station during 1977.

LABORATORY WORK

Tooth collections for 1976 and 1977 are being processed by courtesy of the Sea Mammal Research Unit, Cambridge, UK. The 1977 ovary collections have been examined but have yet to be sectioned.

RESEARCH RESULTS

The catch rate for males ⩾35 ft was the same for 1977 as for 1976 while the sightings rate from the spotter aircraft was slightly higher (Tables 1 and 2). The average length of males ⩾35 ft in 1977 was close to that of the previous year (Table 3a) while the proportions caught in various length groupings (Table 3b) were similar to those for 1976, though with a slight reduction in the higher length groups.

Examination of the mature ovary data now available since 1963 (Table 4) for the period June–November indicates a lower proportion of mature females pregnant (on evidence from the presence of a foetus) after 1973, with a range from 33–22% pregnant up to that time and only 10–14% thereafter. However, in the proportions 'pregnant plus doubtful' (where 'doubtful' represents the presence of a corpus luteum but no foetus recorded) the 1976 figure is particularly low but no particular trend is evident over the years.

Further examinations of indices of abundance have been undertaken by Dr G. Kirkwood. Ovary data are being analysed in conjunction with similar data from other sources by Dr D. G. Chapman. Data relevant to the determination of the effect of sonar on the catching operation have also been provided to Dr Chapman for analysis.

Table 1

Catcher operations at Albany, 1971–77*

Year	No. of months catching	No. of catchers	Total catcher tonnage	Total catcher H.P.	Catcher days (gross)	Total hunting hours	Hunting hours per day	Catch for which effort is available: Males	Catch for which effort is available: Females	Catch (Males) per hunting hour
1971	10	3	1,430	5,400	544	3,743	6.4	823(810)[1]	41	0.22
1972	10	3	1,430	5,400	591	4,000	6.8	793(761)	160	0.19
1973	10	3	1,430	5,400	499	3,133[2]	6.3	684(648)	287	0.20[3]
1974	10	3	1,430	5,400	411	2,667	6.6	564(521)	415	0.20
1975	10	3	1,430	5,400	518	3,170	6.1	692(633)	480	0.20
1976	9**	3	1,430	5,400	421	2,709	6.4	658(622)	337	0.23
1977	9	3	1,430	5,400	360	2,154	6.0	508(488)	116	0.23

[1] Figures in brackets are males ⩾35 ft, used in calculating catch (Males) per hunting hour.
[2] Lacks December data for one catcher.
[3] Allows for lack of December data for one catcher.

* Information for earlier years was given in *Rep. int. Whal. Commn* 25: 92.
** April–December.

Table 2

Spotter aircraft operations, Albany, 1971–77*

Year	Total days flying	Hours flown per flying day	Searching speed (knots)	Effective searching hours	Total bulls seen	Total whales seen	Bulls seen per effective searching hour	Bulls seen per effective searching mile
1971	179	8.6	125	1,026	1,980	7,172	1.93	0.15
1972	199	8.5	125	1,031	1,962	8,365	1.90	0.15
1973	171	8.6	125	853	1,506	6.035	1.77	0.14
1974	186	8.6	125	986	1,208	6,465	1.23	0.09
1975	185	9.1	125	1,077	1,386	7,470	1.29	0.10
1976	191	9.2	125	1,067	1,471	5,624	1.38	0.11
1977	174	8.4	125	895	1,422	5,669	1.59	0.13

* Information for 1962 on was given in *Rep. int. Whal. Commn* 25: 93.

Table 3a

Average length of males, Albany, 35 ft and over, 1970–77*

	1970	1971	1972	1973	1974	1975	1976	1977
Feet	43.9	43.8	42.7	43.0	42.9	41.8	43.6	43.1

Table 3b

% of the catch of males, Albany, 35 ft and over, at various length groupings, 1970–77*

	1970	1971	1972	1973	1974	1975	1976	1977
35–38 ft	11	13	23	22	24	31	12	18
39–43	33	34	33	33	29	37	36	34
44–47	31	31	24	22	23	15	33	30
48+	25	22	20	23	25	17	19	17

* Information for 1962 on was given in *Rep. int. Whal. Commn* 25: 94.

Table 4

Proportions of mature females recorded as 'pregnant' or 'doubtful', Albany, 1964–1977, period June–November

Year		Mature	'Pregnant'	'Doubtful'	'Pregnant' plus 'Doubtful'
1964	No.	65	20	12	32
	%	100	31	18	49
1965	No.	46	12	4	16
	%	100	26	9	35
1973	No.	101	24	12	36
	%	100	22	11	33
1974	No.	156	19	42	61
	%	100	12	27	39
1976	No.	153	15	11	26
	%	100	10	7	17
1977	No.	43	6	10	16
	%	100	14	23	37

Mature = all females where ovaries contained one or more corpus (albicans or luteum).
'Pregnant' = all females where ovaries were examined, and a foetus was also recorded at the time of sampling.
'Doubtful' = all females where ovaries were examined, no foetus was recorded, but a corpus luteum was present.

Table 5

Sightings of protected species off Albany, 1962–77 (from aircraft spotter data, Cheynes Beach Whaling Company)

Year	Blue	Humpback*	Right*	Effective searching hours
1962	1	72	0	354
1963	8	0	2	537
1964	8	1	0	608
1965	8	0	0	556
1966	2	1	0	672
1967	1	0	0	622
1968	10	0	0	701
1969	2	1	0	874
1970	4	1	0	917
1971	11	0	0	1,026
1972	10	0	1	1,031
1973	8	0	0	853
1974	13	1	0	986
1975	9	1	1	1,077
1976	12	20	0	1,067
1977	10	3	3	895

* Area covered in 1962 includes a coastal strip during the humpback whaling season. From 1963, only the sperm whaling grounds are included, although some sightings made en route to and from the grounds are also included.

Spotting flights for southern right whales off the southern Western Australia coast confirmed the low incidence of this species there in spring/early summer by comparison with recent South African results. 21 confirmed sightings were made, including 5 calves. Most (14 including 3 calves) were seen on the September flight. In seven flights searching for humpback whales off Carnarvon in July a total of 30 sightings was recorded. The number of flying hours is still very low (25 in 1976) for comparison with aircraft spotter data from 1963 when commercial whaling ceased but these and other recent sightings off the coast suggest that humpback numbers have not decreased since that time.

Records of protected species sighted continue to be obtained from the commercial whaling aircraft spotter logbooks off Albany. A summary of the results available since 1962 for blue, humpback and right whales is given in Table 5.

PUBLICATIONS

Allen, K. R. and Bannister, J. L. 1977. Whaling: then and now. *Environs* 1 (5): 8–9.

Anon. 1977. Australia: progress report on whale research 1975–6. *Rep. int. Whal. Commn* 27: 107.

Anon. 1978. Australia: progress report on whale research 1976–7. *Rep. int. Whal. Commn* 28: 93–4.

Bannister, J. L. 1977. Sperm whales off Albany, Western Australia. *Rep. int. Whal. Commn* 27: 355–8.

SC/30/Prog Rep 2

Canada
Progress Report on Cetacean Research June 1977 – May 1978

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1. SPECIES AND STOCKS STUDIED

Studies were continued on previous biological collections from northwest Atlantic fin, sei and sperm whales. Related work continued on the morphology and life history of smaller cetaceans, and on the history of exploitation of severely depleted species of larger whales.

Research on Arctic cetaceans was concerned mainly with field surveys of beluga, narwhal and bowhead whales, and compilation of catch statistics (by D. E. Sergeant, K. Hay and others).

North Pacific cetacean research concentrated on abundance and movements of groups of killer whales off British Columbia (M. A. Bigg, I. B. MacAskie).

2. FIELD OBSERVATIONS AND COLLECTIONS

No special permits were required. Limited work continued on collections of biological materials from whales killed off Nova Scotia and Newfoundland during the last episode of Canadian whaling. A few stranded animals were examined and limited tagging operations were carried out on an opportunity basis. A summary of these follows:

M. A. Bigg began a study of feeding habits of killer whales off British Columbia by examining fish scales recovered on the sea surface at ten sites during or following a feeding session; salmon were identified in all cases.

Summer work on Arctic whales (D. E. Sergeant and staff) included observations from a field camp at Cunningham Inlet and an adjacent small river estuary on north Somerset Island, and by fixed wing aircraft and helicopter out of Resolute Bay between 15 July and 8 August 1977. Flights were made around Somerset Island, southwest Devon Island and the western shore of the Brodeur Peninsula in Prince Regent Inlet. Narwhals were seen in Prince Regent Inlet. Two remote sensing devices were tested for taking aerial photographs of the herd of beluga in Cunningham Inlet: findings indicate that all size classes of white whales are present in the concentrations, including groups of adult males, a large proportion of grey, immature animals and adult females and calves.

W. Doidge observed sea mammals on the CGS *Louis St Laurent* from 18 to 31 May 1977, including: white whales as far north as Melville Bugt, narwhals in the North Water at the entrance to Jones and Lancaster Sounds, and twelve bowheads along the east–west trending lead to the north side of Lancaster Sound.

F. G. Whoriskey reported a stranding of a long-dead, 58 ft 9 in (17.9 m) male fin whale on 25 June 1977 on Gallienne Beach, approximately 19 miles E of Sept Iles (50° 17′ N, 66° 00′ W), and he collected one anterior baleen plate before the carcass was brought ashore ½ mile E of the Matamek Research Station on 26 June. A. Macfarlane, J. Martin and H. Malcolm inspected a fin whale carcass on 25 June 1977 at Pointe aux Anglais (49° 41′ N, 67° 10′ W), and estimated its length at 36–38 ft (10.97–11.58 m) from partial measurements. This might be a second fin whale, since the reported length of the longest baleen plate, 10 in, is much shorter than would be expected in a 59 ft fin whale.

P. Beamish and L. Dumoulin reported the stranding of a long-dead 60 ft (18.28 m) fin whale on 18 August 1977, near Westport, Brier Island, Nova Scotia (44° 15′ N, 66° 22′ W). L. Dumoulin (Ontario Science Centre) collected the complete skeleton and transported it for display in Toronto (see L. Dumoulin, Ontario Sci. Cent., *Center News*, Oct. 1977, p. 2).

J. E. Maunder (Newfoundland Museum) reported that in August 1977 a fisherman dredged a portion of a large certacean braincase from the sea floor near Port aux Choix (50° 42′ N, 57° 25′ W) in the Gulf of St Lawrence; I have identified it from photographs as *Balaenoptera* cf. *B. musculus.* The specimen is in the Newfoundland Museum.

L. Dumoulin reported a 68 ft 3 in (20.8 m) male blue whale stranding (18 April 1977) at Sally's Cove, Gros Morne National Park, Newfoundland (49° 46′ N, 57° 53′ W). When first seen, the whale was floating in ice, belly up, marked with a red flag. The carcass was buried intact for later recovery by park officials.

A pod of 14 killer whales were trapped in Usualuk, a small fjord on Kikertelung Island about 40 miles from Pangnirtung, Cumberland Sound, Baffin Island, in the last week of September 1977. The killers became trapped in the fjord, actually a salt water lake, when the tide went out. Inuit hunters killed all of the killer whales: seven on 1 October (2 beached, 5 sank); seven on 3 October (2 beached, 5 sank). One male calf was 11 ft 8½ in (3.55 m) long, and a tooth was collected from it. RCMP Constable Harris took photographs, and subsequently J. Parsons (MacLaren Atlantic Ltd) sampled teeth and stomach contents from the carcasses.

On 27 February 1978, J. Edmunds and C. Pelley reported the entrapment in ice of four large humpback whales and one small whale, possibly a "juvenile", in Hall's Bay, near Springdale; and the entrapment of a single humpback near Port Anson, Notre Dame Bay, Newfoundland. V. M. Kozicki visited the localities on 28 February to 8 March 1978, and confirmed that there were four humpbacks and a small whale, possibly a narwhal, in an area of open water near Springdale. The whales had been there since the beginning of February when the Bay began to freeze over. Kozicki made aerial surveys 1–2 March, tagged all four humpbacks in the open water area on the 4th, made aerial surveys outside the Bay on the 5th and saw no other whales in open water, then flew over the Port Anson area on the 6th and confirmed a single trapped humpback there and tagged this fifth animal on the 7th at Miles Cove.

Local people kept us informed of the survival of these whales for the next few weeks. On 28 March V. M. Kozicki and G. Horonowitsch departed to inspect the Port Anson humpback, now dead 7 days. Only three live humpbacks were confirmed in the Springdale area. On the 29th, Kozicki flew over the Springdale humpbacks and confirmed that the previously reported "small whale" was in fact a narwhal by observing the tusk. All three humpbacks were reidentified by means of the previously implanted visual tags and by distinctive scars. Three live humpbacks and one narwhal were by now restricted to a polynya approximately 50 by 100 m. From 31 March to 4 April, Kozicki and Horonowitsch dissected the humpback in the ice near shore at Port Anson. This approximately 45 ft (13.71 m) female was so thoroughly decomposed that, by this time, about 12 days after death, few useful samples could be collected: the ovaries were decomposed, as were the earplugs. After severing the head, both bullae and one periotic were collected. Samples of fat and muscle were taken for future analyses of the rate of diffusion of the drug Quinacrine used in the tags. Opportunity was taken to test-fire 12 streamer-type "Discovery" tags into the carcass to study the problem of inconsistent deployment of filament and tape streamers. On 5–6 April observations were made on behaviour of the humpbacks and narwhal in the small polynya. Kozicki and Horonowitsch returned on 7 April. Others who studied these whales included J. Lien and B. Merdsoy (Memorial University), and P. Beamish (Bedford Institute).

On 10 April the icebreaker CGS *Labrador* broke a channel into Hall's Bay and by the 14th the ice cleared sufficiently to allow the whales to escape. Pelley made an aerial search on the 14th and did not spot the whales. The Hall's Bay humpbacks escaped on Friday; P. Beamish flew two hours on Saturday, 15 April, confirmed that there was open water eastwards along the coast and saw no whales. He reports that a fisherman saw three large whales approximately 30 miles east of Hall's Bay several days later. On 5 June a fisherman found a rotten carcass beached on the north side of Pelley Island in Long Island Tickle at the mouth of Hall's Bay. This was the fifth, previously flensed carcass as the head was severed.

On 19 May 1978, B. Beck found an approximately 12 ft long carcass of a male *Lagenorhynchus* on Sable Island, which he estimated to have been dead one month or less.

3. TAGGING

No major cruises were run and few whales were tagged in the North Atlantic. There were no reported recoveries of tags in stranded or other whales. V. M. Kozicki tagged five humpbacks trapped by ice in Newfoundland (details above, and in Table 1).

Four belugas were tagged in late July 1977 at Cunningham Inlet by G. Sleno, W. Hoek, R. Greendale and W. Doidge.

4. LABORATORY WORK

Work continued on entry of data from the 1966–1972 eastern Canadian fishery into a computerized system. Entry of all data from individual whales landed, and the catch per unit effort and associated sightings data is about half completed and should be finished in 1979.

Several side trips were made before, during and after meetings or expeditions. These included: Los Angeles, Jan.–Feb. 1977 and May 1977; Washington, Oct. 1977; and Wellington, Christchurch, Dunedin, Melbourne, Sydney, Perth, Singapore, Bangkok, Cairo and London, all in July 1977.

Limited laboratory work on the 1973–75 Gulf of St Lawrence whale sighting project continued. P. Bupp Edds (University of Maryland) continued a preliminary analysis of minke whale circling behaviour, and D. Young (University of Illinois) worked on a quantitative examination of finner whale respiratory patterns.

A. Pivorunas (Yale University) is completing his Ph.D. thesis on the feeding mechanisms of baleen whales, and is preparing papers for publication on the squamosal cleft, feeding, and the engulfment mechanism in mysticetes. Y. Ottaviano (McGill University) added the final data to the manuscript on male fin whale reproduction. K. Hay (McGill University) is completing a Ph.D. thesis on the narwhal. Studies continued on Cunningham Inlet white whales (D. E. Sergeant and staff). A. B. Clarke began an age and size variation study of periotics and bullae from 75 bowhead whales sampled from Thule Eskimo sites.

5. DEVELOPMENT OF TECHNIQUES

The results of the 1976 radio-tagging experiments with fin and blue whales in the Gulf of St Lawrence using a system developed by W. A. Watkins and W. E. Schevill, have been written up for publication in collaboration with C. Ray, D. Wartzok, V. M. Kozicki and R. Maiefski.

6. RESEARCH RESULTS

Results for the period of this review are given in papers and documents cited below.

7. 1977 CATCHING OPERATION

Commercial whaling for large cetaceans was terminated in Canada in December 1972. Catches of small cetaceans by Eskimos in the Canadian Arctic have continued, as have catches of white-beaked dolphins for local consumption off Labrador. Available catch statistics are continued from the previous Progress Report (and references cited therein) by species and by settlements for the Canadian Arctic for 1977 in Table 2 (where 0 indicates none were taken, "–" indicates no knowledge of any taken, ( ) indicates unconfirmed report).

These statistics compiled by D. Dowler (Yellowknife) through the management division of the Freshwater Institute of Environment Canada, Winnipeg, are provisional and must be regarded as minimum kills. For 1977 and earlier years the figures represent confirmed landings. The totals do not include lost or abandoned carcasses or moribund losses. There are no firm published data on loss rates.

These statistics are grouped by area, and compared with earlier catches, are shown in Table 3.

There were no live-capture operations for killer whales off the British Columbia coast in 1977.

Table 1

Species	Size	Date	Position	Method	Type of tag	Tag identification
Humpback	≅45 ft	4 III 78	49° 31′ N, 56° 00′ W (Hall's Bay)	Shotgun (from boat *The Willing Lass*)	12 ga "Discovery" (Visual orange flag/ Quinacrine)	FRBC 1860
Humpback	≅45 ft	4 III 78	49° 31′ N, 56° 00′ W (Hall's Bay)	Shotgun (from boat *The Willing Lass*)	12 ga "Discovery" (Visual orange flag/ Quinacrine)	FRBC 1859
Humpback	≅45 ft	4 III 78	49° 31′ N, 56° 00′ W (Hall's Bay)	Shotgun (from boat *The Willing Lass*)	12 ga "Discovery" (Visual dacron streamer/ Quinacrine)	FRBC 1478
Humpback	≅45 ft	4 III 78	49° 31′ N, 56° 00′ W (Hall's Bay)	Shotgun (from boat *The Willing Lass*)	12 ga "Discovery" (Visual orange flag/ Quinacrine)	FRBC 1858
					12 ga "Discovery" (Visual dacron streamer/ Quinacrine	FRBC 1481
					12 ga "Discovery" (Visual dacron streamer/ Quinacrine)	FRBC 1483 (Protrude)
Humpback	≅45 ft	7 III 78	49° 34′ N, 55° 47′W (Miles Cove)	Shotgun (from ice)	12 ga "Discovery" (Visual orange flag/ Quinacrine)	FRBC 1852[1]
				Shotgun (from ice)	12 ga "Discovery" (Visual dacron streamer/ Quinacrine)	FRBC 1343[1]
				Shotgun (from ice)	12 ga "Discovery" (Visual dacron streamer/ Quinacrine)	FRBC 1585[1] (Protrude)

[1] Recovered 1 April 1978, Port Anson.

Table 2

Area	Community	Narwhal	Beluga	Killer Whale	Bowhead
Eastern Arctic	Arctic Bay	42	0	0	0
	Broughton Island	35	0	0	0
	Clyde River	42	0	0	0
	Frobisher Bay	0	0	0	0
	Grise Fjord	0	11	0	0
	Pond Inlet	107	0	–	–
	Pangnirtung	3	178	14	–
	Resolute Bay	3	17	–	–
	Creswell Bay	10	–	0	0
Subtotal		242	206	14	0
Hudson and James Bay	Port Burwell	–	–	–	–
	Cape Dorset	0	7	0	0
	Lake Harbour	0	26	–	–
	Igloolik	0	15	–	–
	Hall Beach	13	18	–	–
	Coral Harbour	0	52	–	–
	Repulse Bay	8	30–40	–	–
	Chesterfield Inlet	0	18	0	0
	Rankin Inlet	0	12	0	0
	Whale Cove	0	30 (est.)	–	–
	Eskimo Point	0	39	0	0
	Sanikiluaq (Belcher Islands)	0	14	0	0
Subtotal		21	261–271	0	0
Western Arctic	Mackenzie Delta	0	148	0	0
Totals		263	615–625	14	0

Table 3

Species		Western Arctic	Eastern Arctic	Hudson and James Bay	Total
Narwhal	1973	–	330	11	341
	1974	–	291	–	291
	1975	–	251	–	251
	1976	0	282	18	300
	1977	0	242	21	263
White whale	1973	297	63	178	538
	1974	118	136	255	509
	1975	149	111	61	321
	1976	154	156	219	529
	1977	148	206	261–271	615–625
Bowhead	1974	–	–	–	–
	1975	–	1	–	1
	1976	–	–	–	–
	1977	0	0	0	0
Killer whale	1977	0	14	0	14

8. MANAGEMENT

Discussions continued to be held internally within the Canadian Government regarding recent catch rates of killer, narwhal, beluga and bowhead whales, and the significance of these removals to the respective populations.

9. PUBLICATIONS

Listed here are publications for the period 1977–1978 including those not cited in final form in the last Progress Report, resulting principally from research on cetaceans carried out by the staff of the Arctic Biological Station, or supported directly or indirectly by that institute.

Bree, P. J. H. van, Sergeant, D. E. and Hoek, W. 1977. A harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758), from the Mackenzie River delta, Northwest Territories, Canada (Notes on Cetacea, Delphinoidea VIII). *Beaufortia* 26 (333): 99–105.

Davis, R. A., Richardson, W. J., Johnson, S. R. and Renaud, W. E. 1978. Status of the Lancaster Sound narwhal population in 1976. *Rep. int. Whal. Commn* 28: 209–16.

Gaskin, D. E. 1977. Harbour porpoise *Phocoena phocoena* (L.) in the western approaches to the Bay of Fundy 1969–75. *Rep. int. Whal. Commn* 27: 487–92.

Ljungblad, D. K., Leatherwood, S., Johnson, R. A., Mitchell, E. D. and Awbrey, F. T. 1977. Echolocation signals of wild Pacific bottlenosed dolphins, *Tursiops* sp. *Proc. (Abs.) Second Conf. Biol. Marine Mammals, San Diego*, p. 36.

Maul, G. E. and Sergeant, D. E. 1977. New cetacean records from Madeira. Bogagiana, Museu Municipal do Funchal, Madeira, No. 43, p. 1–8.

Milne, A. R. and Smiley, B. D. 1978. *Offshore Drilling in Lancaster Sound: Possible Environmental Hazards.* Institute of Ocean Sciences; Patricia Bay, Sidney, B.C., [i–iv] + i–iv + 95 pp. + 14 pp. photos.

Mitchell, E. D. 1978. Minority statement on southern minke stock assessment. *Rep. int. Whal. Commn* 28: 84–5.

Mitchell, E. 1978. Canadian progress report on whale research – June 1976 to May 1977. *Rep. int. Whal. Commn* 28: 95–9.

Mitchell, E. D. and Kozicki, V. M. 1978. Sperm whale regional closed seasons: proposed protection during mating and calving. *Rep. int. Whal. Commn* 28: 195–8.

Mitchell, E. D. and Mead, J. G. 1977. History of the gray whale in the Atlantic Ocean. *Proc. (Abs.) Second Conf. Biol. Marine Mammals, San Diego*, p. 11.

Mitchell, E. D. and Tillman, M. F. 1978. Scientific review of IWC Scientific Permits. *Rep. int. Whal. Commn* 28: 269–70.

Perrin, W. F., Mitchell, E. D., van Bree, P. J. H. and Caldwell, D. K. 1977. Spinner dolphins, *Stenella* spp., in the Atlantic. *Proc. (Abs.) Second Conf. Biol. Marine Mammals, San Diego*, p. 12.

10. WORKING DOCUMENTS

Not all documents listed will be formally published, and those that are may be substantially modified in the final form:

Breiwick, J. M., Mitchell, E. D. and Chapman, D. G. 1978. Ms. Initial population size of Bering Sea stock of bowhead whale *Balaena mysticetus*: An iterative method. Paper SC/30/Doc 43 presented to the IWC Scientific Committee, June 1978.

Darling, J. 1978. Ms. Abundance and behaviour of gray whales which spend the summer off the west coast of Vancouver Island. Paper SC/30/Doc 37 presented to the IWC Scientific Committee, June 1978.

Ford, J. K. B. 1977. White whale – Offshore exploration acoustic study. F. F. Slaney & Co. Ltd, Vancouver, Canada (for Imperial Oil Limited), i–vii + 21 pp. + [i–v] + 3 maps + 4 tables + 13 figs.

Fraker, M. A. 1976. Summer Environmental Program, Mackenzie River Estuary. Volume 2 White Whale Studies. F. F. Slaney and Co. Ltd, Vancouver, Canada (for Imperial Oil Limited). i–vii + 62 pp. + 5 maps + 4 figs + 6 tables + [7 Appendices: 28 pp. + 1 map].

Fraker, M. A. 1977. The 1976 white whale monitoring program, Mackenzie Estuary, N.W.T., F. F. Slaney and Co. Ltd, Vancouver, Canada (for Imperial Oil Limited), [i–vii] + 73 pp. + 9 maps + 16 tables + 3 figs. + [6 Appendices: 16 pp.]

Fraker, M. A. 1977. The 1977 whale monitoring program, Mackenzie Estuary, N.W.T., F. F. Slaney and Co. Ltd, Vancouver, Canada (for Imperial Oil Limited), i–vii + 53 pp. + 15 maps.

Fraker, M. A., Sergeant, D. E. and Hoek, W. 1977. Bowhead and white whales in the southern Beaufort Sea. Beaufort Sea Project Technical Report No. 4, Department of Fisheries and the Environment, Sidney, B.C., [i] + i–vii + 114 pp. + *frontis.*

Mitchell, E. D. 1979. Ms. Canadian Progress Report on Whale Research – June 1977 to May 1978. Paper SC/30/Prog. Rep. 2 (published in this volume).

Mitchell, E. D. 1978. Ms. Collection of scientific data from "Aboriginal" whale fisheries. Paper SC/30/Doc 42 presented to the IWC Scientific Committee, June 1978.

Mitchell, E. D. 1979. Comments on magnitude of early catch of east Pacific gray whale *Eschrichtius robustus.* Paper SC/30/Doc 41 (published in this volume).

Mitchell, E., Blaylock, G. and Kozicki, V. M. 1978. Ms. Modifiers of effort in whaling operations: With a survey of anecdotal sources on searching tactics and use of Asdic in the chase. Paper SC/30/ Doc 40 presented to the IWC Scientific Committee, June 1978.

Mitchell, E. D. and Kozicki, V. M. 1978. Ms. Example of daily activity log for a shore-based whale catcher vessel. Paper SC/30/ Doc 39 presented to the IWC Scientific Committee, June 1978.

Mitchell, E. and Stawski, M. 1978. Ms. A bibliography of whale killing techniques, especially "Humane" methods. Paper SC/30/ Doc 38 presented to the IWC Scientific Committee, June 1978.

Sleno, G. A. and Mansfield, A. W. 1978. Ms. Aerial photography of marine mammals using a radio-controlled model aircraft. Fish. and Mar. Serv. MS Rept. 1457, i–iv + 7 pp. Mimeo.

SC/30/Prog Rep 3

Denmark
Progress Report on Cetacean Research June 1977 – May 1978

SPECIES AND STOCKS STUDIED

Statistical information on the catch of whales in Greenland has been collected in the usual way. Preliminary results are given in Table 1.

As usual a great number of small cetaceans have been caught, including harbour porpoises (*Phocoena phocoena*), narwhals (*Monodon monoceros*), belugas (*Delphinapterus leucas*), some pilot whales (*Globicephala melaena*), a few 'dolphins' (probably the whitesided dophin, *Lagenorhynchus acutus*), and two killer whales (*Orcinus orca*). The five 'not specified whales' were probably also small cetaceans.

Of medium-sized and large whales, minke whales (*Balaenoptera acutorostrata*) were taken in greater numbers than in the preceding four years. The extremely good, calm early summer in Greenland partly explains this. Nine fin whales (*Balaenoptera physalus*) and ten humpback whales (*Megaptera novaeangliae*) were taken mainly in the Autumn, although there was a surprising report of one fin whale caught in January.

FIELD OBSERVATIONS AND COLLECTIONS

Field work was carried out in July–September in the regions between Holsteinsborg (67° N) and Umanak (71° N), with special emphasis on collecting information and biological materials from the minke whale catches in Godhavn (c. 69° N) and the Umanak district.

Unfortunately, the greater part of the catch in both areas this year took place very early in the season, before field work started. Only five specimens could be examined, and for three of these only the head was left on the beach. Body length was measured for two whales, the bulla and baleen plates sampled for all specimens. An attempt to sample ear plugs had limited success (2+, 3÷). Information on the local catch of minke whales and other marine mammals in this and previous years was collected.

On the basis of experience gained in 1977, a programme for similar field work in the same areas is being carried out in the summer of 1978.

RESEARCH RESULTS

The history of exploitation of large whales in Greenland in this century has been studied, and is presented in SC/30/Doc 23, including preliminary results of observations carried out in the summer of 1977 by biologists on board supporting ships at oil-drilling sites.

PUBLICATIONS

Apart from papers presented at IWC meetings, a detailed analysis of the by-catches of sea birds and marine mammals in salmon drift-nets in 1972 has been published:

Christensen, O. and Lear, W. H. 1977. By-catches in salmon drift-nets at West Greenland in 1972. *Medd. om Grønl.* 205 (5), 28 pp.

Table 1

Provisional figures for the catch of whales in Greenland, 1977[1]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	?	Total	(Estim.)
Minke whale	–	–	–	8	26	46	36	35	30	29	7	1	19	237	(250)
Fin whale	1	–	–	–	2	–	–	–	1	5	–	–	–	9	
Humpback whale	–	–	–	–	1	–	–	1	4	2	1	1	–	10	
Narwhal	19	9	9	9	24	10	5	34	5	6	87	15	–	232[2]	(350)[3]
Beluga	125	51	43	88	118	1	–	2	37	189	26	8	2	690[2]	(800)[3]
Pilot whale	–	–	1	–	2	–	–	6	42	20	–	–	–	71	
Killer whale	–	–	–	–	–	2	–	–	–	–	–	–	–	2	
Harbour porpoise	1	–	4	5	10	33	46	314	203	70	2	2	320	1010	(1025)
"Dolphins"[4]	–	–	–	–	–	–	–	–	20	10	–	–	1	31	
Not specified	–	5	9	–	–	–	–	40	3	–	2	–	8	67[5]	

[1] Information lacking for some areas, e.g. Thule and Jakobshavn districts.
[2] Excluding Thule.
[3] Including Thule.
[4] Probably the white-sided dolphin, *Lagenorhyncus acutus*.
[5] Most likely small cetaceans.

SC/30/Prog Rep 4

Japan
Progress Report on Cetacean Research June 1977 – May 1978

(This refers to work at the Far Seas Fisheries Research Laboratory)

SPECIES AND STOCKS STUDIED

One whaling expedition, *Kyokuyomaru No. 3*, operated in the North Pacific pelagic whaling ground in 1977 taking Bryde's and sperm whales. Three whaling companies engaged in Japanese coastal whaling in the 1977/78 season, also taking Bryde's and sperm whales.

Only one whaling expedition, *Nissinmaru No. 3*, engaged in pelagic whaling in the Southern Hemisphere, taking sei, minke and sperm whales. The Far Seas Fisheries Research Laboratory was granted a special permit to take no more than 120 Bryde's whales in the Southern Hemisphere, and this investigation was undertaken with the co-operation of the *Nissinmaru No. 3* expedition.

Small-type whaling took minke, Baird's beaked, Cuvier's beaked, killer and pilot whales in the coastal waters of Japan.

WHALE SIGHTING

The Government has continued to help to financially maintain the research level of whale sighting by scouting boats attached to pelagic whaling expeditions in the North Pacific and the Southern Hemisphere.

The research area covered in the North Pacific is shown in Fig. 1, and the total research distance covered in the 1977 summer season was 22,143 miles. This is 3,602 miles more than in 1976. A catcher boat *Takamaru* (618.6 gross tons) was chartered by the Fisheries Agency to carry out a whale sighting and whale marking cruise in the tropical waters of the North Pacific from 25 January–25 March 1978. The results are shown in Table 1. The research distance was 7,341 miles, which is 2,910 miles more than the previous season. Dr Y. Masaki of our laboratory was on board the vessel to carry out research.

The total research distance covered by scouting boats in the Southern Hemisphere was 73,758 miles which was 82,369 miles less than the previous season because of the reduction in the size of the expedition.

Whale sighting records were also collected by the operating catcher boats which engaged in coastal and pelagic whaling in the North Pacific and the Southern Hemisphere in 1977/78. The numbers of protected whale species seen and CDW data are shown in Tables 2 and 3.

Table 1

Research results from the *Takamaru* cruise in the North Pacific, 25 January–25 March 1978

10° square	Research (miles)	Whales sighted		Whales marked	
		Bryde's	Sperm	Bryde's	Sperm
M20	181	–	–	–	–
M21	133	–	–	–	–
L20	308	–	–	–	–
L21	135	–	–	–	–
L22	256	–	–	–	–
K19	487	–	–	–	–
K22	140	–	–	–	–
K23	268	3	–	1	–
K24	404	3	15	2	1
K25	283	–	–	–	–
J20	762	1	8	1	3
J21	938	17	9	16	–
J22	842	7	–	5	–
J23	611	2	–	1	–
J24	556	–	1	–	–
J25	308	1	–	1	–
J26	598	5	–	4	–
H25	131	–	42	–	6
Total	7,341	39	75	31	10

Table 2

Protected species observed by operating catcher boats in the North Pacific, 1977

Sector	Blue	Fin	Sei	Hump-back	Right	Gray	Effort (CDW)
			Pelagic whaling				
IV M	–	–	–	–	–	–	64
V M	–	–	–	–	–	–	168
IV L	–	–	–	–	2	–	24
V L	–	1	–	4	–	–	404
VI L	–	–	–	–	–	–	15
Total	–	1	–	4	2	–	675
			Coastal whaling				
Total	–	4	–	1	1	–	1,282

Table 3

Protected species observed by operating catcher boats in the Antarctic, 1977/78

Sector	Blue	Fin	Hump-back	Sei	Right	Effort (CDW)
III B	–	–	20	–	–	103
IV D	76	119	2	435	294	441
IV A	10	29	–	–	–	34
IV B	–	3	1	2	–	65
V F	2	3	7	–	–	109
V D	–	–	–	38	–	6
V B	1	2	7	–	–	115
VI F	–	–	4	–	–	23
VI E	–	–	–	1	–	13
VI B	1	1	9	–	–	42
Total	90	157	50	476	294	951

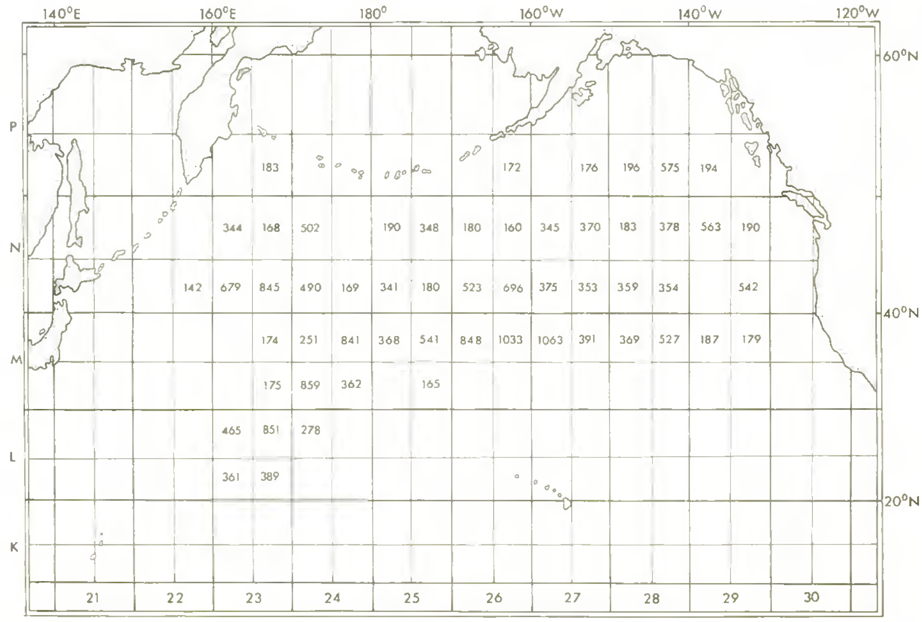

Fig. 1. Scouting distance (miles) covered by Japanese scouting boats in the North Pacific in 1977 (by 5° square).

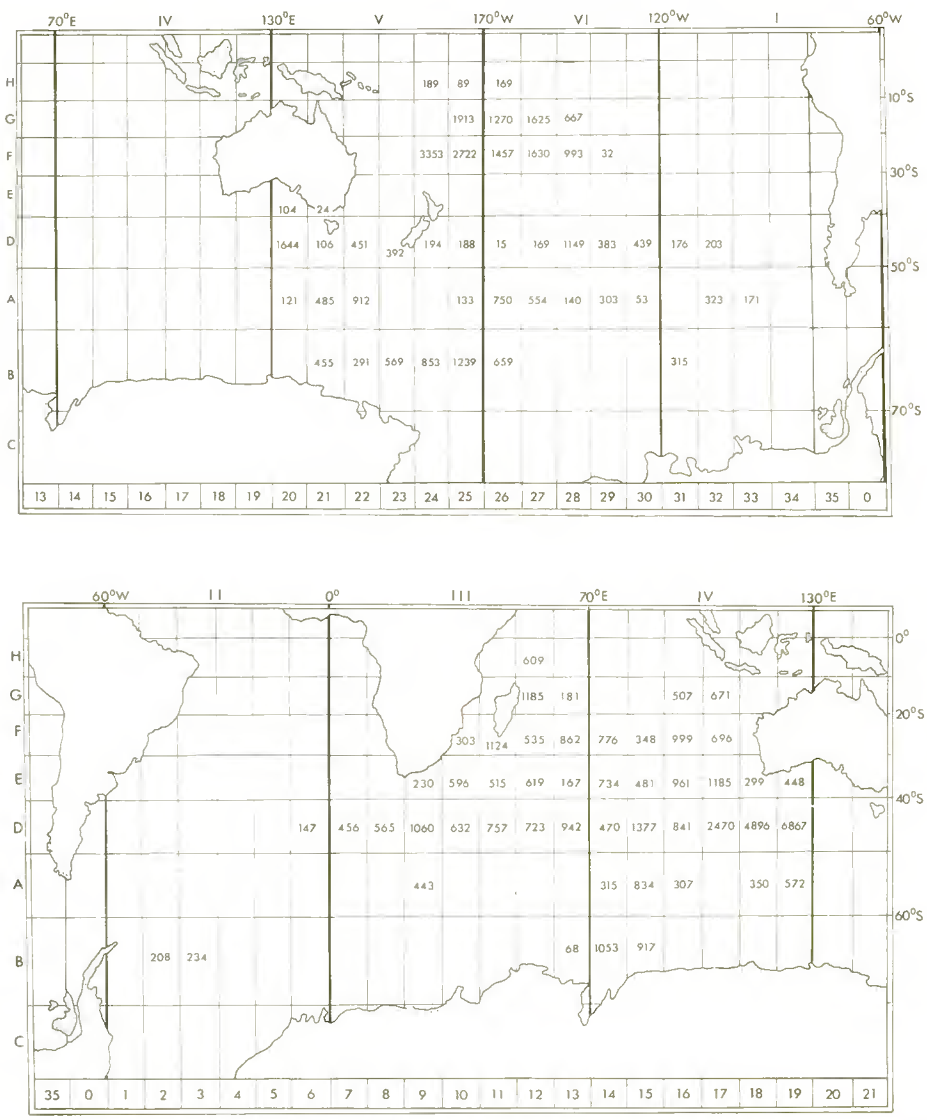

Fig. 2. Scouting distance (miles) covered by Japanese scouting boats in the Southern Hemisphere in the 1977/78 season (by 10° square).

WHALE MARKING

Scouting boats engaged in whale marking in the pelagic whaling ground of the North Pacific in summer 1977, and 41 whales were effectively marked (18 whales more than the previous season) using Japanese marks (Table 4). *Taka-maru* marked 41 whales (34 whales more than the previous season) in the tropical waters of the North Pacific during a whale sighting cruise in winter (Table 1).

Table 4

Number of whales marked effectively by scouting boats in the North Pacific, 1977

10° square	Fin	Sei	Bryde's	Sperm	Total
M25	–	–	1	–	1
M28	–	1	–	–	1
M29	–	1	–	–	1
N23	1	5	–	1	7
N24	1	1	–	–	2
N25	2	2	–	–	4
N26	1	4	–	–	5
N27	–	3	–	–	3
N28	–	5	–	–	5
N29	1	4	–	–	5
P23NP	2	–	–	–	2
P28	1	1	–	–	2
P29	–	3	–	–	3
Total	9	30	1	1	41

In the Southern Hemisphere, 476 whales (218 whales more than the previous season) were effectively marked by scouting boats, using 925 ordinal and .410 Discovery marks as shown in Table 5.

Japanese whalers recovered 3 Japanese and 2 Soviet marked whales in the North Pacific in the 1977/78 season (Table 6). They also recovered 2 Discovery marks and 1 Soviet mark in the Southern Hemisphere in 1977/78 as shown in Table 7.

LABORATORY WORK

Processing of biological materials (earplugs, teeth, ovaries, baleen plates, testes, etc.) collected from coastal and pelagic whaling grounds was continued. Biological materials were also collected by small-type whaling adjacent to Japan, and they are now being investigated.

Mr S. Wada of our laboratory visited the Ohzuchi Marine Research Center of the Ocean Research Institute, University of Tokyo, to develop new techniques of biological analysis for stock identification, in August and September 1977.

STUDIES

Studies were mainly concentrated on matters concerning the population assessment of the North Pacific sperm whale and the Southern Hemisphere minke whale.

Table 5

Number of whales marked effectively by scouting boats in the Southern Hemisphere, 1977/78

10° square	B	F	H	Se	Br	Mi	Sp	Total
H26	–	–	–	–	1	1	–	2
G12	–	–	–	–	3	–	3	6
16	–	–	–	–	2	–	–	2
17	–	–	–	–	2	3	–	5
25	2	–	–	–	10	2	10	24
26	–	–	–	–	4	5	1	10
27	1	–	–	–	5	3	3	12
28	–	–	–	–	8	–	–	8
F 10	–	–	–	–	1	–	–	1
11	–	–	–	1	6	1	–	8
12	–	–	–	–	2	–	3	5
13	–	–	–	–	–	–	2	2
14	–	–	–	–	2	–	–	2
16	–	–	–	–	2	–	–	2
17	–	–	–	–	3	2	–	5
25	–	–	–	–	2	–	10	12
26	–	–	2	–	4	2	3	11
27	–	–	1	–	13	2	13	29
28	–	–	–	–	–	2	8	10
E 10	–	–	–	–	–	1	3	4
11	–	1	–	–	1	–	–	2
12	–	–	–	–	–	1	–	1
14	–	–	–	–	–	1	–	1
15	–	–	–	–	1	–	1	2
16	–	–	–	–	2	–	3	5
17	–	–	–	–	1	1	–	2
D 6	–	1	–	–	–	–	–	1
7	–	2	–	3	–	1	–	6
8	–	2	–	3	–	3	–	8
9	–	–	–	2	–	–	–	2
10	–	2	–	2	–	–	–	4
11	–	–	–	3	–	–	–	3
13	–	3	–	6	–	–	–	9
20	–	1	–	6	–	2	–	9
22	–	–	–	4	–	–	–	4
23	–	–	–	1	–	–	–	1
24	–	4	–	–	–	–	–	4
25	–	–	–	5	–	1	11	17
27	–	–	–	3	–	1	–	4
28	–	–	–	15	–	3	1	19
29	–	–	–	2	–	–	–	2
30	–	1	–	12	–	–	–	13
31	–	–	–	–	–	3	2	5
32	–	–	–	1	–	1	–	2
A 9	–	–	–	2	–	2	4	8
14	–	1	–	4	–	–	5	10
15	–	8	–	–	–	–	8	16
18	–	–	–	–	–	3	3	6
19	–	6	–	–	–	7	13	26
20	–	–	–	–	–	2	2	4
22	–	8	–	3	–	–	11	22
26	–	3	–	–	–	–	3	6
27	–	–	–	7	–	4	11	22
28	–	3	–	4	–	1	8	16
29	–	6	–	–	–	–	6	12
32	–	–	–	–	–	2	2	4
33	–	1	–	–	–	–	2	3
B 13	–	–	–	–	–	11	–	11
14	–	–	–	–	–	1	–	1
21	–	–	–	–	–	2	–	2
22	–	–	–	–	–	2	–	2
23	–	–	–	–	–	1	–	1
24	–	–	–	–	–	3	–	3
25	–	–	–	–	–	2	2	4
31	–	4	–	1	–	5	1	11
Total	3	57	3	90	75	90	158	476

Table 6

Whale marks recovered by Japanese and Soviet whalers in the North Pacific season 1977

Mark No.	Species	Sex	Body length (m) at recovery	Date mark	Date recovered	Position marked	Position recovered
Japanese marks							
13166	Bryde's	M	12.6	2/III/75	4/ VI /77	25° 06′ N, 134° 04′ E	26° 01′ N, 162° 39′ E
13466	Bryde's	M	12.4	18/ II /76	25/ V /77	00° 04′ N, 162° 27′ E	27° 35′ N, 161° 54′ E
13469 13470[1]	Bryde's	F	13.3	21/ II /76	26/ V /77	00° 47′ N, 165° 27′ E	27° 43′ N, 161° 54′ E
USSR marks							
2727	Sperm	M	12.9	–	20/VII/77	–	27° 56′ N, 175° 20′ E
C1330	Bryde's	F	12.3	–	23/ V /77	–	27° 15′ N, 163° 08′ E

[1] Recovered at cutting of meat.

Table 7

Whale marks recovered by Japanese whalers in the Antarctic season 1977/78

Mark No.	Species	Sex	Body length (m) at recovery	Date mark	Date recovered	Position marked	Position recovered
Discovery marks							
15399	Sperm	M	15.4	–	28/III/78	–	46° 46′ S, 89° 30′ E
28281	Sei	F	16.1	27/XI/69	5/ I /78	40° 50′ S, 121° 49′ E	44° 25′ S, 126° 39′ E
USSR marks							
690343[1]	Sperm	–	–	–	9/XI/77	–	28° 02′ S, 175° 06′ W

[1] On deck after flensing.

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SC/30/Prog Rep 5

Iceland
Progress Report on Cetacean Research
June 1977 – May 1978

MINKE WHALES

In the 1977 season a catch quota of 200 minke whales, *Balaenoptera acutorostrata,* was decided as Iceland's share from a total quota of 320 animals in the East Greenland–Iceland–Jan Mayen area. As in recent years the whaling in 1977 was under government control. Fourteen licences were issued and a total of 194 minke whales was caught from 23 March to 22 August, when the catching operations were stopped early by mistake. The whaling mainly took place in shallow waters off the central north coast of Iceland. Catch data have been received from the whalers for each whale caught; four boats caught less than ten whales each.

Systematic investigations on minke whales were started in 1977 by the Marine Research Institute in Reykjavik, including biological studies in Icelandic waters. The research programme was worked out in co-operation with the Institute for Marine Biology and Limnology at the University of Oslo. The following topics were dealt with in 1977:

(a) The historical background of minke whale catches in Icelandic waters.
(b) Available catch data from recent years.
(c) Biological material collected in the 1977 season, including gonads from 53 animals, ear plugs from 9 and tympanic bulla from 36.
(d) Data on catch effort.

MARKING

During 3–17 September 1977 the Marine Research Institute had at its disposal a 12 ton catcher boat, 'Njordur EA 208', with the aim to mark minke whales in the catching areas. The marks used were the .410 version of the 'Discovery'-type mark, presented to us by the Marine Research Institute in Bergen. Because of very adverse weather conditions only 7 whales were effectively marked; the marking data are given in Table 1.

Table 1

Minke whale marking in Icelandic waters in 1977

Mark No.	Date	Hour	Position	Approx. length	Note
31721	19/8	14.20	52 d	Average	Miss, took water
31722	8/9	14.00	51 c	Average	Possible hit, poorly observed
31723	9/9	07.00	51 c	Rather small	Miss, took water 1–2 m from whale
31728	9/9	10.10	51 c	Average	Possible hit, took some water
31734	10/9	10.20	51 c	Rather small	Hit
31735	10/9	12.10	51 d	Small	Hit
31737	10/9	12.35	51 d	Rather small	Possible hit, took water 0.5 m from whale
31740	10/9	17.00	52 c	Small	Hit
31741	12/9	17.30	54 a	Rather small	Hit
31744	17/9	07.50	51 d	Average	Hit
31745	17/9	09.30	51 d	Big	Hit
*31746	17/9	09.35	51 d	Small	Possible hit, took water 0.5 m from whale
*31749	17/9	10.10	51 d	Small	Miss, ricochet?
N 1021	17/9	13.30	51 d	Average	Hit

* The same animal.

All the marks were labelled 'SENDES TIL HAVFORSKNING BERGEN', except one, no. N1021, which was labelled 'RETURN HAVFORSKNING – BERGEN NORWAY'. The letters a–d indicate where in statistical area the whale was marked.

SC/30/Prog Rep 6

New Zealand Progress Report on Cetacean Research June 1977 – May 1978

M. W. Cawthorn

Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington, New Zealand

This report summarises cetacean research conducted by the Fisheries Research Division of the Ministry of Agriculture and Fisheries and the National Museum.

SPECIES AND STOCKS STUDIED

During the past year studies were continued on the following:

(a) Sperm whales: south west Pacific and Tasman Sea.
(b) Right whales: south west Pacific, Tasman Sea and sub-Antarctic area of New Zealand.
(c) Rorquals: south west Pacific and Tasman Sea.
(d) Small cetaceans: Hector's dolphin between 41° 12′ S, 174° 02′ E and 41° 35′ S, 174° 20′ E.

FIELD OBSERVATIONS AND COLLECTIONS

Sightings of all species were gathered monthly by vessels, aircraft and shorebased observers cooperating in a large scale sighting programme.

A monthly aerial schoolfish survey initiated by the Fisheries Research Division is also being utilised for the collection of cetacean observations.

Sightings of cetaceans were recorded during a 21-day cruise over the Auckland Is. shelf, Pukaki Rise and Campbell Plateau to the south of New Zealand.

Strandings have been attended and material collected where possible.

MARKING

G.R.V. *James Cook* carries a marking gun and Discovery marks in the series 25071–25120. No whales have been marked this year.

Fourteen Hector's dolphins (*Cephalorynchus hectori*) were marked by freeze branding and colour-coded plastic tags as part of a detailed study on the species now being undertaken by the National Museum.

LABORATORY WORK

Material collected from stranded whales is being analysed for age, maturity and feeding studies. Samples of blubber, internal organs and muscle are being analysed for persistent pesticides and heavy metals.

Two Hector's dolphins, incidentally caught in commercial gill nets are deep frozen awaiting processing.

DEVELOPMENT OF TECHNIQUES

A visible tag, suitable for both large and small cetaceans, is being developed jointly by Mr C. A. Murdoch of Timaru and M. W. Cawthorn of the Fisheries Research Division. Design of all component parts is complete and ballastic tests have proven the stability of the unit in flight. All components are inert and can be sterilised before application by immersion in a solution of sodium metabisulphite. Maximum muzzle velocity of the tag on firing will be in excess of 215 ms^{-1} and it is conservatively estimated by the designers that the stainless steel implant will have sufficient inertia to penetrate more than 20 cm of blubber at 70–80 metres.

Field trials should be completed in early 1979 and tagging of sperm, humpback and right whales will commence shortly thereafter.

The system is highly versatile and can be readily converted to chemical and dye marking. Development of the unit as a radio tag is also planned.

Catching and handling techniques for *Cephalorynchus hectori* have been developed during the study by Dr A. N. Baker of the National Museum, Wellington. Experiments have been carried out on a freeze-branding system using pressurized dichlorodifluromethane. No results are yet to hand on the effectiveness of this method of marking. A photographic record of individuals with malformed dorsal fins is being maintained to supplement the marking programme.

RESULTS

During two 18-day deep water trawling cruises to the sub-Antarctic area south of New Zealand, 23 sightings of cetaceans were made.

Species	Number of sightings	Number of animals
Balaenoptera acutorostrata	1	1
Delphinus delphis	6	40
Lagenorynchus obscurus	10	70+
Tursiops truncatus	2	4
Unidentified small cetaceans	4	6+
Total	23	121+

The total recorded observations, by species, made by ships, land based observers (meteorological stations and lighthouses) and aerial schoolfish survey flights are shown in Tables 1a and 1b.

A total of 27 right whales was sighted over the period June 1977 to May 1978. Four were recorded from vessels working round the coast and the remainder from Campbell Island. The staff of the Meteorological Station at Campbell Island recorded the first sightings for 1978 in the first week of May when '4 adult right whales and at least one calf were seen in North West Bay'.

Callosity patterns on right whales at Campbell Island are now being recorded systematically using high resolution

Table 1a

	Sperm	Humpback	Fin	Sei	Bryde	Minke	Right
Ships	188	56	10	55	3	–	4
Meteorological stations and lighthouses	–	29	1	4	–	–	23
Schoolfish survey	–	–	–	5	–	–	–
Total	188	85	11	64	3	–	27

Table 1b

	Dolphins	Unidentified	
		Rorquals	Odontocetes
Ships	–	17	2
Met. stations and lighthouses	–	8	9
Schoolfish survey	2,500±	4	2
Total	2,500±	29	13

photography. Data derived from this work will be analysed in co-operation with Dr R. Payne.

Fifty-six humpbacks were recorded from vessels and twenty-nine from lighthouses – a total of 85. Winter months observations were low because of poor conditions. The maximum number of humpbacks sighted by land based observers was 23, which moved north past Moko Hinau lighthouse (35° 48′ S, 175° 07′ E) in September 1977. The maximum observed by any vessel was 5 seen travelling east at 41° 45′ S, 175° 07′ E in February 1978.

Humpbacks – Tonga Islands

The Tongan area is thought to be the breeding area for the bulk of the southwest Pacific humpback stock. Whales congregate in the sheltered waters round the islands of Ha'Apai and Vava'U from July to September for mating and parturition.

Local inhabitants have traditionally exploited this seasonal gathering since the mid-19th century, fishing from open boats using hand harpoons. Effort is concentrated on pregnant females, calves and females with calves. Although no systematic catch statistics have been kept, records (largely anecdotal) have shown catches to be small but significant. Landed catches recorded by the Tongan Government Fisheries Officer are as follows:

1973	3	
1974	4 plus one calf	The females taken had an
1975	8 plus one calf	estimated average length of
1976	6	30 ft (10 m).
1977	5	

A population survey for the area is currently being planned.

Sperm Whales

Sperm whale sightings covered the entire Tasman Sea, the waters round Fiji, the Kermadec Islands, and the eastern seaboard of New Zealand. A total of 188 whales were sighted. Maximum pod sizes were 60, west of North Cape in December, and 30 sighted in eastern Cook Strait in February 1978.

The three New Zealand areas chosen for comparison with sightings of sperm whales made in the 1960s, all produced fewer sightings than expected, largely because of intermittent traffic through or over the areas and poor conditions.

All movements emphasised the sperm whales penchant for following the shelf edge in this area, with large numbers of whales concentrating in and around areas of high productivity and upwelling. Observers noted 7 sperm whales closely following the line of the Kermadec Trench south to New Zealand during March.

Animals sighted southwest of Fiji during March and September (11 sightings) were all females accompanied by juveniles or calves.

Area	Month	Number sighted	Predominant heading
East Cape	January	6	SW
Kaikoura	December January	5	S
	February	12	S
	March–April	16	N
Puysegur	January	3	N

Small Cetaceans

A detailed study of *Cephalorynchus hectori* has been undertaken by Dr A. N. Baker of the National Museum.

A survey of 70 boat hours over 500 km² produced 305 individual sightings. Five dolphins were alone, others in schools of 3–30. Six calves were sighted. Specimens were not collected. Fourteen dolphins were captured using a tail-grab, each was sexed, weighed, measured and marked by freeze branding and application of colour-coded nylon tags prior to release. Three marked animals were re-sighted 28 and 64 days after release, within 6 km of the release location.

Preliminary results suggest that a small localised population of *C. hectori* consisting of several discreet schools, exists in the survey area – at least during the summer. Austral spring and early summer calving is confirmed. Analysis of morphometric data has not yet been undertaken. It is planned to continue the catch and release programme over the next 12 months.

Incidental Kills of Small Cetaceans

C. hectori: 12–20 per annum in commercial and amateur gill nets, principally round Banks Peninsula and to a lesser extent Taranaki.

Strandings

From 9 June 1977 to 23 May 1978, 811 cetaceans stranded in 23 separate occurrences on the shores of the North and South Islands and Chatham Island. Of these 25 strandings, 17 involved one or two animals only, the remaining 6 were massed strandings with numbers ranging from 12 to 253. The two species best represented were *Globicephala malaena* (5 massed strandings, 538 animals) and *Pseudorca crassidens* (1 stranding, 253 animals).

Date	Species	No.	Sex	Length (m)	Location	Examined
1977						
9 June	*Delphinus delphis*	1	–	–	Fitzroy Bay, Wellington	
18 June	Sperm	1	F	10.0	Ninety Mile Beach	
24 June	*Globicephala malaena*	12	–	–	Farewell Spit	*
21 July	Sperm	1	M	14.37	Napier	*
29 August	*Hyperodon planifrons*	1	F^P	7.16	Te Wai Wai Bay	*
13 September	Sperm	1	F	11.00	Waipoua River, Dargaville	
19 October	*Lagenorynehus obscurus*	1	M	1.72	Waerongomai Beach	*
14 November	*G. malaena*	33	–	–	Havelock	
26 November	Sperm	1	M	12.80	Anaura Bay	*
30 November	*G. malaena*	96	–	–	Te Kaha	*
21 December	Sperm	1	M	17.06	Greymouth	*
1978						
2 January	*D. delphis*	2	–	–	Merons Bay	
10 January	*Berardius* sp.	1	M	6.3	South Beach, Wanganui[1]	
14 January	*Mesoplodon grayi*	1	M	4.11	Ohope	*
17 January	*G. malaena*	174	–	–	Te Ori Ori, Chatham Is.	
18 January	*M. grayi*	2	F	3.50	Te Kaha	*
			M	3.45	Te Kaha	*
27 February	Sperm	1	M	17.06	Okawa, Chatham Is.	
27 February	*G. malaena*	223	–	–	Okawa, Chatham Is.	
31 March	*Pseidorca crassidens*	253	–	–	Awhitu Pt, Manakau Hbr	*
1 April	*Mesopoldon* sp.	2	F	4.70	Whakatane Beach	*
			–	2.43	Whakatane Beach	*
25 April	*Ziphius cavirostris*	1	M	6.18	New Brighton	*
27 April	*M. grayi*	1	–	2.42	New Brighton	*
23 May	*Lissodelphis peroni*	1	–	–	Invercargill area	*

* In all instances where the strandings were examined, staff were from either Ministry of Agriculture and Fisheries, National Museum, or Internal Affairs.
[1] Successfully towed out to sea and released.
F^P Pregnant.

MANAGEMENT

It is proposed that a new Marine Mammals Protection Act be introduced to Parliament this session by the Minister of Fisheries.

The bill makes provision for the protection, conservation and management of all marine mammals within New Zealand and within New Zealand fisheries waters, i.e. the New Zealand 200 mile Extended Economic Zone (EEZ).

SC/30/Prog Rep 7

Norway
Progress Report on Cetacean Research
June 1977 – May 1978

SPECIES AND STOCKS STUDIED

In 1977, 1,772 minke whales and 7 killer whales were reported caught by 87 Norwegian vessels engaged in whaling in the North Atlantic Ocean. The Norwegian catches in the four separate areas regulated by quotas were as follows: Canadian East Coast 0 (total quota 48); West Greenland 75 (total quota 325, Norwegian quota 75); East Greenland–Iceland–Jan Mayen 0 (total quota 320, Norwegian quota 120); Svalbard–Norway–British Isles 1,697 (total quota 1,790). SC/30/Doc 61 gives statistical information on the animals caught.

One Norwegian vessel operated off West Greenland, none in the Denmark Strait and 86 in the eastern North Atlantic. Except for West Greenland, whaling was closed by the Norwegian Government from July onwards. In addition to the quotas set by The International Whaling Commission, the Norwegian whaling operations were limited by fishing effort restrictions put into force by the Government.

FIELD OBSERVATIONS AND COLLECTIONS

Biological field work has been performed by the Institute of Marine Research, Bergen on board four of the vessels operating. In the Barents Sea, 78 minke whales were examined by three observers in May and June. In the North Sea, 12 minke whales were examined. This work is a continuation of previous years' work, mainly including measurements of body proportions and collection of sexual organs, ear plugs and bulla tympanica. The material is now being worked up at the Institute.

MARKING

Only a small scale marking program was carried out in the 1977 season. One of the observers marked a humpback whale in Bear Island waters and a killer whale off Svalbard.

During the 1977 season five minke whales marked in the Bear Island area in 1975 were caught in about the same area as the marking had taken place. SC/30/Doc 60 details results of Norwegian minke whale marking in 1977.

RESEARCH

At the Department of Marine Zoology and Marine Chemistry, University of Oslo, biological material from large whales collected in post-war seasons at the shore stations in Norway continues to be analysed. A paper on the eastern North Atlantic sei whale has been published. Studies in the propagation of fin whales (*Balaenoptera physalus*) off the coast of Norway have now been almost completed, and a report will probably be available in 1979.

SC/30/Prog Rep 8

South Africa
Progress Report on Cetacean Research
June 1977 – May 1978

This report summarises cetacean research conducted by the Sea Fisheries Branch of the Department of Industries.

SPECIES AND STOCKS STUDIED

During the past year field studies were conducted on the following:

(a) Right whales (*Eubalaena australis*): south coast of South Africa.
(b) Small cetaceans: animals stranded on the South West African and South African coast west of Mossel Bay, and observed at sea off the coast of South West Africa and the west coast of South Africa.

FIELD OBSERVATIONS AND COLLECTIONS

The annual aerial survey of right whales along the south coast was conducted from 28 September to 4 October 1977, and extended from Woody Cape in the east to Lamberts Bay on the west coast.

Sightings of cetaceans were carried out during a 14-day cruise between Cape Cross, SWA and Cape Town in October 1977.

Material was collected from 27 cetaceans that either stranded or were taken by fishing vessels. Two dolphins were also collected at sea.

MARKING

No whales were marked. Uncertainty regarding funding prevented the continuation of the streamer tag project.

LABORATORY WORK

Processing of material collected at the Durban whaling station was continued. In particular, all minke whale ovaries were sectioned and examined and minke whale ear plugs sectioned on a freezing microtome and stained.

RESULTS

A total of 197 right whales (including 36 calves) was seen during the right whale survey. Within the normal survey area (Muizenberg to Woody Cape) 130 adults and 35 calves were seen, these being the highest totals for both categories since surveys started in 1969. The regression equations for the annual counts are

$$y = 34.44 + 10.40x \text{ (adults)}$$

$$y = 13.31 + 2.05x \text{ (calves)}$$

where x = year of survey (1969 = 1)
and y = number of whales seen.

Both regression coefficients are significant at the 1% level, indicating that the population has been increasing since 1969. In addition, the number of whales seen on the west coast between Muizenberg and Lamberts Bay was the highest so far recorded. Comparable counts are shown below.

Year	Whales seen: Adult	Whales seen: Calves	Total	% on west coast to normal survey area
1970	2	0	2	2.9
1972	3	1	4	3.2
1975	11	4	15	10.8
1977	31	1	32	16.2

This clearly shows that the proportion of right whales found on the west coast outside the normal survey area is increasing, so that the population is apparently not only expanding in size but also in range.

During a 14-day cruise in October 1977 (for the collection of seals at sea), 14 sightings of cetaceans were made.

Species	Number of sightings	Number of animals
Eubalaena australis	1	1
Cephalorhynchus heavisidii	8	63
Lagenorhynchus obscurus	1	6
Unidentified dolphin	3	10
Unidentified whale	1	1

In addition, two female *Cephalorhyncus heavisidii* were collected for biological observations.

The following animals were stranded on the coast of South Africa or South West Africa (west of Mossel Bay) and examined by staff of the Sea Fisheries Branch:

Eubalaena australis	1♂
Balaenoptera edeni	1♂
Kogia simus	1♀
Kogia breviceps	1♂
Mesoplodon layardi	1♂
Mesoplodon mirus	1♂
Mesoplodon densirostris	1♀
Mesoplodon sp.	1 (sex indet.)
Hyperoodon planifrons	1♂
Delphinus delphis	3♂, 1 (sex indet.)
Lagenorhynchus obscurus	1♂, 1 (sex indet.)
Stenella coeruleoalba	1♀

In addition, two stranded new born sperm whale (*Physeter catodon*) calves (1♂, 1♀) were examined at Durban, two *C. heavisidii* (1♂, 1♀) were obtained from a Portuguese stern trawler, and skulls (or skull portions) of the following species were obtained as beach pick-ups or from bottom trawls – *P. catodon, Ziphius cavirostris, Grampus griseus, Globicephala melaena, D. delphis* and *Tursiops aduncus*.

MANAGEMENT

No commercial whaling took place from South Africa in 1977.

The following dolphins were caught under permit for public display during 1977:

Date	Species	Length (m)	Sex	Locality	Status
28.2.77	*Tursiops aduncus*	2.1	♀	Algoa Bay	In captivity 1.6.78
7.3.77	,, ,,	2.42	♀	,, ,,	In captivity 1.6.78
7.4.77	,, ,,	2.36	♀	,, ,,	Released 3.5.78
18.4.77	,, ,,	2.13	♀	,, ,,	Released same day
22.7.77	,, ,,	1.95	♂	,, ,,	In captivity, 1.6.78
9.9.77	,, ,,	–	♂	,, ,,	Released same day
13.9.77	,, ,,	2.17	♀	,, ,,	In captivity 1.6.78

A total of 20 dolphins was reported to have become entangled in shark nets off Natal in 1977. The seasonal and geographical separation of these were as follows:

Month	Number taken: Area A[1]	Area B[2]	Area C[3]	Total
January	0	1[4]	0	1
February	0	0	0	0
March	2	0	0	2
April	0	0	0	0
May	0	0	0	0
June	1	0	0	1
July	0	0	6[4]	6
August	0	1	4[4]	5
September	1	1	2	4
October	0	0	1	1
November	0	0	0	0
December	0	0	0	0
Total	4	3	13	20

[1] Zinkwazi to Durban.
[2] Amanzimtoti to Mtwalume.
[3] Hibberdene to Port Edward.
[4] Of which one released alive.

The pattern of mortality was similar to previous years, the majority of animals being recorded from Area C, though the timing of the peak occurrence of mortalities (July to September) was about one month later than normal.

Four animals from the nets were retained for examination by G. J. B. Ross and all proved to be *Tursiops aduncus*.

PUBLICATIONS

(This refers to publications on Cetacea from all South African institutes).

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SC/30/Prog Rep 9

Soviet Union
Progress Report on Cetacean Research
June 1977 – May 1978

SPECIES AND STOCKS STUDIED

Pelagic whaling was conducted by the USSR in the North Pacific and the Southern Hemisphere. Two fleets operated in each area throughout the 1977 and 1977/78 seasons.

The catches are shown in Table 1. Table 2 gives the Soviet catch of gray whales from 1948–77.

Biological investigations were carried out in both whaling areas: on Bryde's whales and sperm whales in the North Pacific and on sei whales, minke whales and sperm whales in the Southern Hemisphere.

FIELD OBSERVATIONS AND COLLECTIONS

Sightings data continued to be collected for all whale species by catcher boats, including the catcher *Zvezdnyi* which caught gray whales for the needs of the local population off the Chukotsk (Tables 3–5).

Collections of biological material (ear plugs, teeth, ovaries, testis tissue samples, etc.) were made by the whaling fleets in the North Pacific and the Southern Hemisphere. Further accumulation of data regarding population structures was continued.

Table 1

Results of Soviet whaling in 1977 and 1977/78 (Where two figures are given the first is the male catch and the second the female catch.)

	Gray	Sei	Bryde's	Minke	Sperm	Bottlenose	Killer	Total
North Pacific, 1977								
FF *Dalnyi Vostok*	–	–	103/109	–	720/555	–	–	1,487
FF *Vladivostok*	–	–	22/41	–	1,061/930	–	–	2,054
Cb *Zvezdnyi*	86/100	–	–	–	–	–	–	186
Total	186	–	275	–	3,266	–	–	3,727
Southern Hemisphere, 1977/78								
FF *Sovietskaya Ukraina*	–	129/182	–	255/570	1,679/476	–	30	3,321
FF *Sovietskaya Rossiya*	–	–	3/2	452/1,323	1,612/474	3	47	3,916
Total	–	311	5	2,600	4,241	3	77	7,237

FF = Floating factory.
Cb = Catcher boat.

Table 2

Catch of gray whales[1] by the USSR, 1948–77

Season	Catch	Season	Catch
1948	19	1963	179
1949	26	1964	188
1950	10	1965	175
1951	12	1966	194
1952	42	1967	125
1953	37	1968	135
1954	36	1969	139
1955	69	1970	146
1956	121	1971	150
1957	95	1972	181
1958	145	1973	173
1959	187	1974	181
1960	156	1975	171
1961	207	1976	163
1962	147	1977	186

[1] Other whales were taken in certain seasons.

(a) Bowhead whales: 1972–1; 1973–2; 1974–3; 1975–2.
(b) Fin whales: 1969–9; 1972–2; 1973–3; 1974–1; 1975–1.
(c) Humpback whales: 1969–2; 1972–4.

MARKING

During the period of investigation only whales in the Southern Hemisphere were marked (a total of 84 whales). Preliminary marking results are given in Table 6.

During the season, five Discovery marks were found on board Soviet factory ships in the Southern Hemisphere. Apart from these, 12 Soviet marks were found, two of which were from whales marked the day before. Six marks were found in sperm whales (unfortunately, their size and sex were not determined).

One Japanese mark was found in a whale taken in the North Pacific. Details of mark recoveries are given in Table 7.

LABORATORY WORK

Baleen whale ear plugs and sperm whale teeth collected in earlier seasons continued to be examined by research institutes. Testis samples were also analysed.

Table 3

Sightings data from Soviet operations in the North Pacific, 1977

Sector	Blue	Fin	Humpback	Sei	Minke	Bryde's	Sperm	Effort
III N	9	28	–	–	–	–	2	83
II M	–	2	–	–	–	–	721	263
II L	–	–	–	–	–	1	1,071	311
II K	–	–	–	–	–	–	8	12
III N	5	19	10	7	–	–	351	242
III M	–	–	–	4	–	12	231	258
III L	–	–	–	–	–	2	511	72
IV N	11	54	–	17	7	4	664	222
IV M	–	–	–	17	57	38	407	361
IV L	–	–	–	–	–	8	–	24
V N	2	16	–	2	–	7	373	153
V M	1	2	–	7	–	146	307	321
V L	–	–	–	–	–	256	2,222	530
VI M	–	–	–	–	–	79	334	217
VI L	–	–	–	–	–	218	2,294	578
Total	28	121	10	54	64	771	7,545	3,647

Table 4

Sightings data from the catcher *Zvezdnyi* off Chukotsk, 1977

Month	10° square	Gray	Fin	Minke	Distance (miles)	Vessel per day spent	No. of gray whales per one vessel per day	No. of gray whales per 100 miles
June	Q25	81	–	–	682	3	27.0	11.8
July	Q25	399	–	–	5,771	27	14.5	6.9
July	Q26	29	–	–	469	3	10.0	6.1
August	Q25	348	–	2	5,326	28	12.4	6.5
August	Q26	10	1	4	237	1	10.0	4.2
September	Q25	280	1	–	3,507	23	12.2	8.0
September	Q26	109	–	–	534	5	21.8	20.4
October	Q25	310	–	–	3,956	29	10.7	7.8
Total		1,566	2	6	20,482	119	13.2	7.6

DEVELOPMENT OF TECHNIQUES

Investigations on sperm whale age determination were continued by Ju. A. Michalev.

RESEARCH

Investigations related to the population structure of whales and to the revealing of stock boundaries were continued.

Data obtained from minke whales in the Southern Hemisphere and sperm whales in the North Pacific were of great interest.

Investigations conducted by V. M. Mednikov and E. A. Shubina (1977) led them to conclude that the hypothesis that the Cetacea are polyphyletic was invalid.

An analysis of the karyotypes of eleven species of toothed and baleen whales showed them all to be consistent, with a diploid number of 44 (except for the sperm whale where $2n = 42$). The whale karyotype was found to be very similar to that of ungulates. Experiments on the precipitation of albumens in the blood serum served to confirm this conclusion.

Inter-cetacean relationships were examined by the technique of molecular hybridisation. DNA extracted from the testes of a sei whale was marked with tritium and then hybridised with DNA from a fin whale and a sperm whale. The degree of hybridisation is a measure of the propinquity of one genome to the other. The hybridisation of DNA from one sei whale with another was taken as 100%.

The analysis showed that despite the great present day morphological divergence, the Cetacea can be considered monophyletic, branching off from the ungulate line at about the same time as the Carnivora.

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(Names of the authors and the titles of publications are given in English.)

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Table 5

Sightings data from Soviet operations in the Southern Hemisphere, 1977/78 (preliminary data)

Area and Zone	Right	Blue	Fin	Humpback	Sei	Bryde	Minke	Sperm	Effort (CDW)
November									
II H	–	–	–	2	21	–	–	43	36
III H	–	–	–	–	44	–	–	1,496	156
III G	–	–	–	8	11	–	1	169	24
III F	–	1	2	16	48	22	43	2,109	157
III E	–	1	–	–	13	30	54	3,192	160
IV F	–	–	–	–	1	–	1	61	9
IV E	–	–	4	–	8	2	4	1	12
Total	–	2	6	26	146	54	103	7,071	554
December									
III E	–	22	7	39	40	–	8	2,332	204
III D	–	1	–	–	–	–	10	24	24
III A	–	–	–	–	–	–	–	–	24
III B	–	–	63	44	1	–	8,625	494	336
IV D	–	–	–	–	3	2	39	31	36
IV A	–	–	3	2	2	–	51	21	24
IV B	–	–	–	–	–	–	3,714	3	96
Total	–	23	73	85	46	2	12,447	2,905	744
January									
I B	–	21	48	22	55	–	1,711	11	132
II A	–	–	6	–	–	–	114	13	24
II B	3	3	1	7	–	–	3,085	169	168
III B	2	3	21	44	16	–	3,560	700	168
IV B	–	1	23	90	6	–	5,249	560	144
V B	–	–	–	2	1	–	3,598	14	108
Total	5	28	99	165	78	–	17,317	1,467	744
February									
I B	2	3	214	61	474	–	4,189	287	324
V B	–	–	7	22	4	–	1,048	323	144
VI A	–	–	7	–	23	–	3	2	24
VI B	–	6	119	99	10	–	4,869	155	180
Total	2	9	347	182	511	–	10,109	707	672
March									
I B	–	–	92	13	509	–	800	–	96
II E	–	–	–	–	–	–	–	587	84
II D	–	–	2	–	–	–	–	814	168
II A	–	–	6	2	21	–	30	–	24
VI E	–	–	–	–	1	2	3	68	36
VI D	–	–	–	–	25	–	42	1,368	324
VI A	–	–	–	–	1	–	15	13	12
Total	–	–	100	15	557	2	890	2,850	744
April									
II E	–	–	8	–	19	–	–	539	120
III F	–	–	6	–	8	–	–	390	36
III E	2	–	3	–	–	–	–	268	48
V F	–	–	–	–	–	–	–	222	12
VI F	–	–	–	–	–	–	–	1,200	60
VI E	–	–	–	–	–	–	–	420	24
Total	2	–	17	–	27	–	–	3,039	300
Grand total	9	62	642	473	1,365	56	40,866	18,099	3,758

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Table 6

Whale marking by the Soviet fleets 1977/78

	Humpback	Sei	Minke	Sperm	Killer	Total
Northern Hemisphere[1]						
North Atlantic	–	–	–	4	–	4
North Pacific	–	3	–	27	–	30
Southern Hemisphere						
Equator to 40° S	1	–	1	24	4	30
South of 40° S	8	4	35	12	1	60
Total	9	4	36	36	5	90
Total – both Hemispheres	9	7	36	67	5	124

[1] By non-catcher boat.

Table 7

Marks recovered by Soviet factory ships in the 1977/78 Antarctic season and 1977 North Pacific season

Mark No.	Species	Sex	Body length at recovery (m)	Date recovered	Position marked	Position recovered
			Southern Hemisphere			
Discovery marks						
19041	Sperm	–	Meat[1]	11.12.77	–	31° 32′ S, 42° 48′ E
19042						
23954	Sperm	–	Meat[2]	11.12.77	–	32° 07′ S, 42° 59′ E
26575	Sperm	F	10.6	11.12.77	–	31° 21′ S, 42° 28′ E
31311	Sperm	F	10.7	12. 3.78	–	39° 02′ S, 162° 40′ W
			North Pacific			
J7389	Sperm	M	11.4	28. 9.77	–	27° 29′ N, 150° 11′ E

[1] M 13.5, F 10.1, F 10.7, F 11.0 m.
[2] M 13.3, M 13.5, F 10.6, F 10.6 m.

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SC/30/Prog Rep 10

United Kingdom Progress Report on Cetacean Research June 1977 – May 1978

(This refers to work at the Sea Mammal Research Unit of the Natural Environment Research Council)

SPECIES AND STOCKS STUDIED

Studies are continuing of fin, sei and sperm whales in the Southern Hemisphere and in Icelandic waters, where the occurrence of blue and humpback whales is also being examined. The occurrence of some cetaceans in British waters is being studied.

FIELD OBSERVATIONS AND COLLECTIONS

With the co-operation of the Icelandic whaling company, Hvalur H F and the Marine Research Institute, Reykjavik, a biologist made observations and collections from fin, sei and sperm whales at the Icelandic Whaling Station in 1977.

Records of sightings of protected blue and humpback whales on the whaling grounds were collected by the whaling company as in previous seasons. An analysis of the records is shown in the Appendix. Sightings of cetaceans from British weather ships are also being reported. Reports of the activities of the wild but sociable adult male *Tursiops truncatus* on the Cornish coast continue to be received. A brief visit to Ayr, Scotland confirmed the temporary presence there of a second animal of this species which exhibited similar behaviour to the Cornish animal.

WHALE MARKING

The possibility of producing a suitable modified design for the experimental visible streamer mark is being examined. A report on Antarctic whale marking carried out by Japanese expeditions as part of the international marking scheme during the six whaling seasons 1971/72 to 1976/77 has been prepared.

LABORATORY WORK

The study of Japanese collections of fin and sei whale ear plugs, begun at the Far Seas Fisheries Research Laboratory, Shimizu, in April–June 1977, is continuing at Cambridge. All the pre-1977 collections of ear plugs, etc., from Iceland have now been examined and work is in progress on the 1977 collections.

DEVELOPMENT OF TECHNIQUES

Teeth from a specimen of *Lagenorhynchus albirostris* have been decalcified, sectioned and stained for studies of age determination.

RESEARCH

Studies of the decline in age at sexual maturity of fin and sei whales, correlated with changes in population size are continuing.

The results of several seasons' work on the biology of fin and sei whales taken at the whaling station in Iceland are being written up for publication. Records of blue and humpback whales sighted on the Icelandic whaling grounds are being reanalysed to provide further information on the status of the stocks.

Theoretical studies of growth and energy budgets of sperm and sei whales are continuing. A new programme of collections of tissue and food samples for biochemical and energetics analyses, from fin and sei whales taken in Icelandic waters, is planned for the 1978 whaling season. Papers have been prepared for the special Scientific Committee meeting on minke whales, on weight, the biomass of catches, and the effects of possible size limitation of catches, in this species, and on the results of marking in the Southern Hemisphere. Whale marking techniques for large whales have been reviewed, and an account of a specimen of *Mesoplodon hectori* from the Falkland Islands is in preparation.

SEA MAMMAL RESEARCH UNIT

On 1 December 1977 the Whale Research Unit was amalgamated with the Seals Research Division of the Institute for Marine Environmental Research, which is also housed in the British Antarctic Survey building at Cambridge, to form a new Sea Mammal Research Unit. The new unit is a separate organisation from the British Antarctic Survey but, like the Survey, is under the direction of Dr R. M. Laws. The officer-in-charge of the Unit is Dr C. F. Summers (formerly in charge of the Seals Research Division) and the present complement of thirteen includes ten scientific staff.

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Appendix

BLUE AND HUMPBACK WHALE SIGHTINGS ON THE ICELANDIC WHALING GROUNDS 1977

As in previous whaling seasons, the four whale catchers operating from the whaling station of Hvalur H F kept a record of all blue and humpback whales sighted during the whaling season on the whaling grounds. For each day of the season, the following information was recorded for each catcher: Noon position (by statistical square), visibility and wind direction and force at noon, position of any sighting, and number of whales seen. For the present preliminary analysis, as in previous years, weather conditions have been ignored and all days have been included as days on which sightings could have been made, except for days spent sheltering inshore in very bad weather, and days in port in Reykjavik.

The results for the 1977 season, together with those of the 1976 season for comparison, are:

Season	Total days	Number of sightings	Sightings/ day	Number of whales	Whales/ day
		Blue Whales			
1976	422	134	0.32	288	0.68
1977	391	174	0.45	628	1.61
		Humpback Whales			
1976	422	41	0.10	67	0.16
1977	391	81	0.21	231	0.59

The number of sightings, and numbers of whales seen, for both blue and humpback whales are considerably higher in the 1977 season than in 1976 in spite of the shorter season. The figures for blue whales in 1977 are the largest recorded since the sightings scheme started in 1969. The number of humpback whale sightings and numbers of whales seen in 1977 are not so large as in some earlier seasons, but are much larger than in 1976. It should be remembered that that the records refer to a relatively restricted area and that no corrections have been made for possible repeated sightings of the same animal.

SC/30/Prog Rep 11

United States
Progress Report on Cetacean Research
June 1977 – May 1978

This report summarises cetacean research conducted by the Marine Mammal Division of the Northwest and Alaska Fisheries Center, Seattle, except for studies on bowhead whales which are covered in separate reports.

Research supported by the US Marine Mammal Commission is summarised in the Appendix.

Studies on dolphins in relation to the tuna fishery, conducted by the Southwest Fisheries Center, La Jolla, are reported separately.

SPECIES AND STOCKS STUDIED

During the past year observations were made on the following species and stocks:

(a) Humpback whale (*Megaptera novaeangliae*): Hawaiian and Mexican stocks.
(b) Bryde's whale (*Balaenoptera edeni*): eastern North Pacific stock.
(c) Blue whale (*Balaenoptera musculus*): eastern North Pacific stock.
(d) Gray whale (*Eschrichtius robustus*): California stock.
(e) Bowhead whale (*Balaena mysticetus*): Bering/Chukchi/Beaufort Sea stock.
(f) Killer whale (*Orcinus orca*): inside waters of Washington State.

FIELD OBSERVATIONS AND COLLECTIONS

An improved version of the radio-tag developed by Ocean Applied Research of San Diego was field-tested on humpback whales in southeastern Alaska from 21–30 July 1977. Flukes of humpback whales were photographed for individual identification.

The third annual census of humpback whales was conducted around all the main Hawaiian Islands from 8–19 February 1978.

Studies on whales were conducted off the Mexican states of Baja California, Sinaloa, Jalisco and Nayarit from 6 March–4 April 1978. Census tracks were run, flukes of humpback whales were photographed for individual identification, phonations of humpbacks were recorded, and biopsy darts for cytological sexing were field-tested.

An experimental census of southward migrating gray whales was made at Cape Sarichef, Unimak Island, Alaska from 20 November–9 December 1977.

The regular annual censuses of the southward migrating gray whales were made in California at Granite Canyon, Monterey County and at Point Loma, San Diego County from 10 December 1977–5 February 1978.

Studies on the resident population of killer whales in the inside waters of Washington and adjacent parts of British Columbia were resumed from 23 July–31 December 1977, to monitor recruitment and losses since the 1976 study.

MARKING

Five radio-tags were implanted in humpback whales in southeastern Alaska. One tag malfunctioned; the other four were tracked for periods of up to five days.

No whales were marked with Discovery marks, and no recoveries of whales previously marked by the United States were reported.

LABORATORY WORK

A file of identification photographs of the flukes of North Pacific humpback whales is being compiled at the Marine Mammal Division in Seattle. This file provides a central repository for such photographic data, and is open to all contributing researchers to facilitate studies on humpback whale migrations, population dynamics and behaviour.

Teeth of killer whales were sectioned and the growth layers counted for a study of age, growth and sexual dimorphism.

A workshop on the status of the Dall porpoise (*Phocoenoides dallii*) was held on 9 and 10 January 1978 in Seattle. Scientists from Japan and the United States attempted to estimate current sizes of the porpoise populations that are incidentally exploited by the Japanese salmon gill-net fishery in the North Pacific, to determine if current stock sizes are above levels of maximum productivity and to determine the magnitude of the incidental catch and its effect on the population.

RESULTS

The 1978 census of humpback whales wintering in Hawaii resulted in a count of 321 along the established census track (compared with 373 in 1976 and 411 in 1977). Three additional census tracks were run across Penguin Bank, the most important area, to provide a more reliable estimate of the whale population there. A supplementary census track was run in the Auau Channel west of Molokai, the second most important area, to provide more complete coverage of that region. The total population of humpbacks wintering in the Hawaiian Islands is estimated at about 500, distributed around all the main islands within the 183 m isobath.

The 1978 survey of humpback whales wintering off the west coast of Mexico revealed that the whales were generally distributed in four areas: (1) over the continental shelf along the coast of Sinaloa, Nayarit, and Jalisco, from about Mazatlan south to Cabo Corrientes; (2) around the Islas Tres Marias; (3) on the Gorda Banks and adjacent areas from Cabo Falso to Los Frailes, Baja California del Sur; and (4) around Isla Socorro. This distribution was similar to that observed during cruises from 1965 to 1967, except that Isla Clarion, another known winter ground, was not surveyed in 1978. The census transect data have not yet been analysed, but the total population appears to be only a few hundred – less than the Hawaii stock.

Additional data on the distribution and numbers of the coastal stock of Bryde's whales were also obtained during the cruise off western Mexico.

Several blue whales were seen moving southward in March along the east coast of Baja California, just north of Cabo San Lucas. These additional observations corroborate the hypothesis that some of the eastern North Pacific blue whales enter the southern Gulf of California in the spring before continuing northward up the west coast of the Baja California peninsula.

The results of the gray whale censuses are presented in a separate report.

The four resident pods of killer whales that range in the inside waters of Washington State contained about 72 individuals in 1976. In the summer of 1977 five calves were found to have been born in the interim and one adult male (found dead) was the only known loss.

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Appendix

SUMMARY AND ABSTRACTS OF CETACEAN RESEARCH AND STUDY PROJECTS SUPPORTED BY THE MARINE MAMMAL COMMISSION June 1977–June 1978

Cetacea (General)

Comparative Population Dynamics: Search for Management Criteria
(C. W. Fowler, Utah State University)

Workshop on Marine Mammal Strandings
(J. R. Geraci and J. H. Prescott, New England Aquarium)

Marine Mammals at the Farallon Islands
(D. G. Ainley and H. R. Huber, Point Reyes Bird Observatory)

Status of Cetaceans in Hawaiian Waters
(E. W. Shallenberger, Manta Corporation, Hawaii)

Inventory of Whaling Logbooks
(S. C. Sherman, Brown University)

Management Implications of the Mathematical Demography of Long-Lived Animals
(D. Goodman, Scripps Institution of Oceanography)

Whales

Photo-Identification of Humpback Whales
(S. K. Katona and S. Kraus, College of the Atlantic)

Workshop on Humpback Whales in Hawaii
(E. W. Shallenberger, Sea Life Park, Hawaii)

Comparative Aerial-Shipboard Surveys of Humpback Whales on Silver and Navidad Banks, West Indies
(H. E. Winn, University of Rhode Island)

Interaction between Gray Whales and Boat Traffic in San Ignacio Lagoon, Baja California
(C. W. Fowler, Utah State University)

Analysis of Data on Bowhead Whales
(J. Breiwick, University of Washington)

Re-Analysis of Data on North Pacific Sperm Whales
(C. W. Fowler, Utah State University)

Comparative Aerial-Ground Survey of Gray Whales in San Ignacio Lagoon, Baja California
(B. Mate, Oregon State University)

Small Cetaceans

Dentinal Aging of *Tursiops*
(C. A. Hui, Naval Ocean Systems Center, San Diego, California)

Aerial Survey of *Tursiops* Off-Shore Texas
(J. S. Leatherwood, Naval Ocean Systems Center, San Diego, California)

Review of Literature on the North American Harbor Porpoise
(J. H. Prescott, New England Aquarium)

Tuna-Porpoise

Passive Behavior of *Stenella* spp. in Purse Seines
(K. Norris and W. E. Stuntz, University of California, Santa Cruz)

Comparative Population Dynamics: Search for Management Criteria

(C. W. Fowler, Utah State University)

The intent of the Marine Mammal Protection Act is to obtain and maintain optimum sustainable populations of marine mammals. To achieve this goal, we must have reliable population models as a basis for management decisions. Dr Fowler is assessing selected population data and management models to determine how existing management practices might be modified to better achieve the management objectives set forth in the MMPA. The study is to be completed in late summer 1978.

Workshop on Marine Mammal Strandings

(J. R. Geraci and J. H. Prescott, New England Aquarium)

Stranded marine mammals are important sources of information on the distribution, movements and life histories of marine mammals. Unfortunately, this data source has not been used to the fullest extent possible, primarily because methods for collecting, recording and storing data have not been systematised. The purposes of this workshop, convened in August 1977, were to: (1) review data and theories concerning mass strandings; (2) identify how data from stranded marine mammals can be used to monitor the status of marine mammal populations and their habitats; (3) develop standard techniques for collecting, analysing, and recording data from marine mammal strandings; and (4) develop a plan for a nationwide marine mammal stranding network. The workshop report has been completed and will be published by the National Technical Information Service.

Marine Mammals of the Farallon Islands

(D. G. Ainley and H. R. Huber, Point Reyes Bird Observatory)

Observations of pinnipeds and cetaceans on or near the Farallon Islands have been conducted since 1970, the last four years under contract from the Marine Mammal Commission. The purpose of this study is to detect and describe year to year variation in the kinds and numbers of marine mammals found on or near the islands. From 1 September 1976 to 31 August 1977, five species of pinnipeds and six species of cetaceans were observed. Reports on the studies carried out from 1970 through 1977 are available from the National Technical Information Service (see the Commission's Annual Report for 1977).

Status of Cetaceans in Hawaiian Waters

(E. W. Shallenberger, Manta Corporation, Hawaii)

Available information on the distribution, abundance and productivity of cetaceans in waters off-shore Hawaii has never been summarised. Therefore, the investigator is compiling and summarising data from published and unpublished sources. This information will enable the Commission to determine what, if any, additional research might be needed to protect these populations from the adverse effects of human activities. The investigator is also preparing a cetacean field guide and developing a plan for a whale sighting network in Hawaii.

Inventory of Whaling Logbooks

(S. C. Sherman, Brown University)

Management decisions concerning cetaceans must be based, in part, on a comparison of present and historical abundance. Whaling logbooks and journals contain information that can be used to estimate pre-exploitation abundance. However, the logbooks and journals are scattered throughout numerous libraries and private collections. This study will provide an indexed, annotated list of available whaling logbooks and journals and a computerised system for updating and supplementing the list so that the logbook information will be more accessible to researchers.

Management Implications of the Mathematical Demography of Long-Lived Animals

(D. Goodman, Scripps Institution of Oceanography)

Analysis of the life history strategies of long-lived mammals may provide insight into the ways in which marine mammal populations will respond to harvesting and/or environmental perturbations. This contractor is compiling, summarising and analysing literature on mathematical demography and the evolution of life history strategies. The work will be completed in 1978.

Photo-Identification of Humpback Whales

(S. K. Katona and S. Kraus, College of the Atlantic)

Certain kinds of marine mammal studies require the ability to recognise individual animals. This investigator is compiling and analysing photographs of humpback whales to determine whether natural marks can be used to identify individual whales. Such photographic identification would not require taking and, in some studies, would provide a less costly alternative to tagging. The report is expected to be available in 1978.

Workshop on Humpback Whales in Hawaii

(E. W. Shallenberger, Sea Life Park, Hawaii)

In 1976 and 1977, the Commission received a number of reports that human activities (e.g., whale-watching and pleasure boating) possibly were having an adverse effect on humpback whales that assemble off the main Hawaiian Islands in winter to calve and breed. To better identify the nature and the magnitude of possible effects, a workshop was held in Honolulu, Hawaii in July 1977. Participants evaluated available information on human-whale interactions and concluded that more effective regulation of boat and aircraft operations was needed. The workshop report served as a basis for Commission recommendations to the National Marine Fisheries Service.

Comparative Aerial–Shipboard Surveys of Humpback Whales in Silver and Navidad Banks, West Indies
(H. Winn, University of Rhode Island)

Aerial surveys are useful for providing information on the distribution and density of whales. However, because of their high speed, aircraft can easily overfly areas while whales are submerged. To estimate the numbers of humpback whales that winter in the West Indies, and to compare the relative utility of shipboard vs. aerial surveys, the contractor and his colleagues carried out coordinated aerial–shipboard surveys during late February and early March 1978. The report, which is scheduled to be completed in early 1979, should contribute to developing better survey methods for all species of cetaceans.

Interaction between Gray Whales and Boat Traffic in San Ignacio Lagoon, Baja California
(S. L. Swartz, San Diego Society of Natural History)

The increased popularity of whale-watching in the lagoons of Baja California may be adversely affecting the gray whales that calve and breed there during the winter months. The purpose of this study, initiated in late January 1977, is to determine how tour boats may be affecting the distribution, movements and behaviour of the gray whales in San Ignacio Lagoon. The report of the first year's study is available from the National Technical Information Service.

The report of the second year's study will be available from NTIS in late 1978.

Analysis of Data on Bowhead Whales
(J. Breiwick, University of Washington)

Bowhead whale populations throughout the world were severely depleted by commercial exploitation. Although commercial exploitation ended in the early 1900s, the populations have not recovered and there is concern that increasing levels of native subsistence hunting may be adversely affecting the population in the western Arctic. The objective of this study is to evaluate all available information and provide the best possible assessment of the current status of the population and the risks associated with various levels of native subsistence hunting. The report is to be completed for consideration at the June 1978 meeting of the International Whaling Commission.

Re-Analysis of Data on North Pacific Sperm Whales
(C. W. Fowler, Utah State University)

There is concern about the reliability of data and models that have been used to estimate the maximum allowable catch of sperm whales in the North Pacific. This investigator is re-analysing available data and models to identify possible sources of error and bias. The results of the study will be presented at the June 1978 meeting of the International Whaling Commission.

Comparative Aerial-Ground Survey of Gray Whales in San Ignacio Lagoon, Baja California
(B. Mate, Oregon State University)

The Commission is supporting a study to assess the effects of boat traffic on gray whales that calve and breed in San Ignacio Lagoon (S. L. Swartz, San Diego Society of Natural History). Mr Swartz conducted ground counts of the whales inhabiting the lagoon and Dr Mate conducted an aerial survey to determine how aerial counts compare with ground counts. The report of the survey is to be completed in 1978 and will be published by the National Technical Information Service.

Dentinal Aging of *Tursiops*
(C. A. Hui, Naval Ocean Systems Center, San Diego, California)

The numbers of dentinal layers in the teeth of bottlenose dolphins vary with age and with tooth position in the jaw. The purpose of this study was to determine which teeth have the highest probability of providing a true index to age. Results suggest that each dentinal layer represents one year's growth and, since posterior teeth continue to grow and accumulate dentin after anterior teeth cease growing, teeth in the posterior part of the jaw provide the truest indicator of actual age. The report is scheduled to be completed and published by the National Technical Information Service in late 1978.

Aerial Survey of *Tursiops* Off-Shore Texas
(J. S. Leatherwood, Naval Ocean Systems Center, San Diego, California)

Under the terms of the Marine Mammal Protection Act, permits are required to take marine mammals for purposes of public display or scientific research. Before issuing permits, the issuing agencies, in consultation with the Marine Mammal Commission, must make a determination that the proposed taking will not be to the disadvantage of marine mammal populations or the ecosystems of which they are a part. There is concern that live-capture fisheries may have adversely affected certain local populations of bottlenose dolphins and this survey was carried out from 26 March to 1 April 1978 to determine the numbers of bottlenose dolphins inhabiting the inter-coastal waterway and inland bays of Texas from the northern end of Corpus Cristi Bay to the northern end of Mategordo Bay. Preliminary results of the survey indicate that 1,164 plus or minus 224 animals were present in the survey area and it has been decided that up to 17 animals (about 2% of the minimal population estimate) could be removed from this population annually without adverse effects. The survey report will be concluded and published in 1978.

Review of Literature on the North American Harbor Porpoise

(J. H. Prescott, New England Aquarium)

The harbor porpoise, *Phocoena phocoena,* is a coastal species which may be vulnerable to environmental pollution and human-caused mortality. There are reports of high incidental mortality relative to some fisheries (most notably the salmon gillnet fishery off Greenland where an estimated 1,500 porpoise are killed annually). In addition, the harbor porpoise is the most frequent single stranded cetacean. At present, information on the species is fragmentary and there has been no determination as to the research/management actions needed to ensure that the species is not adversely affected by human activities. This study will assess the available information and determine what actions and/or data are necessary for conservation of the species and its habitats.

Passive Behavior of *Stenella* spp. in Purse Seines

(K. Norris and W. E. Stuntz, University of California, Santa Cruz)

In 1976, the investigators confirmed that spotted porpoise sometimes lie passively at the bottom of tuna purse seines. Standard back-down procedures are ineffective for removing these animals from the net and they may be killed during sacking-up operations. This behavior may be maladaptive and in 1977, Dr Stuntz initiated studies to determine whether 'passive' behavior is caused by psychological and/or physiological stress. Preliminary studies were inconclusive and more detailed studies have been initiated by the National Marine Fisheries Service.

SC/30/Doc 1

Towards an Improved Whale Management Procedure

K. Radway Allen

Division of Fisheries and Oceanography, CSIRO, Cronulla, Australia

The "New Management Procedure" introduced in 1974–75 was a great advance on the previous situation, in that it firmly established the objective of bringing all whale stocks to an optimum level as far as this could be determined. It also laid down precise procedures for achieving this, which were to be based on the Scientific Committee's quantitative assessment of the condition of each stock. It thus removed the major management decisions to be made by the Commission from the arena of political argument.

WEAKNESSES OF THE PRESENT SCHEME

Experience has, however, shown that the procedure has a number of serious shortcomings. These adversely affect the effective conservation of the stocks, the efficient development and operation of the industry, and the development of rational scientific advice by the Scientific Committee.

Among these weaknesses are:

(a) Lack of any generally acceptable definition of optimum stock level which can be used as a target in development of a quantitative management strategy. The great diversity of possible objectives relating to the consumptive and non-consumptive use of the resource make it very unlikely that any general consensus will be achieved in the near future. The objectives of consumptive uses alone are still far from being fully reconciled.

(b) Lack of sound evidence as to the relation of Maximum Sustainable Yield (MSY) levels to unexploited population levels. A value for this is required when MSY level is used as an interim substitute for optimum level, as the current procedure provides. The relative MSY levels used by the Scientific Committee were based originally on the employment of the Schaefer model as a convenient basis for studying whale populations. This incorporates a 50% MSY level. The more recent value or 60% has been adopted simply as a more conservative measure, and not on any improved evidence. Only for male sperm whales is the MSYL based on a detailed population model incorporating observed parameters as far as possible. Even in this model the density-dependence of individual parameters is assumed to follow a 60% MSYL model, although the actual MSY level for the male population is considerably lower.

(c) The requirement on the Scientific Committee to produce, as a basis for management, estimates of stock sizes and yields with a precision which greatly exceeds any level of accuracy likely to be achieved in the near future.

(d) The frequency with which assessments may change as a result of modifications to models, or changes in estimates of biological and other parameters. These changes in assessments arise from changes in the structure of models, adoption of new parameter values based on additional data, and, generally to a lesser extent, availability of an up-dated time series on apparent population abundance. They do not reflect real changes in stock size, but only a revision by the Scientific Committee of the best estimate it can make on the evidence available to it.

(e) The large and abrupt changes in permitted catches which may follow from relatively small changes in assessments.

(f) The very heavy load which is thrown on the limited resources of the Scientific Committee by the need to carry out a thorough assessment of every stock every year.

(g) The strategy of bringing all stocks to the vicinity of the MSY level as quickly as possible, and then holding them at that level, minimises the opportunity of studying the way in which the biological characters of populations change as their size varies. Without this information it becomes almost impossible to observe the true density-dependence of the parameters, and obtain a sound basis for determining optimum population levels.

(h) No provision is made for adjusting the permitted catches for individual stocks according to the degree of reliability of the assessments.

AN ALTERNATIVE STRATEGY

A strategy which would overcome many of these difficulties, while at the same time retaining the basic objectives, might be developed on the following lines:

A. Retain the concept of optimum population level as an ultimate target (or MSYL as an interim measure), but change the strategy by which this is approached, so that all stocks should be permitted to increase, unless there is specific evidence that further increase would not add to the yield (or benefit) obtained from them. Catches which reduced population levels would only be permitted if there was reliable evidence that this would increase the yield (or benefit).

B. Retain the principle that stocks below a defined critical level should be protected from all exploitation: this level to be set high enough to render the risk of descent to extinction in the foreseeable future highly unlikely.

C. In determining whether stocks should be protected or exploited, and, in the latter case, the rate of increase to be aimed at, use the population prior to modern whaling as the reference level, and not the MSY level as at present. The former can be estimated with much greater certainty because it is less dependent on assumptions as to the nature of density-dependence. The proposed principle of allowing stocks to increase avoids the need to define a target level with exactitude.

D. In fixing quotas, use as a reference level the current replacement yield, instead of the MSY. This can be determined more directly and with greater reliability than the MSY, since it does not involve extrapolation on a model. At least two fairly direct methods of estimating it are available. It is also a measure of the existing capacity of the population to increase.
E. In determining the quota from the replacement yield take account both of the rate at which we wish the population to increase and of the degree of reliability of the estimate of replacement yield. The quota should therefore be calculated in two stages. First, by adjusting the proportion of the replacement yield which may be taken according to the population level relative to the pre-exploitation level. The lower the population level the greater should be the rate of increase, and therefore the smaller the proportion of the replacement yield which should be taken. Secondly, the quota calculated in this way should be further reduced by a factor dependent on the possible errors of sustainable yield: the smaller the error the less the reduction in the proportion which may be taken.
F. Quotas to be fixed for a term of years, and only changed during this period if the Scientific Committee finds positive evidence that a decrease in stock size is taking place, or important new data become available.
G. Each stock to be thoroughly re-assessed by the Scientific Committee at regular intervals. These reviews should be on a rotating basis so as to even out the work-load.
H. Stocks which have been previously unexploited must decrease if any exploitation is allowed. For such stocks quotas would initially be calculated as a fixed proportion of original stock size, subject to an error factor. The condition of these stocks would then be reviewed on the regular cycle, and they would be transferred to the standard scheme when this became appropriate.

OPERATING DETAILS

The length of the standard period between reviews would have to be a compromise between the natural desire of the Commissioners and other interested groups to be fully satisfied at frequent intervals as to how the stock is progressing, and the need for a long enough period to provide significant evidence of any changes: probably about five years is the maximum acceptable on the first count, and the minimum which has any chance of producing any valid new data.

To reap the full advantage from a scheme in which all important stocks were reviewed at regular intervals, it would be necessary to arrange that they were reviewed in rotation, with only a few being examined each year. Such an arrangement would greatly improve the efficiency of the Scientific Committee's operations. Its establishment would require an initial decision as to the order in which the stocks were to be examined, and longer or shorter times for the individual stocks on the first round.

The proportion of the replacement yield which could be taken should be varied on a sliding or stepped scale between zero at a lower population level, below which stocks would be fully protected, and a maximum value reached at a population level somewhere in the vicinity of the optimum. To provide smoother operation and avoid the present abrupt changes, the range between these two population levels should be wide, extending from below the present Protection Stock level to above the probable MSY level.

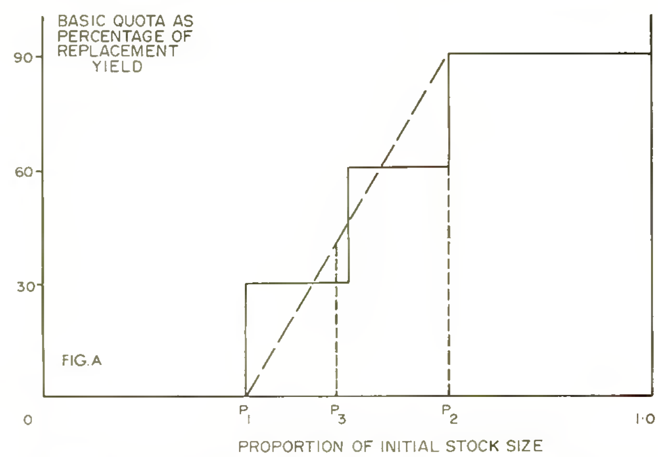
Since the RY will change from year to year, the value used as a basis for calculating the fixed quota for the term of years should be the estimated mean RY for the period.

The probable errors of estimate of current or initial stock sizes and of replacement yields are even more difficult to determine than the stocks or yields themselves. To avoid giving a spurious air of accuracy to the results, and possibly involving the Scientific Committee in meaningless calculations, it would be desirable that the adjustment of quotas for the reliability of estimate should be on a very coarse stepped scale. For example, the reliability could be expressed as "good", "medium", or "poor", with three corresponding adjustment factors.

A HYPOTHETICAL EXAMPLE

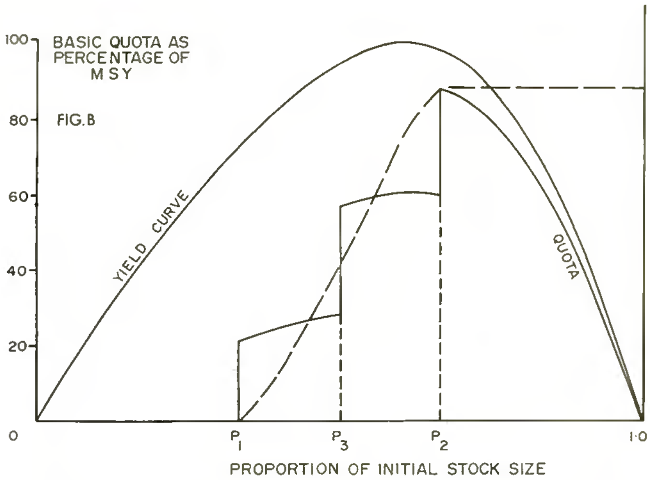
This section describes a hypothetical scheme using the principles outlined above. The numerical values are intended only to illustrate the way in which the calculations would be made, and are not being advocated as appropriate for use in an actual scheme.

The first step in the classification of a stock and the calculation of a quota would be carried out by determination of the appropriate adjustment for stock size by means of a scheme such as Figure A. In this figure, the horizontal axis is the current stock size relative to the original unexploited level, and the vertical axis is the proportion of the current replacement yield which may be taken under the basic quota. Thus, a stock at relative level below P1 would be a Protection Stock, one above P2 would have a basic quota of 90% of current replacement yield, and one at an intermediate level would have a percentage of replacement yield determined, for example, by either a sliding scale (broken line), or stepped scale (solid line).



Note that the vertical axis is the percentage of the yield which may be taken, and not the quota itself. Applying such a scheme to a hypothetical yield curve, and ignoring the difference between replacement and sustainable yields, produces a relation between stock size and quota such as that shown in Figure B, in which the vertical axis is the actual basic quota as a percentage of RY.

At a level somewhat above P2 the fact that an increase in population was not bringing about a further increase in yield would be detected, and the population would be stabilised by setting the basic quota equal to the replacement yield. Theoretically this would occur at the MSY or other optimum level, but since, under this scheme, stabilisation would depend on detection of a balance, the exact point at which stabilisation would be attempted cannot be pre-determined.



Only if there was clear evidence that the long-term replacement yield would be increased by reducing the population level would the basic quota be greater than the current replacement yield.

One advantage of the step procedure which may be noted is that the proportion of the replacement yield which could be taken under the basic quota would be independent of the ratio of current population size to original size over quite wide ranges. Thus the Scientific Committee would only have to determine in which of several ranges the relative population size lay. This would often remove the requirement on it to determine relative population size with an unrealistic degree of precision.

The basic quota has now to be adjusted for the probable level of accuracy of the estimated replacement yield. For purposes of illustration, the adjustment factors are taken as:

good accuracy	0.8
medium accuracy	0.6
poor accuracy	0.4

Definition of these levels of accuracy is not attempted here and will clearly require much consideration.

This hypothetical management procedure has been applied to a set of hypothetical stocks, and the results are given in Table 1.

ADVANTAGES OF THE NEW PROPOSAL

It is believed that the procedure outlined in this paper could have a number of advantages over the present system. Some of these can be summarised as follows:

For the conservation and protection of whale stocks

It firmly embodies the principle of permitting stocks to increase unless they are demonstrably above the optimum level, while reducing dependence on predetermined optimum levels which are difficult to define.

It does not establish the much-criticised MSY level as even a temporary pre-determined target.

It specifically reduces quotas to allow for uncertainty in the estimates of stocks and yields.

It would substantially reduce the level of uncertainty in the estimated quantities used in calculating quotas.

For the more efficient development and operation of the industry

The system of reviewing stocks at regular intervals would provide better continuity and allow forward planning.

For improvement of scientific advice, and more effective working of the Scientific Committee

Spacing out of the major reviews of important stocks on a rotational system would allow more time for these studies to be properly carried out: it would also facilitate arrangements for the accumulation of essential data.

The requirement on the Scientific Committee to express its assessments with an unrealistic degree of precision in order to calculate quotas would be reduced.

Calculation of quotas would be more dependent on estimates of current stock levels and yields, and less on extrapolation on models which are not fully based on observable data.

Table 1

Initial stock size	Current stock size	Replacement yield	Reliability of estimate	Stock category**	Stock size factor	Basic quota	Reliability factor	Final quota	Step (G) or sliding (S)
10,000	5,000	250	G	M	0.6	150	0.8	120	G
10,000	5,000	250	M	M	0.45	112	0.6	67	S
7,000	5,000	250	P	M	0.9	225	0.4	90	G/S
15,000	4,000	250	G	P	–	0	–	0	G/S
15,000	10,000	250	M	M	0.9	225	0.6	135	G/S
10,000	4,000	200	P	M	0.3	60	0.4	24	G
10,000	4,000	200	M	M	0.2	40	0.6	24	S
10,000	4,800	240	M	M	0.3	72	0.6	43	G
10,000	4,800	240	M	M	0.4	96	0.6	58	S

** Only two categories – Protected (P) and Managed (M) – are suggested here.

SC/30/Doc 2

International Co-operation in Antarctic Whale Marking 1971 to 1977

S. G. Brown

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Whale marking continues to be carried out in the Antarctic by Japanese whaling expeditions as part of the scheme for international co-operation in whale marking. The present report covers marking during the six Antarctic whaling seasons 1971/72 to 1976/77. For marking in earlier seasons see references in Brown (1974).

The marking results from the very generous co-operation and support of a number of Japanese whaling companies, and with the aid of contributions from the International Whaling Commission and the co-operation of the Far Seas Fisheries Research Laboratory in Japan. Thanks are due to the whaling companies, to the gunners, masters and catcher crews, and to those who have kept the marking records.

Details of the marking accomplished during the six seasons are given in Table 1. This does not contain any details of Antarctic marking by USSR expeditions which have continued with their separate scheme. It should be noted that for classifying sei and minke whale stocks, and determining catch limits, the northern boundary of the six whaling Areas was changed in 1975 from 40° south latitude, to the equator (*Rep. int. Whal. Commn* 27, p. 7). The area boundary for fin whale stocks was similarly revised later. In 1975 also, the Southern Hemisphere sperm whale stocks were classified in nine Divisions extending between the ice-edge and the equator. In Tables 1 and 2 the northern boundaries of the six Areas have been revised accordingly and the numbers of whales marked within the Areas are therefore not comparable with those tabulated in the previous reports on the international marking scheme.

574 whales are estimated to have been effectively marked in the six seasons. They include 7 blue, 88 fin, 12 humpback, 125 sei, 57 minke, 7 southern right and 278 sperm whales. Three Bryde's whales were also marked. The largest numbers of whales have been marked in Areas III, IV and V. Very few whales were marked in Areas I, II and VI. Marking continues to be concentrated on fin, sei and sperm whales. With the increasing importance of minke whales in the Antarctic catches, an attempt has been made in the last two seasons to mark this species also.

Table 2 includes the total numbers of all species estimated to have been effectively marked by international co-operation in Antarctic marking in the international scheme, and in earlier marking during the thirty-two seasons from 1945/46 to 1976/77 inclusive, 3,642 whales have been marked. The largest number is in Area III (1,234 animals) and Areas III, IV and V together account for 77% of the total number marked within the six Areas. Fin whales account for 48% of the total number of all species marked, and humpback and sperm whales for a further 16% each of the total. Smaller numbers of blue and sei whales have been marked and negligible numbers of minke, southern right whales and the remaining species.

Considering the numbers of the different species which have been marked in relation to the continuation of Antarctic whale marking in the immediate future, it is obviously important to mark more minke whales in order to increase the numbers from which recoveries can be made. Evidence from returned marks of the movement of this species in the Antarctic zone is needed, together with returns accompanied by biological material for checks on age determination studies. Although the number of sei whales marked is small, the reduction of catches of this

Table 2

The total numbers of all species estimated to have been effectively marked in the Antarctic in the international marking scheme, seasons 1945/46 to 1976/77 inclusive

Species	Whaling Areas I	II	III	IV	V	VI	All Areas
Blue	64	25	109*	25	43	10	276
Fin	124	274	826	240	195	90	1,749
Humpback	40	13	45	113	335	27	573
Sei	4	62	64	133	77	17	357
Bryde's	–	–	2	–	1	–	3
Minke	1	3	41	8	4	8	65
Right	–	3	1	20	–	1	25
Sperm	6	30	146	205	175	23	585
Killer	–	1	–	–	–	–	1
Pilot	–	–	–	–	–	4	4
Beaked whales	–	–	–	2	–	2	4
All species	239	411	1,234	746	830	182	3,642

* Includes 3 pigmy blue whales.

Table 1

International cooperation in Antarctic whale marking. Whales estimated to have been effectively marked in the Southern Hemisphere whaling areas from 1971/72 to 1976/77.

Seasons	Species	Whaling Areas I	II	III	IV	V	VI	All Areas	All Species
1971/72	Blue	–	–	–	–	–	–	–	84
	Fin	–	–	1	3	–	–	4	
	Humpback	–	–	–	2	–	–	2	
	Sei	–	–	3	18	1	–	22	
	Minke	–	–	–	–	–	–	–	
	Right	–	–	–	5	–	–	5	
	Sperm	–	–	27	24	–	–	51	
1972/73	Blue	–	–	–	–	–	–	–	129
	Fin	–	–	1	–	2	3	6	
	Humpback	–	–	–	–	2	2	4	
	Sei	–	–	9	8	10	4	31	
	Minke	–	–	–	–	–	–	–	
	Right	–	–	–	2	–	–	2	
	Sperm	–	–	7	29	46	4	86	
1973/74	Blue	–	–	2	2	–	–	4	93
	Fin	–	–	9	–	–	4	13	
	Humpback	–	–	–	–	4	2	6	
	Sei	–	–	2	9	21	5	37	
	Minke	–	–	–	–	–	–	–	
	Right	–	–	–	–	–	–	–	
	Sperm	–	–	26	–	4	3	33	
1974/75	Blue	–	–	–	–	–	–	–	42
	Fin	–	–	–	5	–	–	5	
	Humpback	–	–	–	–	–	–	–	
	Sei	–	–	–	4	1	–	5	
	Minke	–	–	–	–	–	–	–	
	Right	–	–	–	–	–	–	–	
	Sperm	2	–	5	24	1	–	32	
1975/76	Blue	–	–	–	3	–	–	3	70
	Fin	–	–	–	2	–	–	2	
	Humpback	–	–	–	–	–	–	–	
	Sei	1	–	–	12	–	–	13	
	Minke	1	3	16	–	3	–	23	
	Right	–	–	–	–	–	–	–	
	Sperm	1	2	–	5	21	–	29	
1976/77	Blue	–	–	–	–	–	–	–	156 *
	Fin	3	2	8	16	21	8	58	
	Humpback	–	–	–	–	–	–	–	
	Sei	1	1	8	2	2	3	17	
	Minke	–	–	25	2	1	6	34	
	Right	–	–	–	–	–	–	–	
	Sperm	–	–	–	1	42	4	47	
1971/72–1976/77	Blue	–	–	2	5	–	–	7	574
	Fin	3	2	19	26	23	15	88	
	Humpback	–	–	–	2	6	4	12	
	Sei	2	1	22	53	35	12	125	
	Minke	1	3	41	2	4	6	57	
	Right	–	–	–	7	–	–	7	
	Sperm	3	2	65	83	114	11	278	
1971/77	All species	9	8	149	178	182	48	574	

* In addition 3 Bryde's whales were marked during this season, two in Area III and one in Area V.

species in recent seasons has much reduced the chances of returns. Fin whales have been added to the list of protected species and it is therefore unnecessary to mark them in the immediate future. With the present situation in Antarctic whaling, with reduced catches providing fewer mark returns, it may be that the present general marking programme in the Antarctic could be more profitably replaced by specific marking projects concentrated on particular species and/or regions, with a view to possible mark returns providing specific information. A programme of minke whale marking in all six Areas, using the .410 mark, is one such possible project.

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SC/30/Doc 3

On Some Problems of Estimating Population Abundance from Catch Data

J. R. Beddington[2]

INTRODUCTION

One of the central problems of fisheries management of any kind is to be able to estimate population abundance. The usual method is to obtain an index of population abundance which is then used with information on recruitment, mortality and catch history to predict the time path of the population from the start of exploitation (De Lury, 1947; Chapman, 1974). One such index that is in universal use within fisheries is the Catch per Unit of Effort (CPUE). This involves the basic assumption that the catch C is proportional to population abundance N and some measure of effort E. The usual measure of effort is in terms of number of boats fishing k per unit of time T. Formalising this assumption one obtains

$$C = qkTN \qquad (1)$$

where q is sometimes called the catchability coefficient. Hence (C/kT) the catch per unit of effort is equal to qN and thus is an index of population abundance.

Most data on catch per unit of effort come from the history of the development of a fishery, during which the efficiency of the boats may be expected to change. Such changes can either be directional, for example the gradual implementation of more efficient techniques, or non-directional involving weather factors or the catch of alternative species. The problem of "effort modification" thus involves adjusting the measure of effort to allow for these temporal changes. Effectively this involves scaling the parameter q.

In this paper it will be argued that both the estimation of population abundance from CPUE data and the process of effort modification are fundamentally in error. The former producing overestimates of the level of population abundance relative to initial abundance when the population is depleted and underestimates when it has increased, and the latter incorrect scaling of the efficiency of effort. The paper is in three parts, in the first an alternative model to that of equation (1) is developed and its implications for the problems of abundance estimation and effort modification discussed. The second develops this basic model to allow for certain important characteristics of sperm whale hunting and their implications, and in the third part some consideration is given to the problems of the baleen whale fisheries where significant multi species catches occur.

A SIMPLE MODEL FOR FISHING

Viewed as a simple prey-predator process equation (1) can be considered within this literature as a functional response with k predators and T_s the searching time (Holling, 1965; Hassell, Lawton and Beddington, 1976). The catch per predator N_c being then given by

$$N_c = qNT_s \qquad (2)$$

If we recognise that (2) involves the implicit assumption of random encounters and that T_s is the searching time we can proceed to examine the implications of using equation (1) when T, the total time that boats are engaged in the entire fishing process, is used not T_s. Define T_w as the time spent by a boat in activities unrelated to the fishery for the species we are interested in, e.g. it can include the time spent catching alternative species. Let T_h be the time spent by a boat handling and processing the catch. Then by definition

$$T = T_s + T_w + T_h \qquad (3)$$

To avoid confusion with the standard fisheries literature let us say that

$$N_c = aNT_s \qquad (4)$$

where a is the characteristic efficiency of a boat. If we now define h as the time spent handling a unit of catch then we can write by definition

$$T_h = hN_c \qquad (5)$$

and eliminating T_s between (3), (4) and (5) we obtain.

$$N_c = aN(T - T_w)/(1 + ahN) \qquad (6)$$

Let us consider first the simplest case where $T_w = 0$ and hence

$$N_c = aNT/(1 + ahN) \qquad (7)$$

If there is no cooperation between the boats then total catch for k boats

$$C = kaNT/(1 + ahN) \qquad (8)$$

and the catch per unit of effort

$$\frac{C}{kT} = aN/(1 + ahN) \qquad (9)$$

If we assume that the efficiency remains unchanged during exploitation Fig. 1 illustrates the relationship between CPUE and population abundance for the two models (1) and (8).

Let us now consider an example of this case, where there is no effort modification problem as the efficiencies of the fishing process are unknown constants, but that there is transitory recruitment to the exploitable stock. Chapman (1974) used a modified De Lury method to estimate initial population size of sei whales in the Antarctic from CPUE catch and mortality data. Data for Area III are the only ones that give a significant regression by the normal method

[1] This research was conducted with the aid of a grant from the Centre for Environmental Education, USA.

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and this method gives an estimate of 13,226 for the initial population size. Modifying the De Lury equations to allow for the relationship of equation (8) results in a non linear least squares estimation problem. For this data set the algorithm used BMDP3R gave an excellent fit and an estimate of initial number of 12,482 indicating an overestimate of approximately 5% from the estimation procedures using the model 1. This non linear procedure also allowed estimates of the parameters a and h to be made for this particular fishing process. The estimated value for "h" was 0.168 of a day indicating a rather high value for the "handling time". As will be seen when considering the sperm whale fishing model this implies some cooperative hunting amongst the catcher boats.

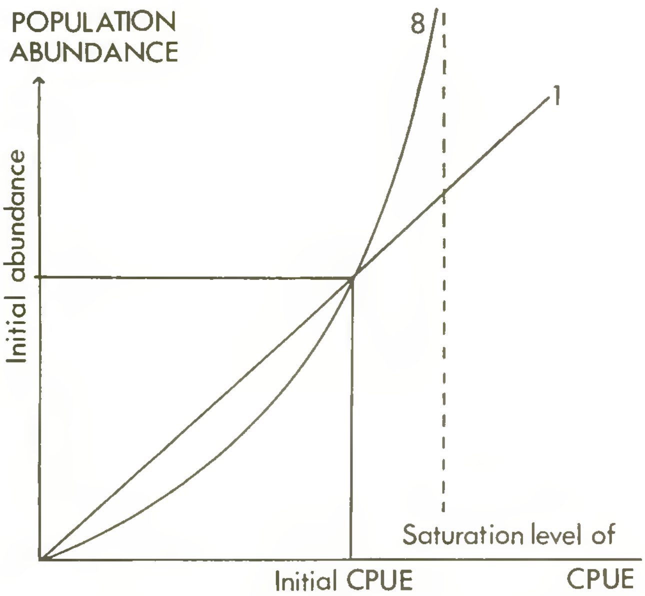

Fig. 1. Illustrates the hypothetical relationship between population abundance and CPUE for models (1) and (8). Both models have the same characteristic CPUE at the initial level of abundance. Model 1 overestimates population abundance for levels below the initial, the degree of overestimation depending on the size of the parameter h and the level of "initial CPUE" relative to the "saturation level of CPUE". The overestimation varies with degree of depletion reaching a maximum at intermediate levels (i.e. close to MSY for populations with simple logistic style recruitment).

The problem of effort modification can now be seen to depend on which of the time processes are affected, whether time wasted, time searching or time handling. Only in the case of an alteration to the time wasted will the effort modification method used previously, be appropriate. A change either to searching efficiency or in handling time will affect the relationship between catch and abundance in a non linear way. Furthermore the degree of modification as can be seen in Fig. 1 will depend on the level of population depletion relative to the initial level. What is clear is that simple comparisons of CPUEs of different boats in different circumstances are inappropriate; what is required is a comparison of the timing of operations in the different circumstances. Thus the data requirements of this model, although simple, are fundamentally different to that normally given for whaling operations, with the notable exception of the sperm whale fishing in the North Pacific (Ohsumi, 1977). Some of the characteristics of sperm whale fishing are considered in the next section.

A MODEL FOR SPERM WHALE FISHING

In a remarkably comprehensive document Ohsumi (1977) details the fishing operations and timing of different processes in the Japanese pelagic fishery in the North Pacific. One clear difference from the simple model considered previously is that there is cooperation between the catcher boats, thus when one boat finds a pod of whales other boats are alerted by radio and join the original boat in the attempt to catch all the animals in the pod that may legitimately be caught. This process, although relatively complex, permits modelling in the manner of the previous section. Some considerable extension of notation is however required.

Symbols

n = number of pods.
α = average number of legitimate quarry per pod.
N = αn = Total population size.
T = Total time (1 day).
T_w = Time wasted by each boat.
T_h = Total handling time by each boat.
T_{si} = Time searching by boat i.
h = Time spent handling one animal.
g = Average time spent moving to a pod following an encounter by another boat.
E_{ai} = Number of encounters of a boat i with a pod of whales when it is the first boat.
E_{bi} = Number of encounters of a boat i with a pod of whales following an encounter by another boat.
γ_1 = Number of whales caught following encounter of type a.
γ_2 = Number of whales caught following encounter of type b.
N_{ci} = Number of whales caught by boat i.
k = Number of catcher boats.
a = Efficiency of catcher boats.

General derivation

By definition*

$$N_{ci} = \gamma_1 E_{ai} + \gamma_2 E_{bi} \tag{10}$$

$$T = T_w + T_h + T_{si} \tag{11}$$

$$T_h = \gamma_1 ahnT_{si} + (h+g)an \sum_{j=1}^{k} T_{sj} + (\gamma_2 - 1)ahn \sum_{\substack{j=1 \\ j\neq i}}^{k} T_{sj} \tag{12}$$

Noting that $T_{si} = T_s$ for all i and eliminating T_s we obtain

$$N_{ci} = \frac{(\gamma_1 an + \gamma_2(k-1)an)(T - T_w)}{1 + \gamma_1 ahn + (k-1)(h+g)an + (\gamma_2 - 1)(k-1)ahn} \tag{13}$$

which for $\gamma_1 = \gamma_2 = 1$ (i.e. each boat takes only one whale per pod) simplifies to

$$N_{ci} = \frac{(kan)(T - T_w)}{(1 + ahn + (k-1)(h+g)an} \tag{14}$$

* Note the implicit restriction that $\alpha \geqslant \gamma_1 + (k-1)\gamma_2$.

Thus

$$\text{Total Catch } C = \sum_{i=j}^{k} N_{ci}$$

noting that $N = \alpha n$ and Total Effort = kT, for $T_w = 0$ we obtain

$$CPUE = kaN/(\alpha + ahN + (k-1)(h+g)aN) \quad (15)$$

with similar more complicated forms being possible using the more general assumptions of (13) not (14).

Discussion

Fig. 2 illustrates the relationship of these models and models (1) and (8) for a situation where all parameters are constant.

Although these equations (13) and (14) are considerably more complicated than those for the simple model it must be emphasised that they are of the same underlying form

$$C = \frac{AN(T - T_W)}{1 + BN} \quad (16)$$

as those for the simple model previously derived. Hence non linear estimation procedures of the modified De Lury type, described previously, will permit estimates of the gross parameter conglomerations. Accordingly, as long as it is not necessary to obtain estimates of the individual parameters, this method can be used. However this only applies to the situation where parameters are invariant over time. Where they vary either systematically or randomly the problem becomes more difficult. Nevertheless, if the correct time components are altered the error modification will be reasonable as was the case for the simple model (8).

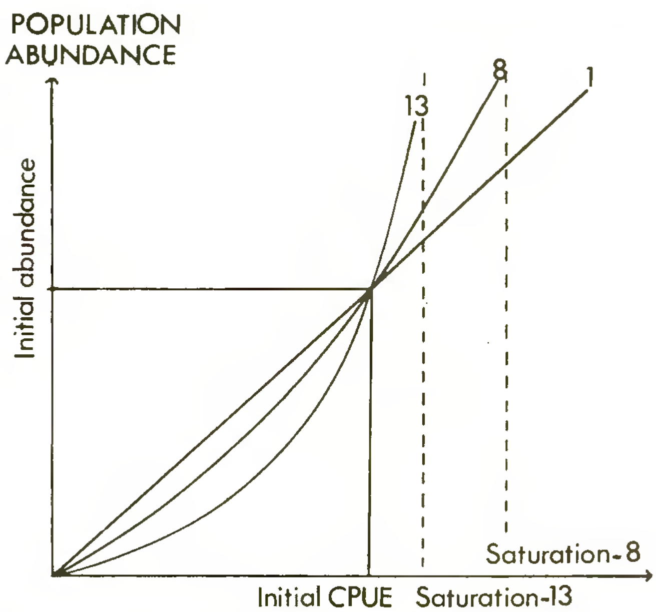

Fig. 2. Illustrates the hypothetical relationship between the models of equations (1), (8) and (13). It can be seen that if the true situation is that described by (13) using both (1) and (8) will result in overestimates of population abundance.

In the case of the sperm whale fishery a new time varying component needs to be considered, namely the number of catcher boats that operate cooperatively on an expedition. Furthermore, an additional time parameter, the time taken on average to join a boat which has first encountered a pod of whales must also be known. Unfortunately even Ohsumi's extensive documentation of the Japanese operations in the North Pacific omit these two components.

Using data given by Ohsumi for the 1977 season (his Table 1), it is possible to look at the static picture illustrated in Fig. 2 for the current situation of Japanese pelagic whaling in the North Pacific. We do this using both the simple model (8) and a variety of assumptions about the two unknown parameters for model (13). Kirkwood (1977) gives data on levels of CPUE at the start of the fishery which vary between 3 and 4 and both values have been chosen to correctly scale the models. The results of this exercise are given in the Appendix. Two things should be recognised about this static picture. Firstly the extent of overestimation of the population abundance is likely to be an underestimate. Increases in efficiency which have shortened the chasing time (incorporated into handling time) such as have been suggested about Asdic will result in even greater levels of current bias. Nevertheless, the extent of this bias is still marked, typically being between 10 and 20% at a level of CPUE half that of the initial level. There are thus serious grounds for concern about the level of abundance of the North Pacific sperm whale populations. The second point is that to correctly assess the initial and current population level, knowledge of the time varying parameters during the history of the fishery is required; these can then be used with recruitment and mortality estimates to assess the time path of abundance since exploitation started. In the event that these data are unavailable an alternative is to specify their likely time path using anecdotal evidence already available. In concluding this section it must be emphasised that although certain problems remain, e.g. the effect of weather and tonnage on catch efficiency, the current estimation procedures and the technique of effort modification are resulting in overestimates of the abundance of the North Pacific population. One final factor that complicates the North Pacific effort modification and estimation procedures is that CPUE data are for male catches, but there is a substantial current female catch. At the special meeting in Cronulla on the suggestion of Chapman, this was correctly used effectively as a "time wasted" alteration. It was noted earlier that the ordinary effort modification procedures are unbiased in this way. This whole problem of a two sex catch is part of the general problem of a multi species fishery. This is considered in the next section.

A MODEL FOR MULTI SPECIES BALEEN WHALE FISHING

Considerable effort has been put into screening catch per unit effort data to exclude situations where a catch of an alternative species is taken. In earlier sections of this paper it was noted that if the time spent searching for, chasing and handling the other species were included as time wasted in some appropriate model, then correct estimation and modification procedures could be applied. Often such data are unobtainable and the available data set consists of catches and total time (effort) spent on the mixed fishery. In this final section a preliminary model is developed to consider the possibilities of using data of this type. The model is similar to one developed within the literature on arthropod predation (Lawton, Beddington, Bonser, 1974) and is developed here only for the situation where no cooperative hunting occurs. Some extension of notation is required.

Symbols

s = Number of species in fishery.
N_i = Abundance of species i.
N_{ci} = Catch of species i.
h_i = Handling time per unit catch of species i.
a_i = Searching efficiency (including preference) for species i.
T_{hi} = Total handling time for species i.
T = Total time.
T_s = Searching time.
T_W = Time wasted.

General derivation

By definition

$$T = T_s + \sum_{i=1}^{s} T_{hi} + T_W \qquad (17)$$

and

$$T_{hi} = h_i N_{ci} \qquad (18)$$

if encounters occur randomly then

$$N_{ci} = a_i N_i T_s \qquad (19)$$

Eliminating T_s between (17), (18) and (19) we obtain

$$N_{ci} = \frac{a_i N_i (T - T_W)}{1 + \sum_{i=1}^{s} a_i h_i N_i} \quad i = 1, s \qquad (20)$$

if s = 2 as for typical baleen whale data two equations are obtained of the form

$$N_{c1} = \frac{a_1 N_1 (T - T_W)}{1 + a_1 h_1 N_1 + a_2 h_2 N_2}$$
$$N_{c2} = \frac{a_2 N_2 (T - T_W)}{1 + a_1 h_1 N_1 + a_2 h_2 N_2} \qquad (21)$$

By eliminating either N_1 or N_2 between these equations it is possible to arrive at the somewhat complex relationship between the catch of one species, its density and the catch of the alternative species. It is planned to investigate both estimation procedures involving non linear least squares techniques and effort modification problems in a further study.

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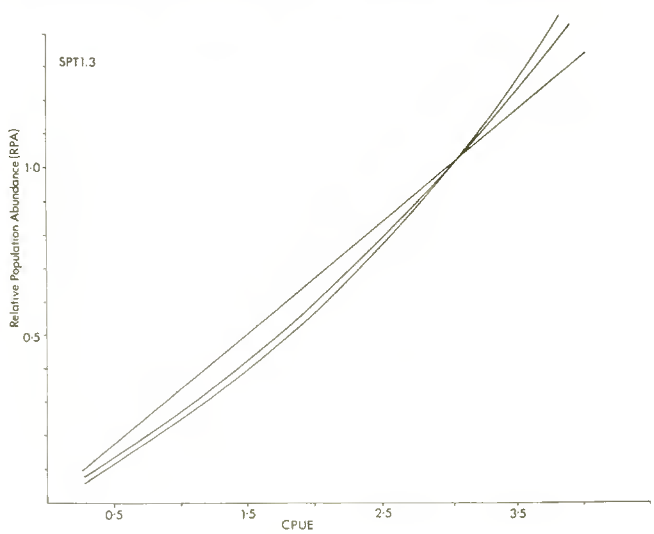
Appendix

Data are presented in both graphical and tabular form for the three models, those from equation (1), (8) and (13). In graphs SPT1.3 and SPT1.4 the time wasted and handling times are expressed as proportions of a day using data from Ohsumi, 1977, Table 1. Initial levels of CPUE are 3 and 4. For model (13) the parameters k and g are 8 and 0.0208 (½ hour) respectively. In graphs SPT1.3H1 and SPT1.4H1 all parameters are the same as before except that the chasing time has been doubled and the total handling time therefore increased accordingly. In SPT1.34 the basic data is again used, but this time the parameter k (number of co-operatively hunting boats) in model (13) is reduced to 4.

Comparison of estimated abundance can then be made for different levels of CPUE.

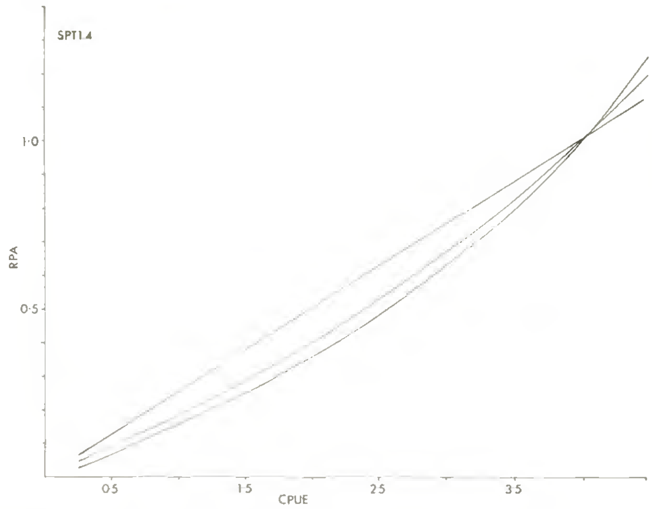
CPUE	Model (1) h = 0 T_W = 0	Model (8) h = 0.0477 T_W = 0.4139	Model (13) a = 8 k = 8
0.25	0.0833	0.0643	0.0576
0.50	0.1667	0.1313	0.1186
0.75	0.2500	0.0212	0.1832
1.00	0.3333	0.2742	0.2517
1.25	0.4167	0.3506	0.3246
1.50	0.5000	0.4304	0.4022
1.75	0.5833	0.5141	0.4851
2.00	0.6667	0.6018	0.5737
2.25	0.7500	0.6939	0.6687
2.50	0.8333	0.7907	0.7709
2.75	0.9167	0.8926	0.8810
3.00	1.0000	1.0000	1.0000
3.25	1.0833	1.1133	1.1291
3.50	1.1667	1.2331	1.2696
3.75	1.2500	1.3599	1.4230
4.00	1.3333	1.4943	1.5913
4.25	1.4167	1.6371	1.7767
4.50	1.5000	1.7891	1.9819
4.75	1.5833	1.9512	2.2103
5.00	1.6667	2.1244	2.4662

(a) Scaled Estimates of Population Abundance (Initial = 1)



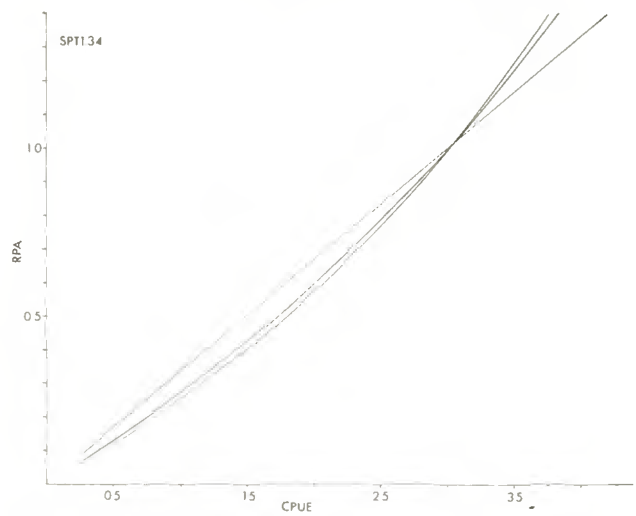
		Model (1) h = 0 T_W = 0	Model (8) h = 0.477 T_W = 0.4139	Model (13) a = 8 k = 8
	0.25	0.0625	0.0430	0.0362
	0.50	0.1250	0.0879	0.0745
	0.75	0.1875	0.1347	0.1151
	1.00	0.2500	0.1835	0.1582
	1.25	0.3125	0.2346	0.2040
	1.50	0.3750	0.2881	0.2528
	1.75	0.4375	0.3440	0.3048
	2.00	0.5000	0.4027	0.3605
C	2.25	0.5625	0.4644	0.4202
P	2.50	0.6250	0.5292	0.4844
U	2.75	0.6875	0.5973	0.5536
E	3.00	0.7500	0.6692	0.6284
	3.25	0.8125	0.7450	0.7095
	3.50	0.8750	0.8252	0.7978
	3.75	0.9375	0.9100	0.8943
	4.00	1.0000	1.0000	1.0000
	4.25	1.0625	1.0956	1.1165
	4.50	1.1250	1.1973	1.2455
	4.75	1.1875	1.3057	1.3890
	5.00	1.2500	1.4217	1.5498

(b) Scaled Estimates of Population Abundance (Initial = 1)



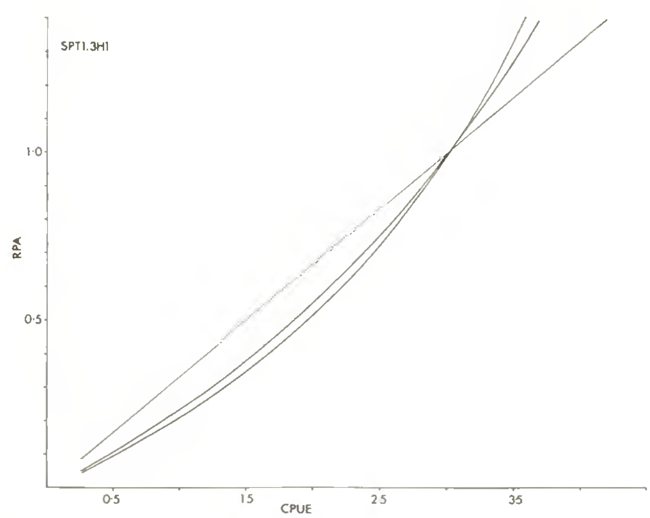
		Model (1) h = 0 T_W = 0	Model (8) h = 0.0477 T_W = 0.4139	Model (13) a = 8 k = 8
	0.25	0.0833	0.0643	0.0592
	0.50	0.1667	0.1313	0.1215
	0.75	0.2500	0.2012	0.1874
	1.00	0.3333	0.2742	0.2570
	1.25	0.4167	0.3506	0.3307
	1.50	0.5000	0.4304	0.4089
	1.75	0.5833	0.5141	0.4920
	2.00	0.6667	0.6018	0.5805
C	2.25	0.7500	0.6939	0.6748
P	2.50	0.8333	0.7907	0.7757
U	2.75	0.9167	0.8926	0.8838
E	3.00	1.0000	1.0000	1.0000
	3.25	1.0833	1.1133	1.1251
	3.50	1.1667	1.2331	1.2603
	3.75	1.2500	1.3599	1.4067
	4.00	1.3333	1.4943	1.5659
	4.25	1.4167	1.6371	1.7396
	4.50	1.5000	1.7891	1.9300
	4.75	1.5833	1.9512	2.1394
	5.00	1.6667	2.1244	2.3709

(c) Scaled Estimates of Population Abundance (Initial = 1)



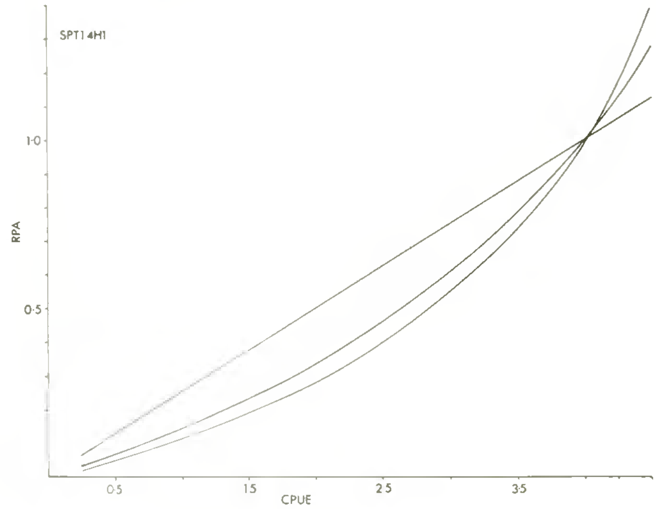
		Model (1) h = 0 T_W = 0	Model (8) h = 0.0477 T_W = 0.4139	Model (13) a = 8 k = 8
	0.25	0.0833	0.0542	0.0474
	0.50	0.1667	0.1119	0.0987
	0.75	0.2500	0.1736	0.1543
	1.00	0.3333	0.2396	0.2148
	1.25	0.4167	0.3104	0.2810
	1.50	0.5000	0.3866	0.3537
	1.75	0.5833	0.4687	0.4338
	2.00	0.6667	0.5576	0.5226
C	2.25	0.7500	0.6540	0.6215
P	2.50	0.8333	0.7591	0.7324
U	2.75	0.9167	0.8739	0.8575
E	3.00	1.0000	1.0000	1.0000
	3.25	1.0833	1.1390	1.1636
	3.50	1.1667	1.2931	1.3533
	3.75	1.2500	1.4649	1.5759
	4.00	1.3333	1.6576	1.8410
	4.25	1.4167	1.8752	2.5582
	4.50	1.5000	2.1229	2.5582
	4.75	1.5833	2.4075	3.0601
	5.00	1.6667	2.7378	3.7164

(d) Scaled Estimates of Population Abundance (Initial = 1)



		Model (1) h = 0 $T_W = 0$	Model (8) h = 0.0477 $T_W = 0.4139$	Model (13) $a = 8$ k = 8
	0.25	0.0625	0.0327	0.0257
	0.50	0.1250	0.0675	0.0536
	0.75	0.1875	0.1047	0.0838
	1.00	0.2500	0.1445	0.1167
	1.25	0.3125	0.1873	0.1527
	1.50	0.3750	0.2332	0.1921
	1.75	0.4375	0.2828	0.2356
	2.00	0.5000	0.3364	0.2838
C	2.25	0.5625	0.3946	0.3376
P	2.50	0.6250	0.4580	0.3978
U	2.75	0.6875	0.5272	0.4658
E	3.00	0.7500	0.6033	0.5432
	3.25	0.8125	0.6872	0.6320
	3.50	0.8750	0.7801	0.7351
	3.75	0.9375	0.8838	0.8560
	4.00	1.0000	1.0000	1.0000
	4.25	1.0625	1.1313	1.1743
	4.50	1.1250	1.2807	1.3895
	4.75	1.1875	1.4524	1.6622
	5.00	1.2500	1.6517	2.0186

(e) Scaled Estimates of Population Abundance (Initial = 1)



SC/30/Doc 5

A Simple Model of Pelagic Whaling

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ABSTRACT

A theoretical analysis is presented of the consequences for assessments of breaking down the "catchers' day's work" statistic into its operational components, and assuming that stock density is proportional to catch per unit searching time by catchers' per unit area of operations. The searching time available per catcher day is dependent on the density and hence on the daily catch rate of whales; there is thus a consistent bias in estimates from catch per catcher day indices, of the rate of change of stocks such as to tend to underestimate the time rate of decline in density. The critique is based on data for sperm whaling in the North Pacific, the consequences for assessment of the effects of multi-species baleen whaling operations in the Antarctic are roughly indicated. The paper suggests other factors of bias that should be taken into account, and an agenda for further study of these factors.

In his account of sperm whaling operations, Ohsumi (1979) provided information which permits a re-appraisal to be begun of the validity of the "catch per catchers' day's work" as an index of the abundance of whales. The basic assumption in the application of this index is that in a certain area, over a short time, and with a particular kind of catching unit, the catch per unit time is proportional to searching success and hence to population density. There are, of course, numerous ways in which this assumption departs from reality. It is widely accepted that, for both whaling and some pelagic fishing operations, a more suitable measure of time for this purpose than the total time of operation would be the time spent searching. Such a measure is not yet available for whaling on a historical basis (although information could presumably be extracted from log-books of catcher boats), and the effective searching time must be inferred from statistics for total days work. This paper indicates the nature and order of magnitude of important biases in the application of such statistics by methods used to date, and suggests how better abundance indices might be obtained from historical data.

The catch per unit searching effort in whaling can be regarded as the product of the sightings per unit searching time, the probability that a whale sighted will be chased and the probability that a chased whale will be killed. It is said that individual whales and pods are, despite the availability of electronic equipment, still found visually, although in recent years the probability of finding them may have been increased by the application of correlations with oceanographic features and by the accumulation, through whaling experience, of knowledge about their distribution and movements. Such improvements in searching and finding will cause declines in whale abundance as deduced from simple CPUE statistics to be underestimates of the true degree of depletion, but we have no obvious method of estimating this bias.

The time spent searching for whales is essentially the hours of daylight less the time spent chasing, killing and handling the catch and any daylight time spent towing or resting. Most resting time and some towing time is, however, expended at night, except when catch rates were very high in the early years of pelagic whaling and "stop catch" was declared for a period for an expedition to permit processing of a backlog. In the early effort data provided by the BIWS, "stop-catch days" were identified and could be subtracted from the total days work to improve abundance estimates; we are not here concerned with this.

If the total time spent chasing, killing and/or handling whales occupies a significant part of daylight hours, then changes in the abundance of whales, and hence in the catch rate, will affect the fraction of time available for searching and hence the frequency of sightings. In the simplest model of this phenomenon, the time spent each day chasing, killing and handling might be considered to be proportional to the number of whales caught that day. This leads to a non-linear relation between catch per catchers' day's work and abundance such that, as a stock declines, the relative decline from an initial abundance will be underestimated. Further, if the absolute stock size or density is estimated by the De Lury or modified De Lury method it will be underestimated. This means that unless appropriate corrections are made there could be a tendency to classify some stocks that should be Initial Management Stocks as Sustained Management Stocks, and some as Sustained Management Stocks that should be Protected Stocks. In addition, the quotas set for Initial and Sustained Management Stocks, as some given percentage of the estimated initial or present or MSY stock size, could be too high.

We define

T_d as the total daylight time
T_s as the time available for searching
T_c as the time spent chasing
T_h as the daylight time spent handling and towing
w as the time spent chasing or handling a whale
C as the catch
D as the fraction of a 24-hour day in which it is light enough to search and chase

so that

$$T_d = T_s + T_c + T_h \quad \text{and} \quad (T_c + T_h) = wC$$

* Since the work reported here was begun, it has come to my attention that John Beddington, Charles Fowler and perhaps others were pursuing similar lines of analysis. I have consulted the two scientists mentioned, and others, and in order to simplify consideration of this matter by the Scientific Committee I have adopted Beddington's notation where that is applicable (see Beddington, 1979 and Fowler, 1978).

Further defining

where $C = pAT_sq$
A = abundance of whales
C = catch
p = probability of successful chase
q = efficiency of search

Then the catch per catcher's days work (CPUE) is

$$\frac{CD}{T_d} = \frac{DpqA}{1 + wpqA}$$

If D, pq and w are constant, this reveals a non-linear relationship between CPUE and abundance, as in Fig. 1.

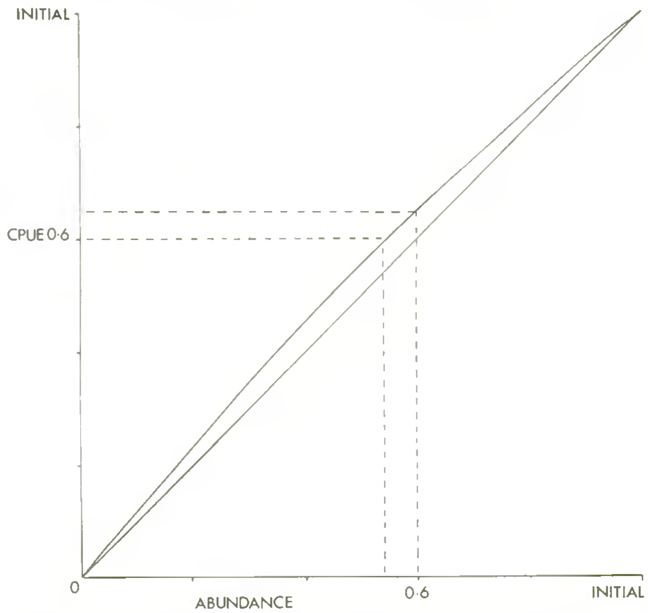

Fig. 1. Relation of catch per unit effort, as % of initial, with abundance as % of initial, for case when at initial abundance about 14% of total daylight time is occupied with chasing and handling.

If we further define A as the abundance relative to an initial abundance, and CPUE′ as the corresponding catch per catchers' day's work then we have

$$(1 + wpq) = Dpq$$

and

$$CPUE' = \frac{(1 + wpq)A'}{1 + wpqA'}$$

It may be readily shown that the bias (CPUE′–A′) is maximal for $A' \leqslant 0.5$. In fact A'_m, the value of A′ at which bias is maximal, is given by

$$A'_m = \frac{\sqrt{1 + wpq} - 1}{wpq}$$

Thus even for small values of wpq, e.g., when w is a short time, the greatest bias is in the mid-level of A′ and somewhat below the value usually taken as that giving maximum sustained yield, so that as a stock declines toward MSY level the bias increases continuously.

Ohsumi's data show that the fraction of the hours of daylight spent chasing and handling each sperm whale in the North Pacific in 1977, when an average of two were caught per day, was 0.07. In the early years the catch rate was about twice that in recent years and from such information the specific curve of the form of Fig. 1 can be calculated. It shows that when the CPUE has fallen to say 60% of the initial value, the abundance will have fallen to about[1] 54% or less of its initial value. When the CPUE has fallen to 44% of initial (MSY level for male sperm whales predicted by the Allen model with parameter values as adopted by the IWC Scientific Committee) the abundance will actually be about[1] 35% or less of the initial.

Conversely, if we seek to reduce a stock to not less than 44% of its initial level it would be necessary to hold the CPUE at not less than 55% of the initial value. In the first example given, the current stock and hence the quota, would have been determined 15% too high; in the second example, of course the stock would have been classified as just in the sustained management category, when it should have been protected, and by a substantial margin.

A further factor is revealed by Ohsumi's data. His Fig. 2 shows that the chasing time per whale (which is the main element in daylight hours not spent searching) increases in direct proportion with the length of the whale, as might be expected from the relation of swimming speeds and diving duration with size. Over the period during which pelagic sperm whaling was conducted, the average size of male sperm whales caught declined and also, with increasing catches of females, the average size of all sperm whales caught declined even further. This would introduce an additional bias, in the same direction, in estimates of changes in abundance from CPUE data treated in the usual manner.

The analysis is complicated in the case of baleen whaling by the fact that chasing and handling an individual of one species of whale takes time that might otherwise be spent searching for that and other species simultaneously. The catch per catcher's day of the four large baleen species in the Antarctic has ranged from as much as four in the mid-fifties to less than one in the seventies. The change has not, however, been smooth, as the concentration on different species (essentially pairs of species) has changed over the post-Second World War period. During this time, the average size of all baleen whales caught has steadily declined from just over 70 ft to 50 ft or less. If this, or other inter-specific changes, are associated with substantially decreased chasing and handling times per whale, the two factors of declining catch rate and size would introduce substantial bias in the estimates of stock abundance changes based on catchers' day's work. If it took, say, 20–30 minutes on average to catch and kill a baleen whale (before the introduction of Asdic), it could mean that fin and sei whale estimates on which the Scientific Committee has based its classification and quota recommendations could be biassed on the optimistic side by about 10–20%.

The above analysis suggests how one might better approach the problem of "effort corrections" for factors such as tonnage or engine power, weather and Asdic. In each case, the factor in question may affect searching efficiency, chasing time or both, as well as the probability of successful chase. The effect on catches per catchers' day and hence the biasses in estimation of abundance will be linear and/or non-linear. Thus, higher operational (cruising) speeds should increase search efficiency proportionally, and

[1] The approximations expressed here arise from uncertainties in how to deal with towing time – some of which was not recorded, or took place in the dark when searching and chasing were not possible. Furthermore, although total towing time might increase with numbers to be towed it presumably would not do so proportionally; also when whales are scarce, distance and hence time spent towing might be increased as catchers might be successful on average further from the mother ship.

increased maximum speeds would reduce average chasing time, possibly in approximately inverse proportion. Asdic, which apparently is not used in searching, would both decrease the chasing time and increase the probability of successful chase – the former especially in the case of baleen whales and the latter in the case of sperm whales. Changes in the weather conditions presumably affect both searching efficiency and chasing time and success.

Table 1

Antarctic pelagic baleen catches

Season	Catch per catcher day		i
	blue + fin + sei	+ minke	
1946/47	1.51		0.88
48	1.46		0.79
49	1.30		0.62
50	1.34		0.58
51	1.31		0.52
52	1.52		0.58
53	1.47		0.53
54	1.79		0.64
55	1.70		0.59
56	1.82		0.61
57	1.81		0.58
58	1.79		0.53
59	1.75		0.47
60	1.45		0.36
61	1.39		0.34
62	1.08		0.25
63	1.12		0.24
64	1.09		0.22
65	1.56		0.31
66	1.52		0.25
67	1.30		0.20
68	1.28		0.20
69	1.06		0.17
70	1.12		0.18
71	1.13		0.18
72	0.97	1.35	
73	0.73	1.47	
74	0.85	2.01	
75	0.62	1.53	
76	0.36	1.45	
1976/77	0.50	2.64	

i = indicator of daily chasing/handing time = catch per day x mean length of whales caught = average IHP of catchers.

When a terrestrial mammal population is depleted there has often been noted a tendency for the area inhabited by the population to be diminished. As whales are social animals in communication with each other, possibly over considerable distances, it may be reasonable to suppose that as stocks have been reduced the feeding range has been reduced. If, as expected, the whaling expeditions are at least to some extent successful in "homing" in on the highest concentrations of whales, the catch per unit effort might be an index of relative density, but not of total abundance relative to that at some other date. The direction of bias would, yet again, be in the same direction – leading to overestimates of stock size, and underestimates of the degree to which initial stocks had been reduced. It has not been possible to make an analysis of this effect in time for the present meeting, but such should be possible from detailed catch and effort data. In later years, when the number of pelagic expeditions operating in the Antarctic was substantially reduced, the area in which whaling effort was expended has, of course, in any case reduced and its distribution would not be an indication of the contraction of whale stocks. However, a few years earlier, in the period when the fin whales of the Southern Hemisphere were being reduced (1948/49–1964/65), the number of catchers and the total effort did not change greatly from one year to the next; in such a period it might be possible to determine the degree of stock contraction which occurred, if any.

Certain other factors could also be taken into account from existing data which may be having an effect on observed changes in CPUE, although in directions which cannot immediately be foreseen. One of these is the change in the duration of daylight with changes in mean latitude of operation, which have occurred. The other is the mean length of day as a function of the dates of beginning and end of season. It does not seem likely that these will have affected greatly the estimates of abundance of any particular baleen species; it may, however, have affected sperm whale estimates because the time and place of catch of this species has changed substantially over the period of pelagic whaling in the Southern Hemisphere. It is evident that other factors must be brought into a fully realistic model of whaling operations, including particularly the consequences of cooperation among catchers and of the distribution of whales in pods rather than singly. Technological advances tend to reduce the time spent catching each whale, and to increase the efficiency of utilizing the remaining searching time. It is not unreasonable to assume that even when effort data have been "corrected" for some such factors, there will be other as yet unknown factors not taken into account and which are more likely than not to lead to further excessive optimism in assessments. In this situation, even if all other factors are not allowed for, estimates would always be improved if the non-linear relation between CPUE and abundance, arising from the fact that time available for searching increases with declining catch rates, is applied, using the best available estimates of chasing/handling time per whale in the past no matter how approximate these are. Furthermore, if we wish to be reasonably conservative in our estimates it would be better to use values of chasing time per whale from earlier rather than from later years, i.e., from before the introduction of the present types of powerful catchers equipped with electronic devices.

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SC/30/Doc 6

Reclassification of Protected Baleen Whale Stocks

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ABSTRACT

The paper discusses some questions that call for examination before any Protected Stocks are presumed to have increased sufficiently to warrant reclassification as Sustained Management Stocks. It is argued that neither forward extrapolation of the model on which the original protection was based, nor field evidence of some increase in numbers are sufficient evidence for reclassification. Necessary analyses include the effects of continued small scale whaling after protection, new evidence on the relation between catch per unit effort (catchers' day's work) and density, new facts and hypotheses about inter-specific interactions, any evidence that the "initial" year taken as the original starting point for assessments was not in fact early enough.

The recovery of stocks which have been classed as "protected" under the New Management Policy can be simulated by back-calculating from the population models and parameter values on which the original decision to protect was based. Such simulation leads to the conclusion that certain at present protected Southern Hemisphere fin whale stocks and possibly one or more of the sei whale stocks might be classified as Sustained Management Stocks in the 1977/78 season or soon thereafter. There is, we think, no question that any of the stocks of humpback or blue whales could have recovered sufficiently for reclassification to be seriously considered in the near future. The case of the eastern Pacific gray whale, which has increased in numbers substantially under protection, calls for special consideration for several reasons, including (a) its dependence for continued existence on the safeguarding of critical breeding habitat from excessive human interference, and on the abstention of the North American countries from hunting it within their coastal waters, and (b) the fact that it is, so far, uniquely the source of high non-consumptive values which are realized through a recognisable industry. This note is, therefore, concerned only with the problem of the fin and sei whales, some Protected Stocks of which have been judged to be close to the boundary stock size between Protection and Sustained Management.

The shortness of the time elapsed since stocks of these species have been protected means there is no possibility of estimating the degree of change in stock size from sightings by commercial expeditions – the only source of direct observations. Reclassification can, at present, be discussed only in terms of population models. In that short time, however, there have been considerable developments in such models and their application and important questions have been raised as to their validity and adequacy for prediction. Here we briefly examine some of these matters with reference to the reclassification problem.

(a) **The presumed linear relationship between stock density and catch-per-unit-effort as measured by catch per catchers' day's work adjusted by various multipliers, mainly for size of catcher and average weather conditions.**

Until now very few data have been made available to the Commission concerning the breakdown of total time of pelagic operations into its components such as searching, chasing, handling, towing, resting. At the IWC Special Meeting in Cronulla, November 1977, important data were submitted by Ohsumi (1979) concerning this breakdown with respect to sperm whaling. From these we can deduce that the relationship is definitely not linear and that the direction of bias introduced by the linear assumption is such that the degree of depletion of stocks has almost certainly been significantly underestimated. The density of whales is expected to be essentially proportional to sightings per unit searching time. The amount of searching time available in the daylight hours is increased as the stock density – and hence the catch per day – declines, because the time spent chasing and handling, and possibly towing, increases roughly in proportion to the number of whales caught. This effect might be offset, but surely only partially, and in a limited way, by the decrease in the length of the working day as a result of changed labour conditions in the Japanese fleet, as referred to by Ohsumi.

Clearly, specific data on baleen whaling operations are needed, but if we assume that the average time taken to chase, handle and tow a baleen whale is about the same as for a sperm whale in the North Pacific, we can deduce that the densities of stocks which might have been reduced by whaling have been significantly overestimated with respect to the "initial" densities. The overestimation would, in some cases, be of the order of 20–30% (Beddington, 1979; Fowler, 1978; and Holt, 1979). That is to say, stocks, which in recent years were classified as Protected because they were thought to be at levels a little less than 60% of initial levels, are likely in reality to have been, at the time of such classification, at substantially lower levels. This effect is enhanced by the fact that it takes a shorter time to chase and catch a smaller whale than a larger one (in sperm whales the time is roughly proportional to length, other things being equal) and the average size of whales taken has declined because of the decline in average size of each species and an increase in the proportions of the smaller species in the baleen catch.

Further, if as suggested by Holt (1978) the change of mean density in the area where whaling is carried out is an underestimate of the decline in absolute abundance of whales then the stock size at the date of protection would be less than was thought.

(b) The effects of the introduction of Asdic in pelagic whaling in increasing the effectiveness of a catchers' day's work have not been taken into account in assessments made so far.

From the information that has been made available to the Scientific Committee about sperm whaling operations, we might presume that Asdic is also not of any great significance in increasing searching efficiency in baleen whaling, although it would be desirable to have direct evidence on this point. We know, however, that Asdic is used in the chasing operation and, in the absence of further information, it must be presumed that it has increased overall efficiency considerably; if it had not done so it would hardly be likely that the expense and trouble of installation and of training crews in its use would have been worthwhile to the whaling enterprises, since it has been argued that it is of relatively little importance in sperm whaling. This means that the chasing and killing efficiency itself must have been greatly increased either by reducing several-fold the average time taken to chase a baleen whale (which seems the more likely effect, considering that it has been said that Asdic is used primarily to induce and maintain a fast shallow flight reaction, with consequent rapid exhaustion of the whale) or by increasing the likelihood that a sighted whale will in fact be captured, or both. Operational data are needed to substantiate or correct these hypotheses and could no doubt be provided for consideration at future meetings. In the absence of such data it must be presumed that at the time of protection, which occurred later than the general introduction of Asdic (1958–62 in Japanese pelagic operations, 1960–70 in coastal operations), the relative abundances of stocks under consideration were overestimated.

(c) Beddington (1979) has suggested that efficiency of catchers' day's work changes with changes in the numbers of catchers per expedition.

This factor, too, will have introduced biases into the abundance estimates on which protection decisions were based.

(d) Since the various fin and humpback whale stocks were protected, it has proven necessary, especially in considering the status of sei whale stocks, to take into account the interactions between the baleen whale species.

These interactions are presumed to derive mainly from the strong dependencies on krill, their main food resource. In particular, unprotected stocks of whales, even if as in the case of the minke whale they are being reduced, may be benefiting from the relief of predatory pressure on the krill by feeding more intensively themselves and either increasing in number or biomass, or by not decreasing under whaling as fast as might have been expected. We must also note that over the period of intensive whaling for fin and humpback whales other predators on krill in the Southern Hemisphere, particularly crabeater seals, have been increasing. Thus the single-species models used as the basis for classification of Protection Stocks cannot simply be "put into reverse gear". It seems unlikely that the Protected Stocks will be increasing as rapidly as would be expected from the original assessments.

(e) Whaling, albeit on a small scale, has continued on some Protected Stocks.

We know that individuals from Protected Stocks continue to be taken by commercial operations not bound by decisions of the IWC and not subject to the Commission's Observer Scheme; for example, humpback whales by Spain and possibly humpback and blue whales by Chile (Casinos, Filella and Pelegri, 1977; Ottaway, 1978). In addition, *any* catches, for example by "aboriginal" whaling for local consumption, could affect adversely the recovery of very small residual stocks, especially as such whaling operations usually involve the loss and likely death of numerous whales which are struck but not caught. Such seems to be the case in the Kingdom of Tonga, for example, with respect to a South Pacific breeding stock of humpback whales, where the numbers caught or struck are likely to have reduced the recovery rate, or even completely impeded recovery.

It is particularly serious that subsistence catches, taken especially by unmechanised means, include high proportions of calves and pregnant and lactating females. Humpbacks, for example, are taken by native fisheries in Bequia (Caribbean Islands) and in Greenland. The Bequia fishery concentrates on mothers accompanied by calves or yearlings and may be preventing recovery of the stock (Winn, 1976); the Greenland fishery taking 5 to 10 a year may be having a similar effect (IWC, 1978).

While these examples do not involve fin and sei whales, other operations of which we are not aware may do so, and these latter species are at risk from unmonitored whaling operations such as are conducted by MV *Sierra* and from the possible increase in whaling by non-member countries of the IWC. Exact prediction of the consequences of such activities depends in part on which catch data were taken into account in the original assessments, but we clearly should not necessarily assume that all stocks are recovering at the originally predicted rate.

Since such information as we have strongly suggests that both the abundances of Protected Stocks and their rates of recovery may be less than previously assumed, it would seem inadvisable to reclassify any of the stocks which are now protected, solely on the basis of extensions of the original calculations. To permit classification to be reconsidered, the following work is needed at least:

(a) A full re-analysis of existing catch, effort and biological data.
(b) Submission and analysis of new data including, especially, detailed operational information.
(c) A re-examination of the models used to see to what extent conclusions will be modified if, as seems necessary, a multi-species approach to baleen whaling management is adopted.
(d) The preparation of a programme of sightings for scientific purposes. This could be supplemented by marking and by planned scientific sampling on a minimal scale. However, such sampling would be unlikely to provide the information required with minimal impact on the Protected Stocks unless it were more precisely planned and more strongly coordinated than results from the application of the IWC provision for issuance of scientific permits. It would be timely therefore for a start to be made in designing an appropriate international programme of research on Protected Stocks.

(e) Acquisition of more data pertaining to continuing catches by non-members of IWC, and to all catches for subsistence purposes. This the authors have been doing for Tongan humpback catches, with the collaboration of the Government fishery officer there, Mr. W. Wilkinson, and also with the FAO Fishery Expert, Mr. Davidson Thomas, who, with his colleagues, has logged sightings in the area by local fishery research vessels operating an FAO/UNDP development project. The Scientific Committee may also need to assure itself that the present arrangements under the Commission for "observing" whaling operations are, in fact, ensuring the full availability of information from the fleets about sightings and possible occasional catches of protected species.

If, following careful analysis, planning and research, taking into account the factors indicated above, it appears that some at present Protected Stocks should be reclassified in accordance with New Management Policy, consideration should be given to an experimental approach to resumed whaling, along the lines suggested by ACMRR in the light of the Bergen Consultation (FAO/ACMRR, 1977). Thus, even if improved estimates are made of the current sizes of Protected Stocks, both in absolute terms and in relation to "initial" sizes, considerable uncertainty will remain as to the levels of yield they can sustain. In this case, if the "best" estimates of two stocks of, for example, Southern Ocean fin whales, indicate that they both have increased to levels just above presumed MSY levels, it could be desirable to open only one of them to whaling while keeping the other protected for a few years, even if the quota for the first stock were to be set somewhat higher than would otherwise have been done. It is suggested that such possibilities should be critically evaluated by the Scientific Committee in the near future.

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SC/30/Doc 9

The Net Catcher Day as a Measure of Effort

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ABSTRACT

The possible biases in the use of a net rather than gross catcher day as a measure of effort are discussed. It is shown that catch per net catcher day may seriously overestimate relative abundance for small fleets and low true abundance. A method of converting net to gross catcher days is illustrated.

INTRODUCTION

The basic assumption that must be satisfied if catch and effort data are to be used for the estimation of exploited population sizes is that the unit of effort is so measured that the average catch per unit effort during a period of time is proportional to the average population density during that period. A discussion of the measurement of effort in the fisheries field may be found in Rothschild (1977). The obvious candidate for such a unit for whales is the time spent actively hunting whales on the grounds. This has traditionally been measured by the catcher day, standardised for changes in catcher efficiency. If a single catcher is operating, in principle the time spent actually chasing and catching a whale should be subtracted from the time on the grounds. This point is developed by Beddington (1978). The principle is not quite as clear if a fleet is catching and searching cooperatively.

Unfortunately the measure of effort is simple to obtain only when there is just one target species (and sometimes sex) of whale. Such a situation is all too rare in modern whaling. The problem of allocation of days worked among the various species caught led to the concept of a net catcher day. A net catcher day was counted each day an animal of the species of interest was caught. The problems with such a concept were immediately obvious. On the one hand, days when no animals were caught were totally ignored, while on the other hand a net catcher day was allotted even if only a tiny percentage of the day's catch was of the species of interest. In some situations the problems could be overcome by using effort data only from those areas in which the species of interest predominated, but inevitably there remain ambiguous cases.

In the following sections we investigate the magnitude of the effect of using net rather than total, or gross, catcher days as a unit of effort. The analysis is based on the assumption that the catch taken as a result of expenditure of one unit of effort is Poisson distributed, the same assumption made in Kirkwood (1978).

COMPARISON OF GROSS AND NET CATCHER DAYS

If only target animals are caught, and the catches taken each day are independent, it is reasonable to assume that at population size P the catch, C, resulting from x gross catcher days is Poisson distributed with mean qxP for some q. Then

$$E(C/x) = qP$$

and if the average catch per gross catcher day is compared in years o and t,

$$E\left(\frac{C_t/X_t}{C_o/X_o}\right) = \frac{P_t}{P_o} + 0\left(\frac{1}{\min(x_o, x_t)}\right) \qquad (1)$$

if only one vessel is operating, a net catcher day is defined as a day when at least one target animal was caught. Then the expected number of net catcher days, x′, resulting from x gross catcher days is

$$E(x') = x(1 - e^{-qP}),$$

so that

$$E(C/x') = \frac{qP}{1 - e^{-qP}} + 0\left(\frac{1}{x}\right),$$

and comparing years o and t,

$$E\left(\frac{C_t/x_t'}{C_o/x_o'}\right) = \frac{P_t}{P_o}\cdot\frac{1 - e^{-qP_o}}{1 - e^{-qP_o}} + 0\left(\frac{1}{\min(x_o, x_t)}\right) \qquad (2)$$

If there are n vessels operating in a fleet, it appears from whaling statistics that n net catcher days are counted each day at least one target animal is caught by the fleet. Then, if each vessel in the fleet operates independently, and if the fleet operates for x days, the expected number of net catcher days is

$$E(x') = nx(1 - e^{-nqP}),$$

and

$$E\left(\frac{C_t/x_t'}{C_o/x_o'}\right) = \frac{P_t}{P_o}\cdot\frac{1 - e^{-nqP_o}}{1 - e^{-nqP_t}} + 0\left(\frac{1}{\min(x_o, x_t)}\right) \qquad (3)$$

Note that if the fleet operates cooperatively, so that the assumption of independence is violated, the "effective" fleet size that should be substituted in the above equations is less than n.

It is clear from (2) and (3) above that as the population declines, the number of days when a target animal is not caught will increase, and thus declines in catch per net catcher day will underestimate the true population decline. To quantify the degree of underestimation, Table 1 shows the ratios of the expected proportional decline measured by catches per net catcher day to the true population decline. These are calculated for varying true proportional population declines and initial expected catches per gross catcher day, for fleet sizes of 1, 5 and 10.

Table 1

Values of $E \dfrac{C_t/x'_o}{C_o/x'_o} \Big/ \dfrac{P_t}{P_o}$

(a) n = 1

		Expected initial catch per gross catcher day			
		0.5	1.0	5.0	10.0
	0.75	1.258	1.198	1.017	1.001
P_t/P_o	0.50	1.779	1.607	1.082	1.007
	0.25	3.349	2.858	1.392	1.089

(b) n = 5

		Expected initial catch per gross catcher day			
		0.5	1.0	5.0	10.0
	0.75	1.084	1.017	1.000	1.000
P_t/P_o	0.50	1.287	1.082	1.000	1.000
	0.25	1.975	1.392	1.002	1.000

(c) n = 10

		Expected initial catch per gross catcher day			
		0.5	1.0	5.0	10.0
	0.75	1.017	1.001	1.000	1.000
P_t/P_o	0.50	1.082	1.007	1.000	1.000
	0.25	1.392	1.089	1.000	1.000

This table shows that if the expected initial catch per gross catcher day is 1.0 or less, then serious underestimation of the decline in the population will result for small fleet sizes. If only net catcher day data are available, expected catches per net catcher day may be converted to expected catches per gross catcher day.

For a fleet size of 1, we have approximately

$$E(C/x') = \frac{qP}{1 - e^{-qP}}$$

so that

$$E(C/x') = \frac{E(C/x)}{1 - e^{-E(C/x)}} \qquad (4)$$

This equation may be solved iteratively for E(C/x). Some conversions are given in Table 2. If the fleet size is more than one, the conversion factors apply to expected catches per net or gross "fleet" days. These conversion factors suggest the possibility of calculating modifiers to convert net to gross catcher days. The following example illustrates the application of these modifiers.

Table 2

Conversions of catch per net catcher day (C/NCD) to catch per gross catcher day (C/GCD) for one vessel

C/NCD	10.0	5.0	2.0	1.75	1.50	1.20	1.10
C/GCD	10.000	4.965	1.594	1.247	0.874	0.376	0.194

EXAMPLE

Starting with an initial population of 20,000 animals, the catch per net catcher day resulting from 100 gross catcher days from one vessel was simulated. Each subsequent year the population was reduced by a factor 0.07, and the resulting catches per net catcher day simulated, using q = 0.0001. The results of the simulation are given in Table 3. The corresponding catches per gross catcher day were estimated from (4) above.

Table 3

Simulation of catches per net catcher day

Year	Population size	C/NCD	Estimated C/GCD
1	20,000	2.30	1.984
2	18,600	2.30	1.984
3	17,298	2.09	1.713
4	16,087	2.07	1.687
5	14,961	1.80	1.318
6	13,914	1.89	1.444
7	12,940	1.76	1.262
8	12,034	1.75	1.247
9	11,192	1.66	1.116
10	10,408	1.50	0.874
11	9,680	1.58	0.997
12	9,002	1.57	0.982
13	8,372	1.42	0.748
14	7,786	1.32	0.584
15	7,241	1.43	0.764
16	6,734	1.33	0.600
17	6,263	1.34	0.617
18	5,824	1.40	0.715
19	5,417	1.37	0.667
20	5,937	1.20	0.376

A log linear regression analysis was performed on the estimated catch per gross catcher day data, yielding an estimated reduction of 0.072 (true value 0.070) and an estimated ratio of final to initial population sizes of 0.244 (true value 0.252). Contrast the closeness of the latter estimate to its true value with the raw estimate 1.2/2.3 = 0.522 from the catch per net catcher day data.

The value of q chosen for the simulation was such that the expected catch per gross catcher day ranged from 2.0 down to 0.5, in which case it was to be expected that there would be considerable differences between the catches per net and gross catcher days. Inspection of Table 2 suggests that had a higher value of q been chosen, the differences would not have been nearly as marked.

DISCUSSION

We have seen that provided only the target species is caught, the use of net rather than gross catcher days as a unit of effort may in some circumstances lead to severe underestimation of the rate of decline of a population. In principle the same applies when more than one species is taken, but in this case the serious question is whether catch per gross or net catcher day still provides a reliable index of population size. Clearly the catch per unit effort of a species incidental to the main catch is *not* a reliable index of the density of the incidentally caught species. An example of this is provided by the pelagic sperm whaling operations prior to the change in size limit.

During the 1960s, with a 35 ft size limit in force and without sex differentiated quotas, the catch of female sperm whales in pelagic operations was certainly an incidental catch, with the target animals being male sperm whales. In this case, it would seem most appropriate to simply subtract, from the time actively hunting males, those periods of time between the first decision to catch a female and the recommencement of searching for males. An approach similar to this was taken at the Special Meeting on North Pacific sperm whales at Cronulla, Australia, 1977. This approach assumes that hunting takes place always in areas where males may be expected and are the target catch. It is not quite as clear that this applies, at least for the North Pacific in the last few years, with separate quotas for each sex of whale, and in particular sizeable quotas for females. Note that the word "target" used here indicates both that male sperm whales are the desired catch, and that it is this population (and not females, the incidental catch) for which population estimates are to be made from the catch and effort data. As an aside, it should also be noted that the definition of a net catcher day is also cloudy for sperm whales – a net catcher day is a day when a sperm whale (of either sex) is caught.

Right at the other end of the scale lies the historical blue and fin whale fishery. In that fishery, as blue whale availability declined, the fleets progressively began to concentrate on fin whales, and in fact eventually began to concentrate on sei whales when fins declined. Here there is certainly no incidental catch. Both blue and fin whales were desired species. One could still take the above approach if blues and fins were randomly dispersed over the hunting grounds, but we know this is not the case. Given the aggregational behaviour of whales, if a concentration of (say) blue whales was found, fin whales would be effectively forgotten until as many blue whales as possible could be taken, and it is quite likely that the area would then also be searched for further blue whales. Thus simply subtracting the time spent catching blue whales from the fin whale effort will not be appropriate.

This leads to consideration of a final point. Not only are there local concentrations of one species (or sex) of whale, there are also areas in which a single species predominates. It is this fact that allows some progress to be made. Provided the predominating population in an area is not an isolated pool unable to be replenished by whales of the same species outside the area, catch per unit effort data from this area may be used to estimate the overall population size of that species. This is likely to lead to more reliable estimation (given the above proviso) due to the greater reliability of the effort data.

In conclusion, if the species of interest predominates in the catch, the gross catcher day suitably adjusted for the time spent on incidental catches probably provides a reliable measure of effort. If further the average catch per gross catcher day is relatively large, the use of net catcher days will not greatly bias the detection of declines in population abundance, and in any case approximate factors for conversion of net to gross catcher days are available. In circumstances when no more than one species is actively sought, raw catches per catcher day may not be reliable indicators of population abundance, and the detailed daily records of fleet operations will need to be studied.

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SC/30/Doc 13

The Effects of Interspecific Competition on the Choice of Management Policies for Fin and Sei Whales

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ABSTRACT

The effects of interspecific competition on the stability of baleen whale populations managed in different ways is considered, using the Icelandic industry as an example and evaluating the effects at the critical point on the yield surface. The stability of exploited fin and sei whale populations is affected little by the degree of competition if effort quotas are used for each species. If a fixed quota is set for each species, or if a joint quota is used, stability is low if there is little competition between the two species. At higher levels of competition fixed quotas can produce an acceptable level of stability, however, the potential yield in these circumstances is considerably less than the yield if there is no competition. The joint quota system is always more stable than one based on separate quotas.

INTRODUCTION

The diets of blue, fin, sei and minke whales overlap to varying degrees (Mitchell, 1975; Nemoto & Kawamura, 1977), and changes in the numbers of any one species are likely to influence the dynamics of the others. Gambell (1975) has described the effects of changes in the size of the Antarctic fin whale population on the reproductive parameters of sei whales. The importance of these interspecific effects has raised some doubts about the value of single-species models which ignore them (Beddington, 1978a). Horwood (1978) incorporated the biomass of other baleen whale species in a model of the dynamics of Antarctic sei whales; however, he effectively assumed complete overlap between all the species involved. Theoretically, predation can affect the degree of competition that can be tolerated by two species (Cramer & May, 1972; Fujii, 1977), and it is worth considering the effects of competition on the outcome of different management policies. If all possible species are considered simultaneously a plethora of parameters and possible equilibria is generated. More insight can be gained by considering a simpler system, and the Icelandic whaling industry provides a good example. Fin and sei whales appear to be the most abundant species to the west of Iceland – although the numbers of minke whales are not known – and the operation of the industry is well documented (Rørvik, Jónsson, Mathisen & Jonsgård, 1976).

BASIC MODEL

If we consider only adult animals, and assume that the minimum calving interval is two years, then the dynamics of unexploited Icelandic fin and sei whales may be represented by a pair of time-lagged Lotka-Volterra equations:

$$F_{t+1} = 0.96F_t + 0.96^8F_{t-8}$$
$$\times (0.25 - \beta_1(F_{t-8} + \alpha_1 S_{t-8})/K_1)$$
$$S_{t+1} = 0.94S_t + 0.94^8S_{t-8}$$
$$\times (0.25 - \beta_2(S_{t-8} + \alpha_2 F_{t-8})/K_2)$$

where α's are competition coefficients and K's are carrying capacities. Because the average metabolic requirement of a fin whale is approximately eight times that of a sei whale (Lockyer, 1978) these equations can be simplified:

$$F_{t+1} = 0.96F_t + 0.96^8F_{t-8}$$
$$\times (0.25 - b_1(F_{t-8} + \alpha S_{t-8}/8))$$
$$S_{t+1} = 0.94S_t + 0.94^8S_{t-8}$$
$$\times (0.25 - b_2(S_{t-8} + \alpha 8F_{t-8}))$$

Assuming that only adult animals are taken by the industry, the implementation of a fixed quota for each species changes the first term on the right-hand side of each equation to:

$0.96(F_t - Q_f)$ for fin whales

and to

$0.94(S_t - Q_s)$ for sei whales

since one fin whale yields approximately 2.8 times as much muscle as one sei whale (figures from Lockyer, 1976), the actual yield is $(2.8Q_f + Q_s)$. For any particular value of this yield there are an infinite number of equilibrium values for F and S. However, at the stationary point (where $(\delta Y/\delta F) = (\delta Y/\delta S) = 0$, see Appendix 1) only a single pair of values of F and S is possible. For simplicity I shall consider this case although the behaviour at this point does not completely characterise the system. The joint yield at this point is a maximum for

$\alpha < \sqrt{5.46b_1b_2}/(0.26b_1 + 5.19b_2)$,

for greater values of α there is a saddle point.

Since fixed quotas produce fragile equilibria (Clark, 1976; Beddington & May, 1977) I consider two other management policies:

If the number of each species to be taken is set by an effort quota the first term on the right-hand side becomes:

$0.96F_t(1 - E_f)$ for fin whales

and

$0.94S_t(1 - E_s)$ for sei whales.

This assumes a linear relationship between catch and effort. Because effort quotas may be difficult to implement, an alternative policy is to set a joint quota for the two species. This is particularly easy to use in Iceland where the majority of sei whales arrive late in the season. If a certain amount of effort is set aside for fin whales and the remainder of the quota is filled with sei whales, the two expressions become:

$0.96F_t(1 - E_f)$ for fin whales

and

$0.94(S_t - (Q - 2.8E_fF_t))$ for sei whales.

Q is the size of the joint quota.

EVALUATION

One method of evaluating these three policies at the critical point is to examine the behaviour of the equilibrium populations following a small pertubation (Appendix 2). This can provide an indication of the stability of the equilibria (Holling, 1973). This analysis gives some insight into the relative sensitivity of the equilibrium populations to environmental fluctuations. The stability properties depend only on the value of α; for an unexploited population stability declines rapidly as competition increases (Fig. 1) a familiar result from models which do not incorporate time lags (May, 1976). The level of stability is low for values of α in excess of 0.2, and it is unlikely that the competition effects between the two species are greater than this. The effects of exploitation over the likely range of α are shown in Fig. 2. Exploitation can increase stability as the degree of competition increases. However, this is at the expense of yield. Interspecific competition inevitably decreases the potential yield from a population (Clarke, 1976); in this example the yield at the critical point decreases markedly as the degree of competition increases. Stability under the effort system varies little with the degree of competition. Both fixed and joint quotas have low stability when competition is slight, but the joint quota is always more stable. At higher levels of competition all three policies have similar levels of stability. Since it is very difficult to estimate the actual value of α, the effort system must be preferred. If this is difficult to implement, a joint quota is better than a fixed quota, but its stabilising properties depend on there being a considerable degree of competition between the two species.

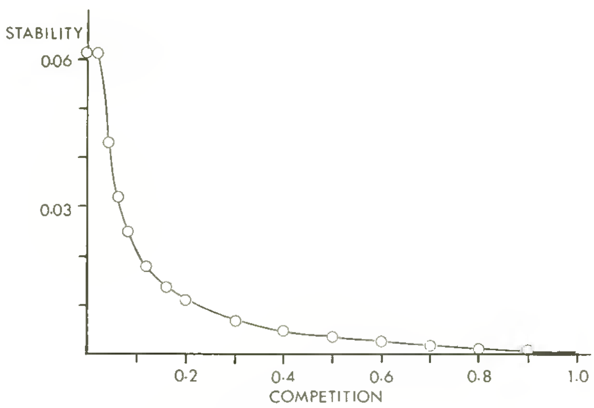

Fig. 1. The effect of degree of competition on the stability (as indicated by $|\ln \lambda_1|$ – see Appendix 2) of competing populations of fin and sei whales.

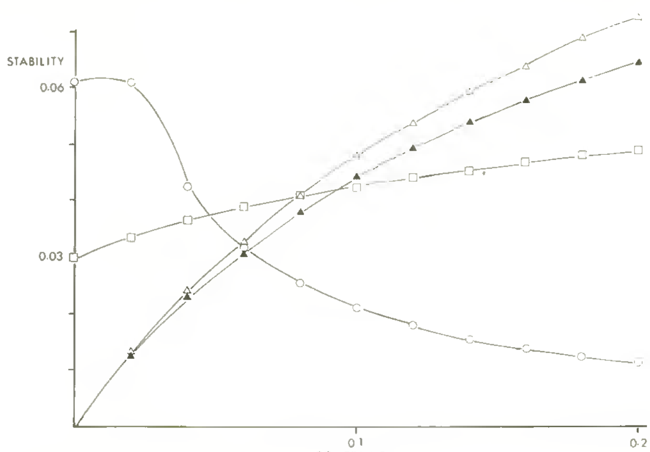

Fig. 2. The effect of competition and management policy on the stability (as indicated by $|\ln \lambda_1|$) of competing populations of fin and sei whales.

–○– unexploited. –△– fixed quota.
–□– effort quota. –▲– joint quota.

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Appendix 1

In the unexploited condition equilibrium occurs when:

$$F^* = \frac{1.556b_2 - 0.152\alpha b_1}{8b_1b_2(1-\alpha^2)}$$

$$S^* = \frac{0.152b_1 - 1.556\alpha b_2}{b_1b_2(1-\alpha^2)}$$

If we assume that the Antarctic population levels in the 1930s represent unexploited equilibrium levels, we can use the fact that $F^* = 3S^*$ to write b_2 in terms of b_1 and α. With a fixed quota:

$$Q_f = \frac{0.96^7}{8}(1.556 - b_1(8F^* + \alpha S^*))F^*$$

$$Q_s = 0.94^7(0.152 - b_2(8\alpha F^* + S^*))S^*$$

at equilibrium. Total yield (Q) is $(2.8Q_f + Q_s)$.

When $\frac{\delta Q}{\delta F^*} = 0 = \frac{\delta Q}{\delta S^*}$

$$F^* = \frac{3.112b_2 - 0.152\alpha A}{32b_1b_2 - \alpha^2 AB}$$

$$S^* = \frac{2.425b_1 - 1.556\alpha B}{32b_1b_2 - \alpha^2 AB}$$

where $A = (b_1 + 19.720b_2)$ and $B = (8b_2 + 0.406b_1)$.

The equilibrium conditions elsewhere are more complex due to the non-linearity of the equations, but they can be determined.

Appendix 2

In time honoured fashion (e.g. Beddington, 1978b) consider the effects of small deviations f and s from the equilibrium values F^* and S^*, taking the effort quota as an example:

$$F^* + f_{t+1} = 0.96(F^* + f_t)(1 - E_f) + 0.96^8(F^* + f_{t-8}) \times (0.25 - b_1(F^* + f_{t-8})) - \frac{0.96^8}{8} \times \alpha b_1(F^* + f_{t-8})(S^* + s_{t-8})$$

and similarly for sei whales. Ignoring cross-product terms in f and s we get:

$$f_{t+1} = 0.96(1 - E_f)f_t + 0.96^8\left(0.25 - 2b_1F^* - \frac{\alpha b_1}{8}S^*\right) \times f_{t-8} - 0.96^8\frac{\alpha b_1}{8}F^*s_{t-8} \quad (1)$$

$$s_{t+1} = 0.94(1 - E_s)s_t + 0.94^8(0.25 - 2b_2S^* - \alpha b_2 8F^*) \times s_{t-8} - 0.94^8\alpha b_2 8S^*f_{t-8} \quad (2)$$

The general form of these equations is.

$$f_{t+1} = a_1f_t + b_{11}f_{t-8} + b_{12}s_{t-8}$$

$$s_{t+1} = a_2s_t + b_{21}f_{t-8} + b_{22}s_{t-8}$$

Their characteristic equation is:

$$\lambda^{18} - (a_1 + a_2)\lambda^{17} + a_1a_2\lambda^{16} - (b_{11} + b_{22})\lambda^9 + (a_1b_{22} + a_2b_{11})\lambda^8 + (b_{11}b_{22} - b_{12}b_{21}) = 0$$

The condition for the populations to return to equilibrium is that all roots of the polynomial lie within the unit circle. The rate of return will be dominated by the largest root (λ_1), the closer it is to unity the slower the rate of return. Thus the absolute value of ln λ_1 is a crude indicator of the resistance of the population to small perturbations. It is only a crude indicator because the other roots for the matrix play a role in the return, and these tend to be large (and thus important) for certain management policies.

SC/30/Doc 18

Risk and Stability in Whale Harvesting

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INTRODUCTION

In earlier studies (Beddington and May, 1977; Beddington, 1978) the suggestion was made that the characteristic return time of a population model could be used as a measure of the relative stability of a harvested system, short return times occurring where a system is substantially damped and able to absorb random perturbations, long return times occurring in systems where random perturbations can play a dominant role. Application of these ideas to a model in use for sei whale management indicated that there was an increase in the return time as harvesting levels increased beyond 50% of the MSY level. It was suggested that the return time could act as a qualitative measure of the safety of the management regime, being correlated with the mean time $\bar{t}$ to move to protection status from some specified population level. Clearly to assess the degree of safety of the management regime, some quantitative measure of the tendency of the stock to be reduced to protection status should be obtained. Horwood, Knights & Overy (1978) attempted to quantify this using Monte Carlo techniques to estimate $\bar{t}$ and have concluded from their analysis that "the present IWC management policy" . . . "does not endanger the stocks of whales with respect to random fluctuations in density". They of course recognised that their results were dependent upon the amount of variability and thus their rather unequivocal conclusion is somewhat qualified. In this paper the problem of the safety of whale management strategies in the face of environmental variability is considered with somewhat different conclusions. The estimates of $\bar{t}$ of Horwood *et al.* are shown to depend upon the problematic assumption that natural mortality is invariant with time. As emphasised in Beddington (1977) environmental variability can be measured as the variability on the birth and death rates of the population. The Horwood *et al.* study excludes any variation in natural mortality, but inclusion of even rather a small amount of variability in the natural mortality rate changes the results substantially. Finally, the utility of $\bar{t}$ as a measure of the safety of the regime is questioned. It is shown that the frequency distribution of times to protection are far from normal and change markedly with slight changes in parameters. Accordingly the mean is a very poor measure of the risk of the system moving to protected status. An alternative measure using the probability of the population moving to protection in t years is investigated as an improved alternative. It is concluded that there is still a need as suggested by Doubleday (1976), Sissenwine (1977), Beddington & May (1977) and Beddington (1977) to compromise between yield and safety. Particularly so as the results shown are all based on the assumption of perfect information about stock performance and dynamics.

MODEL AND RESULTS

The model used is the difference equation analysed by Beddington (1977) and is typical of those used in baleen whale studies.

$$N_{t+1} + S(N_t - C_t) + S^k N_{t-k} P_{t-k} \qquad (1)$$

in which the stock at time t + 1, N_{t+1}, derives from that of the previous year, N_t, modified by exploitation, C_t, and by mortality, 1 – S, as well as from recruitment. The latter is controlled by the pregnancy rate k years previously, P_{t-k}, so that k is the age of sexual maturity. We may approximate P as a non-linear function of the current adult stock, such that:

$$P_{t-k} = \tfrac{1}{2}(a + b(1 - (N_{t-k}/N_0)^Z)) \qquad (2)$$

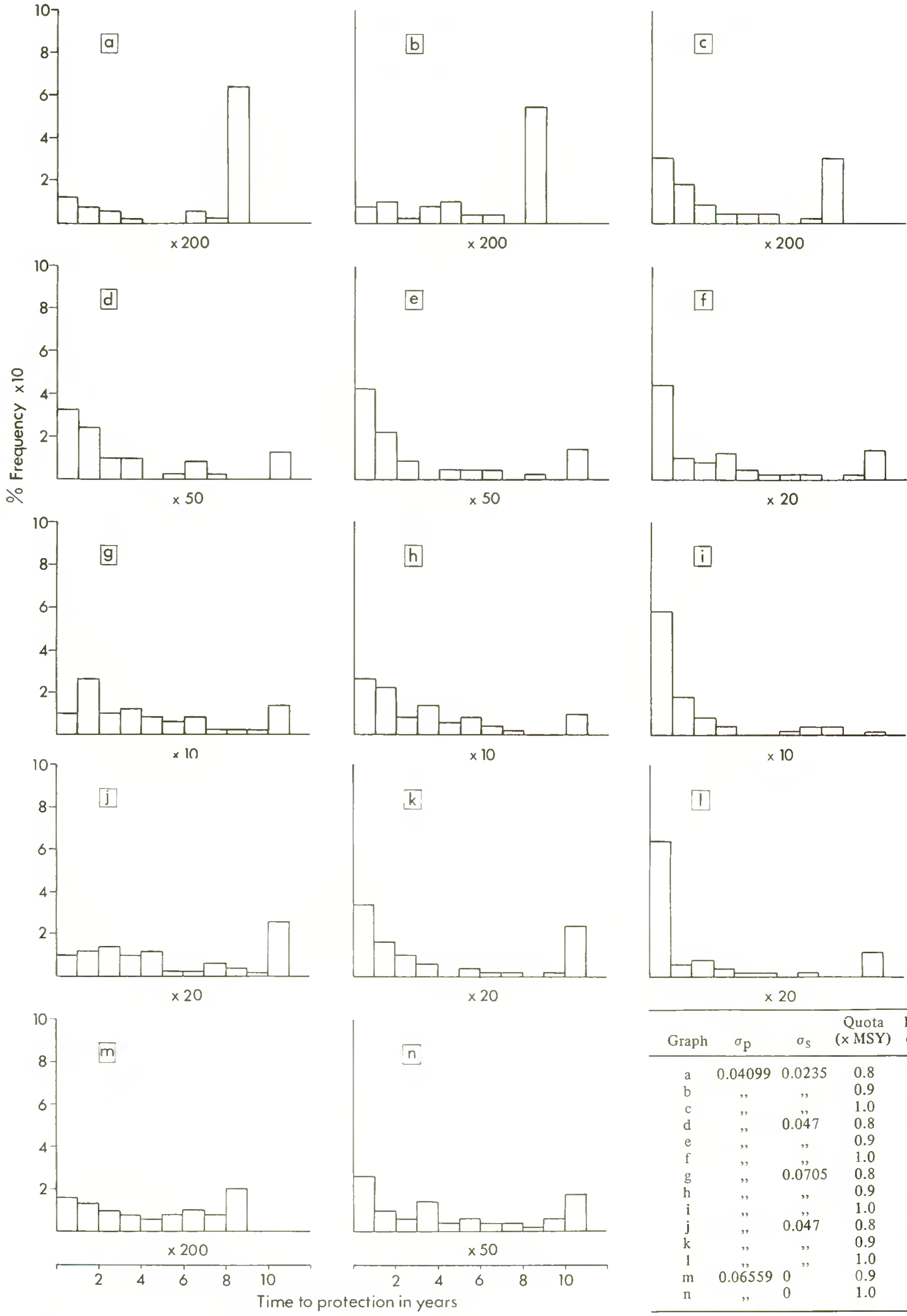
In particular, for baleen whales,

No = 20,000
S = 0.94
k = 8
a = 0.1968
b = 0.186
Z = 2.39.

Monte Carlo simulations were performed using a range of harvesting levels and strategies. The IWC strategy of harvesting Initial Management Stocks at 5% and stocks below MSY level at a reduced level were included as options. Noise was introduced into the model by assuming that both the proportional yearly survival S and the number of female births $\bar{P}$ were normally distributed random variables; $S \sim N(0.94, \sigma_s^2)$, $P \sim N(\bar{P}, \sigma_p^2)$, where $\bar{P}$ is the calculated pregnancy rate from equation 2.

A range of values for σ_s of 0.235–0.705 was chosen to give a mean deviation of approximately 2%–6%, for σ_p the range chosen was 0.04099–0.06559 giving a mean deviation of 20%–32%. It was assumed that random variations affected all age specific mortality rates synchronously; accordingly the overall survival to recruitment in any year was determined by the product of the k previous survival rates.

For each harvesting level, management strategy option and noise level the mean time to protection and the distribution of times to protection of a series of 50 runs was calculated. The main results are given in Table 1 and Fig. 1. In Table 1, although details vary, the pattern of behaviour of both the mean time to protection and the probability of movement to protection after a fixed period can be seen to be reflected by the characteristic return time of the model. What is perhaps more important is the observation that the mean time to protection is a very poor measure of the safety of the management regime. This is illustrated drama-



Graph	σ_p	σ_s	Quota (x MSY)	Lower cutoff
a	0.04099	0.0235	0.8	YES
b	,,	,,	0.9	,,
c	,,	,,	1.0	,,
d	,,	0.047	0.8	,,
e	,,	,,	0.9	,,
f	,,	,,	1.0	,,
g	,,	0.0705	0.8	,,
h	,,	,,	0.9	,,
i	,,	,,	1.0	,,
j	,,	0.047	0.8	NO
k	,,	,,	0.9	,,
l	,,	,,	1.0	,,
m	0.06559	0	0.9	YES
n	,,	0	1.0	,,

Fig. 1. Frequency histograms for t, the time to protection.
The upper tails of the distributions are truncated into the last frequency class.

Table 1

Estimates of t (upper figure) and probability of movement to protection after 10 years (lower figure).

		σ_p = 0.04099 Harvesting level as proportion of MSY			σ_p = 0.06559 Harvesting level as proportion of MSY		
	σ_s	0.8	0.9	1.0	0.8	0.9	1.0
Reduced harvest below MSY level	0.0235	1471.24 0	1359.56 0	842.7 0.02	798.56 0	364.26 0	133.18 0.18
	0.047	248.2 0	244.06 0.08	141.42 0.22	131.3 0.06	130.02 0.06	69.68 0.36
	0.0705	61.68 0.1	52.94 0.24	19.6 0.58	40.3 0.16	38.12 0.2	15.24 0.58
No reduced harvest below MSY level	0.0235	1196.36 0	608.66 0	195.44 0.06	441.22 0	234.66 0.02	63.02 0.42
	0.047	191.98 0.04	218.14 0.12	91.58 0.06	181.02 0	69.14 0.1	28.36 0.64
	0.0705	56.34 0.16	37.58 0.18	15.6 0.7	48.86 0.16	29.56 0.28	15.54 0.66

tically for the medium variance case where a mean time to protection at MSY harvesting level is estimated as 141.42, but that there is a probability of 0.22 that protection will occur before ten years. The changing shape of the frequency distribution of these times to protection with different values of environmental variance and harvesting strategies is well illustrated in Fig. 1. It may be concluded that an appropriate measure to assess risk is the probability of movement to protection after some specified time. However, it should be emphasised that even if this statistic has a high sampling variance more extensive simulation experiments should be performed to estimate it accurately.

Whatever the management strategy employed, there would clearly be some delay before reassessment, so sample simulations were run both with and without delays. Unsurprisingly the delay appeared to be approximately additive to the time to protection and was ignored.

In Fig. 1 graphs (m) and (n) the frequency histograms obtained with no variance in mortality illustrate clearly the long tailed distribution of time to protection. They are similar to the results reported by Horwood *et al.* which implicitly reflect the same distribution. In particular, although these authors obtain a mean time to protection for MSY harvesting of 160 years seven of the twenty two simulations reach protection in twenty five years or less.

CONCLUDING REMARKS

It seems clear that the mean time is a poor measure of the resilience or safety of a management strategy for models of this type. The better measure suggested the probability of reaching protection after t years being much less liable to sampling error and being a better measure of risk. It is to be expected that similar results would be obtained for much depleted populations like the bowhead whale and simulation experiments aimed at assessing the likelihood of extinction should use a similar measure.

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SC/30/Doc 19

Taxonomic Status of the 'South-Western Stocks of Spinner Dolphin *Stenella Longirostris* and Spotted Dolphin *S. Attenuata*'

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ABSTRACT

Spinner dolphins, *Stenella longirostris,* and spotted dolphins, *S. attenuata,* from south of the equator in the eastern Pacific are modally different from dolphins of the same species just to the north in coloration, size, shape and skeleton. These populations, called here "southern spinner dolphin" and "southern spotted dolphin" are potential management entities.

At the time a workshop meeting to assess stocks of dolphins involved in the seine fishery for tropical tuna in the eastern tropical Pacific convened at La Jolla in August 1976 (SWFC, 1976), sketchy information was available for both the spinner dolphin, *S. longirostris,* and the spotted dolphin, *S. attenuata,* suggesting that animals observed south of the equator and west of the Galapagos Islands are morphologically different from those to the north and east. Pending further study, these tentatively identified "South-western stocks" were provisionally lumped with the offshore stocks of the respective species for assessment. The purpose of this report is to present the results of study of series of "Southwestern" spotted and spinner dolphins, with recommendations for partition of management units in the two species in the eastern Pacific.

SPINNER DOLPHIN

Several geographical forms of the spinner dolphin exist in the eastern tropical Pacific (Perrin, 1975a, 1975b). These include the "eastern spinner", occurring near the coast of Mexico, south to at least the equator and offshore several hundred miles. The range of the eastern spinner broadly overlaps that of the more offshore "whitebelly spinner", which extends west to about 145° W longitude. The "Costa Rican spinner" occurs only along the Pacific coast of Central America, and the "Hawaiian spinner" occurs close to shore around the Hawaiian Islands. These geographical forms were defined on the basis of shape, size, coloration and skeleton (Perrin, 1975a, 1975b) and have been considered to be more or less independent "stocks" for purposes of assessment and management (SWFC, 1976).

The first indication of existence of a morphologically distinct form of spinner dolphin south of the equator came from observations by W. E. Evans and D. W. Rice on a US–USSR cooperative whale-tagging cruise of the R/V *Vnushitel'nyi* in early 1975. They sighted several schools of spinner dolphins during the cruise (Fig. 1) and noted unusual coloration in animals seen south of the Galapagos. Both observers have had extensive prior field experience with spinner dolphins north of the equator. Following is an excerpt from Rice's field journal describing animals seen at about 4° S latitude, 99° W longitude on 13 March 1975:

> "These animals resembled Hawaiian spinner porpoises in their three-tone color pattern, but had shorter beaks. The lateral gray area was somewhat darker immediately adjacent to the sharply defined white belly, giving the appearance of a faint lateral stripe. The dorsal fins were high and triangular – even slightly canted forward on some of the larger ones. The animals appeared to have dark-tipped snouts and eye-to-flipper stripes."

Field sketches by both Evans and Rice and a photograph by Evans all show the ill-defined lateral stripe described by Rice and not seen by these or other observers as part of the color pattern of "whitebelly spinners" to the north.

Unusually marked spinner dolphins were seen again in February 1976 by W. A. Walker (also experienced in identifying spinner dolphins) during a survey cruise of the R/V *David Starr Jordan* (Fig. 2), at three locations south of the Galapagos. Following is an excerpt from his sighting notes for 15 February 1976:

> "These animals more closely resemble Hawaiian stock than those in vicinity of Clipperton [Island]. Lateral overlay of cape gives an almost stripe like effect running from eye to vent, . . .".
>
> "The border of the cape and lateral white field was distinct on these porpoise. No mottling was evident."

The summary report for the cruise[1] stated concerning the seven sightings of spinner dolphins during the cruise:

> "Four of the seven schools were classified as whitebelly spinners. All of these observations were slightly outside the historically understood boundaries. However, the three observations made at about 05°–06° S appear, from color pattern differences, to be a separate stock from those normally encountered in the far offshore waters from approximately 800 km offshore to 140° W longitude."

The observations from the cruises of the R/V *Vnushitel'nyi* and the R/V *David Starr Jordan* constituted the information available to the stock assessment workshop at La Jolla in August 1976 and were the basis for provisionally considering a "tentatively identified southwestern stock" (NMFS, 1977). Specimens collected south of the equator subsequently became available and have allowed further evaluation of the "southwestern stock".

MATERIALS AND METHODS

Treatment of Specimens

Fifteen frozen carcases of *S. longirostris* from south of the equator and west of 90°W longitude were available for study (Table 1). They were collected by NMFS observers during

[1] Barham, E. 1969. Cruise Report, R/V *David Starr Jordan,* Cruise J-76-1(100), Porpoise Cruise No. 169. Unpubl. Rep., Southwest Fisheries Center, La Jolla, Calif. 92038.

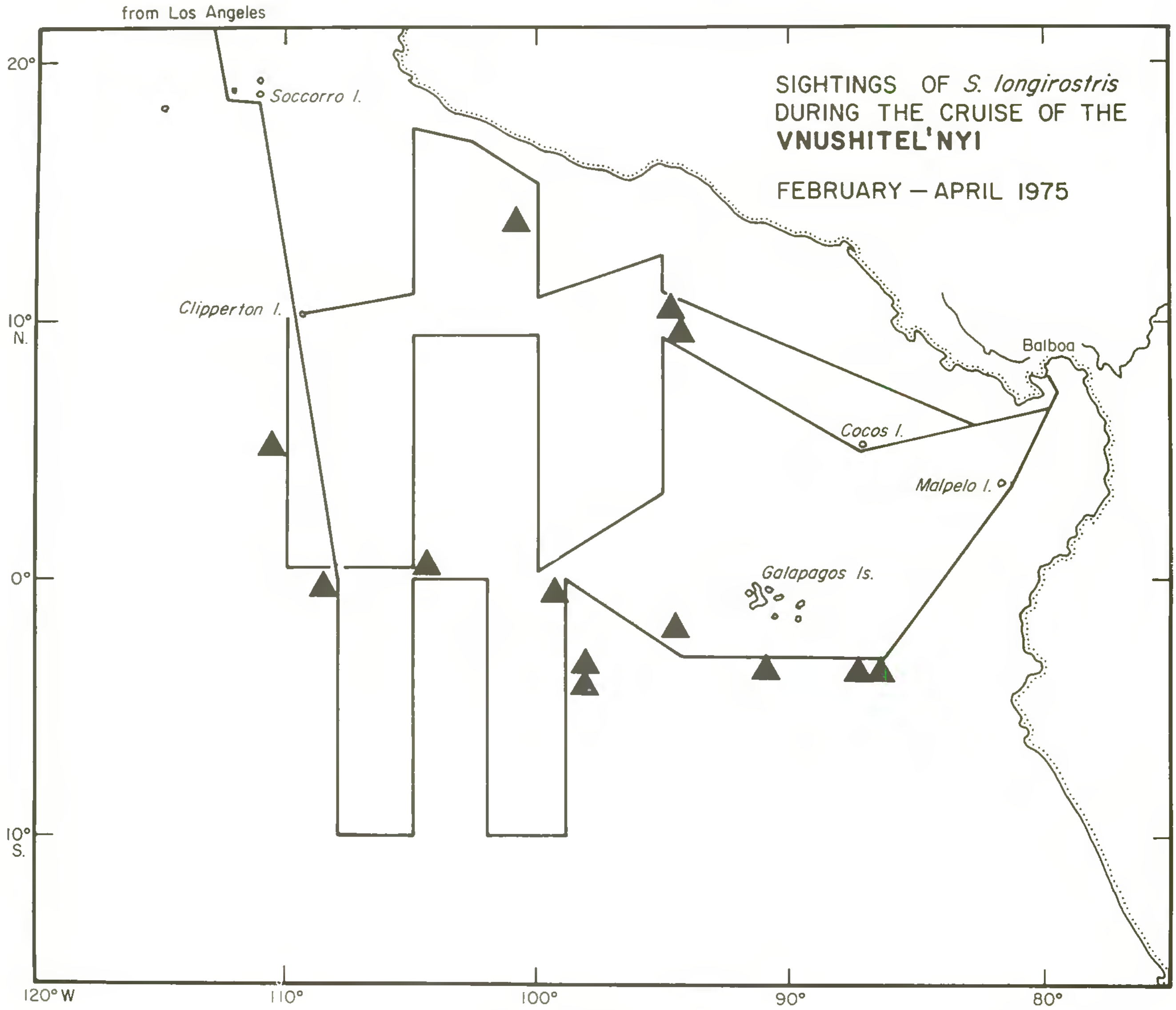

Fig. 1. Sightings of *Stenella longirostris* during the cruise of the *Vnushitel'nyi*, February to April 1975.

seining operations in early 1976. The specimens were thawed in water, weighed to the nearest pound on a platform balance, and photographed in color. External measurements were taken with a large set of calipers with adjustable jaws. Lengthwise measurements were taken parallel to the long axis of the body. Enough flesh was then removed from the carcase to allow vertebral counts to be made. The terminal 20–30 cm of the vertebral column was severed and x-rayed to determine the number of vertebrae. The flippers were also detached and x-rayed for phalangeal counts. The skulls were fleshed, sun-dried, and cleaned with dermestid beetles. Skull measurements were taken as described by Perrin (1975a). After measurement, the skulls were placed in the marine mammal collection of the Museum of Comparative Zoology, Harvard University, Cambridge, Mass. The postcranial skeletons were not saved.

In addition to the extensive data from the 15 whole specimens, a lesser set of data was available for 118 adult specimens (61 males and 57 females) examined at sea by government scientists aboard commercial tuna seiners in the area south of the equator and west of 90° W longitude (Fig. 3). These data included total length, reproductive condition (weight of testes for males; uterine, ovarian and lactation data for females), and, in some cases, field sketches and photographs.

RESULTS

Color Pattern

The modal color pattern (Fig. 4) indeed more resembles that of spinner dolphins from around Hawaii than that of the whitebelly spinner dolphin as described from north of the equator (Perrin, 1973, 1975a, 1975b), in two respects:

(1) The dorsal overlay is sufficiently light that the dorsal cape shows through distinctly, yielding a pronounced tripartite pattern, as opposed to a basically two-part pattern in the northern whitebelly form yielded by a more dense dorsal overlay; and
(2) the ventral margin of the dorsal overlay is relatively sharp and smooth, as compared to a usually more diffuse margin in the typical whitebelly spinner, again emphasizing the three-part character of the pattern.

The reported lateral stripe turns out not to be an actual stripe, but an increase in density of the dorsal overlay toward its ventral margin. On close inspection the animal does not have a well-defined stripe, but in the water it appears striped. Again, the appearance is quite like that of many Hawaiian spinners in this respect (Fig. 5).

The color pattern differences between this animal and the whitebelly spinner to the north are modal differences

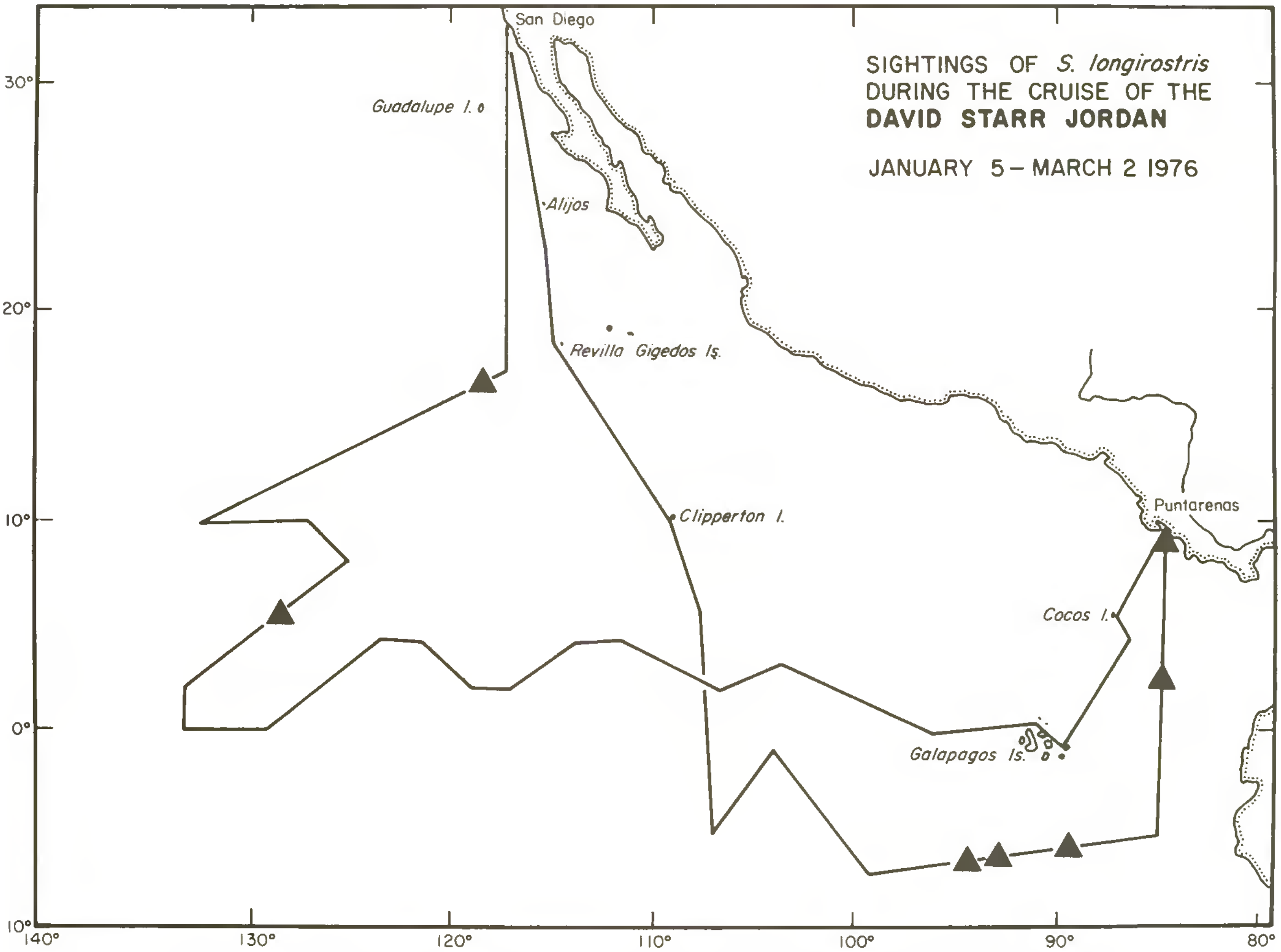

Fig.2. Sightings of *Stenella longirostris* during cruise of *David Starr Jordan,* 5 January to 2 March 1976.

and do not occur with the same density for every animal in the population. As is the case for populations where morphological characters vary in this manner geographically, some individuals from either of the adjacent areas (north or south of the equator) most resemble typical animals from the other area. For example, some of the 15 individuals examined here (specimen numbered DBF 026 in Fig. 4, for example) had a more dense dorsal overlay with a less-emphasized ventral margin than the others and appeared more "whitebelly-like".

External Size and Shape

Both males and females (Fig. 6) are on the average 2–3 cm longer than whitebelly spinners (Table 2 and Fig. 13 in Perrin, Holts and Miller, 1976), a statistically significant difference ($\alpha = 0.05$). The sample sizes for other external measurements (Table 2) are small, but the means for the "southwestern" series are greater than those for a similarly sized series of whitebelly spinners (Table 16 in Perrin, 1975a) for all the measurements except "tip of snout to blowhole", for which the means are the same. For the two external measurements which most reflect length of the beak, that is, "tip of snout to apex of melon" and "length of gape", the ranges for the series fall below the ranges for the small series of Hawaiian spinners, but for the remaining measurements the ranges overlap considerably, suggesting that while the "southwestern spinner", like the Hawaiian spinner, is on the average larger than the whitebelly spinner, its beak is not proportionately as long as that of the Hawaiian spinner, a finding consonant with the above-cited field observations.

The dorsal fin (Fig. 7) is shaped differently in males and females but is highly variable and not apparently different from that of the whitebelly spinner (Perrin, 1975a).

Skeleton

The means for nearly all the skull measurements (Table 3) fall between the means for whitebelly and Hawaiian spinners (Table 19 in Perrin, 1975). The exceptions are "premaxillary width at rostrum midlength" and "internal nares width", for which the "southwestern" means exceed the Hawaiian means. The "southwestern" skulls fall between the whitebelly series and Hawaiian series in shape as well as size, as shown by a scatterplot (Fig. 8) on two orthogonal discriminant axes based on all 25 measurements for Costa Rican, eastern, and whitebelly series (loading coefficients in Perrin, 1975).

SPOTTED DOLPHIN

As in the spinner dolphin, several geographical forms of the spotted dolphin, *Stenella attenuata*, exist in the eastern tropical Pacific (Perrin, 1975a, 1975b). A "coastal" form (formerly known as *S. graffmani*) is found close to shore from the Gulf of California to Colombia. Offshore and

Table 1

Collection data for whole frozen specimens of *S. longirostris* from south of the equator and west of 90° W longitude. Museum of Comparative Zoology (MCZ) number in parentheses

Specimen no.	Locality (lat./long.)	Date	Sex	Length (cm)
1. DBF 010 (57240)	4° 00′ S/94° 25′ W	30 Oct. 76	F	180
2. DBF 011 (57241)	,,	,,	M	170
3. DBF 012 (57242)	,,	,,	F	177
4. DBF 013 (57243)	,,	,,	M	183
5. DBF 017 (57244)	5° 05′ S/94° 26′ W	31 Oct. 76	M	183
6. DBF 020 (57245)	,,	,,	M	182
7. DBF 024 (57246)	,,	,,	F	170
8. DBF 026 (57247)	,,	,,	M	182
9. DBF 031 (57248)	,,	,,	F	187
10. DBF 035 (57249)	,,	,,	M	181
11. DBF 036 (57250)	,,	,,	M	188
12. DBF 038 (57251)	5° 25′ S/92° 33′ W	4 Nov. 76	M	186
13. DBF 040 (57252)	,,	,,	F	175
14. DBF 042 (57253)	3° 41′ S/92° 36′ W	6 Nov. 76	F	187
15. DBF 043 (57254)	,,	,,	F	177

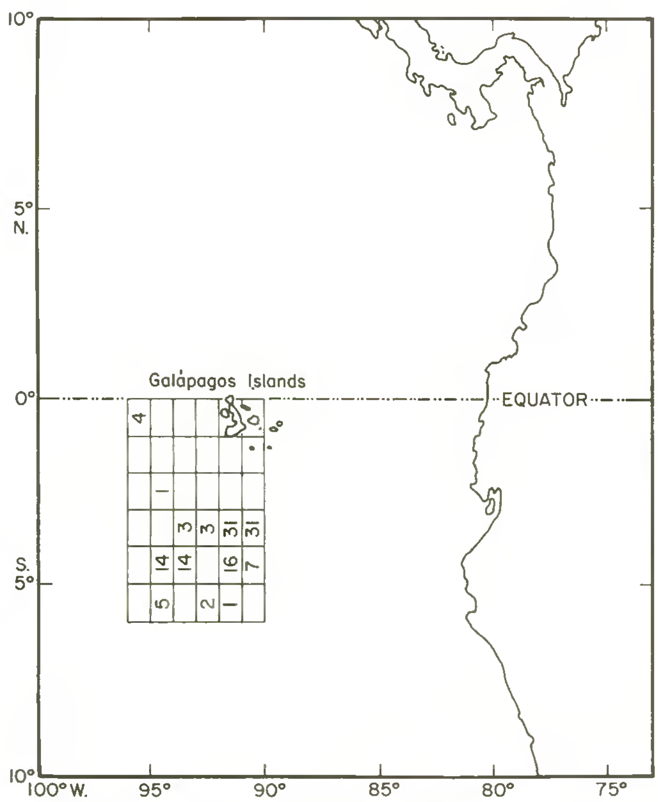

Fig. 3. Collection localities of 132 adult specimens of *Stenella longirostris* used in analysis of total length, by one-degree square areas.

north of the equator, the "offshore" spotted dolphin ranges west to about 145° W longitude. As for the spinner dolphin, the first indication of the existence of an additional geographical form south of the equator came from observations made on the R/V *Vnushitel'nyi* in 1975. One school of spotted dolphins was seen south of the equator during the cruise, at 00° 52′ S latitude, 98° 44′ W longitude. These animals had an overall lighter color pattern, with more contrasting elements, and were more lightly spotted than typical spotted dolphins to the north. W. E. Evans' field notes for the sighting on 17 March state:

> "All spotters looked like two-tone or speckled [early coloration growth phases in more northerly spotted dolphins (Perrin, 1970)] – cape very visible."

Such coloration is characteristic of spotted dolphins in the far-western regions of the range in the eastern Pacific and around Hawaii (Perrin, 1975a). Because of this seemingly parallel situation to that for the spinner dolphin, spotted dolphins south of the Galapagos were considered by the stock assessment workshop in 1976 in a provisional "southwestern stock" like that erected for the spinner dolphins (SWFC, 1976).

MATERIALS AND METHODS

Nineteen whole carcases (6 males and 13 females) were available for study, from two localities southwest of the Galapagos (Table 4). Treatment was the same as for the specimens of *S. longirostris.* Total length and color pattern data were available for 34 additional adult males and 78 adult females examined at sea aboard commercial tuna seiners (Fig. 9). Testis samples were not collected for the males examined at sea, so an approximate criterion of adulthood of 170 cm total length (see Perrin, Coe and Zweifel, 1976) was used for inclusion in the sample of "adult" animals here.

RESULTS

Color Pattern

Of the 11 specimens with "adult coloration" (defined in Perrin, 1970), 1 showed heavy dorsal spotting, 6 had medium spotting, and 4 had sparse spotting. This distribution is similar to that in spotted dolphins from the far-offshore portion of the range in the eastern Pacific (Perrin, 1975a). The animals were generally more heavily spotted, however, than animals from around Hawaii.

External Size and Shape

Spotted dolphins south of the equator are on the average about 2–1/2 cm shorter than those to the north. Not enough gonadal specimens have been collected to allow comparison of means for sexually mature adult males, but the 91 sexually mature females examined here (Fig. 10) averaged 184.8 cm, as opposed to 187.2 cm (range 165–211, SD 7.12) for 2,433 "offshore" females from north of the equator (data collected by government scientists aboard commercial tuna seiners). This difference is significant at the 0.1% level. Despite this overall lesser size, several anterior external measurements (Table 5), especially that of "tip of snout to anterior insertion of flipper" are comparable for specimens from north (Table 5 in Perrin, 1975a) and south of the equator, indicating that the southern animals have proportionately larger heads. This is supported by the skull measurements discussed below.

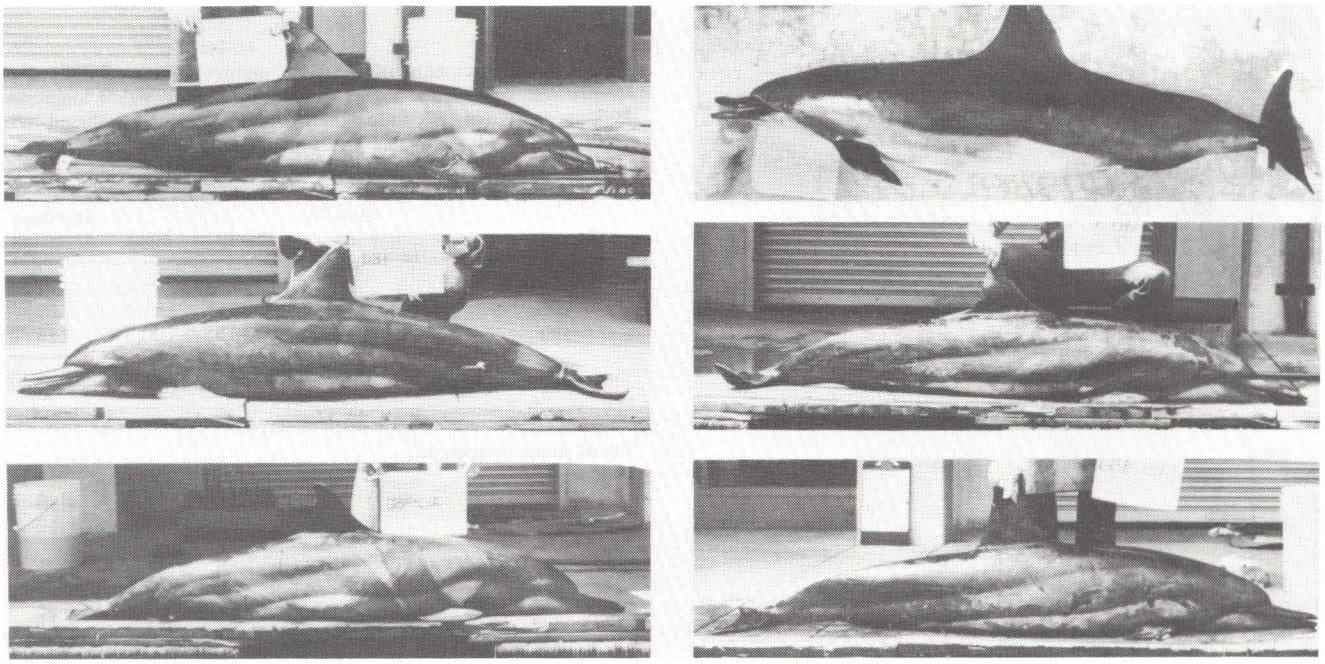

Fig. 4. External appearance (after freezing and thawing) of spinner dolphins from below the equator and west of 90° W longitude.

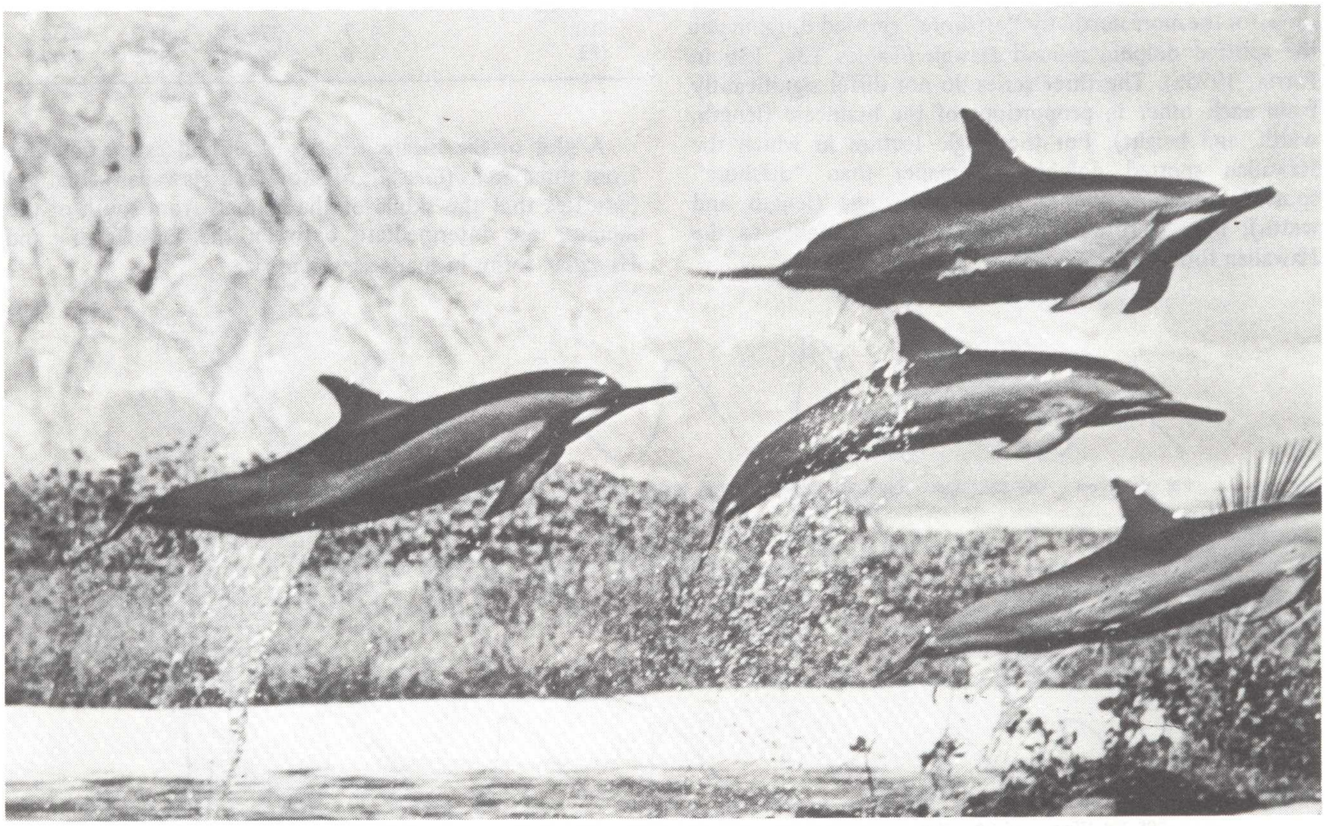

Fig. 5. Captive Hawaiian spinner dolphins.

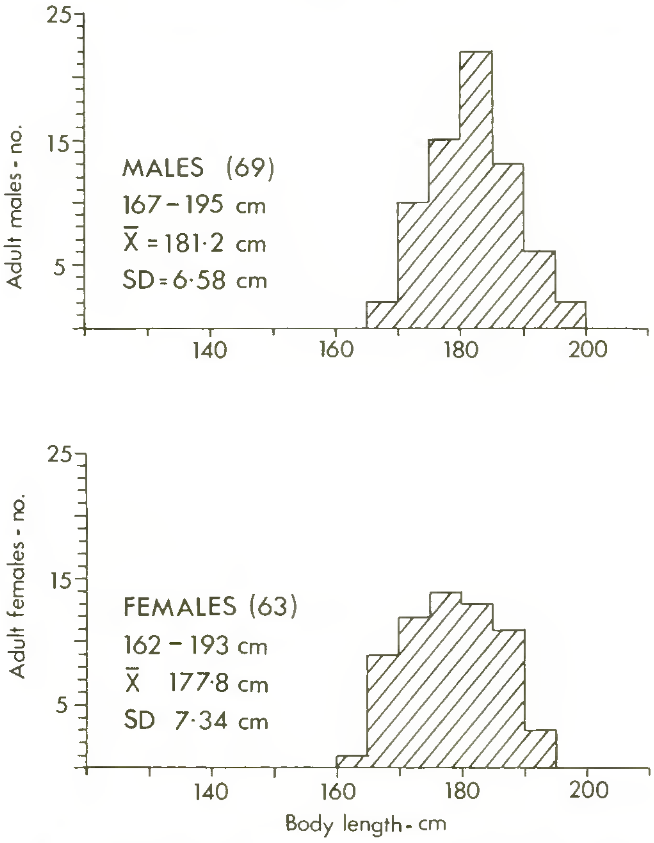

Fig. 6. Total length of adult spinner dolphins from south of the equator and west of 90° W longitude.

Skeleton

For most skull measurements, the means for the series of specimens from below the equator (Table 6) falls between those for the more northerly "offshore" spotted dolphin and the spotted dolphin around Hawaii (Tables 13a, 13b in Perrin, 1975a). The three series do not differ significantly from each other in proportions of the braincase (length, width, and height). For the single feature in which the Hawaiian spotted dolphin is smaller than "offshore" spotted dolphins, the post-temporal fossa (length and width), the "southwestern" series is comparable to the Hawaiian form.

Table 2

External measurements of sexually mature spinner dolphins, *S. longirostris*, from south of the equator and west of 90° W longitude. Measurements (in cm) follow Perrin (1975a). Males included have testis weight ≥94 g. Males and females pooled for dimensions in which spinner dolphin not sexually dimorphic (ibid.).

Measurement	Sample size	Range	Mean	Standard deviation
Total length				
(M)	7	170–186	181.0	5.03
(F)	6	175–187	180.3	5.15
Tip of snout to center eye	13	28–33	30.3	1.41
Tip of snout to apex of melon				
(M)	7	13–16	14.8	1.30
(F)	6	14–17	15.2	1.12
Length of gape	13	24–30	26.2	1.53
Tip of snout to blowhole	12	25–33	29.4	2.27
Tip of snout to anterior insertion of flipper	13	40–44	41.6	1.08
Tip of snout to tip of dorsal fin				
(M)	7	98–104	100.4	2.28
(F)	6	99–109	104.6	4.39
Tip of snout to umbilicus	13	84–95	88.8	3.81
Girth at axilla				
(M)	7	78–90	83.6	4.53
(F)	6	80–87	88.3	2.50
Flipper length to axilla	13	18–22	20.7	1.12
Fluke span				
(M)	7	37–45	41.3	3.36
(F)	6	36–41	38.5	2.07

A plot of the means for two skull indices for dolphins from three areas (coastal, offshore and Hawaiian) (Fig. 11) indicates that the skulls of the animals from south of the equator are intermediate between the far-offshore and Hawaiian forms in shape as well as size.

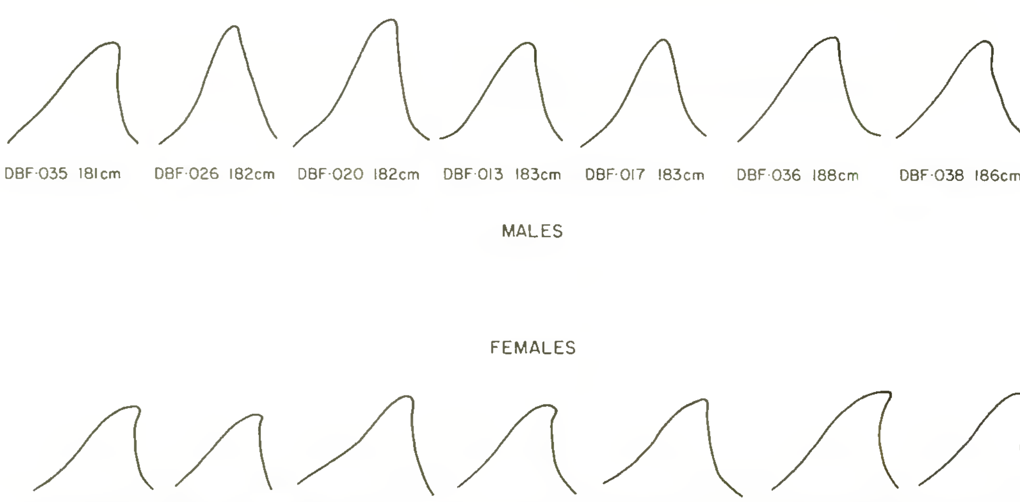

Fig. 7. Dorsal fins of male (upper) and female (lower) spinner dolphins from south of the equator and west of 90° W longitude. Specimen numbers and length (cm) given.

Table 3

Skeleton measurements (in mm) and meristics of spinner dolphins, *S. longirostris,* from south of equator and west of 90° W longitude. Numbering system follows Perrin (1975a). Sample for meristics includes all specimens, sample for measurements includes sexually mature specimens (using criterion of distal fusion of maxillaries and premaxillaries).

	Variable	Sample	Range	Mean	Standard deviation
1.	Condylobasal length	12	398–438	415.8	11.86
2.	Rostrum length	12	250–278	265.3	10.36
3.	Rostrum width at base	14	71–83	76.4	3.00
4.	Rostrum width at 60 mm	14	51–60	53.4	3.56
5.	Rostrum width at midlength	11	41–51	42.3	2.70
6.	Premaxillary width at rostrum midlength	12	17–23	20.8	1.89
7.	Rostrum width at ¾ length	12	29–36	32.0	2.17
8.	Rostrum tip to external nares	12	287–318	304.3	10.19
9.	Rostrum tip to internal nares	12	291–327	308.2	10.76
10.	Preorbital width	14	138–150	143.6	3.81
11.	Postorbital width	14	154–167	159.6	4.10
12.	Least supraorbital width				
13.	External nares width	14	38–46	42.1	2.24
14.	Zygomatic width	14	156–165	158.1	4.36
15.	Greatest width of premaxillaries	14	60–67	63.9	2.44
16.	Parietal width	14	123–139	130.4	5.04
17.	Braincase height	14	86–98	90.3	3.64
18.	Braincase length	14	102–113	105.2	3.42
19.	Posttemporal fossa length	14	41–56	49.9	4.31
20.	Posttemporal fossa width	14	37–45	41.3	2.12
25.	Orbit length	14	39–45	40.7	1.48
26.	Internal nares width	14	44–50	46.4	1.65
32.	Upper tooth row length	12	208–246	229.0	10.62
33–36.	Teeth (no.) U.L. | U.R. L.L. | L.R.	13 | 13 15 | 12	46–59 | 49–59 44–59 | 46–58	53.1 | 53.5 51.1 | 51.9	4.05 | 3.50 4.26 | 4.23
37.	Lower tooth row length	14	193–236	221.6	11.79
38.	Ramus length	14	322–374	351.4	13.34
39.	Ramus height	14	51–60	55.2	2.32
48.	Thoracic vertebrae (no.)	15	15–17	16.1	0.59
49.	Lumbar vertebrae (no.)	15	16–18	16.5	0.63
50.	Caudal vertebrae (no.)	15	32–38	34.5	1.40
51.	Total vertebrae (no.)	15	72–77	74.1	1.24

CONCLUSIONS AND RECOMMENDATIONS

The "southwestern" spinner dolphins are clearly modally different from the whitebelly spinners to the north and very much like the spinner dolphins around Hawaii, albeit with proportionately smaller beaks. This morphological difference between the animals north and south of the equator leads to the inference that some degree of genetic isolation exists, i.e., that the spinner dolphins south of the equator largely belong to a different breeding population than those to the north. This conclusion speaks for consideration of separate management of the apparent two populations.

Fig. 8. Plot of "southwestern" specimens (squares) on two discriminant axes based on 25 skull measurements (discriminant functions in Perrin, 1975a). Circled symbols are group means.

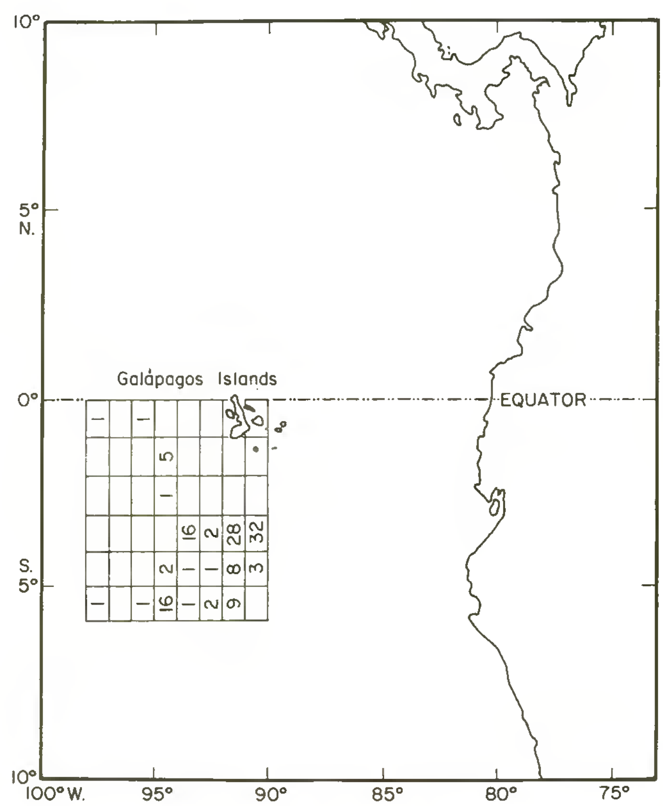

Fig. 9. Collection localities of 131 adult specimens of *Stenella attenuata* used in analysis of total length.

Table 4

Collection data for whole frozen specimens of *S. attenuata* from below the equator and west of 90° W longitude. Museum of Comparative Zoology number in parentheses.

Specimen no.	Locality (lat./long.)	Date	Sex	Length (cm)
1. DBF 014 (57257)	5° 05′ S/94° 26′ W	31 Oct. 76	F	171
2. DBF 015 (57258)	,,	,,	F	186
3. DBF 016 (57259)	,,	,,	M	176
4. DBF 018 (57260)	,,	,,	F	188
5. DBF 019 (57261)	,,	,,	F	188
6. DBF 021 (57262)	,,	,,	F	190
7. DBF 022 (57263)	,,	,,	F	189
8. DBF 023 (57264)	,,	,,	M	183
9. DBF 025 (57265)	,,	,,	F	188
10. DBF 027 (57266)	,,	,,	M	173
11. DBF 028 (57267)	,,	,,	F	179
12. DBF 029 (57268)	,,	,,	F	189
13. DBF 030 (57269)	,,	,,	M	204
14. DBF 032 (57270)	,,	,,	M	174
15. DBF 033 (57271)	,,	,,	F	177
16. DBF 034 (57272)	,,	,,	F	191
17. DBF 037 (57273)	5° 25′ S/92° 33′ W	4 Nov. 76	F	170
18. DBF 039 (57274)	,,	,,	F	187
19. DBF 040 (57275)	,,	,,	M	193

While the specimens analyzed here were nearly all collected in the single 5-degree block just southwest of the Galapagos, the distribution of reliable records of *S. longirostris* (Fig. 12) suggests a range extending south to about 12° S and from near the coast of South America west to at least about 103° W. Spinners observed in January 1977 at 11° 30′ S latitude, 93° 48′ W longitude on a research cruise of the R/V *David Starr Jordan* exhibited the typical "southwestern" color pattern (field notes of B. Lee). Sightings further to the west leave open the possibility that the distribution may be continuous with the range of spinner dolphins around the Marquesas Islands and elsewhere in the south Pacific. Specimens from the Marquesas and Tuamotus show affinities to the present specimens in that they are in some characters intermediate between the typical whitebelly and Hawaiian states, based on examination of photographs and sketches of several specimens collected by R. Costello and J. D. Bryant in that area in 1970 (K. S. Norris, University of California, Santa Cruz, pers. comm.). There is a near hiatus in records just below the Galapagos (Fig. 14), and a line drawn at 1° S latitude is a reasonable provisional northern boundary for the stock and the possible management unit. Since the range probably extends east to near the coast of South America, a better name for the stock than "southwestern spinner dolphin" is "southern spinner dolphin".

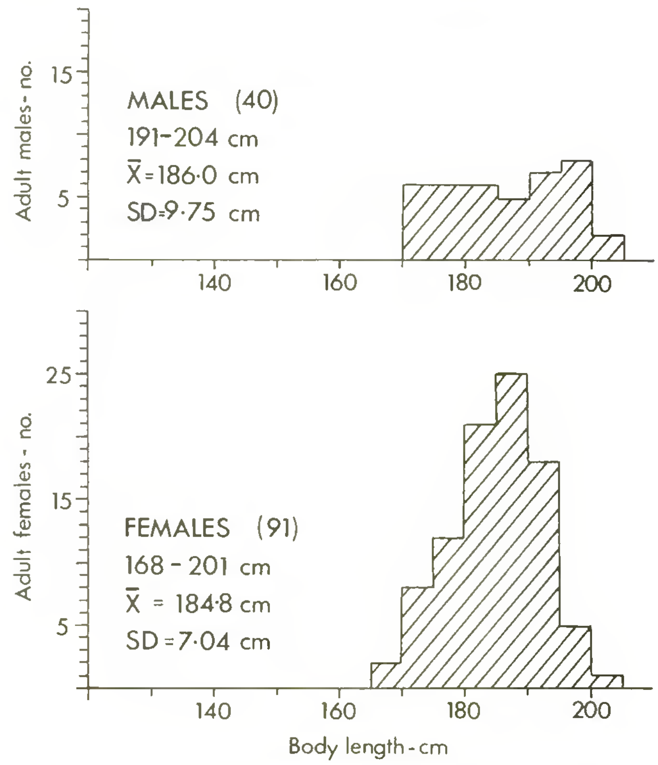

Fig. 10. Total length of adult spotted dolphins from south of the equator and west of 90° W longitude.

Table 5

External measurements (in cm) of adult spotted dolphins from south of the equator and west of 90° W longitude. Males with testis weight greater than 100 g, epidymis included (Perrin *et al.*, 1976).

Measurement	Sample size	Range	Mean	Standard deviation
Total length				
(M)	2	193–204	184.1	7.27
(F)	13	169.8–190.9		
Tip of snout to center of eye	15	25.0–28.4	27.2	0.86
Tip of snout to apex of melon				
(M)	2	8.4–10.8		
(F)	13	9.0–11.8	10.1	0.76
Length of gape	15	21.2–24.6	23.4	0.87
Tip of snout to blowhole	15	25.1–27.5	26.3	0.70
Tip of snout to anterior insertion of flipper	15	34.7–40.5	38.3	1.63
Tip of snout to tip of dorsal fin				
(M)	2	112.4–117.3		
(F)	13	73.1–111.1	104.3	9.59
Tip of snout to umbilicus	15	80.9–91.6	88.2	3.50
Girth at axilla				
(M)	2	82.5–86.5		
(F)	13	77.0–86.0	82.7	2.86
Flipper length to axilla	15	16.0–21.1	18.1	1.22
Fluke span				
(M)	2	42.0–44.0		
(F)	13	35.5–44.5	40.4	2.21

Table 6

Skeleton measurements (in mm) and meristics of adult spotted dolphins, *S. attenuata*, from south of the equator and west of 90° W longitude. Numbering system follows Perrin (1975a). Criteria of adulthood as for *S. attenuata* in Table 3.

	Variable	Sample	Range	Mean	Standard deviation
1.	Condylobasal length	17	382–414	398.9	8.98
2.	Rostrum length	17	228–257	239.8	7.24
3.	Rostrum width at base	17	79–91	84.4	3.10
4.	Rostrum width at 60 mm	17	54–62	58.2	2.10
5.	Rostrum width at midlength	17	38–46	43.8	2.10
6.	Premaxillary width at rostrum mid-length	17	20–25	23.2	1.33
7.	Rostrum width at ¾ length	16	25–34	29.6	2.22
8.	Rostrum tip to external nares	16	266–295	279.5	8.61
9.	Rostrum tip to internal nares	16	270–291	282.3	6.64
10.	Preorbital width	17	148–160	152.7	3.83
11.	Postorbital width	17	167–178	170.6	3.65
12.	Least supraorbital width				
13.	External nares width	17	40–47	43.1	2.58
14.	Zygomatic width	17	166–178	169.8	3.98
15.	Greatest width of premaxillaries	17	62–73	67.4	2.95
16.	Parietal width	17	125–147	137.4	5.62
17.	Braincase height	17	89–104	94.1	3.46
18.	Braincase length				
	(M)	5	110–116	113.8	2.48
	(F)	12	103–118	111.2	3.29
19.	Posttemporal fossa length	17	59–70	63.9	3.05
20.	Posttemporal fossa width	17	45–57	50.6	3.29
25.	Orbit length	17	45–50	47.9	1.61
26.	Internal nares width	17	46–52	49.1	1.74
32.	Upper tooth row length	17	194–221	205.4	6.58
33–36.	Teeth (no.) U.L. | U.R.	19 | 19	38–45 | 37–45	40.2 | 40.3	2.33 | 2.56
	L.L. | L.R.	18 | 18	35–43 | 36–42	38.7 | 38.6	1.97 | 1.85
37.	Lower tooth row length	17	189–219	200.5	7.31
38.	Ramus length	17	324–360	338.7	8.30
39.	Ramus height	17	54–60	56.3	2.25
48.	Thoracic vertebrae (no.)	19	15–17	16.1	0.70
49.	Lumbar vertebrae (no.)	19	17–21	19.2	1.08
50.	Caudal vertebrae (no.)	19	34–39	36.8	1.34
51.	Total vertebrae (no.)	19	78–82	79.1	1.14

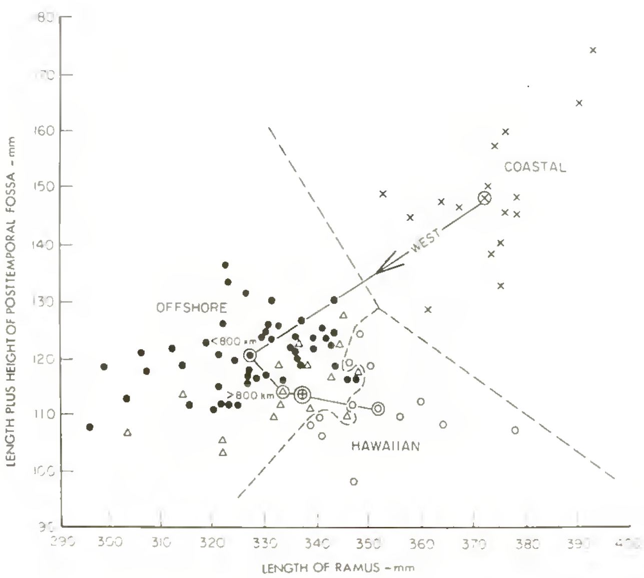

Fig. 11. Geographical variation in the skull of the spotted dolphin (from Perrin, 1975a), with mean for "southwestern" series (circled cross). Other sample means circled. Offshore specimens divided into two series, from less than and from more than 800 km from nearest point on the coast of the Americas. Arrow indicates relative location of coastal, offshore and Hawaiian series.

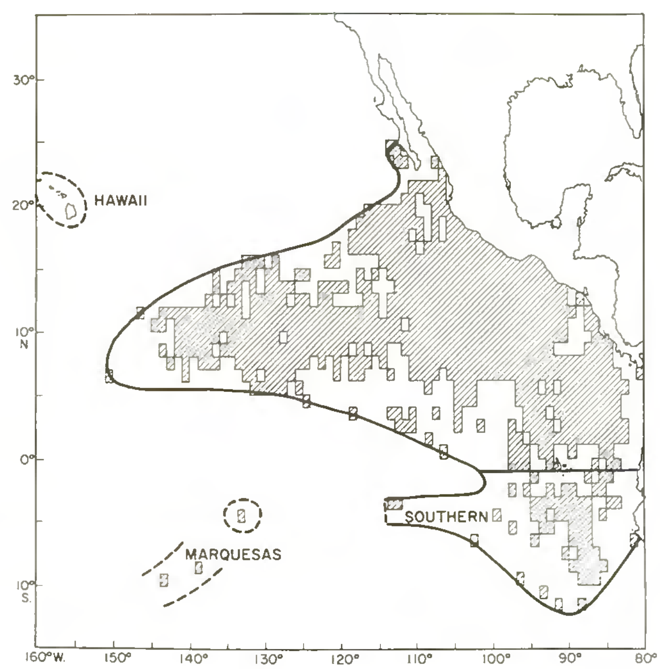

Fig. 12. Known range of *Stenella longirostris* in the eastern tropical Pacific (data from the tuna fishery, research cruises and other unpublished sources), with recommended northern boundary for possible southern management unit.

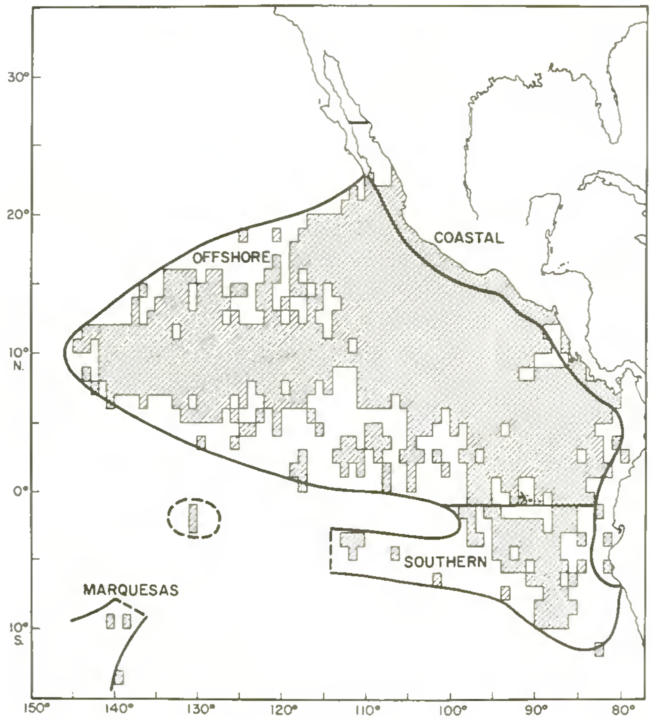

Fig. 13. Known range of *Stenella attenuata* in the ETP (data from tuna fishery, research cruises and other unpublished sources), with recommended northern boundary for possible southern management unit.

A very similar situation appears to exist for the spotted dolphin. The differences in morphology between the animals from below the equator and those to the north suggest some degree of isolation of the southern portion of the known distribution of the species in the eastern tropical Pacific, and a "southern" population can be defined (based again on a near hiatus in records, Fig. 13). This population or stock should be considered as a possible management unit.

The possibility that the modal differences between the populations in one or both cases are due to differential exploitation (perhaps affecting age and length at maturity) cannot be completely eliminated. However, it is unlikely, in that the size difference relationship is opposite in the two species; for one the southern form is larger, for the other it is smaller. It appears more likely the differences are genetically based. Such differences have been encountered in every adequate (using large samples and an array of characters) morphological comparison of populations of small cetaceans (Perrin, 1975a).

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SC/30/Doc 20

A Review of Recent Biological Data for the Fin Whale Population off Iceland

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ABSTRACT

Biological material and data collected between 1975 and 1977 inclusive for fin whales off Iceland have been collated and analysed. Length, sex and sexual condition were originally recorded, and ear plugs collected, and ovaries and testes collected and analysed for sexual maturity.

Age was determined from examination of ear plugs of which more than about 70% were usable for this purpose. Between 67% and 96% of the catch were sampled for ear plugs in the three seasons.

The sex ratio of the catch is about 1:1 in all seasons, and the average lengths of the catches are 58.8 ft for males and 60.0 ft in females. A mean of 220 fin whales has been taken annually between 1975 and 1977. The initial age at full recruitment is 5 years for both sexes. The total mortality coefficient for the exploited stock is about 0.06 in both sexes.

Curves of mean length at age are presented for seasons 1967 to 1977 inclusive and the mean maximum lengths attained over 25 years are 62 ft for males and 66 ft for females.

The mean lengths at sexual maturity are 55 ft for males and 59 ft for females. The mean ages at maturity are about 6 years in both sexes.

The ovulation rate for females, determined from the number of corpora in the ovaries and age from ear plugs is one corpus per 1.6 years.

INTRODUCTION

Since the previous report on age data for Icelandic fin whales (Lockyer, Gambell and Brown, 1977) the collections and data from a further three whaling seasons, 1975, 1976 and 1977, have been analysed. In the 1975 and 1976 seasons, the collections of ear plugs and of a few ovaries were made mainly by Mr Snorrason, the Icelandic whaling inspector at the station. During 1977, a biologist was appointed to collect material throughout most of the whaling season, so that with the additional coverage of the ends of the season, June and September, by the Canadian observer, Mr Horonowitz, and by Mr Snorrason, a comprehensive collection of age and reproductive materials was achieved.

In this report, much of the original data used in the 1977 paper have either been augmented for more detailed analyses or updated.

MATERIALS

During the seasons 1975, 1976 and 1977, ear plugs were collected and preserved in 10% neutral formalin for age determination. These have all been cut and examined for growth layers, and the results are shown and discussed presently. During 1976 and 1977, ovaries were collected and preserved in 10% neutral formalin. These have been sectioned at 3–5 mm thickness and examined for corpora, and the data are discussed later. In addition to female reproductive material, testis tissue was collected from males during 1977, fixed in 10% neutral formalin (a few in Bouin's fluid) and this too has been examined and analysed. The testis tissue was sectioned (after wax-embedding) at 6–10 μ thickness, stained with haematoxylin and counterstained with eosin. The state of maturity was assessed after examining tissue taken from both the periphery and the centre of the testis, and the presence or absence of closed, open, and part-open tubules, corresponding with immature, mature and pubertal states, recorded.

AGE RELATED PARAMETERS FROM EAR PLUG DATA

1. Readability of ear plugs

The ages used in all analyses for the 1975, 1976 and 1977 seasons are the agreed age readings of at least three persons' separate counts of growth layers. The numbers of ear plugs collected and the percentages of agreed layer counts are shown in Table 1.

In Figs 1 and 2 are shown the number of readable ear plugs expressed as percentages of the catches of whales in each size group.

It will be noticed that in comparing males with females, the mean percentage of readable plugs is consistently higher for males in each season, by about 8–10%. This is because of actual greater difficulty in interpreting growth layers in ear plugs taken from females.

Since 1975, the percentage of readable ear plugs has increased each season in both sexes. This is mostly explained by 96% of the catch being sampled in 1977 and only 82% and 67% in 1976 and 1975 respectively.

Table 1

Numbers of fin whale ear plugs collected each season at Iceland and the percentage of agreement on age readings from the plugs

	Seasons			
	1975	1976	1977	Total
MALES				
Number of plugs collected (pairs treated as two plugs)	101	120	109	330
Agreed layer counts	74	107	102	283
% Agreement	73	89	94	86
FEMALES				
Number of plugs collected (pairs treated as two plugs)	95	130	128	353
Agreed layer counts	66	109	105	280
% Agreement	69	84	82	79

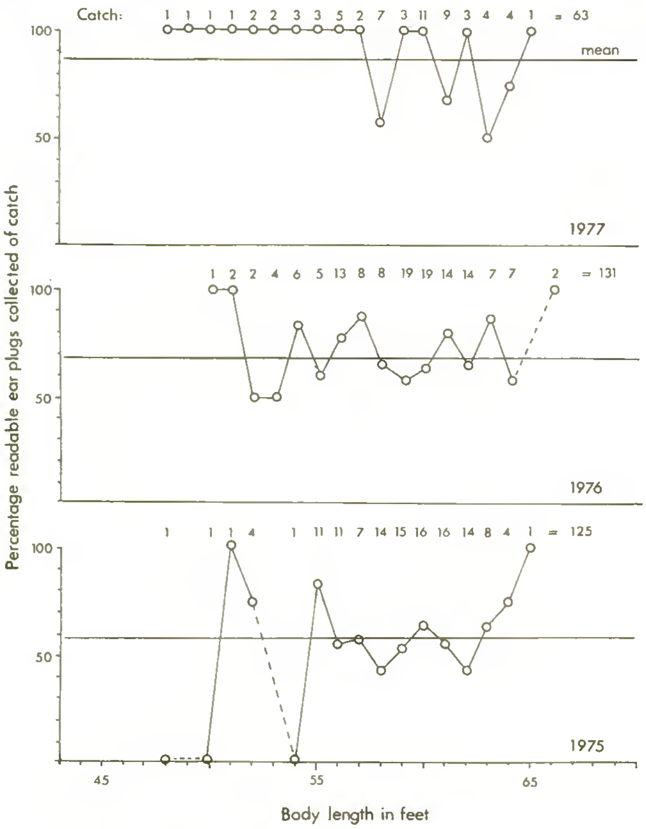

Fig. 1. Readability of male ear plugs as percentages of total fin whales caught in 1975, 1976 and 1977.

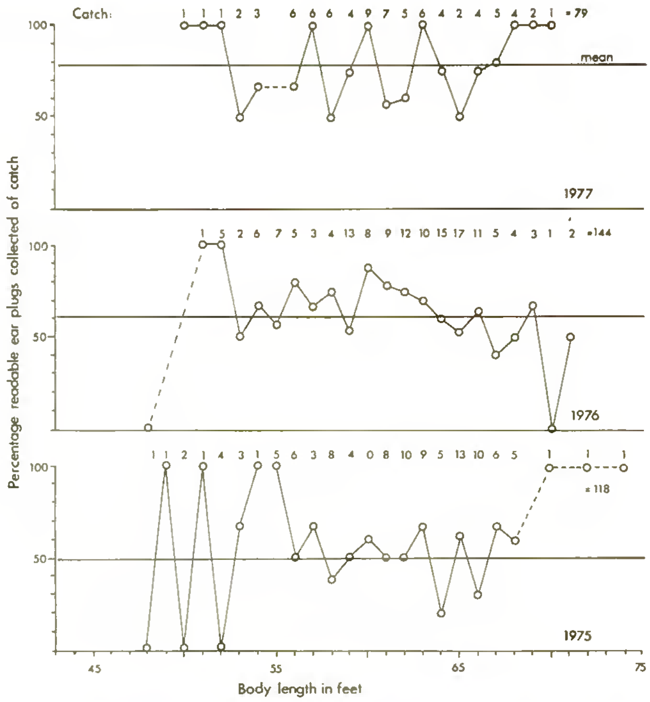

Fig. 2. Readability of female ear plugs as percentages of total fin whales caught in 1975, 1976 and 1977.

2. Length and Age Data for the Catch

In Table 2, data on catch and mean length by sex for each season are shown. The catch of each sex was approximately in the ratio 50:50 over all seasons. The size of the catch was comparatively low in 1977, when only about 50–60% of the two previous seasons' catches was taken. The mean lengths of the catches are similar in each season and overall, average 58.8 ft in males and 60.0 ft in females. The overall average catch of fin whales (both sexes) is 220 whales over the three seasons. This is a number lower than the figure quoted by Gambell, Jónsson and Jonsgård (1973) of 241 for the period 1948–1972. During this period the lowest catch taken was 142 in 1962, exactly the same as in 1977.

Undoubtedly unusual circumstances prevailed in 1977 affecting the catch, because the season which usually commences in early June, did not start until late June as a result of industrial problems. This meant a loss of 2–3 weeks catching effort during the part of the season normally busy with fin whales. Hence the 1977 fin whale catch does not represent the result of a full season's catching effort.

The modes of the age frequency distributions for the three seasons, regardless of sex, fall in the range 4–7 years with an average mode of 5 years (see Figs 3 and 4). This is similar to that in Gambell *et al.* (1973), and might be taken as the initial age at full recruitment to the fishery.

3. Mortality Coefficients

In Figs 3 and 4, the combined seasons' age frequency distributions up to age 45 years are shown for males and females. These distributions, shown on a logarithmic scale for number, have been used to calculate the total mortality coefficient, Z, for the exploited stock between the ages 5–45 years. The values of Z with 95% confidence limits are 0.0617 ± 0.0098 for males, and 0.0638 ± 0.0082 for females. These values are not significantly different from values of Z, 0.067 and 0.077, given by Gambell *et al.* (1973) for males and females respectively.

Making the same assumptions concerning natural mortality as Gambell *et al.* (1973), M = 0.04, in order to estimate fishing mortality, F, from Z, the population size, P, calculated from

$$P = \frac{C}{F}$$

Table 2

Catch and length data for the Iceland fin whale fishery

Season	Male		Female		Total	
	Catch	Mean length (ft)	Catch	Mean length (ft)	Catch	Mean length (ft)
1975	127	59.0	118	61.1	245	60.0
1976	132	58.9	143	61.5	275	60.2
1977	63	58.4	79	60.8	142	59.7
Total mean	107	58.8	113	61.2	220	60.0

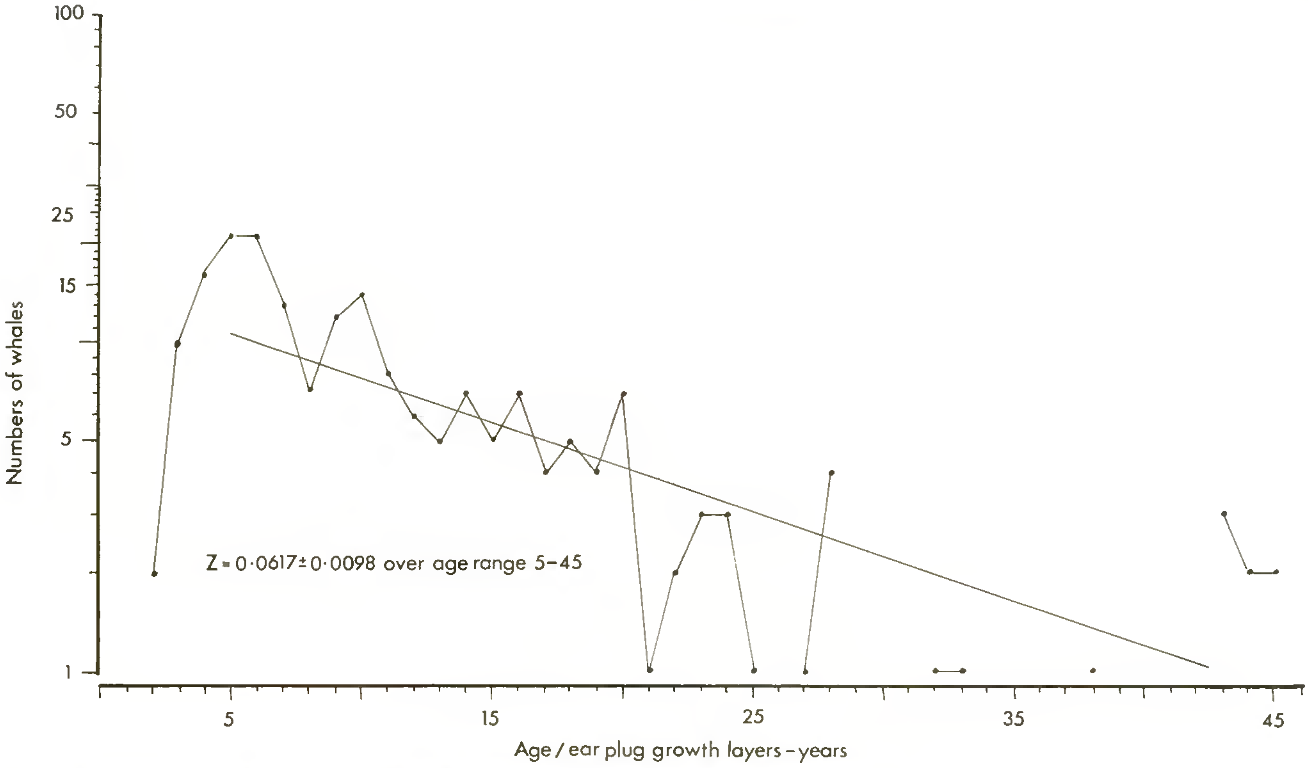

Fig. 3. Log-frequency age distribution of male fin whales and total mortality coefficient, Z.

when C is the same mean catch figure as previously, gives an estimate higher than that of Gambell *et al.* (1973), i.e. 8,300. However, it is no more reliable owing to the assumptions made concerning natural mortality and the insignificant differences in the values of Z.

The most recent population estimate, using the method of tag recapture was 6,900 (Report of the Working Group on North Atlantic Whales, Oslo, 1976).

4. Growth Curves

All fin whale length at age data collected from Iceland between 1967 and 1977 inclusive have been combined for the calculations of mean length at age curves, shown in Figs 5 and 6 for males and females. The average maximum length is about 62 ft in males and 66 ft in females. These lengths are attained at about age 25 years onwards.

The curves are almost certainly unrepresentative of the true growth curves below age 5 years because of the cut-off at length 50 ft imposed by the IWC whaling regulations.

The number of points beyond 40 years is relatively small, and for this reason the curves in Figs 5 and 6 are only shown up to this age.

REPRODUCTIVE PARAMETERS

1. Mean Length and Age at Sexual Maturity

The data from examination of testis tissue collected in 1977 have been added to those from earlier seasons. In

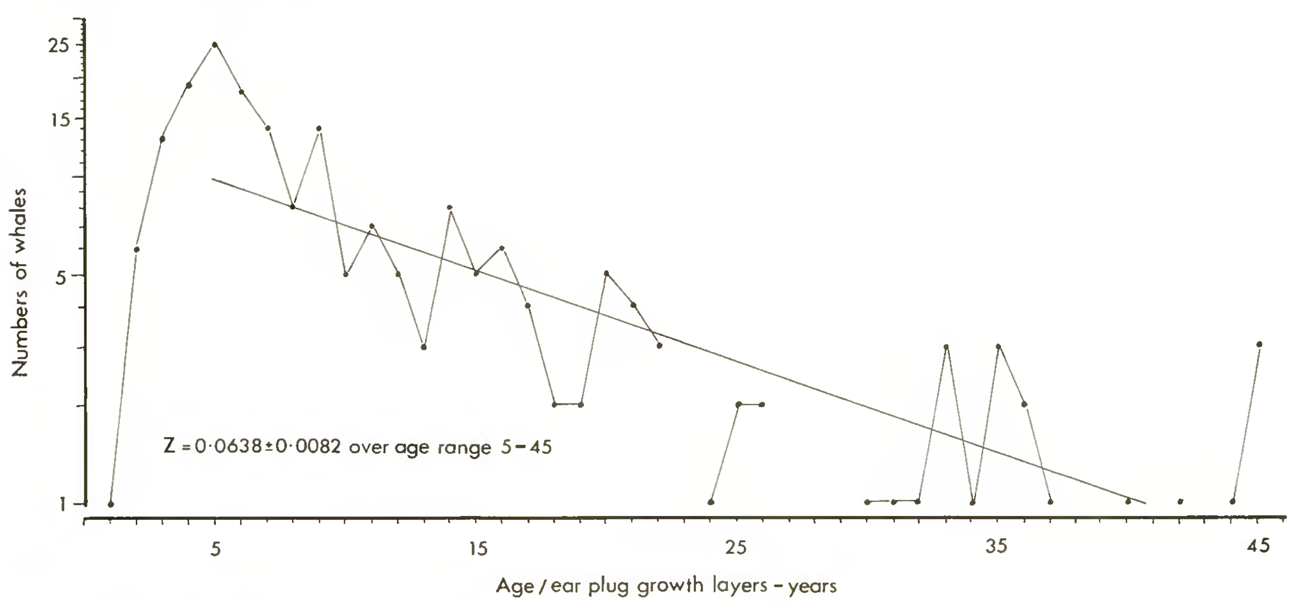

Fig. 4. Log-frequency age distribution of female fin whales and total mortality coefficient, Z.

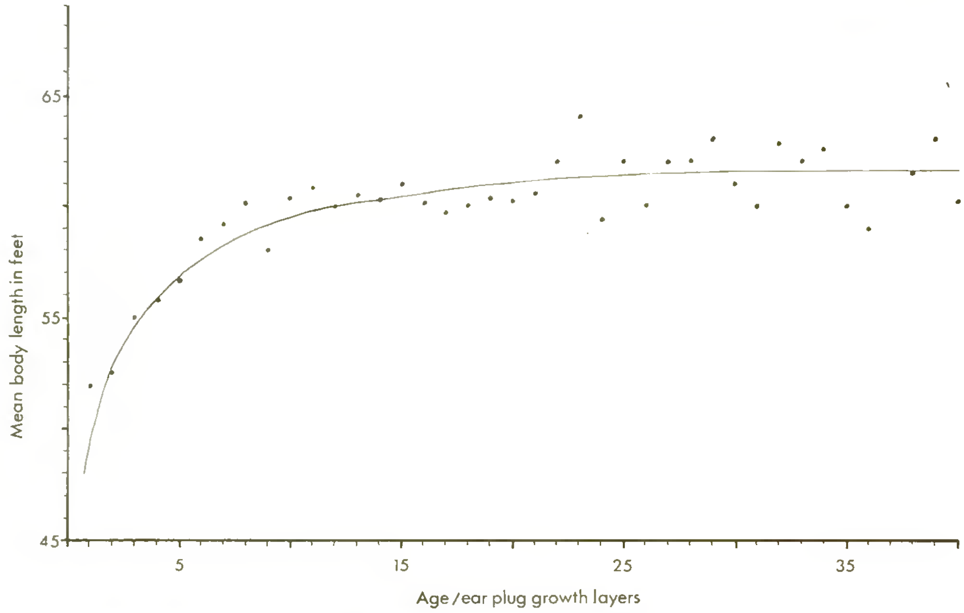

Fig. 5. Mean length at age curves for male fin whales.

Fig. 7, the percentage of sexually mature and pubertal whales are shown by length and age. The sample sizes are rather small, and the fitted curves are based on mean positions between points. However, the 50% level of maturity corresponds with a length of 55 ft and an age of between 5 and 6 years.

In Fig. 8, the percentages of sexually mature females by age and length are shown. The criterion used for assessing maturity is the presence of one corpus in the ovaries. The 50% level of maturity indicates a length of 59 ft and 6 years. Lockyer *et al.* (1977) gave similar estimates of mean length and age at maturity for males and females, based on very sparse data. The results given in this paper are considered more reliable.

For comparison, Mitchell (1974) found that the mean ages and lengths of sexual maturity for fin whales off eastern Canada were 11–12 years and 58–60.5 ft in females, and 10–13 years and 55.5–57.5 ft in males depending on the area. Jonsgård (1966) indicated that sexual maturity in female fin whales off Norway took place at around 60 ft off western Norway and around 61–62 ft off north Norway.

2. Ovulation Rate

The information on corpora number present in the ovaries (only animals from which both ovaries were collected were used) and ear plug data were available for a total of 111 females. These data are plotted in Fig. 9.

A straight line was fitted to the points using the method of Bartlett (1949), and the resulting formula indicated an ovulation rate of one corpus every 1.61 years. Lockyer *et al.* (1977) gave an estimate of one corpus per 1.39 years using a similar method but with less data. An age-independent method shown in the same paper produced an estimate of ovulation rate of 0.64 corpus per annum,

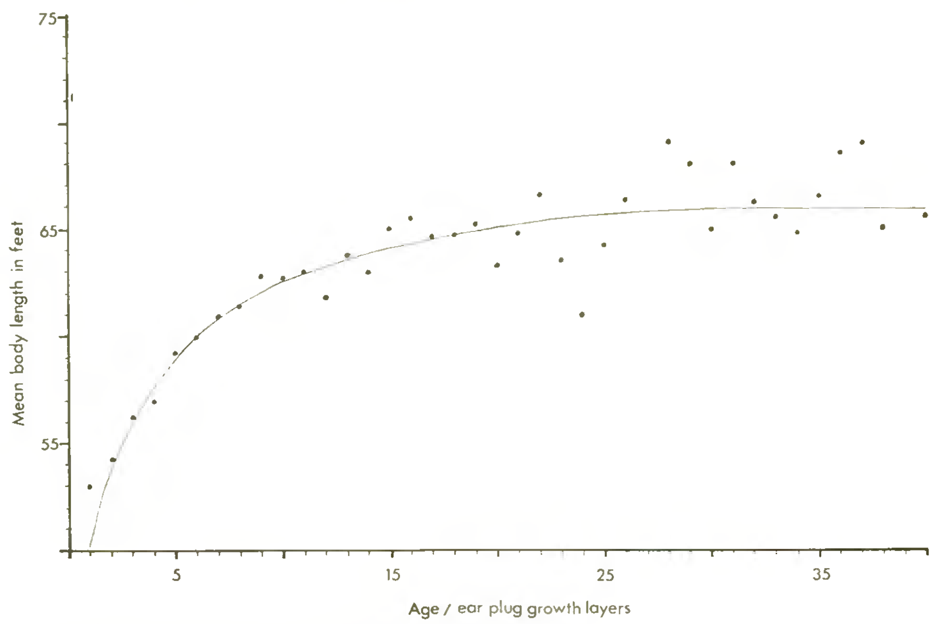

Fig. 6. Mean length at age curves for female fin whales.

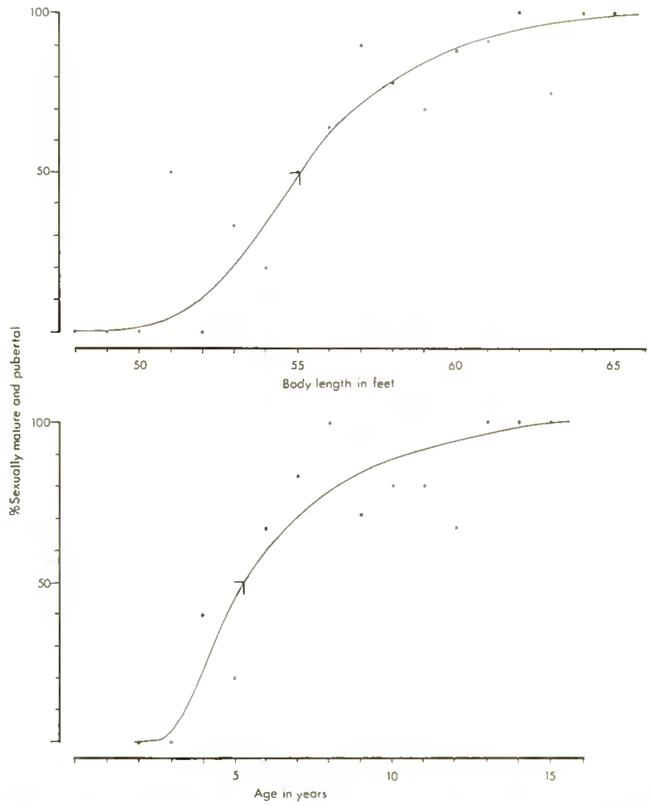

Fig. 7. Percentage sexually mature male fin whales at length and age.

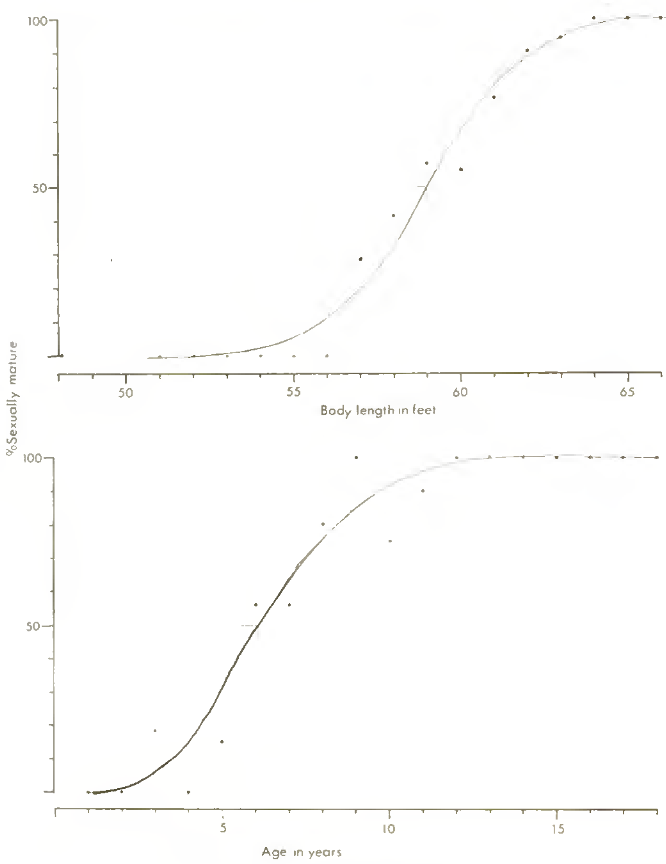

Fig. 8. Percentage sexually mature female fin whales at length and age.

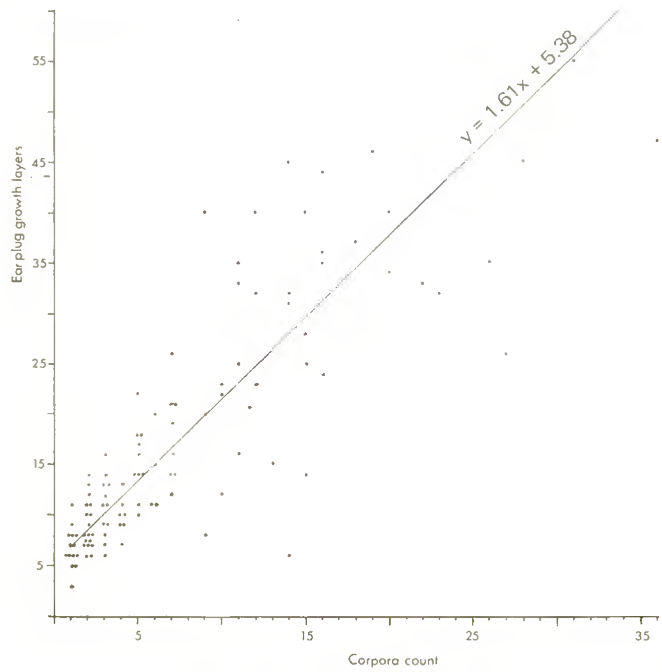

Fig. 9. Ear plug layer and ovarian corpora number correlation in female fin whales.

equivalent to one corpus per 1.57 years. The present estimate is very close to this lower value, suggesting that an ovulation rate of about one corpus per 1.6 years is probably fairly reliable.

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Changes in a Growth Parameter Associated with Exploitation of Southern Fin and Sei Whales

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ABSTRACT

Material examined included ear plugs from fin and sei whales taken in six Areas of the Antarctic and South Africa between 1955 and 1975 for the former species and 1960 and 1975 for the latter species. The total age and the age at the transition phase corresponding with the age at sexual maturity were recorded from all ear plugs. Each Area, where possible, was analysed separately by sex, for trends in changes in age at sexual maturity with year classes between 1890 and 1955.

Declines in age at maturity were observed in both sexes of both species in all Areas. These declines however, were not statistically significant in Area V for fin whales and Areas IV and V for female sei whales. All detectable declines commenced after 1930.

The apparent overall declines in age at sexual maturity were observed to be greatest in Areas II, I, III and V for fin whales, in decreasing order of magnitude. For sei whales, the declines were greatest in Areas III, I and II in decreasing order of magnitude. The Areas showing maximum decline are similar for both species except for Area V sei whales.

The history of the duration of the exploitation in the six Antarctic Areas shows some correlation with the extent of the decline in age at maturity of the Area. However, there does not appear to be any definite correlation of decline in age at maturity with the degree of depletion by exploitation.

In all Areas since exploitation began, except Area III, the balance between the biomass of fin and sei whale populations has been altered, especially Area V, where sei whales now greatly dominate.

The pattern of decline in age at sexual maturity is concluded to be the result of complex changes in the ecosystem, many of which have not yet been fully identified or explored.

INTRODUCTION

The nature of the structure of the ear plug of at least two balaenopterid species has proved to be a useful means of determining

(a) total age, from annual growth layers, and
(b) age at sexual maturity, from the transition phase, Lockyer (1972, 1974).

This has made it possible to calculate the year class of individual whales, and also to provide indirectly information on growth rate up to the age of sexual maturity.

In both fin and sei whales from the Southern Hemisphere, it is quite clear that there have been changes in growth rate, reflected in the lowered age at sexual maturity in more recent year classes (Lockyer, 1972, 1974, 1977). Explanations for these changes have been various, and as yet are unresolved owing to a lack of direct proof of the correlation of likely factors involved. However, one of the most likely factors would appear to be a probable increased availability of food brought about by the depletion of other balaenopterid whales, chiefly blue and humpback whales, which are known at least to feed on a similar euphausiid diet in the Antarctic as fin whales.

Evidence for a decline in age at sexual maturity has been mainly for Antarctic Areas II (0°–60° W) and III (0°–70° E), for both fin and sei whales. However, Lockyer (1977) produced evidence for a decline in fin whales in another Antarctic Area, Area I (60° W–120° W). The evidence in fin whales was inconclusive for Areas IV (70° E–130° E), V (130° E–170° W) and VI (170° W–120° W) owing to sparsity of data.

The subject of the present investigation was to discover whether or not changes in the age at maturity have occurred in all Areas, and whether or not changes in this parameter have taken place in both fin and sei whales.

MATERIALS AND METHODS

All data analysed previously by Lockyer (1972, 1974, 1977) have been included in the present study. These comprised fin and sei whale ear plug data from Antarctic Areas I, II and III collected at some time between 1955 and 1965, and also data from South Africa during the 1960–65 period. In addition, some fin whale data was made available from Areas III, IV, V and VI by courtesy of the Far Seas Fisheries Research Laboratory, Japan, from the period 1973–1975.

The Far Seas Fisheries Research Laboratory very kindly made available further material for age studies during 1977. This work was undertaken through the courtesy and funding of the Science and Technology Agency of the Japanese Government, at the laboratory in Shimizu, where much assistance was given. The material included ear plugs collected from all six Areas of the Antarctic, and the collections examined are shown below:

Antarctic season	Whale species	Factory ship expeditions	
1972–73	Fin	K, N, T	
1973–74	(Fin (Sei	K, N, T) K, N, T)	
1974–75	(Fin (Sei	K, N, T) K, N, T)	Additional to that analysed by Lockyer (1977)
1975–76	(Fin (Sei	K, T) K, N, T)	

K: *Kyokuyo maru No. 3*
N: *Nishin maru No. 3*
T: *Tonan maru No. 2*

The method of ear plug examination was the same as previously described. The formalin-preserved ear plug was cut along the longitudinal mid-line to expose the layered core. In order to facilitate layer counting, a lens or binocular microscope was used when required, especially for sei whale ear plugs.

The total layer count and the transition phase were recorded for each ear plug examined. Hence the year class and the arithmetic mean of the age at sexual maturity were deduced.

In the analyses, the ear plug data were separated according to species, sex and Area, and the age at maturity plotted against year class. In some Areas the data were too sparse to keep sexes separate, and in order to detect overall trends in otherwise scattered distributions, the arithmetic means of blocks of years were calculated and linear regression analyses done on these means over the period a change was suspected. The 95% confidence limits of the means were also calculated in order to detect significant changes in age at maturity.

In Figs 1 and 2, only unbiassed means are shown. The data in the period after 1960 become progressively more

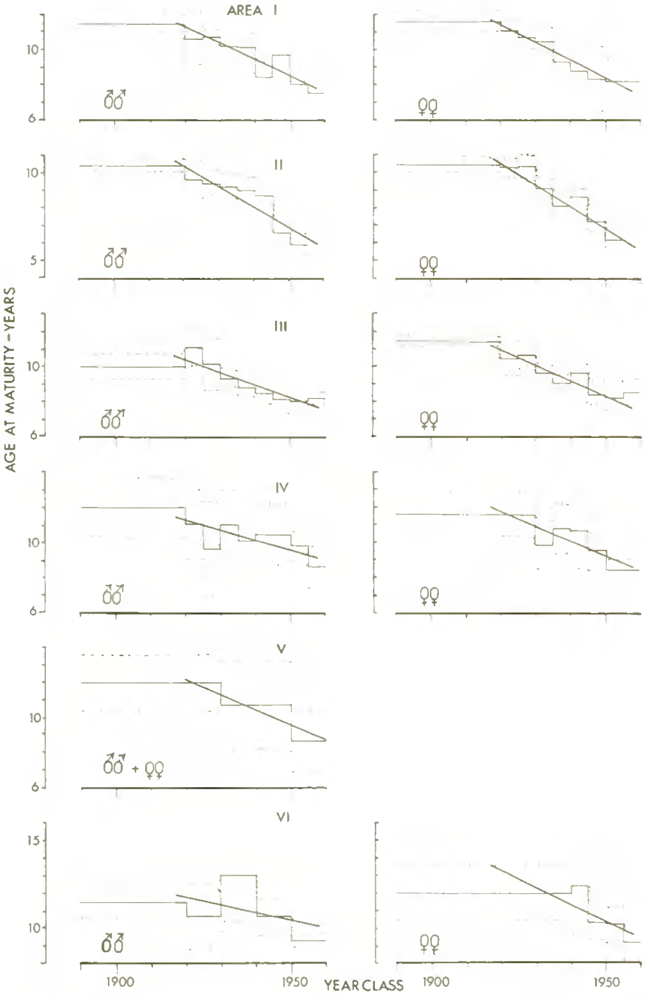

Fig. 1. Mean age at sexual maturity in fin whales with year class. The 95% confidence limits for the means are shown, and the fitted regression lines.

biassed and are therefore omitted. These biasses are the result of late maturing whales not being recognised by the method of transition phase. This means that the complete spectrum of ages at sexual maturity is not represented, thus skewing the normal distribution to give an underestimate of the true mean.

RESULTS

1. Fin Whales

The plots by Area and by sex of age at maturity with year class are shown in Fig. 1. The age at maturity has been

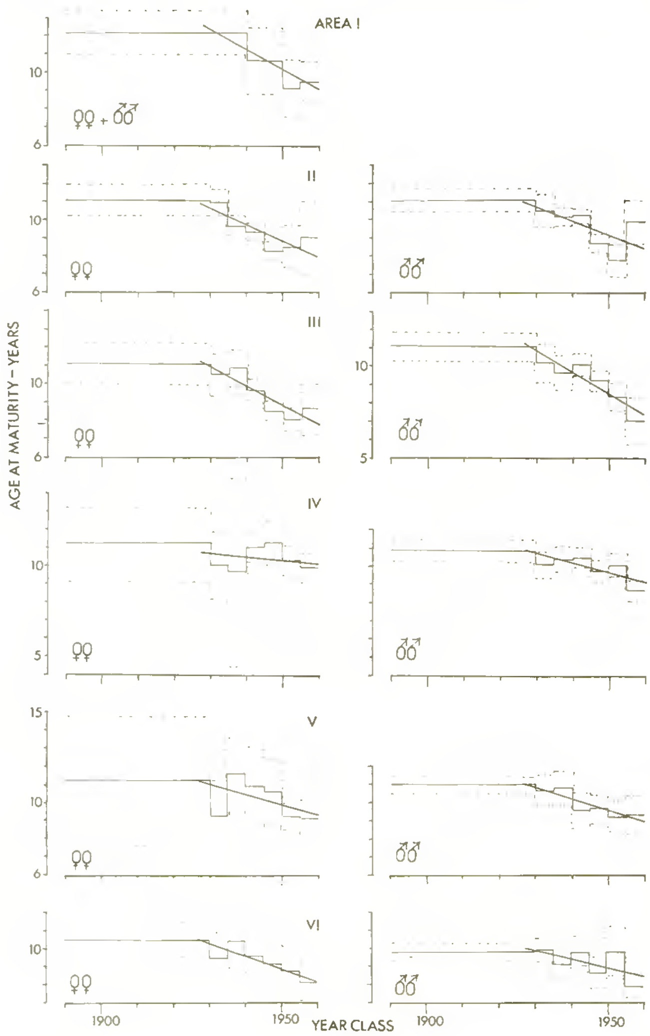

Fig. 2. Mean age at sexual maturity in sei whales with year class. The 95% confidence limits for the means are shown, and the fitted regression lines.

shown as a mean value for blocks of year classes, with attached 95% confidence limits. The trend lines drawn in for each Area have been calculated by linear regression analysis. In every example illustrated, the trend line indicates a decline in age at maturity with time.

The initial levels of mean age at maturity in the pre-1920 year classes are least in Areas II and III, ranging between 10.5 and about 11.0 years for both sexes. The Areas I, IV, V and VI all have higher initial levels than Areas II and III, ranging between about 11.5 and 13.5 years.

The mean levels of age at maturity for the post-1955 year classes are lowest in Areas I, II and III, ranging between 6.0 and about 7.8 years. The mean levels in Areas IV and V are between about 8.5 and 9.0 years. The mean level in Area VI is about 9.7 to 10.2 years. In Table 1, the post-1955 levels are expressed as percentages of the original levels.

The decline in Area II is relatively greater than in any other Area, followed by Areas I, III and V in order of magnitude. The indications are that the decline in Areas IV and VI may be different between the sexes. However, the data from Areas IV, V and VI are not as plentiful as from the other Areas, and the differences observed between the sexes at least may be due to small sample sizes.

Table 1

Comparison of relative decline in age at maturity in fin whales between Areas. The post-1955 level is expressed as a percentage of the pre-1920 level.

Area	Male	Female
I	68	66
II	56	55
III	73	69
IV	80	72
V	72	
VI	86	71

By inspection of the range of confidence limits, it appears that the post-1955 values are significantly lower than the original values in each Area for both sexes. There is no significant change in Area V where the sample size is too small to say more than that there is a trend to decline.

The first suggestion that the decline is statistically significant occurs in the pre-1935 year classes in Area II in both sexes. The decline in Areas I and III also occurs within the pre-1935 to pre-1945 year class groups. However, the decline in Areas IV and VI does not become significant until the post-1950 year classes or later.

2. Sei Whales

The plots of mean age at maturity with year class are shown similarly to those for fin whales in Fig. 2. A trend to decline in age at maturity can be seen in all Areas in both sexes.

The initial levels of mean age at maturity in the pre-1930 year classes fall in the range 11 to 12 years in all Areas, the highest value being observed in Area I. The initial levels are similar for both sexes and all Areas, unlike fin whales where there appears to be some variation by Area at least.

The mean age at maturity for the post-1955 year classes falls to between about 7.6 and 8.7 years in Areas II and III, and between about 9.2 and 10.3 years in the remaining Areas. Like the fin whales, the mean age at maturity has fallen to the lowest levels in Areas II and III.

In Table 2, the post-1955 levels are expressed as percentages of the original levels.

The decline seems to be greatest in Areas III, I and II, in order of magnitude. The overall decline regardless of sex, appears least in Areas IV and VI, similar to fin whales.

A comparison of 95% confidence intervals indicates that the declines observed are not all significant. There is no

Table 2

Comparison of relative decline in age at maturity in sei whales between Areas. The post-1955 level is expressed as a percentage of the pre-1930 level.

Area	Male	Female
I	74	
II	79	74
III	69	72
IV	86	94
V	83	83
VI	88	83

significant difference between the pre-1930 and post-1955 levels for females in Areas IV and V, although the differences are significant for males in these Areas.

The first indications of a significant change in age at maturity occur within the post-1935 to post-1945 year classes in Area II, and post-1945 in Area III. Despite there being no significant changes in Areas IV and V in females, the opposite occurs in males in the post-1955 and post-1945 year classes respectively. The decline does not appear to be significant in Areas I and VI until the post-1950 and post-1955 year classes.

DISCUSSION

Many parallels can be drawn from the results on changes in age at maturity for fin and sei whales. Both species show greatest declines in Areas I, II and III, and smallest declines in Areas IV and VI. This suggests a common ecological influencing factor, such as the environment or a common external pressure such as exploitation. The latter could effect the species' response either directly, or indirectly through a common factor such as food availability. Either way, both inter- and intra-specific competition are likely to be involved in the response, but at different times according to the pattern of species exploitation.

A starting point is to examine the history and magnitude of exploitation by species and Area, and observe any correlation with the changes in age at maturity.

Figs 3 and 4 illustrate the cumulative catches of fin and sei whales, respectively, and also relative population sizes, both by Area. Comparing the histories of exploitation in

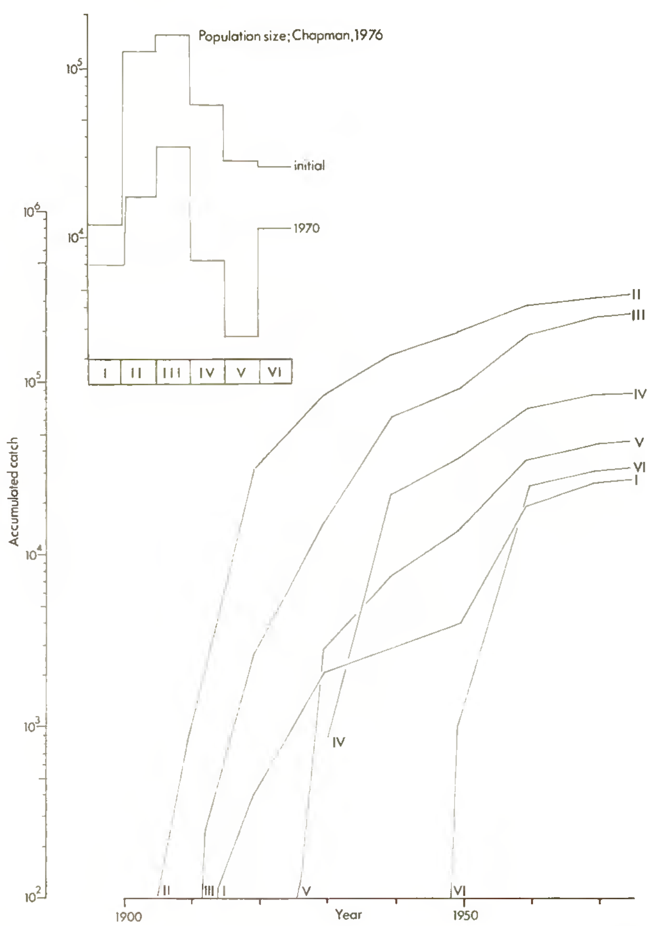

Fig. 3. Cumulative catch of fin whales in the Southern Hemisphere, and initial and current population levels by Area.

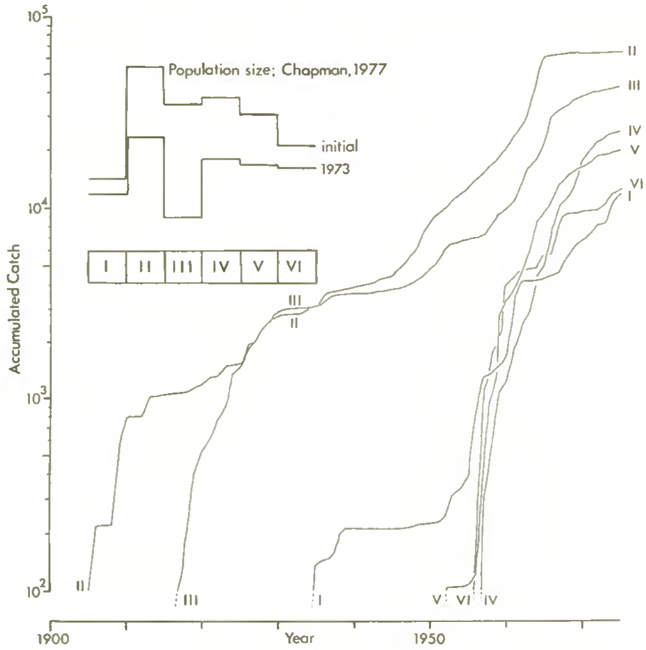

Fig. 4. Cumulative catch of sei whales in the Southern Hemisphere, and initial and current population levels by Area.

the different Areas, the pattern for Areas II and III is similar for both fin and sei whales. The longest history of exploitation is in Area II, going back to pre-1910 years. Exploitation in Area III commenced effectively at a marginally later date before 1920. In fin whales, the chronological order of exploitation is Area I and then Area V, both in the 1920's; then Area IV in mid-1930 and Area VI around 1950.

In sei whales, the order of exploitation is Area I, from about mid-1930 effectively, and Areas IV, V and VI from around mid-1950.

The most interesting correlation of these histories of exploitation is with the magnitude of the decline in age at sexual maturity. Referring back to Tables 1 and 2, the Areas where the greatest changes have taken place are Areas I, II and III which also have by far the longest history of exploitation of both fin and sei whales, although that of the former species is undoubtedly more severe.

In Fig. 5, the relative declines in age at maturity for each sex by Area are plotted against the date of commencement of exploitation by species. This latter co-ordinate is open to discussion because it is uncertain at what level exploitation can be considered effective in the population. However, the dates used are a reasonable indication of the start of exploitation. Despite the scatter shown in Fig. 5, the points plotted tend to indicate some association of degree of decline in age at maturity and history of exploitation. This analysis is only exploratory, but does suggest that pressure of exploitation may be a factor affecting population response.

This type of analysis does not take into account the effective level of exploitation required to induce a response in the population. In Figs 3 and 4, insets are shown giving the relative levels of population size in the initial and current years. At this point, one must consider that year class animals of the 1950s and 1960s periods will be taken as mature adults in the 1960s and 1970s whaling operations. It is apparent that for both fin and sei whales, Area I has never been heavily populated, and Area VI also had a relatively low initial population size. The Areas II, III and IV have higher carrying capacities than all other Areas. It is

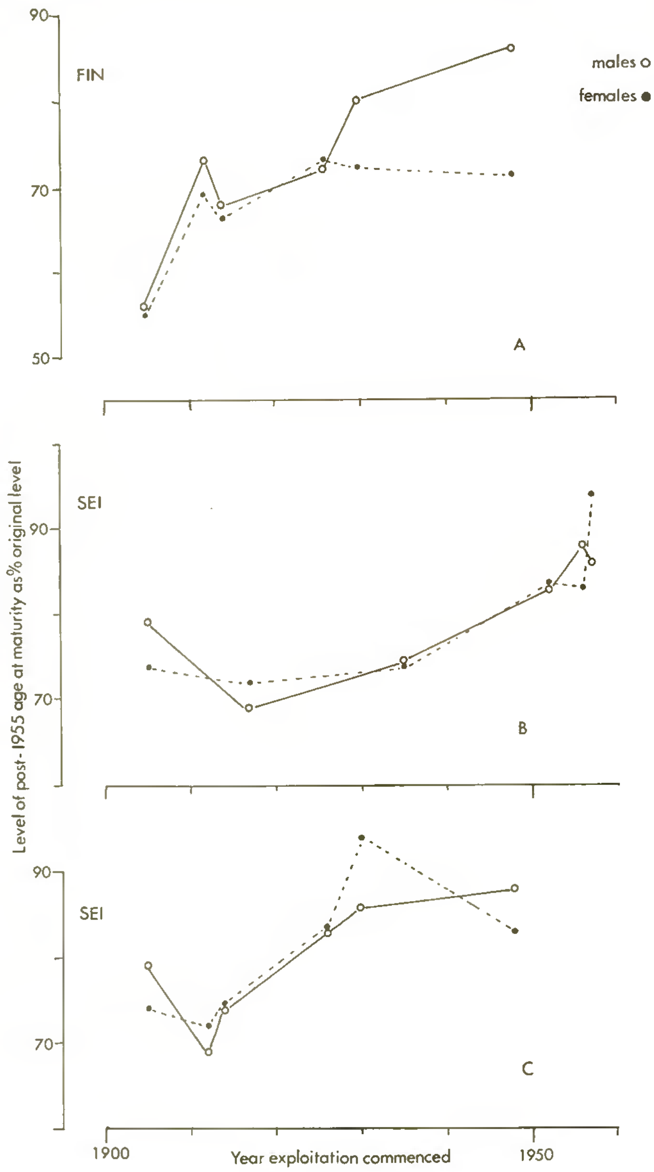

Fig. 5. Fall in age at sexual maturity since the date of commencement of exploitation of fin and sei whales.

A. Fin whale age at maturity and fin whale exploitation.
B. Sei whale age at maturity and sei whale exploitation.
C. Sei whale age at maturity and fin whale exploitation.

Table 3

Proportional reduction in total stock biomass through exploitation

Area	Initial biomass of population (tonnes x 10^{-3}) Fin	Sei	Fin + Sei	% Current biomass of population / Initial biomass of population: Fin / Fin	Sei / Sei	Fin + Sei / Fin + Sei
I	576	252	828	58	84	66
II	5,952	997	6,949	14	42	18
III	7,296	623	7,919	23	25	23
IV	2,880	673	3,553	12	48	19
V	1,344	547	1,891	10	55	23
VI	1,152	378	1,530	46	76	54

obvious that some Areas have been exploited more heavily than others and Table 3 shows the actual depletion by exploitation in terms of biomass. These biomass figures have been derived using mean length/weight conversions using formulae given by Lockyer (1976).

It is immediately apparent from Table 3 that the fin whale stocks are more severely depleted than those of sei whales. Looking at individual species, Areas II, IV and V are the most depleted in fin whales, with Area III also heavily depleted. However, Areas I and VI are still between 45% and 60% of original levels. It is interesting that these are the two Areas where population sizes were always low. In general, it can be said that the pattern is similar for sei whales, in that Areas I and VI are least depleted and also carry the smallest populations. Area III is the most depleted for sei whales, and Areas II, IV and V have all been depleted to a similar extent.

Looking at the combined species depletion, all Areas are below 25% of the original biomass levels excepting Areas I and VI which still carry over 50%.

Because of the different histories and levels of exploitation by species, the relative importance of the fin and sei whales in the combined species biomass has altered. In Table 4, it can be seen that originally the sei whale was consistently of lesser importance than the fin whale. However, the Areas where the sei whale comprised over 30–40% of the combined fin and sei whales biomass were Areas I, V and VI which by reference to Fig. 3, were clearly the least populated Areas by fin whales. Perhaps conditions here favoured sei whales more than fin whales and hence interspecific competition was less for the sei whales. There is some evidence that this argument may have foundation because the initial ages at sexual maturity for fin whales were highest in these Areas, whereas those for sei whales are comparable with values in other Areas. This argument assumes that sei whales always had the harder time for survival than fin whales (Kawamura, 1974). Also, the age at maturity for post-1955 year classes of sei whales, even though at lower levels than the initial levels, do not generally approach quite such low values as those observed for fin whales.

Table 4

Relative importance of individual species in initial and current combined species biomass levels

Area	% Initial population biomass level Sei/Fin	% Current population biomass level Sei/Fin
I	44	63
II	17	50
III	9	9
IV	23	90
V	41	230
VI	33	54

In recent years, the balance of fin and sei populations has altered greatly, except in Area III, to the extent that in the majority of Areas, sei whales greatly outnumber fin whales because of their smaller size. In Area V sei whales now greatly outweigh fin whales. One would suspect that in Area V, competition with fin whales would be negligible, because of the relatively small amount of the latter species.

All these observations have complex bearings on the results discussed for Figs 1 and 2 on age at maturity. One might expect that having seen some association between age at maturity decline and period of exploitation, there could be a correlation between decline in stock biomass and age at maturity.

In Areas II and III of fin whales, the heavy stock depletions are reflected in more marked declines in age at maturity. Also the most depleted Area III of sei whales is linked to the greatest decline in age at maturity. However, the association breaks down for Area I in both species. A large decrease in age at maturity is linked with comparatively light exploitation. Perhaps whales are mingling around South America from adjacent Area II where there is a sharp decline in age at maturity. There is the greatest depletion of fin whales in Areas IV and V, yet the fall in age at maturity is nowhere near as great as Areas I and II.

If fin and sei whales are in competition, looking at the depletion of combined species biomass, one might expect the Areas to show greatest response to be Areas II, III, IV and V. However this is only partly true, so that although exploitation is producing an effect on the population, the mechanism is not a simple one linked solely with reduction of biomass of whales nor history of exploitation.

CONCLUSIONS

It is almost certain that food must be the primary causative agent for faster growth and hence earlier maturation. Prey availability can be increased by removing some of the predators and hence reducing inter- and intra-specific competition in the latter.

Lockyer (1978) demonstrated that in theory a very small increase in food availability (less than 5%) could effect a change in growth rate in fin and sei whales, and alter the age at maturity. Such an increase in food could be brought about by exploitation of the predator, and also by natural environmental fluctuations such as water temperature and ice-cover, which would affect food productivity, e.g. of krill (Mackintosh, 1973).

In theory once a certain initial level of increase in food availability was reached, the population would respond. This would possibly help to explain the situation in Area I. Once enough food was available to the whales for full realisation of genetically determined growth potential, a further increase in food availability would not produce any more effect on growth rate. This would perhaps explain why the most depleted Area V of fin whales does not show greater decrease in age at maturity than for example Areas I or III.

This kind of theory would explain better the observation that duration of exploitation has a greater association with decline in age at maturity than overall reduction in biomass, although the former is bringing about the latter.

The situation is very complex, and to understand it, data on changes of parameters in other species, whales and seals, need to be known by geographical location. Information on environmental factors such as weather and sea conditions, krill abundance and other food availability over the period between 1900 and today also need to be known. Biological data on growth, fecundity and feeding requirements of different species are all important. Some of these data are not available, although some are obtainable, for example information on age at maturity in blue whales from the transition phase in the ear plug.

The whole situation discussed here is not self-contained but is clearly the result of multiple interactions, many of which are as yet unidentified. Despite the reliance for ultimate success of systems modelling on the completeness of the input data, some of the possible interactions taking place could be explored by trial models incorporating a variety of both theoretical and observed data. Such an approach may at least serve to identify factors which are most likely to have some effect on the growth and fecundity of whales, and which ones would merit thorough investigation.

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Exploitation of Large Whales in West Greenland in the Twentieth Century

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ABSTRACT

Three types of whaling in succession have been carried out in Greenland in this century: traditional hunting of humpback whales from small whale-catching boats until 1923, modern whaling by one catcher-boat 1924–39 and 1946–58, and occasional catching by fishing vessels equipped with harpoon cannons since 1948. In the present paper available data on all three activities are summarised.

During the first period only humpback whales were taken. The hunting was centred around Frederikshåb and Godthåb in southwest Greenland, and the yield was 5–10 animals per year.

Modern whaling was brought about by the Greenland Administration both to provide the local settlements with meat, and to supply the oil plant in Copenhagen with blubber. One catcher-boat was in operation until 1950 when it was replaced by a new one. Until 1953 the whales were landed at different settlements along the coast, and the flensing was done by the local people. Between 1954 and 1958 the whales were processed at a land station, from where the meat was distributed along the coast. An average of 20–25 fin whales were taken per year during the whole period, with considerable fluctuations between years. In the initial phase, humpback whales were the second most important species (ca. 10 per year), but catches decreased and were stopped in 1954. In some years sperm whales played a role similar to the humpbacks, and it was the main species during the final years of operation. Blue, sei, and bottlenose whales were only taken in small numbers.

Most harpoon vessels are mainly engaged in fishing, with minke whaling as a secondary activity. Larger whales are only taken occasionally, but are of some importance as a meat supply. Only in the most recent years has the total catch exceeded 10 large whales per year, almost exclusively humpback and fin whales.

Data on the seasonal distribution of the catches, and observations, support previous accounts of a northward migration in the early summer and a southward migration in the autumn for all species. Fin and blue whales and occasionally other species are regular visitors as far north as 71° N. Data on sex ratios, reproduction, body length and feeding are limited, but supplement previous information. Casual observations indicate that fin and humpback whales are more common in Greenland waters than recent catches suggest.

INTRODUCTION

Historically, two types of exploitation of large whales can be traced in Greenland: traditional catches of whales by the Eskimoes, and European whaling activities. The former, of which archaeological evidence also exists, was originally carried out from small skin-covered boats, umiaqs, as described by the first European visitors (Haan, 1720 (1914), pp. 74–75; Egede, 1741 (1925), p. 354; Glahn, 1767 (1921), p. 127; Rink, 1877 (1974), p. 121), and was primarily directed towards the bowhead whale (*Balaena mysticetus*). This species was also the main or sole object of European whaling in the Davis Strait, which was initiated in the 17th century by Biscayan whalers, soon followed by Dutch, British and other whaling fleets.

After the colonisation of Greenland (1721) the Danish government made several attempts to limit the activities of other nations, partly by direct legal and military confrontation, partly by competition through the establishment of land based whaling, but other countries continued to operate in the Davis Strait until the second half of the 19th century. During the first decades of the 20th century a few whaling expeditions also visited the area, but now heading for other species (see below); the bowhead had become scarce, and had completely lost its importance to the Greenlanders. Rink (1877, p. 122) stated: "During a long period it (the whale fishery) has averaged one 'fish' each season". In the 20th century only one or two catches of bowheads have been reported.

The above items will not be discussed further in the present paper, which will mainly deal with the data on catch and occurrence in Greenland waters of the large balaenopterids and the sperm whale, since 1900.

THREE TYPES OF WHALING IN GREENLAND IN THE 20th CENTURY

Since 1900 three categories of whaling have been carried out in Greenland, one after the other:

1. Hunting of Humpback Whales from Small Whale-catching Boats

Originally, humpback whales (*Megaptera novaeangliae*) were caught from umiaqs by the Greenlanders in some regions, especially near Frederikshåb and Godthåb. The animals were approached when sleeping at the surface, harpooned and killed with lances. Detailed descriptions of the hunting technique are given by Fabricius, 1780 (1928), p. 81; Fabricius, 1809, p. 76; Rink, 1877 (1974), pp. 122, 127 and 271.

Soon after the colonisation, the Greenland Trade Department (KGH) began hunting of bowheads from small whale-catching boats with European crews and equipment, but using methods not much different from traditional Eskimo whale-hunting. Later on some Greenlanders participated in the operations, and occasionally boats and equipment were placed at the disposal of the Greenlanders for their catch of humpbacks.

This activity was continuously carried out at Frederikshåb until 1923. At Godthåb the humpback hunting was resumed at the turn of the century, but ceased at the same time as at Frederikshåb (Anon., 1944, p. 627; Møller, 1971, pp. 53–62).

The whale-boat hunting was discontinued when modern catcher-boat whaling was introduced in Greenland in the 1920s.

2. Modern Whaling by One Catcher-boat, 1924–1958

As early as 1912 the idea was put forward that Denmark should start modern whaling in West Greenland (Bang, 1912). Norwegian expeditions in the Davis Strait had proven that this was possible. Although the idea was generally supported, debate about the best way of organising the operations delayed action, World War I intervened, and more than ten years elapsed before the idea was transferred into reality.

Immediately after the war, in the years 1919–1925, Norwegian pelagic fleets composed of 3–4 catcher-boats and a floating factory again operated in the Davis Strait, and the results were quite good. In 1922 three catcher-boats caught 14 blue, 14 fin and 140 humpback whales; 1923 (3 catcher-boats): 20 blue, 20 fin and 150 humpback whales; 1924 (4 catcher-boats): 48 blue, 75 fin, 37 humpback, 2 sei, and 2 sperm whales (Hjort and Ruud, 1929, p. 30; Jonsgård, 1955, pp. 507–510; IWS, 1931, II, p. 33).

In 1924 the Greenland Office began modern whaling with a catcher-boat S/S *Sonja* (127 gross register tons), which had previously been whaling at South Georgia, 1910–1923. It was now given the task of catching blue, fin, humpback and sperm whales off West Greenland, with the purpose not only to supply the oil plant in Copenhagen with blubber, but also to provide the Greenlanders with meat for consumption, and meat and intestinal fat for feeding to dogs (Anon., 1944, p. 628). At this time the human population in Greenland was steadily increasing, whereas seal-hunting was decreasing, especially in southwest Greenland, causing serious problems of meat supply. Three factors influenced the catching operations in various ways: the catch per season never exceeded that necessary for consumption; the area of operation was to some extent chosen so that all districts were supplied with meat. When at last the oil production proved less profitable and the need for meat supply at the same time was considered less pronounced, the whaling operations were stopped.

In the years 1925–28 the catcher-boat was accompanied by a flensing vessel, M/S *Svaerdfisken*, but from 1929 the flensing was done by the local people at the settlement where the whale was landed. The greater number of whales were landed in southwest Greenland, where decreasing results from seal hunting had caused the most pronounced lack of meat for human consumption, but the northern settlements, where the keeping of dog teams is indispensable, were also regularly visited.

The catcher-boat normally began operations in June and stopped in October or November, starting in southwest Greenland, thereafter moving northward to the Disko Bay area and Umanak district, and back again in late summer, taking into account the ice conditions as well as the migration of the whales and the above-mentioned desire to supply all districts with whales.

The whales were brought to the colonies or the smaller settlements where the meat and intestinal fat were given to the Greenlanders as a payment for the flensing and packing of the blubber. No information exists on the amount of these products derived from the whales, only on the production of blubber for industrial use (see below).

The whaling activity was stopped during World War II, but was resumed in 1946. The old *Sonja* was in duty until 1950, but was then replaced by a larger catcher-boat (250 gross register tons), which was named *Sonja Kaligtoq*.

In 1954 a land station was erected at Tovqussaq (64° 52′N, 52° 13′W, between Godthåb and Sukkertoppen), and in the following years the previous practice of landing the whales at different settlements was gradually abandoned. Most whales were landed at Tovqussaq, from where the meat was distributed along the coast. By the end of the 1958 season the whaling was deemed unremunerative; the land station was closed down, and the catcher-boat activity was stopped.

3. Whale Catching by Fishing Vessels Equipped with Harpoon Cannon

As outlined in a previous paper (Kapel, 1978) the first Greenlandic fishing vessel was equipped with a harpoon cannon in 1948, and a few more followed during the next 10–15 years. By 1965 more than 40 vessels had this equipment, although only some of them used their cannon in any particular season.

The whaling activity of these vessels was secondary to their fishing and was mainly directed towards minke whales. Larger species, however, were occasionally taken, in some cases by two or three vessels working together.

The catch of large whales is not used commercially; the meat is exclusively used locally for human consumption or for feeding the dogs.

DATA ON THE CATCH OF LARGE WHALES IN GREENLAND

1. Basic Data and their Reliability

For the catch of humpback whales prior to 1900 information comes from yearly reports from the colonies in Greenland, summarised by Winge (1902, pp. 498–9). Only the number of animals caught in the Frederikshåb district is given, and for 1891 it is just stated that "some" humpbacks were taken. Winge notes that most animals were caught between August and October, but that they occasionally occur as early as June and as late as December. It is also stated that a few whales had previously been caught in other districts.

For the period 1900–23 the Greenlanders' catch of humpback whales is described in a statistical survey issued by the Greenland Administration (Anon., 1944a), which also gives information on the average amount of blubber produced per whale. The above mentioned data are sparse, but probably reliable.

Data for the first catcher-boat period (1924–39) are summarised in the above mentioned statistical survey (Anon., 1944b), and comprise information on seasonal distribution, average length and production of blubber for the different species. Part of this information is also available in the International Whaling Statistics (Vol. III–XV).

For the period 1946–58 the whaling results are published in yearly reports (Anon., 1947–61). They give information on the species, date of catch and place where each specimen was landed. For the years 1946–51 additionally the sex of the animal, and for 1952–58 the production of blubber and meat for human consumption (not the part used for dogs) is given. (The International Whaling Statistics, Vol. XXXI–XLIII, also contain information on sex/length distribution for the period 1952–58). *Sonja*'s original logbooks are not available, but some general information on weather and occurrence of whales off Greenland is contained in the yearly reports.

For the catcher-boat periods all data are considered reliable with the general provision that the length of the animals is probably estimated by an experienced whaler rather than measured. It should also be stressed that the position of the catch is not known exactly (except for 1957), but only the name of the settlement where the whale was landed.

The data base for the last period, the catch by fishing vessels since 1948, is less reliable. Information comes from two sources: the Greenlanders' Lists of Game (Anon., 1954–74), and Whaling Reports filled in by the owner or captain of the vessel. As outlined in a previous paper (Kapel, 1978) some uncertainty exists in respect to this information on date and position of the catch, sex and length of the animal, etc. It appears immediately that some of this information is often lacking, and in the case where it actually is given in the reports we have only a vague idea of the degree of accuracy.

In regard to large whales there is one further uncertainty: only four of the species have well defined designations in Greenlandic: bowhead ("arfivik"), humpback ("qiporqaq"), minke ("tikâgugdlik"), and sperm whale ("kigutiligssuaq"). According to previous authors, the Greenlandic name "túnulik" (or "túnuligssuaq") is used for both blue and fin whales, and the designation "tikagugdliussaq" is used for fin whales in some regions, but may in other areas indicate sei whales (or both species). In brief, the species identification of blue, fin and sei whales is doubtful for the period 1948–76. Enquiries during field work in the summer 1977 lead the present author to conclude that most (if not all) specimens previously recorded by the fishing vessels as sei whales were actually fin whales.

Winge (1902, p. 374) could not report confirmed evidence of the occurrence of sei whales in Greenland waters, but indicated that it was likely that the species visited the area occasionally. The catch of two sei whales by the Norwegian expedition in 1924 and the reports of *Sonja* clearly indicate that their occurrence coincided with a rather long period of slightly increased surface temperatures and withdrawal of the East Greenland drift ice from the waters off southwest Greenland (Hachey, Hermann and Baily, 1954). Since around 1965 the hydrographical situation in this area has changed again, and is comparable with that of the turn of the century. This fact would support the above statement, that "sei whales" reported in recent years are more likely fin whales.

2. Number and Species of Whales Caught

Tables 1A–1C show the number of large whales caught in Greenland since 1886, by year and species. Significant catches were only taken during the two catcher-boat periods: an average of 28 whales per season in 1924–38 (max. 47, min. 5), and of 38 whales (68–21) per season in 1946–58. Prior to 1924, and in the period 1959–72, on average less than five large whales were caught per year in West Greenland, with a maximum of 11 (1900) and several years without any catch. For the last three-four years the average is 15 whales per year.

Humpback whales (Megaptera novaeangliae)

The annual catch of humpback whales in Frederikshåb district (FRH in Table 1A) was around 5 (0–11) per year in the period 1886–1909. In Godthåb district (GHB) 2–3 were taken per year between 1900 and 1914. In the following years catches were small, and the whale-boat activity stopped when the Greenland Office started modern whaling in 1924.

During the first six years of operation S/S *Sonja* took a fair number of humpbacks (average 10 per season), but in the following ten years the average catch was less than four (6–1) per season. 45% of the catch of humpbacks in this period was landed in the traditional humpback-hunting districts (GHB + FRH), the remainder farther north, towards Umanak district (UMK in Table 2B, 71° N).

In the period 1946–53 the catching-boat took a few humpback whales per season (max. 5). Most of these were landed in the southernmost districts (south of 64½° N). When the land station was established in 1954, *Sonja Kaligtoq* stopped catching humpbacks.

Some of the first fishing vessels of Godthåb and Frederikshåb districts to obtain a harpoon cannon for hunting minke whales also took one or two humpback whales in the years 1958–65. Since 1965 the number of harpoon vessels actively engaged in the minke whale fishery did not increase (Table 1C), but the number of humpback whales caught per season went up to 3–5 in the years 1966–72, and for the following four years the average catch was nine per year. The explanation of this increase might be, either that the humpbacks were becoming more abundant in Greenland waters, or that the interest in catching them was increasing. This question will be discussed further below.

Blue whales (Balaenoptera musculus)

Blue whales were never taken in great numbers in Greenland. Altogether 26 specimens, less than two per year on the average, were taken by *Sonja* before World War II (most of which were in the Disko Bay area, Tables 1B and 2A), and for the period 1946–58 the catcher-boat took a total of 15 (seven of which were taken in Umanak district).

For the fishing vessels there are two reports of catches of "blue whales" (species identification uncertain) prior to 1958 and one in 1967.

Fin and sei whales (Balaenoptera physalus and B. borealis)

During the catcher-boat periods, fin whales were the most important species. Catches were rather stable from 1925 to 1935, on the average 23 (16–41) per season, but during the following four years the catch of fin whales rapidly decreased (Table 1B). Among the reasons for this decline the yearly reports mention that the weather was extremely bad during the whole season in 1937 and 1938 and in the last part of the 1939-season (when the catcher-boat was in operation for only three months instead of the usual 5½ months). It is further noted that "the presence of foreign catcher-boats" was a disadvantage in 1937; in the years 1931–33 pelagic fleets took a total of 332 fin whales in the Davis Strait (Jonsgård, 1966, Fig. 1), and for 1937 the figure of 461 fin whales is given for pelagic whaling, part of which took place in the Davis Strait (Jonsgård, 1955, p. 6; Jonsgård, 1977, p. 425).

According to the scope for *Sonja*'s activity, the whales were landed at a number of settlements from Nanortalik (60° N) to Umanak (71° N), with a preference for the Disko Bay area (GOD + EGM, Table 2A) and the southern part of southwest Greenland (GHB + FRH).

Immediately after World War II *Sonja* caught unusually many fin whales (ca. 50 per season), but thereafter the catch stabilized at the same level as previously (22 per season, with a maximum of 35 and a minimum of 15). In the last year of operation only eight fin whales were taken. The distribution of catches along the coast varied greatly

Table 1A

Catch of humpback whales by the Greenlanders in Southwest Greenland, 1886–1923.

	1886	87	88	89	90	91	92	93	94	95	96	97	98	99	1900–04	05–09	10–14	15–19	20–23
GHB	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18	6	10	4	–
FRH	5	5	5	3	–	+	3	8	9	8	3	7	3	7	29	17	5	5	1
SWs	5	5	5	3	–	+	3	8	9	8	3	7	3	7	47	23	15	9	1

Table 1B

Catch of large whales by S/S *Sonja*, 1924–39 and 1946–50, and *Sonja Kaligtoq*, 1951–58

	1924	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	46	47	48	49	50	51	52	53	54	55	56	57	58
Blue whales	–	1	2	7	1	3	1	1	1	3	2	–	–	4	–	–	3	4	2	2	–	–	–	1	–	1	1	1	–
Fin whales	19	30	24	22	24	24	27	16	25	17	24	23	15	9	7	3	47	51	21	21	35	15	16	15	22	22	28	21	8
Sei whales	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	1	–	–	–	–	–	–	3	1	1	–
Humpback whales	10	8	12	9	9	9	6	4	4	1	2	6	5	4	1	2	4	5	1	2	4	5	–	1	–	–	–	–	–
Sperm whales	–	2	9	2	1	2	–	–	–	–	–	–	–	–	–	–	6	6	6	3	5	6	5	4	9	9	14	28	26
Bottlenose whales	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	3
Total	29	41	47	40	35	38	34	21	30	21	28	29	20	17	8	5	60	68	31	28	46	26	21	21	31	35	44	51	37

Table 1C

Catch of whales by fishing vessels in Greenland, 1948–76.

	1948	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	76
Blue whales	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Fin whales	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	1	1	–	–	3	–	–	–	1	2	5	2	9
Sei* whales	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1*	1*	–	2*	–	2*	2*
Humpback whales	–	–	–	–	–	–	–	–	–	–	2	–	1	1	2	–	–	1	4	5	5	3	–	4	3	11	9	9	8
Sperm whales	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	1	–	1	–	–	–	–
Total	–	–	–	–	1	1	–	–	1	–	2	1	2	1	2	–	1	3	4	6	8	3	2	5	5	15	14	13	19
Active vessels	1	1	1	1	1	1	1	1	1	1	4	4	4	7	11	18	25	45	43	53	56	56	41	39	42	45	46	30	39

* Catches recorded as "sei" are doubtfully identified, and may be fin whales.
"Active vessels" are vessels for which catch of minke whales have been recorded.

Table 2A

Number of large whales landed in different regions in Greenland.

		UMK	CHR + JAK	GOD + EGM	NW + CW	HBG + SKT	Tovqussaq	GHB + FRH	South Greenland	SW + S	TOTAL
Blue whales	1924–39	1	2	14	17	5	.	4	–	9	26
	1946–53	7	2	2	11	1	.	1	–	2	13
	1954–58	–	–	1	1	–	3	–	–	3	4
	1959–76	–	–	–	–	–	.	1	–	1	1
	Sum	8	4	17	29	6	3	6	–	15	44
Fin whales (+ sei)	1924–39	18	6	94	118	34	.	107	50	191	309
	1946	9	5	8	22	4	.	3	18	25	47
	47	10	3	9	22	10 b)	.	7	14	31 b)	53 b)
	48	5	–	2	7	4 a)	.	10	1	15 a)	22 a)
	49	6	–	1	7	3	.	2	9	14	21
	50	8	1	3	12	8	.	10	5	23	35
	51	3	1	–	4	3	.	4	4	11	15
	52	–	–	1	1	12	.	3	–	15	16
	53	–	–	3	3	10	.	3	–	13	16
	1946–53	41	10	27	78	54 c)	.	42	51	147 c)	225 c)
	1954	–	–	–	–	10	10	2	–	22	22
	55	–	–	–	–	4 a)	21 b)	–	–	25 c)	25 c)
	56	–	–	–	–	1	27 a)	–	1	29 a)	29 a)
	57	–	–	–	–	–	22 a)	–	–	22 a)	22 a)
	58	–	–	–	–	1	6	1	–	8	8
	1954–58	–	–	–	–	16 a)	86 d)	3	1	106 e)	106 e)
	1959	–	–	1	1	–	.	–	–	–	1
	60–63	–	–	–	–	–	.	–	–	–	–
	64	–	–	–	–	1	.	–	–	1	1
	65	–	–	–	–	1	.	–	–	1	1
	66–67	–	–	–	–	–	.	–	–	–	–
	68	–	–	1	1	–	.	2	–	2	3
	69	–	–	–	–	–	.	–	–	–	–
	70	–	–	–	–	1 a)	.	–	–	1 a)	1 a)
	71	–	–	–	–	–	.	1 a)	–	1 a)	1 a)
	72	–	–	1	–	–	.	–	–	–	1
	73	1 a)	–	1	2 a)	2 a)	.	–	–	2 a)	4 b)
	74	–	–	1	1	4	.	–	–	4	5
	75	–	–	2 b)	2 b)	1	.	1	–	2	4 b)
	76	–	–	3	3	7 b)	.	1	–	8 b)	11 b)
	1959–76	1 a)	–	10 b)	11 c)	17 d)	.	5 a)	–	22 e)	33 f)
	Sum	60 a)	16	131 b)	207 c)	121 f)	86 d)	157 a)	102	466 g)	673 h)

Note
The letters indicate that the following numbers of "sei whales" are included in the figures: a) 1, b) 2, c) 3, d) 4, e) 5, f) 8, g) 13, h) 16.

between years. In the yearly reports several reasons for this and for the low catches in some seasons are mentioned, especially fog and other unfavourable weather conditions. It is further mentioned, that in some seasons the whales appeared to stay in certain areas, so that time in fact was wasted by searching for them in other regions for the purpose of supplying all districts with whales.

This fact was part of the reason for establishing a land station at Tovqussaq, near one of the areas where experience had shown regular abundance of whales. The following years actually gave higher catches of fin whales, especially when an increased effort in hunting sperm whales is taken into account. One reason for the extremely low catch of fin whales in 1958 was, that this year they appeared to stay in more southerly areas than in previous years, whereas the catcher boat was only operating near Tovqussaq.

As mentioned above, a few sei whales were taken by the catcher-boat between 1947 and 1957, all of them in the northern part of southwest Greenland (64½° N–67½° N).

Only four fin whales were taken by the fishing vessels between 1948 and 1967. In the following years fin and "sei" whales were caught more regularly, with an average of 6 for 1973–76.

Sperm whales (Physeter catodon)

During the initial phase of modern whaling in Greenland sperm whales played only a minor role. Altogether 16 speci-

Table 2B

Number of large whales landed in different regions in Greenland.

		UMK	JAK + CHR	GOD + EGM	NW + CW	HBG + SKT	TOV	GHB + FRH	JUL + NAN	SW + S	TOTAL
Humpback whales	1924–39	6	2	19	27	24	.	40	1	65	92
	1946	–	–	1	1	–	.	3	–	3	4
	47	–	1	–	1	1	.	3	–	4	5
	48	–	–	1	1	–	.	–	–	–	1
	49	–	–	–	–	1	.	1	–	2	2
	50	–	–	–	–	–	.	3	1	4	4
	51	–	–	–	–	–	.	–	5	5	5
	52	–	–	–	–	–	.	–	–	–	–
	53	–	–	–	–	1	.	–	–	1	1
	1946–53	–	1	2	3	3	.	10	6	19	22
	1954–58	–	–	–	–	–	.	2	–	2	2
	1959	–	–	–	–	–	.	–	–	–	–
	60	–	–	–	–	–	.	1	–	1	1
	61	–	–	–	–	–	.	1	–	1	1
	62	–	–	–	–	–	.	2	–	2	2
	63	–	–	–	–	–	.	–	–	–	–
	64	–	–	–	–	–	.	–	–	–	–
	65	–	–	–	–	–	.	1	–	1	1
	66	–	–	–	–	–	.	4	–	4	4
	67	–	–	1	1	–	.	4	–	4	5
	68	–	–	–	–	4	.	1	–	5	5
	69	–	–	1	1	2	.	–	–	2	3
	70	–	–	–	–	–	.	–	–	–	–
	71	–	–	–	–	–	.	4	–	4	4
	72	–	–	–	–	1	.	2	–	3	3
	73	1	–	–	1	5	.	4	1	10	11
	74	1	–	–	1	4	.	4	–	8	9
	75	–	–	–	–	5	.	4	–	9	9
	76	–	–	–	–	2	.	6	–	8	8
	1959–76	2	–	2	4	23	.	38	1	62	66
	Sum	8	3	23	34	50	.	90	7	147	182
Sperm whales	1924–39	–	–	5	5	6	.	5	–	11	16
	1946	–	1	3	4	1	.	1	–	2	6
	47	–	–	–	–	1	.	5	–	6	6
	48	–	–	2	2	1	.	3	–	4	6
	49	–	–	–	–	2	.	1	–	3	3
	50	1	–	1	2	–	.	3	–	3	5
	51	–	–	1	1	2	.	2	1	5	6
	52	–	–	1	1	1		1	2	4	5
	53	–	–	–	–	–	.	3	1	4	4
	1946–53	1	1	8	10	8	.	19	4	31	41
	1954	–	–	–	–	2	5	2	–	9	9
	55	–	–	–	–	–	9	–	–	9	9
	56	–	–	–	–	–	14	–	–	14	14
	57	–	–	–	–	–	27	–	1	28	28
	58	–	–	–	–	–	26	–	–	26	26
	1954–58	–	–	–	–	2	81	2	1	86	86
	1959–76	–	–	1	1	2	.	1	–	3	4
	Sum	1	1	14	16	18	81	27	5	131	147

mens were taken in the five-year period 1925–29, with a maximum of nine in 1926.

Between 1946 and 1953 sperm whales were caught more regularly, from 3 to 6 per season (average 5). Most of these were taken early in the season in southwest Greenland, some in the Disko Bay area simultaneously with the fin whale catching in this area.

In the final phase of whaling, increasing numbers of sperm whales were landed at the land station, on the average 17 (9–28) per season. With a few exceptions they were all taken in the Godthåb–Sukkertoppen area.

One general reason for the low catches of sperm whales is that the meat was considered unfit for human consumption and not much appreciated for feeding dogs. With the establishment of the land station it became possible to utilise the products in a more rational way and the sperm whales gained in importance. The development of market prices probably also played a role in this connection.

Since 1959 only four sperm whales have been caught by the fishing vessels.

Bottlenose whale (Hyperoödon ampullatus)

As an exception two bottlenose whales were caught by the catcher-boat in 1950, and three in 1958. They were all taken in late June in Sukkertoppen district.

The meat is not highly estimated by the Greenlanders, either for human consumption or for dog food. (The Greenlandic name for bottlenose whale is "anarnaq", which means "the one with laxative effect"!).

3. Seasonal and Regional Distribution of Catches

Tables 3A–3C give information on the month or half-month, in which the whales were caught in different regions.

Fin, sei and blue whales

For fin whales, information on time of the year exists for 662 out of 665 catches. Very few were caught in late May or in early June, evidently all of them in Frederikshåb and Godthåb districts (61°–64½° N, SWs in Table 3A).

Significant catches were taken by the catcher-boat in southwest Greenland (SWs + SWn) between mid-June and end of July, but rather few in the first half of August. This is true not only for the period 1946–53, when *Sonja* used to operate farther north at this time of the year, but also 1954–58 when all activity was centered around Tovqussaq.

In the Disko Bay area (CW) catches were rather small in July, probably because *Sonja* moved straight north to Umanak district (NW), where large catches were taken from mid-July to mid-August. On the return, a good number of fin whales were caught in the Disko Bay region during August.

From mid-August to the end of September there was another peak period of catching in southwest Greenland, in the years 1946–53 as well as in 1954–58. Finally, *Sonja* caught a few fin whales in South Greenland (south of 61° N) between mid-September and mid-October, especially during the first years of operation.

Obviously, the catching dates obtained from *Sonja*'s logbooks in the first place reflect the movements of the ship, which as previously mentioned operated after a certain plan. This plan, however, did take into account the migrations of the whales, which are therefore to some extent illustrated by the catching dates. The data for the period 1954–58 support the theory that the fin whales occur in southwest Greenland in two waves: a northward migration in early summer, and a southward migration in the autumn.

This evidence is further supported by sighting data from *Sonja*'s logbooks (Anon., 1944b, Diagram LVI, p. 630). The relation between the number of days when baleen whales were caught or observed, and the total number of days when the catcher-boat was operating under good sighting conditions, was calculated for every 10-day interval between 1924 and 1939. When the resulting values are illustrated in a diagram, two waves are clearly seen for southwest Greenland, one with a peak in June–July, the other in September–October. For central and northwest Greenland only one wave is seen, starting in late June, peaking in July–August, and fading out in September.

The number of sei whales caught by *Sonja* is too small to give any conclusive information on their occurrence in the Davis Strait (Table 3B). It is likely that they arrive in and leave Greenland waters simultaneously with the fin whales, but do not reach as far north as that species.

Most catches of blue whales occurred in July and August (Table 3C), and the greater number were taken in central and northwest Greenland (Table 2A). This seems to indicate a more direct northward migration to the Disko Bay area than for fin whales.

The information obtained from the catch by the fishing vessels does not add much to the migration pattern described above, apart from the fact that the whales seem to stay longer in all areas than suggested by the catcher-boat data (until early October in the Disko Bay area, and November–December in southwest Greenland).

Humpback whales

The seasonal occurrence of humpback whales in Greenland waters seems to be very similar to that of other balaenopterids. There are no records of catches in May, and only one in early June (Table 3B), but as the quantity of data is limited, this does not necessarily indicate a later arrival in Greenland waters than for fin whales.

The few catches from north and central West Greenland, for which catching dates are available, were taken in July and August. In southwest Greenland catches are distributed over the months June to November (one in December), with a peak period from late July to mid-September; this is in good agreement with the statements by Winge (1902) referred to above.

Sperm whales

In the period 1924–39 sperm whales were caught from June to October, most of them in July (Table 3C). This fact is probably explained by the circumstance that the catcher-boat started operating in June, and concentrated on fin whales when these arrived at the southernmost catching fields.

In the periods 1946–53 and 1954–58, however, the catcher-boat usually began operations earlier and the highest catches were taken in southwest Greenland from late May to the end of June, before the bulk of fin whales arrived in the catching area. It is explicitly mentioned in the yearly reports (Anon., 1947–61), that sperm whales usually arrive in southwest Greenland waters before the baleen whales.

Table 3A

Seasonal distribution and sex ratio of fin whales landed in Greenland.

		May I	May II	June I	June II	July I	July II	Aug. I	Aug. II	Sept. I	Sept. II	Oct. I	Oct. II	Nov. I	Nov. II	Dec. I	?	Total	♀	♂	NK
Fin whales																					
NW	46–53	–	–	–	–	–	27	14	–	–	–	–	–	–	–	–	–	41	20	21	–
CW	46–53	–	–	–	–	2	2	15	17	–	–	–	–	–	–	–	1	37	16	19	2
SWn	46–53	–	–	–	7	15	7	3	9	9	1	–	–	–	–	–	–	51	23	21	7
SWs	46–53	–	–	–	7	6	1	1	6	15	6	–	–	–	–	–	–	42	16	22	4
S	46–53	–	–	–	–	–	–	–	–	3	20	21	7	–	–	–	–	51	31	20	–
SW (+S)	54–58	–	–	1	5	23	13	7	18	25	9	–	–	–	–	–	–	101	41	60	–
CW + NW	59–76	–	–	–	2	1	–	1	–	2 a)	2 a)	2	–	–	–	–	1 a)	11 c)	2	5 b)	4 a)
SWn	65–76	–	–		1 a)	–	–	–	1 a)	–	–	3	2	3	2	2	1	17 d)	2	7 a)	8 c)
															2 b)						
SWs	68–76	–	1	–	–	–	–	–	2 a)	–	–	–	1	1	–	–	–	5 a)	3	1	1 a)
1946–53	♀	–	–	–	8	8	17	18	11	10	16	13	5	–	–	–	–	.	106	.	.
	♂	–	–	–	6	12	20	15	15	14	11	8	2	–	–	–	–	.	.	103	.
	NK	–	–	–	–	3	–	–	6	3	–	–	–	–	–	–	1	.	6	6	1
1954–58	♀	–	–	–	4	7	2	2	3	8	2	–	–	–	–	–	–	.	28	.	.
	♂	–	–	1	–	11	3	1	6	10	3	–	–	–	–	–	–	.	.	35	.
	NK	–	–	–	1	5	8	4	9	7	4	–	–	–	–	–	–	.	13	25	.
1959–76	♀	–	–	–	–	1	–	–	1	–	1	–	2	1	–	1	–	.	7	.	.
	♂	–	1	–	1	–	–	–	1 a)	2 a)	1 a)	3	1	1	1	1	–	.	.	13 c)	.
	NK	–	–	–	1	–	–	1	1 a)	–	–	2	–	2	1	–	2 a)	.	.	.	13 e)
					1 a)										2 b)						
1924–39		2		22		60		87		85		52		1		–	–	309	.	.	309
1946–53		–	–	–	14	23	37	33	32	27	27	21	7	–	–	–	1	222	112	109	1
1954–58		–	–	1	5	23	13	7	18	25	9	–	–	–	–	–	–	101	41	60	–
1959–76		–	1	3 a)		1	–	1	3 b)	2 a)	2 a)	5	3	8 b)		2	2 a)	33 f)	7	13 c)	13 e)
Sum	♀	–		12		35		35		37		20		1		1	–	.	141	.	.
	♂	1		8		46		38		41		14		2		1	–	.	.	151	.
	NK	2		25		76		108		99		54		6		–	3	.	19	31	323
Total		3		45		157		181		177		88		9		2	3	665	160	182	323

Expl. for letters a)–f) see note, Table 2A.

Table 3B

Seasonal distribution and sex ratio of sei and humpback whales landed in Greenland.

		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.					
		I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	?	Total	♀	♂	NK
Sei whales																					
SWn	1946–53	–	–	–	–	1	–	–	2	–	–	–	–	–	–	–	–	3	–	3	–
	54–58	–	–	–	–	–	–	–	1	–	4	–	–	–	–	–	–	5	4	1	–
Sum	♀	–	–	–	–	–	–	–	1	–	3	–	–	–	–	–	–	.	4	.	.
	♂	–	–	–	–	1	–	–	2	–	1	–	–	–	–	–	–	.	.	4	.
Humpback whales																					
NW + CW	1946–53	–	–	–	–	–	–	2	1	–	–	–	–	–	–	–	–	3	1	2	–
SWn	46–53	–	–	–	–	–	–	1	2	–	–	–	–	–	–	–	–	3	2	1	–
SWs	46–53	–	–	–	2	–	–	–	2	3	–	–	2	1	–	–	–	10	7	3	–
S	46–53	–	–	–	–	–	–	–	–	4	2	–	–	–	–	–	–	6	3	3	–
NW + CW	67–76	–	–	–	–	1	1	1	1	–	–	–	–	–	–	–	–	4	1	2	1
SWn	68–76	–	–	–	4	1	1	1	2	1	1	–	–	3	2	1	–	23	6	7	10
				1		1		4													
SWs + S	58–76	–	–	1	–	1	7	2	5	7	1	1	4	–	3	–	3	41	10	15	16
								3		3											
1946–53	♀	–	–	–	2	–	–	1	3	5	1	–	1	–	–	–	–	.	13	.	.
	♂	–	–	–	–	–	–	2	2	2	1	–	1	1	–	–	–	.	.	9	.
1958–76	♀	–	–	–	3	–	3	–	4	3	–	–	–	–	3	1	–	.	17	.	.
	♂	–	–	–	–	2	4	3	3	4	1	–	3	2	2	–	–	.	.	24	.
	NK	–	–	1	1	1	2	1	1	1	1	1	1	1	–	–	3	.	.	.	27
				1		1		7		3											
1924–39		–		6		29		19		24		14		–		–	–	92	.	.	92
1946–53		–	–	–	2	–	–	3	5	7	2	–	1	1	–	–	–	22	13	9	–
1958–76		–	–	1	4	3	9	4	8	8	2	1	4	3	5	1	3	68	17	24	27
				1		1		7		3											
Sum	♀	–		5		3		8		9		1		3		1	–	.	30	.	.
	♂	–		–		6		10		8		4		5		–	–	.	.	33	.
	NK	–		9		33		28		29		16		1		–	3	.	.	.	119
Total		–		14		42		46		46		21		9		1	3	182	30	33	119

Table 3C

Seasonal distribution and sex ratio of blue and sperm whales landed in Greenland.

		May I	May II	June I	June II	July I	July II	Aug. I	Aug. II	Sept. I	Sept. II	Oct. I	Oct. II	Nov. I	Nov. II	Dec. I	?	Total	♀	♂	NK
Blue whales	1924–39	–		4		6		12		2		2		–		–	–	26	.	.	26
	46–53	–	–	–	1	–	6	4	1	–	–	–	–	–	–	–	1	13	7	5	1
	54–76	–	–	–	–	–	2	–	1	1	–	1	–	–	–	–	–	5	3	1	1
Sum	♀	–		–		2		6		1		1		–		–	–	.	10	.	.
	♂	–		1		5		–		–		–		–		–	–	.	.	6	.
	NK	–		4		7		12		2		2		–		–	1	.	.	.	28
Total		–		5		14		18		3		3		–		–	1	44	10	6	28
Sperm whales																					
NW + CW	1946–53	–	–	–	–	1	3	3	3	–	–	–	–	–	–	–	–	10	–	10	–
SWn	46–53	–	1	1	2	2	–	1	1	–	–	–	–	–	–	–	–	8	–	8	–
SWs	46–53	–	1	12	1	–	–	–	2	1	–	1	–	1	–	–	–	19	–	19	–
S	46–53	–	–	–	–	–	–	–	–	–	–	2	2	–	–	–	–	4	–	4	–
SWn	1954–58	1	8	21	13	5	6	12	6	6	5	–	–	–	–	–	–	83	–	83	–
	1924–39	–		2		7		4		1		2		–		–	–	16	–	16	–
	1946–53	–	2	13	3	3	3	4	6	1	–	3	2	1	–	–	–	41	–	41	–
	1954–58	1	8	22	14	5	6	12	6	6	5	–	1	–	–	–	–	86	–	86	–
	1959–76	–	–	–	–	–	–	1	–	1	–	–	–	–	1	–	1	4	–	4	–
Sum		11		54		24		33		14		8		2		–	1	147	–	147	–

In the period 1954–58 rather high catches of sperm whales were taken in early August, when fin whales, as previously mentioned, were less abundant in the catching area. Altogether the distribution of catches of sperm whales may reflect the activity and preference of the catcher-boat, rather than the movements and availability of the animals.

In this case, the activities of the fishing vessels add little to the picture, apart from the fact that the catch of one sperm whale was reported from late November.

4. Biological Data on the Catch

As mentioned above in the section on the basic data and their reliability, information on stomach contents, length of the animals, their sex, and the presence of foetuses is only available in some instances. Although some doubt may be expressed about the validity of these biological data, they are presented below.

Sex ratio and reproduction

It appears from Tables 3A–3C that information on the sex of the animals is not available for the period 1924–35, whereas it is reported for most catches 1946–58, and for ca. 60% of the whales caught by fishing vessels 1959–76.

Of fin whales the sex is not reported for 323 (49%); 160 (24%) are reported as females and 182 (27%) as males (Table 3A). For the periods 1946–53, 1954–58 and 1959–76 the ♀:♂ ratios were 50:49, 41:59 and 21:39, respectively. These figures suggest an increasing percentage of males in the catches but it must be stressed that the data are limited and less reliable for the last period.

Of seven females caught in the period 1959–76 no information on foetuses exists for three, absence of foetus is reported for three, and presence of a male foetus, 480 cm, for a fin whale caught 22 August.

Of 182 humpback whales the sex is only reported for 63 (35%), 30 females and 33 males (Table 3B). For the periods 1946–53 and 1959–76 the ratios were 59:41 and 25:35, respectively.

For 16 out of 17 females caught 1959–76 information is given on foetuses: absent in 13 and present in 3. The three foetuses were a 37 cm female (23 July), a 320 cm female (28 November), and a 200 cm male (30 November).

For blue and sei whales the data are too sparse to give any valuable information on sex ratios or reproduction.

Length of the animals

Information on total length of the whales is given in Anon. (1944b) (maximum, minimum and mean length for both sexes of the species caught 1927–39), in the yearly reports (Anon., 1947–61), and in the Whaling Reports of the fishing vessels (length of individual animals). Since 1951 the length was given in metres, before that in feet. Unfortunately, it is not stated whether Danish or English units of measurements were used (33 Danish feet equal 34 English feet, or 10.36 m). Hereby is introduced a further uncertainty in addition to the one created by the way measurements were carried out. In Table 4 measurements in metres are converted to English feet and it is assumed that this unit was used until 1950.

The table shows that the data are too sparse to give any definite conclusion about the length of the blue whales caught after World War II, and that no change can be demonstrated in mean length of fin whales taken in 1946–58 as compared to 1927–39. The data indicate that fin whales caught in the Davis Strait appear to be larger than fin whales taken in the Nova Scotia–Newfoundland area, off the west coast of Iceland and off West Norway, but of similar size to those taken off North Norway (Jonsgård, 1966; Mitchell, 1974; Rørvik *et al.*, 1976; Sergeant, 1977). This hypothesis will, however, be difficult to prove, as the existing data are poor, and exact measurement can hardly be obtained, taking into account the magnitude and character of present catches.

The mean length of humpback whales taken after 1946 is smaller than that of those caught before World War II. Even if six males and one female under 35 ft (10.7 m) taken in the period 1959–76 (and one male 1946–51) are not used in the calculation, a difference in mean length of 4–5 ft for males and 3–5 ft for females remains.

The small number of sperm whale measurements from the period 1927–39 does not allow for a comparison with the data for the periods after 1946. The mean length seems to be similar to that of sperm whales taken off Iceland and at high latitudes in other areas of the North Atlantic.

Table 4

Maximum, minimum and mean length of whales caught in Greenland (lengths in feet).

		Blue				Fin				Humpback				Sperm			
		No.	Max.	Mean	Min.	No.	Max.	Mean	Min.	No.	Max.	Mean	Min.	No.	Max.	Mean	Min.
1927–39	♂	25	83	72	62	236	70	60	51	62	58	48	38	5	60	57	54
	♀		81	73	68		73	63	47		59	49	35	–	–	–	–
1946–50	♂	5	80	76	73	88	65	58	47	7	50	42	30	26	55	50	43
	♀	6	77	75	73	87	68	60	46	8	49	44	38	–	–	–	–
1951–53	♂	1	–	75	–	21	68	60	50	3	48	44	38	15	54	50	45
	♀	–	–	–	–	25	70	60	52	3	51	46	37	–	–	–	–
1954–58	♂	1	–	73	–	61	65	60	52	–	–	–	–	86	60	51	41
	♀	2	92	80	78	40	73	63	56	–	–	–	–	–	–	–	–
1959–76*	♂	–	–	–	–	12	90	63	43	24	59	41	26	1	–	36	–
	♀	1	–	71	–	7	85	65	33	17	56	45	33	–	–	–	–

* Accuracy of all measurements for 1959–76 is doubtful. A few sei whales may have been reported as fin whales.

Food

The catcher-boat did report on the stomach contents of the whales, but information on this has only been available to the author for one year of this period (1957), and for some of the whales caught by fishing vessels in 1959–76 (Table 5).

For fin and humpback whales krill and other plankton organisms seem to play a minor role in Greenland waters compared with small fishes, especially sand-eels (*Ammodytes* sp.) and capelin (*Mallotus villosus*). This is in contradiction with the statement by Sergeant (1977, p. 463), that krill were reported in 75% of the stomachs, but in good agreement with the general information given by Winge (1902). Sergeant's source was information on *Sonja*'s whaling in the 1950s obtained from the Bureau of International Whaling Statistics in Sandefjord, and the yearly reports (Anon., 1947–61) repeatedly stress that the presence of "plankton" is of decisive importance for the movements of the whales. This, of course, does not exclude that the whales are attracted by sand-eels or capelins feeding on concentrations of plankton.

The two sei whales taken in 1957 were both feeding exclusively on krill. The same is true for one blue whale taken by *Sonja* in 1957; the report of other food items in two blue whales caught by fishing vessels must be regarded with some reservation.

The sperm whales caught in 1957 were eating larger fishes, especially wolffish (*Anarhichas* sp.) and redfish (*Sebastes* sp.). Other remnants of food items may have been overlooked, but the data do not agree with the information by Winge (1902), that mainly Greenland shark (*Somniosus microcephalus*) and occasionally lumpfish (*Cyclopterus lumpus*) were found in the stomach of sperm whales caught in Greenland.

OBSERVATIONS AND SIGHTINGS

1. Observations from the Catcher-boat

It has not been possible for the present author to trace the original logbooks of *Sonja*, nor the reports which the captain must have sent to the Greenland Administration. Some of the observations by the catcher-boat are, however, incorporated into the survey over the period 1924–39 (Anon., 1944b), and into the yearly reports issued by the Administration (Anon., 1947–61).

The reports for the years 1947 to 1953 include information on weather conditions and number of whales seen:

1947 mid-May to mid-November. Catch 51 fins, 11 other baleen whales, and 6 sperm whales. 436 whales observed, mainly fins. No comments on weather. Abundance of "plankton" from S to N.

1948 late May to late October. Fog in late June limited fin whale catches. Navy ship reported abundance of whales off Holsteinsborg in July–August, when *Sonja* sought for whales farther north, with little success. Many whales off Frederikshåb in late September, but none farther south. (Catch 21 fins, 4 other baleen whales, 6 sperms).

1949 early June to late October. Bad weather, especially fog during most of the season. 95 baleen whales and 19 sperm whales observed (21 fins, 4 others, and 3 sperms caught).

1950 early June to early October. Many whales observed in late June and early July, but bad weather limited the catch. Altogether ca. 300 whales observed, mainly fins (catch 35, 6, 5).

1951 late June to late October. Fog during most of the season. 90 whales observed, 26 caught (15, 5, 6).

1952 mid-June to late October. Fog until end of August limited catch, then three weeks with good catches in the

Table 5

Stomach contents reported for large whales in Greenland.

	Blue		Fin		Sei	Humpback	Sperm
Stomach contents	1957	1956–76	1957	1959–76	1957	1959–76	1957
Krill	1	–	5	3	2	4	–
"Shrimps"	–	–	–	–	–	2	–
Pteropods	–	–	–	–	–	2	–
"Plankton"	–	–	–	–	–	2	–
Krill, etc.	1	–	5	3	2	10	–
Krill + sandeels	–	–	2	–	–	–	–
Pteropods + capelin	–	–	–	1	–	1	–
"Plankton" + capelin	–	1	–	–	–	–	–
Mixed	–	1	2	1	–	1	–
Sandeel, Ammodytes	–	1	14	2	–	8	–
Capelin, Mallotus	–	–	–	5	–	15	–
"Small fish"	–	–	–	2	–	1	–
Cod, Gadus morhua	–	–	–	–	–	1	1
Redfish, Sebastes	–	–	–	–	–	–	3
Wolffish, Anarhichas	–	–	–	–	–	–	7
Cod + redfish	–	–	–	–	–	–	5
Cod + wolffish	–	–	–	–	–	–	3
Redfish + wolffish	–	–	–	–	–	–	9
Fish	–	1	14	9	–	25	28
Total no. reports	1	2	21	13	2	36	28

Sukkertoppen area. Of 139 fin whales observed, 134 were seen in this region (catch 15 fins, 5 sperms).

1953 early June to early October (except late July). No information on weather. 200 whales seen, 21 caught (15, 4, 2).

In general, fin whales seem to have been abundant during this period, especially off Frederikshåb–Holsteinsborg (SW). Factors limiting the catch were weather conditions and the operational strategy of the catcher-boat.

For 1957 the exact positions of the catches are available (Fig. 1). They show clearly that most whales were taken along the western slope of the fishing banks, or on the route to and from the land station. Most sperm whales were taken off Frederikshåb–Godthåb, most baleen whales off Godthåb–Sukkertoppen.

2. Observations from Research Vessels and During Field Work

Sightings by Norwegian scientists on board the whaling vessel *Harøybuen* in 1968 included observations from Southwest Greenland in early August (Jonsgård and Christensen, 1968). Sergeant (1977, pp. 463–465) summarised these, and the information obtained from ICNAF's *Norwestlant* operation in 1963 (Sergeant, 1968). He concludes that fin whales are more abundant at East than at West Greenland. Sightings of other large whales were few during the *Norwestlant* operation.

Christensen (1977, Tables 6 and 9) reported on sightings off West Greenland in 1973 and 1974. Both years the observations in this area took place from mid-June to late

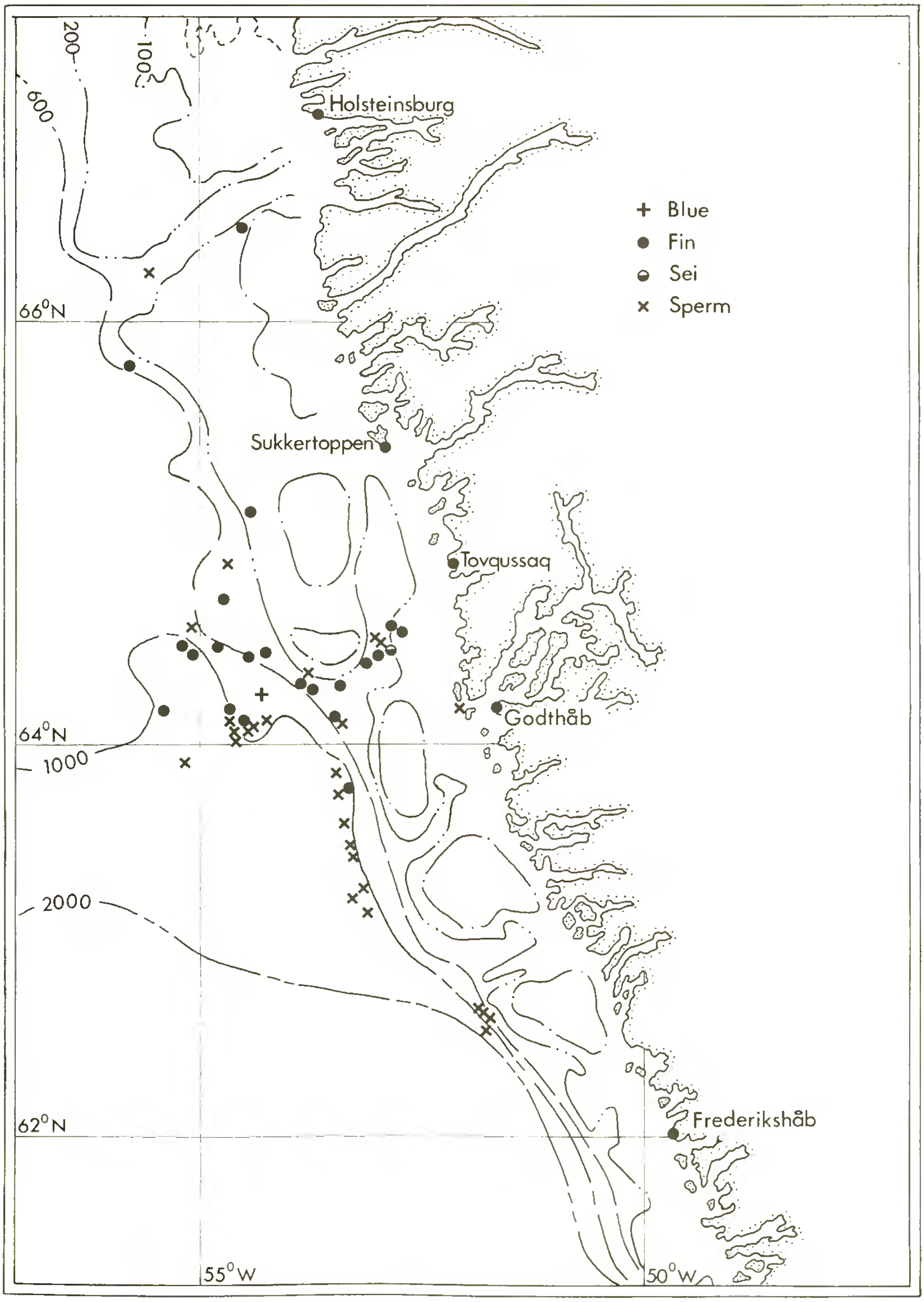

Fig. 1. Position of catches in 1957 by S/S *Sonja Kaligtoq*.

Table 6

Observations of whales by R/V *Adolf Jensen*, 1975–77.

Period	Minke	Fin	Blue	Humpback	"Whale"	Sperm	Other cetaceans
1975							
May II	3	–	–	–	–	–	–
Jun. II	–	–	–	–	–	1	–
Jul. I	–	–	–	–	–	2	1 bowhead
Sept. I	1	–	–	–	–	–	–
Sept. II	2	–	–	–	–	–	20–30 harbour porpoises
Oct. I	1	–	–	–	–	–	–
Total	6	–	–	–	–	3	1 bowhead, 20–30 harbour porpoises
1976							
May I	–	–	–	–	–	2	–
June I	1	–	–	–	–	–	–
June II	–	–	1	3	–	–	4–600 pilot, 1 killer
Aug. I	–	–	–	–	–	–	7 harbour porpoises
Total	1	–	1	3	–	2	4–600 pilot, 1 killer, 7 harbour porpoises
1977							
Mar. II	–	–	–	–	–	2	–
June I	–	–	–	2	–	–	–
July I	3	–	–	5	–	–	10 pilot, numerous white-beaked dolphins
July II	–	–	–	2	–	–	–
Aug. I	1	–	–	1	–	–	1 bottlenose whale
Aug. II	6	1	–	–	–	–	–
Sept. I	1 (?)	–	–	–	–	–	–
Oct. I	1	–	–	6+	–	3	–
Oct. II	–	–	–	–	–	–	*c.* 20 pilot
Total	11 (12?)	1	–	16+	–	5	1 bottlenose whale, *c.* 30 pilot, +++ white-beaked dolphin

Table 7

Observations of whales at offshore oil-drilling sites in West Greenland, summer 1977.

Period	Minke	Sei	Fin	Blue	Humpback	"Whale"	Sperm	Other cetaceans
N (1)								
June II	2 (2)	–	–	–	–	–	–	–
July I	3 (3)	–	–	–	–	–	–	6 (3) killer
July II	2 (2)	–	3 (3)	–	–	2 (2)	–	–
Aug. I	38 (7)	–	–	–	2 (1)	3+ (2+)	1	–
Aug. II	4 (2)	–	3 (3)	–	–	–	–	–
Sept. I	1?	–	1	–	–	–	–	–
Total	50 (7)	–	7 (3)	–	2 (1)	5+ (2+)	1	6 (3) killer
C (2)								
July I	–	–	–	–	–	–	–	200 pilot (200)
July II	1	–	–	–	–	14 (8)	–	50 pilot (50)
Aug. I	9 (3)	–	–	–	–	3 (1)	–	–
Aug. II	2 (2)	–	2 (2)	2 (2)	–	2 (2)	4 (4)	1 bowhead, 3 harbour porpoises (3)
Sept. I	1	–	2 (1)	–	–	–	–	–
Total	13 (3)	–	4 (2)	2 (2)	–	19 (8)	4 (4)	1 bowhead, 3 harbour porpoises, 250 pilot (200)
S (3)								
July I	10 (3)	–	4 (2)	–	13 (3)	–	–	–
July II	2 (1)	1	5 (5)	–	7 (3)	2 (1)	–	–
Aug. I	4 (3)	2 (2)	29 (9)	–	3 (2)	1	–	10 (10) pilot ?
Aug. II	23 (6)	2 (1)	50 (26)	–	26 (6)	4 (2)	–	–
Total	39 (6)	5 (2)	88 (26)	–	49 (6)	7 (2)	–	10 (10) pilot ?

Notes:
(1) *c.* 67° 53′ N, 56° 44′ W, 19 June–9 September (ARCO).
(2) *c.* 66° 56′ N, 56° 35′ W, 11 July – 13 September (CHEVRON).
(3) *c.* 65° 31′ N, 54° 45′ W, 3 July–31 August (MOBIL).
Figures in brackets are maximum number of whales seen at one time within an observation period (duration 10–120 min.).

August, and evidently concentrated in the northern regions (SWn, CW and NW in this paper, ICNAF Divs 1B and 1A). Minke whales were most numerous, but also fin whales were seen frequently (70 and 138++ specimens for 1973 and 1974, respectively). No sei whales were seen, but in 1973 two blue whales were seen in the Umanak Fjord (71° N). In 1974 33 sperm whales and 3 humpback whales were observed, most of them in the southern regions (SWs, ICNAF Divs 1D and1E).

Since 1975 the research vessel *Adolf Jensen* (Greenland Fisheries Investigations) has reported regularly on whales seen occasionally during other work. 18 (19?) minke whales, 1 fin whale, 1 blue whale, 19+ humpback whales, 10 sperm whales, and 1 bowhead whale were recorded 1975–77 (Table 6). As southwest Greenland is the usual area of operation for *Adolf Jensen*, most observations were from this area, and at the fishing banks, i.e. nearer to the shore than the above mentioned observations (Fig. 2). This fact possibly explains the relatively high number of humpbacks observed by the research vessel as compared with other observations. Further, most of these sightings were done in 1977, which indicate that humpbacks this year were unusually abundant off West Greenland.

In summer 1977 the present author visited Godhavn (Disko Island) in early August and Umanak district from mid-August to early September. Local hunters stated that bowheads were frequently seen in April–May quite near the settlement, 2–3 at a time. Fin whales were often seen in small flocks, arriving in early summer but most common in September. Blue and humpback whales were only rarely

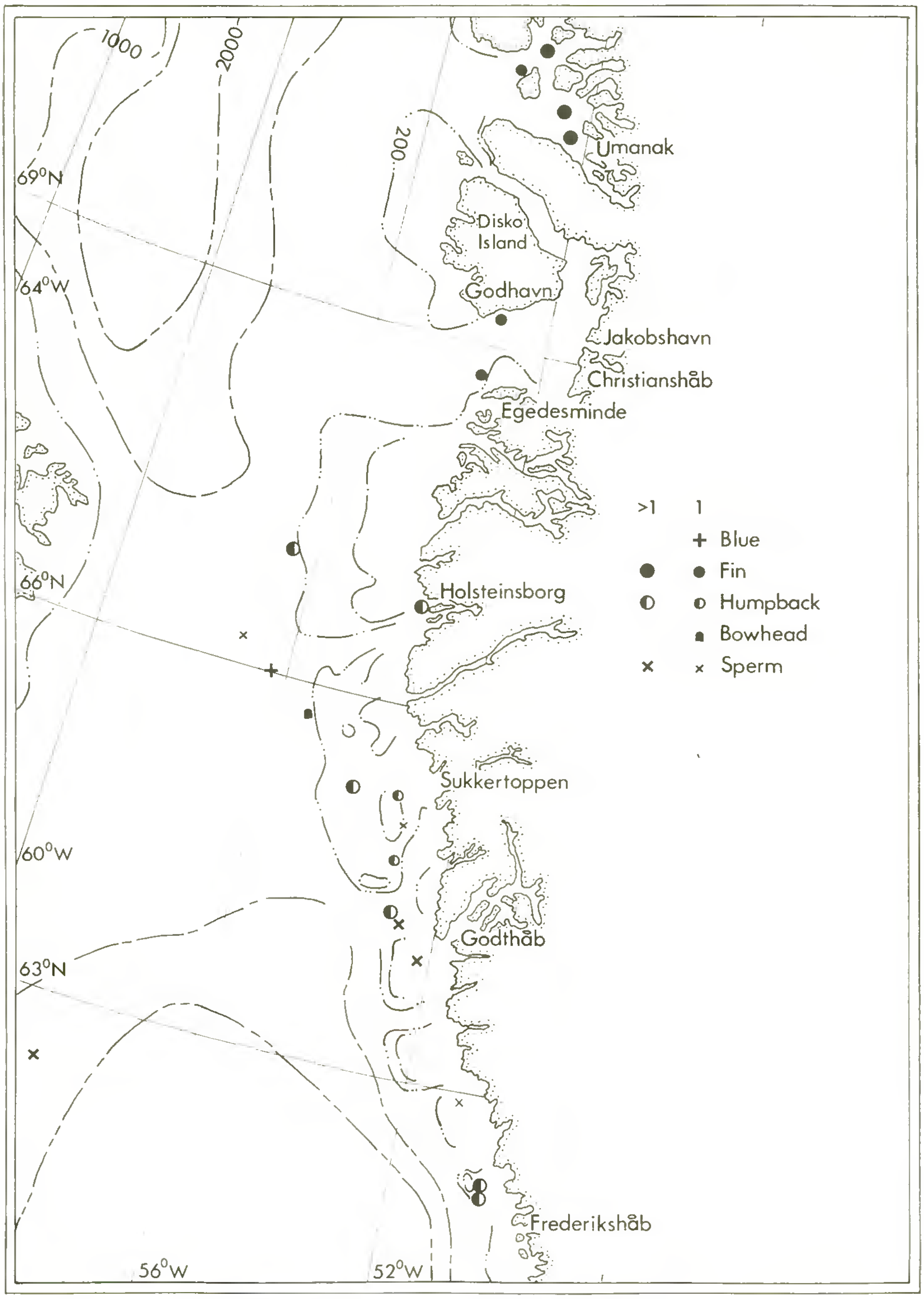

Fig. 2. Observations by r/v *Adolf Jensen*, 1957–77.

seen. One fin whale was seen just west of the settlement when we left in early August. In the Umanak Fjord fin whales were seen on three out of ten trips with a small boat in late August. They appeared single or 2(3) at a time (7–8 whales in 4 sightings).

3. Observations from Research Oil-drilling Sites

In 1977 sightings of seabirds and marine mammals were carried out by ornithologists on board supporting ships stationed at or near the sites for oil drilling investigations (Fig. 3). The observations took place from late June or early July to early September.

Table 7 shows that some uncertainties exist with respect to species identification, especially for the central locality (C).

The greatest number of whales were observed at the southern locality (S), which was also the one nearest to the coast and with more shallow water (ca. 100 m as compared to ca. 450 m for the central and ca. 200 m for the northern site). At the southern locality most observations were in early July and late August. A total of 88 fin whales were seen, of which 26 were during one three-hours observation period (23/8). Also humpbacks were frequently seen at this site, especially in mid-August but also a month earlier. They often approached the ship closely, like the minke whales, and occasionally the fin whales. There was one record of a humpback pair with a calf (15/7).

At the central locality (C) 14 unidentified "whales" were seen in early July; most of these were probably minke whales, which becomes the most common species here at this time. A few fin whales were also recorded, but no humpbacks. Four sperm whales were seen at this deep water locality. The record of two blue whales and one bowhead (21/8) is noteworthy.

At the northern locality minke whales were most frequently seen, especially in early August. Some unidentified whales and fin whales, and a few humpback and sperm whales, were also observed.

Although repeated sightings of the same animals probably occurred, the observations at the drilling sites indicate that both fin and humpback whales were rather common at

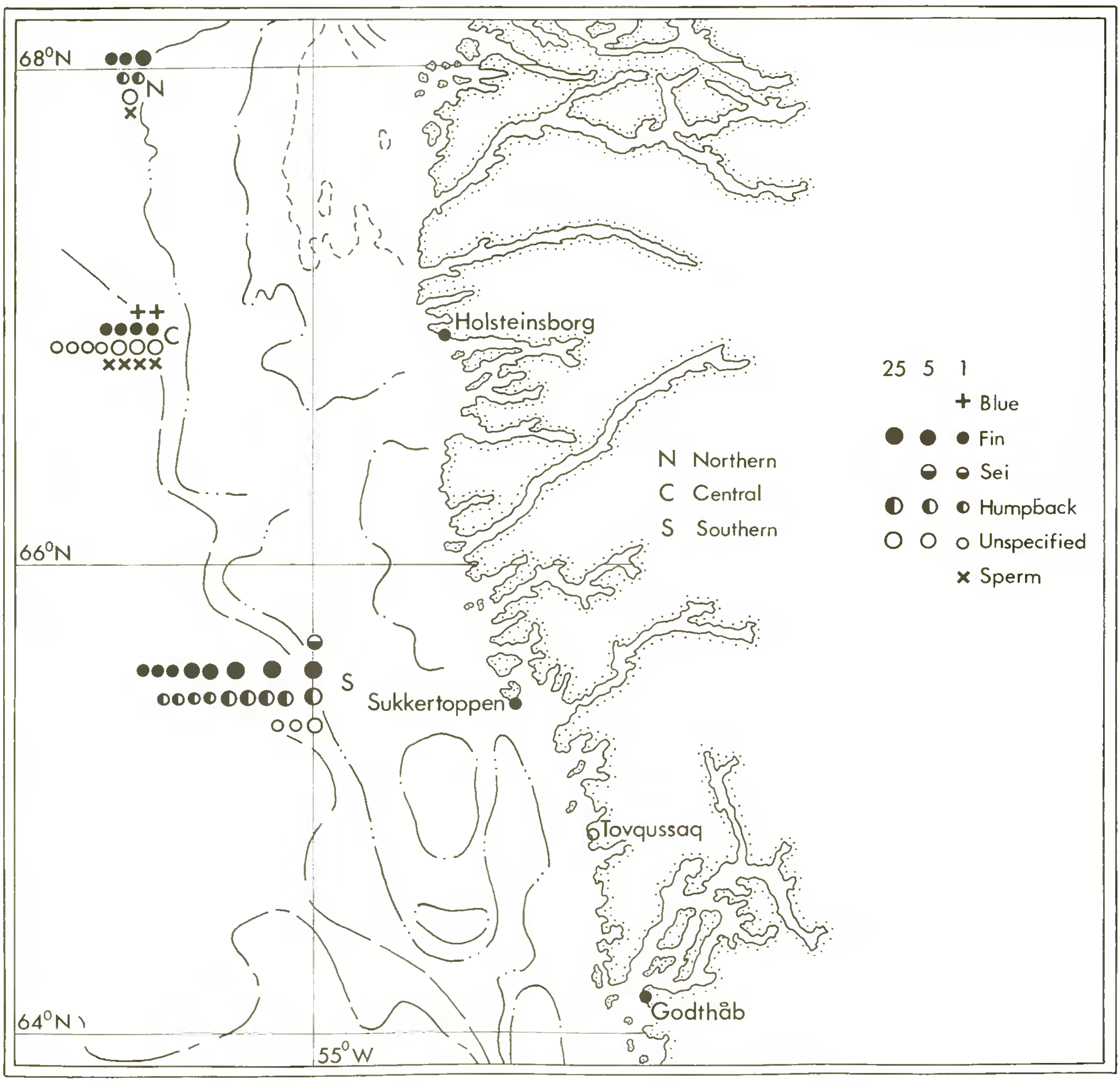

Fig 3. Observations of large whales at oil drilling sites, summer 1977.

the fishing banks off West Greenland in 1977, especially near Sukkertoppen where they in fact were seen more frequently than minke whales.

The information obtained from *Sonja*'s catches in 1957 and the observations from the oil drilling sites in 1977 are in rather good agreement with the distribution of Norwegian catches in 1924: "sei whales and humpbacks were caught well in upon the banks, the sperm whales well outside the banks, and all the blue and fin whales along the slope of the coastal banks" (Hjort and Ruud, 1929, p. 30).

CONCLUSION

For all marine organisms the oceanographic conditions play a decisive role, and environmental fluctuations are likely to change their distribution and abundance. In Arctic waters, where many species are near their northern limit, the effect of climatic fluctuations will probably be more pronounced than in temperate regions. The importance of these factors for marine mammals has been stressed by several authors, e.g. Vibe (1967).

In respect to marine mammals, exploitation by man may also influence the abundance of a species when the exploitation reaches a certain level. Some authors, therefore, consider that the study of the history of exploitation will give the best basis for the understanding of changes of abundance for a given species. In the case of the bowhead it is obvious that the relative importance of the above two points of view is evaluated differently by various workers (e.g. Vibe, 1967; Mitchell, 1977).

The history of exploitation of large balaenopterids and of sperm whales in West Greenland is outlined above. The data are not ideal, but they probably allow some general conclusions. Fin, humpback and sperm whales have been of some importance, whereas other species have played an insignificant role.

Sperm whales were only exploited on a very small scale in the late 1920s and between 1946 and 1958, with a maximum catch of 28 in 1957. Very little can be said about the occurrence of the species in the Davis Strait in recent years, apart from the fact that sights data confirm that it is regularly seen in small numbers. The catch is of no importance at the moment.

Fin whales were the main species for the whole episode of modern whaling in West Greenland between 1924 and 1958. There was a tendency to decreasing catches just before World War II, probably related to large catches taken during the 1930s by pelagic fleets in the Davis Strait, but after the war catches in Greenland stabilised at the same level as previously. It is not known if larger catches could have been taken, because the level of exploitation in Greenland was determined by other factors than the abundance of whales. Between 1959 and 1972 very few fin whales have been caught in Greenland, and recent observations indicate that the species is still a common visitor in these waters. The sightings as well as a slight increase in catches in most recent years (2–9 per year) suggest that fin whales are possibly more abundant now than in the preceding decade. The relationship of the fin whales occurring off Greenland in the summer months to other stocks in the North Atlantic is still an open question.

Humpback whales were previously abundant in Greenland waters, where a small traditional fishery was maintained in some regions off southwest Greenland until 1923. During the subsequent period of modern whaling, humpbacks were exploited initially at the same level (5–10 per year) but with a declining tendency during the 1930s. One reason for this might be the rather substantial number taken by pelagic fleets in the Davis Strait (1922–24) and from the same stock in other areas in the 1920s. Small catches were taken again by the Greenland catcher-boat after World War II until 1953. Since then the species has only been caught in small numbers by local fishing vessels in Greenland. Although the number of these has not increased since 1965, the average catch of humpbacks per year for the last four years has doubled. This evidence of increased abundance of humpbacks in Greenland waters is supported by recent sightings.

For both fin whales and humpback whales available information thus indicate that the two species are more abundant in the Davis Strait than the rather small catches suggest.

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SC/30/Doc 24

Whale Management: Strategy and Risks – a Comment

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ABSTRACT

The precision of stock estimates and validity of projections are considered in light of the implications for management strategy. In particular, the difficulties in defining a maximum sustainable yield level (MSYL) are recognised and the consequent importance of good estimates of stock abundance. Reviews of three topics are recommended.

1. The appropriateness of the MSYL as a reference level for management.
2. Whether multi-species interactions can make any contribution to current management issues.
3. The establishment of confidence limits on estimates of stock size.

A tentative, heuristic alternative management scheme is proposed utilising confidence intervals.

INTRODUCTION

The IWC was established in 1946 to promote the rational use of the large whales which provided the basis of the industry at that time. In recent years its remit has expanded to include also the smaller cetaceans and for all these species the Commission has three fundamental objectives, viz.:

(i) to safeguard whale stocks for future generations;
(ii) to protect whales from over-exploitation and;
(iii) to enable whaling to be carried out on species and stocks able to sustain it.

Regardless of any set-backs in the past, it should be possible to achieve these objectives for the stocks as they stand today given that the scientific basis of the management policy and advice is adequate. But this poses two fundamental questions; are the objectives established by the 1946 Convention still valid and is the scientific basis and detail of management adequate?

The 1946 Convention clearly had in mind the maintenance of physical yield as its principal aim, but the objectives of marine resource management have been the subject of much discussion in recent years (e.g. Anon., 1977) and clearly there are divergent views on the appropriateness of a yield objective. It is equally clear that the relative merits of these views vary with time and context. The only single constraint that might attract unanimity is that resources should be safeguarded for future generations although this itself would provoke arguments on the appropriate level of safeguard and even whether it is necessarily a satisfactory objective from an economic point of view.

The management of whale resources has been subject to a further consideration seldom met in respect of other resources – the ethical question of whether it is "right" to exploit a species of this calibre. We recognise this as a legitimate question, but note that in the Convention establishing the IWC the implicit answer was affirmative at that time and so defined a fundamental guideline of the IWC. That was a decision of countries ratifying the Convention and open to all countries interested in the rational utilisation of whale resources in 1946, and the IWC remains bound by it when judging its policies, irrespective of views held by countries or individuals on the ethical merits in the present climate of opinion. We regard that as a separate issue and thus the IWC must endeavour to meet its three primary objectives until such time as the underlying ethical considerations are reviewed in an appropriate forum.

The responsibility of the IWC itself involves social, economic, political and technical considerations, but recently decisions have leaned heavily on quantitative estimates of the resources and the level of exploitation they can sustain. Attention has therefore been focussed on the precision of these estimates and the relationship between this precision and the management policy to be adopted. The remainder of this paper reviews the scientific basis of whale resource estimates to form a view on their reliability and consequently on the form of management strategy that might be adopted in relation to them.

THE SCIENTIFIC BASIS OF RESOURCE ESTIMATES

All management policy depends upon the facts relating to the resource in question, namely:

(a) stock identity;
(b) an estimate of the current size of a stock;
(c) a knowledge of the dynamics of the stock to estimate its response to exploitation.

This is true irrespective of the specific objectives of a management policy. The choice of objective influences the conclusion one might draw from this information, and the strategy required to achieve it, but the facts of the matter are fundamental.

Our understanding of these three aspects is described briefly below:

(a) *Stock Identity*

The main source of evidence for stock separation in whales comes from tag and recapture experiments. The numbers returned are invariably low giving poor resolution and, comparing the restricted area of exploitation with the global distribution of whales, they only provide a minimum of evidence on which to divide species into management units. Genetic studies have provided some information, but as yet have not been on an adequate scale to help management. Comparisons of length frequency distributions and trends in catch per unit of effort (CPUE) of exploited stocks can be made to see if proposed divisions are independent, but they do not tell us if the management divisions are too big.

(b) *Estimates of Numbers*

There are three independent sources of estimates of numbers, (i) sightings, (ii) mark and recapture and (iii) CPUE statistics.

Sightings are the only source of information on unexploited and fully protected species and can give relative indices of abundance although they may be biased by environmental (sighting) conditions. Attempts have been made to convert these figures to estimates of absolute abundance, but the coverage is poor and estimates seldom compare well with data from other sources. Nevertheless they are valuable, particularly because of their independence from CPUE statistics.

The mark and recapture results suffer from a low number of returns which gives rise to variances that are unacceptably high and cannot be used in determining absolute stock numbers. Given the logistics of an experiment, it is even a moot point whether enough whales could ever be marked to give adequate estimates.

The CPUE statistics provide the main source of information and can be used as a relative index to be interpreted in terms of absolute numbers. Catches appear to be well recorded and should be free of error, but problems exist with the measurement of effort. Effort in each year has to be comparable and variations in wind, tonnage of vessels, sex composition of the catch, introduction of Asdic, etc., affect efficiency and must be compensated for as far as possible. Attempts to do this in respect of North Pacific sperm whale stocks recently led to the unexpected conclusion that the introduction of Asdic search techniques had little effect on the efficiency of sperm whaling in the North Pacific compared to the effect further south. This has drawn attention to our ignorance of how fleets operate and the effect on estimates of the efficiency of their effort, and it is particularly important in view of the changes in operational strategy of fleets to accommodate developments in the IWC management regime. For example, it is possible that the fleets now operating may hunt a series of substocks in sequence maintaining an apparently high but artificial CPUE over short periods of time. In general both the coverage and intensity of whaling has decreased in response to quota regulations; the first may generate bias and the second will increase variability in CPUE data at a time when good estimates of numbers are the single most important source of information for whale management.

These points qualify the reliability of CPUE statistics themselves, but the estimation of the numbers depends on a model fitted by parameters derived from the CPUE data by "least squares" techniques. The estimate assumes the model is correct and the justification for that assumption becomes weaker for models of increasing complexity which attempt more than the simple De Lury-type models. It is possible to estimate the errors in estimates derived from some of the simpler models, but in general one has to conclude that estimates of numbers, of both the current and some historic "initial" stock size, do not have high precision. This is of course a characteristic of all marine resource assessments and forms a central area for scientific judgement.

(c) *Population Dynamics*

Whether it is exploited or not, understanding the dynamics of a stock and its response to changing levels of exploitation usually involves a second type of model which incorporates quantitative estimates of the birth and death rates in order to determine whether a stock will increase, decrease or remain stable. Pregnancy rates and age at maturity can usually be measured and estimates of natural mortality from unexploited adult populations appear satisfactory, but the mortality of young can only be judged by inference. Models of the dynamic behaviour of a population over a range of exploitation levels also require some knowledge of the functional responses of these processes with changes in stock size and so far these have been impossible to define except for some variations in pregnancy rates and age at maturity.

The models are useful to investigate the behaviour of a biological system under assumptions concerning the processes that cannot be measured. But that choice of assumption is largely an individual scientific judgement so that the models are best used only to establish a "feasible" region of population response. They cannot define what a stock is or how it will respond in terms of a unique outcome. In the end their validity and their interpretation depends on the essential prerequisite of any management advice, that is – good estimates of stock numbers.

STOCK LEVELS IN RELATION TO MANAGEMENT OBJECTIVES

Obviously the dynamics of whale stocks are complex and it is difficult to determine vital parameters or functional response with any degree of certainty. But, that said, we do believe the stock units adopted by IWC are an adequate basis for management and that estimates of current stock size are a basis for action although no doubt both can be improved. We also acknowledge that population models have proved invaluable for estimating historic population sizes and judging the present level of exploitation. The more complex models have been important in illustrating principles that must be born in mind in formulating management advice based upon the simpler logistic models. The difficulty arises however in transforming this series of more or less precise estimates and conjectured relationships into advice which is credible, combining positive action with recognition of the limitation of scientific knowledge.

We see the advice as a hierarchy of scientific decisions set in the context of the information available. From the estimates of stock numbers, and a judgement of their precision it is necessary to decide:

(i) whether there are enough animals to safeguard future management options;
(ii) given (i), what is the sustainable yield of the present or some defined minimum stock?;
(iii) given (ii), what is the relationship between this sustainable yield, the MSY and trophic interactions both within and between species?

A comprehensive solution of all three questions implies total knowledge. We are concerned how far scientific advice can usefully be applied, so it is convenient to consider them in reverse order.

In the Southern Ocean, for example, there are three types of trophic relationship to be considered, that between baleen whales and their food resource (krill), the relationships between whales and other species arising from competition for krill, and the relationships within a single stock caused perhaps by the same process. The first will become important if krill is itself exploited bringing Man into competition with the baleen whales. This is developing slowly but the consequences for whales are entirely speculative:

they can have no bearing on current management measures and so the IWC can only keep the problem under review and encourage appropriate research.

Interspecific relationships are of more immediate concern. Effects have already been postulated from changes in pregnancy rates and changes in the species composition of baleen whale stocks in response to exploitation. In particular, sei whale stocks appear to have expanded since 1930 and to be capable of further expansion as they move toward equilibrium with the current stock of baleen whales as a whole. However, our knowledge of how the multi-species population behaved in 1930 is very limited, and how it might behave between now and the achievement of a new equilibrium many years hence, if it exists, can only be conjectured. We believe that in this situation it is only possible to manage on the basis of the current stock size, rather than hypothetical possibilities.

The functional response of a population to variations in its own size are analogous to the interspecific interactions and hardly better understood. The concept of a species or stock specific MSY, and the constraint of the schedule that requires the IWC to consider the stock in relation to its own intraspecific MSY implies that the MSY can be defined exclusive of interspecific effects, but in fact they cannot be distinguished. In short there is little prospect of defining the MSY of an individual species with any precision, and no immediate prospect of defining the MSY of a stock within an interactive complex. So while it may be considered that the sustained yield of some stocks has declined, and that complete protection should promote recovery, it is not yet possible to define a programme of exploitation that will certainly achieve it. If the true MSY cannot be defined, neither can the MSYL associated with it and the third question cannot be answered.

The second position is to estimate the current stock size and its sustainable or replacement yield, and to decide its relationship to the minimum stock required to preserve future management options: it may be possible to maintain a level of yield even though it is not possible to relate it to a theoretical maximum potential. If a stock is capable of growing in numbers, and we assume this to be true of the smallest socially viable group of mammals, then by definition that stock has a sustainable or replacement yield, small though it may be. From a review of information available it is clear that tolerable estimates of current stock size have been achieved for many stocks, giving an estimated level of productivity of about 4%. These provide a usable basis for management action but it is extremely difficult to relate them either to MSYL, or to any biological minimum stock level. Inclusion of the MSYL reference level in the New Management Procedure (NMP) therefore presents an immediate difficulty and hence controversy, but before pursuing the search for an alternative it is necessary to review briefly the safeguards attached to any management advice in the NMP.

SAFEGUARDS IN MANAGEMENT ADVICE

The basic structure of safeguards in the NMP is illustrated in Fig. 1. First the modified logistic form of the underlying model provides MSY at 60% of the unexploited stock level: it is skewed to give an initial safeguard compared to the strict logistic which estimates MSY at 50% of initial stock size. Secondly, harvest at that stock level is restricted to 90% of MSY (i.e. about 3.5% of population numbers) implying that the proximate objective of management is a stock level enhanced above the MSYL. Thirdly, quotas are reduced by 10% for each one percent shortfall of stock below MSYL with a threshold entry to the fully protected category at 90% MSYL. Logically, management will have fallen short of its objective if the current stock size falls short of the enhanced stock level and it could be argued that the graduated reduction in quotas should be referred to that enhanced level as indicated by line 2 of Fig. 1.

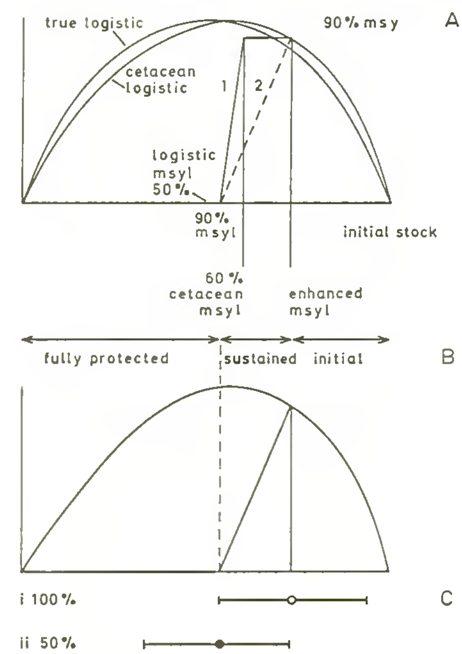

Fig. 1. A. Schematic representation of present NMP showing:

(i) the true (symmetric) logistic;
(ii) NMP baleen whale logistic providing MSYL at 60% Initial Stock size;
(iii) NMP yield to be taken at MSYL (= 90% MSY);
(iv) implied equilibrium stock level (enhanced MSYL) following harvest maintained at 90% MSY;
(v) abatement of quota at stock sizes < MSYL (line 1) to;
(vi) threshold of fully protected category (FPS) – 90% MSYL;
(vii) alternative abatement of quota from yield associated with enhanced MSYL.

B. Schematic representation of an alternative approach based on the NMP baleen whale logistic and a threshold between initial and sustained management categories. At stock levels < threshold IMS/SMS quota abated according to the error on stock estimates, i.e. probability that stock < threshold SMS/FPS.

C. Hypothetical estimates of current stock size with 95% confidence interval ± 25%.

(i) Stock estimated at threshold IMS/SMS
p stock > threshold SMS/FPS = 1.00.

(ii) Stock estimated at threshold SMS/FPS
p stock > threshold SMS/FPS = 0.50.

In both (i) and (ii)

Quota = 90% SY x error factor.

Error factor = 1−2 (normal probability integral of (x) where

$$x = \frac{\text{stock estimate} - \text{threshold SMS/FPS}}{\text{SD of stock estimate}}$$

2 is a scaling factor to reduce quota to zero when p = 0.5.

However, the enhanced level is as uncertain as the MSYL, so that it would in practice be difficult to assess the graduated reduction appropriate to any particular stock size. Apart from the referral to the MSY, the present stepped approach seems to us to be a practicable method consistent with the level of productivity which the flat-topped nature of the yield curve makes applicable over a wide range of stock sizes above and below those recorded for stocks currently being exploited.

Accepting the general format of the NMP, two questions arise from the precision of the stock estimates. First, is it appropriate to refer the NMP to the MSYL when that cannot be properly identified, and second, is the threshold and the form of the graduated reduction in quota the most appropriate in relation to the precision of stock estimates? In this connection we note recent experience that relatively small revision of analysis may have very significant consequences to management action through the sharp graduation scale of the NMP. There appear to us to be five options concerning a reference stock level to which a stepped NMP might be applied, viz.:

(i) the biological minimum stock required to maintain a viable stock;
(ii) a minimum safeguard for future management options, having regard for the timescale of recovery of cetacean stocks to fulfill those options;
(iii) the MSYL;
(iv) an enhanced MSYL;
(v) current stock size relative to some experienced stock level.

Of these (i), (iii) and (iv) cannot be identified with any precision and (ii) is largely a subjective judgement involving a trade-off between present and future objectives. This leaves only (v), the current stock size, as a credible basis for management but it is not obvious how the reference level should be incorporated into the NMP. However, we believe the uncertainty surrounding MSY has contributed to controversy surrounding whale management; there could be advantages in a less theoretical alternative and the remarks below explore this possibility to justify a re-examination of the problem within the IWC.

First it is evidently impossible to use current stock size as a criterion of management: it is essential to form an overall view of a level of exploitation, but we note this may not necessarily have to be closely related to the final advice on a quota for a particular stock. It is possible to envisage a two-tiered structure in which the existing somewhat arbitrary MSY concepts are used to categorise "Initial" and "Sustained" Management Stocks separated at a threshold where the stock is not endangered, but where it is entering a zone of exploitation where greater precision in management is desirable. Management within the "Sustained Management" category could then depend wholly on current stock size. The threshold would be analogous to the enhanced stock level implicit in the present safeguards, but the practical aim would not be to achieve a specified level of stock within the MSY framework, but to ensure that once categorised as a "Sustained Management" Stock then it should not be allowed to decline any further. This will provide the greatest safeguard for the future compatible with current management objectives and these will be met in so far as the recent catches have maintained the economic viability and yield of fleets engaged in whaling.

There remains the fact that many stocks are already within the Sustained Management category and that current stock size may decline for natural reasons or because of imprecise management. There is a necessary lower threshold for entry to a fully protected category. We would set this arbitrarily at 75% of the threshold between Sustained and Initial Management with a reduction in quota scaled to the probability that any given stock estimates falls below that 75% threshold. Given an estimate of the error on the estimate of current stock size there will be a defined probability that a stock has already declined to a "protected" status. The further the decline, the higher the probability and hence the greater the reduction might become.

CONCLUDING REMARKS

One essential difficulty surrounding the NMP is its dependence on the concept and estimation of MSY for whales. Our review of the position suggests that whilst the potential yield framework remains essential to categorise the broad level of exploitation of stocks, there would be benefit in considering the current stock size as a reference level for immediate management regulations. The suggestion made above is not intended as a definitive scheme, but more to illustrate that an alternative approach may exist. The benefit would be to remove the specifics of the MSY of a stock from its present position of immediate relevance to current quotas, and to concentrate scientific thought and effort on the central issue, current stock size, which is at once the statistic which is most reliable, and the most amenable to improvement in the immediate future by, for example, review of sampling protocols to ensure the adequacy of sampling coverage. It seems to us possible that this slight shift in perspective could assist the deliberations of IWC without causing a fundamental change in the decision practice as it exists at present.

RECOMMENDATIONS

1. The NMP should be reviewed to confirm that MSY remains the most appropriate reference for management action, and that the specific safeguards of NMP remain adequate.
2. The scientific basis of management be reviewed to decide whether consideration of multi-species interactions can make any contribution to current management issues.
3. The statistical basis of estimates of current stock size should be reviewed to establish confidence limits and to amend sampling protocols, etc.,
   (a) to encourage more extensive marking experiments, and particularly an increase in recording of sightings;
   (b) to have an annual description of the operational tactics of whaling fleets;
   (c) to ensure adequate area coverage of fishing effort/sampling to reduce residual variability of CPUE data.

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Harvesting of Whale Populations Subject to Stochastic Variability

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ABSTRACT

The effects of stochastic variation in recruitment are considered through the use of a time-lagged logistic model incorporating the present management strategy. The times taken for a population to fall into the protected category (0.9 of MSYL) are calculated for constant quota and cut-off schemes and for variations in recruitment of 2σ equal to 25%, 50% and 100%. Even for variability of ±100% the average times are of the order of hundreds of years but are also associated with a high, skewed variance. A diffusion model gives approximately the same answers as the simulations. Natural populations appear to show variability of less than 50% but sampling variability is included in this figure and it may be much less.

It is concluded that the effects of natural variability in whale populations do not warrant a change in the present management strategy but the need to ensure that MSY is not overestimated remains.

INTRODUCTION

Consideration of the risks associated with any fishing strategy is an integral part of biological management. This has been recognised by the International Whaling Commission (IWC) (e.g. Allen, 1976; Garrod and Horwood, 1978) which, for example, does not allow whaling on stocks where adequate stock estimates are not available. Further, the IWC harvesting strategy for Sustained Management Stocks is for 90% of Maximum Sustainable Yield (MSY) to be taken if the stock is over the Maximum Sustainable Yield Level (MSYL), a procedure which allows for a 10% error in estimates of MSY, and if this strategy fails the quota is reduced by 10% for every 1% that the stock falls below MSYL. However, the theoretical problems, or risks, associated with biological management of populations which have a stochastic component and are not strictly deterministic has been raised by Beddington and May (1977). These risks are associated with the natural rate of dampening of population fluctuations being reduced by an intensive harvesting regime and led to the suggestion that the IWC harvesting strategy should be based on taking less than 90% of MSY.

The stability of fisheries in such a context has been considered previously (e.g. Doubleday, 1976; Sissenwine, 1977). In response to the study by Beddington and May, May *et al.* (1979) and Shepherd and Horwood (1979) have shown that whether stability increases or decreases with fishing effort depends on the specific feed-back mechanisms of the population, and Shepherd and Horwood (1979) and Shepherd (1977) have shown that if noise is introduced into the population in different ways then opposite answers to those found by Beddington and May may be arrived at. However, the population dynamics of the whales may reasonably be represented by Beddington and May's model and the consequences of harvesting populations subject to a stochastic variability should be evaluated using their approach; even though it might be regarded as a worst case example.

This present study considers the introduction of noise into a typical baleen whale population model and evaluates the quantitative effects of noise and different harvesting strategies which have only been considered qualitatively in previous studies.

METHOD

The dynamics of an exploited stock of whales can be approximated by the recurrence relationship

$$N_{t+1} = (N_t - C_t)S + R_t, \qquad (1)$$

where N_t is the exploitable stock at time t
C_t is the catch in years t to t + 1
R_t is the recruitment to the exploited stock, and
S is the survival rate.

The simplest assumption about the form of R is that it decreases linearly with stock size and is regulated through a density dependent pregnancy rate, such that

$$R_t = \tfrac{1}{2}P_{t-M}S^M N_{t-M}, \qquad (2)$$

where P is the pregnancy rate and M is the age at maturity or more strictly age at first parturition. The exploited stock is also assumed to be the mature stock. If P is a linear function it can be expressed as

$$P_{t-M} = a - ((a-b)/N_0)N_{t-M},$$

where N_0 is the unexploited equilibrium stock size and a is the maximum pregnancy rate at N = 0. So that this equilibrium can exist b must be defined as

$$b = 2(1-S)/S^M.$$

The linear nature of equations (1) and (2) means that the equilibrium yield curve takes the familiar symmetric parabolic form with MSYL at $\tfrac{1}{2}N_0$.

Values may be assigned to the various parameters and for a general sei whale population we may set

N_0 = 20,000
M = 9
S = 0.93
a = 0.50 and hence
b = 0.27

(Values are taken from IWC, 1978.)

The equilibrium yield curve is illustrated on Fig. 1 with MSYL at 10,000 and MSY at 322; it must be noted how flat the curve is when drawn to scale.

To simulate the effect of variation within the population, noise has been introduced in one way but with three different magnitudes. R in equation (1) has been replaced by R + E, where E is a normal random variable of mean zero and a standard deviation of, firstly, 250. As the number of recruits entering the population at MSYL is 1,000 then this gives $\pm 2\sigma$ as ±50%. If variation is Gaussian and only the modulus of the deviation from the mean is taken, then the expected value, or mean deviation, is defined as

$$E(x) = (2/\sigma\sqrt{2\pi}) \int_0^\infty x \exp(-\tfrac{1}{2}(x/\sigma)^2)\, dx$$

$$= 2\sigma/\sqrt{2\pi} \qquad (3)$$

An inspection of the graphical data from minke whales (Ohsumi and Masaki, 1975) gives mean deviations of between 20% and 23%, so

$$2\sigma/\sqrt{2\pi} = 20\% \text{ to } 23\%$$

$$\therefore 2\sigma = 50\% \text{ to } 60\%.$$

This range of 50% to 60% includes a component of sampling error and as many of the values were derived from cases with fewer than 10 whales this component may be large. Thus assuming $2\sigma = 50\%$ for the simulation is likely to generate fluctuations in recruitment greater than those which naturally occur.

All simulations were run for a period of 2,000 years for a range of harvesting strategies taking 1.0, 0.95, 0.9, 0.8 and 0.7 of MSY, the model starting each time from its equilibrium position. For each strategy the catch was set at (i) a fixed constant quota (ii) the fixed quota as long as the stock size was above MSYL; if the stock size fell below MSYL, then for every 1% it fell below MSYL the quota was reduced by 10% (see Fig. 2). This is the present IWC "cut-off" mechanism. For the series in which the "cut-off" mechanism was employed the average catch over the 2,000 years was calculated as a percentage of the equilibrium catch (it would always be 100% for the quota system) and the time noted when the stock entered the protected category, below 0.9 of MSYL.

Three simulations have been undertaken with different values of σ. The first series had $2\sigma = 50\%$, at MSYL, and the results for harvesting strategies of 1.0, 0.95 and 0.9 MSY are given in Tables 1, 2 and 3. The results from 0.8 and 0.7 are not included as in no instance did the stock go into the protected category.

The second series was carried out with the assistance of Dr G. Kirkwood at the Division of Fisheries and Oceanography, CSIRO, Cronulla. The noise introduced is less than in the first series with $2\sigma = 25\%$ at MSYL. Only five simulations were undertaken and the results from taking 1.0 of MSY are given in Table 4. For the other runs (0.95–0.7) none went into the protected category over 2,000 years.

The third series had $2\sigma = 100\%$ at MSYL and did not include the 0.7 sequence. Only with a strategy of 0.8 of MSY did some of the runs not go into the protected category and Table 5 gives the mean time for the stock to reach this level and the standard deviation of this time from 22 simulations.

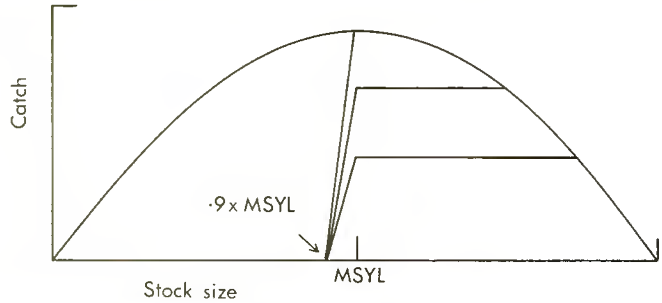

Fig. 2. Schematic representation of the cut-off scheme.

VARIABILITY IN NATURAL POPULATIONS

The mean deviations observed through the age composition of the minke whales from Ohsumi and Masaki must originate from several sources. These will include variations in pregnancy and juvenile mortality which would be observed as variations in recruitment if the data could be finely resolved, variations in adult mortality, errors in composing an age composition and sampling variation of the original animals. The variation is reduced by two years of samples

Table 1

Proportion of MSY to be taken = 1.0 ($2\sigma = 50\%$)

Run	% of equilibrium catch	Years to reach 0.9 x MSYL if cut-off used	Years to reach 0.9 x MSYL if fixed quota used
1	96	*	10
2	97	*	72
3	96	*	78
4	97	*	4
5	96	*	85
6	97	*	117
7	97	*	235
8	97	*	61
9	97	*	23
10	98	1,191	424
11	98	*	90
12	98	*	715
13	98	*	23
14	97	*	51
15	97	*	104
16	98	*	655
17	97	1,067	271
18	97	*	84
19	97	*	5
20	98	*	15
21	98	*	20
22	97	*	376
Average			160

* – not below 0.9 x MSYL in 2,000 years.

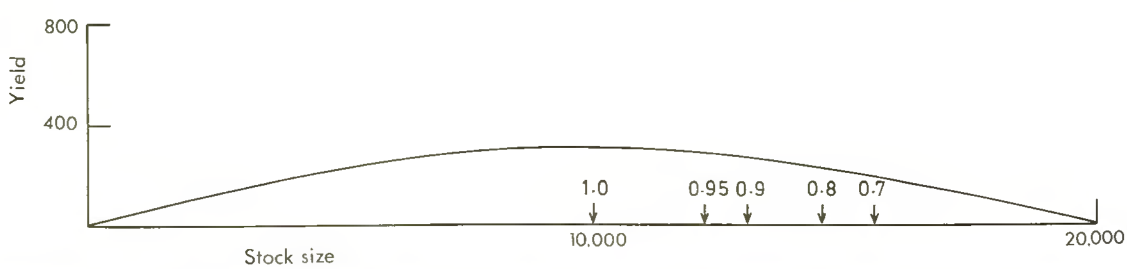

Fig. 1. Equilibrium yield curve for sei whales. Arrows mark the stock levels for equilibrium yields of 1.0–0.7 of MSY. Note yield axis magnified five times compared with stock axis.

Table 2

Proportion of MSY to be taken = 0.95 (2σ = 50%).

Run	% of equilibrium catch	Years to reach 0.9 x MSYL if cut-off used	Years to reach 0.9 x MSYL if fixed quota used
1	99	*	1,190
2	99	*	154
3	99	*	1,031
4	100	*	*
5	99	*	346
6	99	*	939
7	99	*	1,794
8	99	*	372
9	100	*	1,054
10	100	*	1,399
11	100	*	*
12	100	*	*
13	100	*	*
14	99	*	792
15	100	*	393
16	100	*	842
17	99	*	293
18	99	*	189
19	99	*	412
20	100	*	*
21	100	*	*
22	99	*	397
Average (taking * = 2,000)			1,073

* – not below 0.9 x MSYL in 2,000 years.

being grouped together. As described this melange resulted in a mean deviation of 20–23%.

A similar exercise can be repeated with the age composition of North Pacific sperm whales given by Ohsumi (1966). The age structure of the Aleutian male population over the ages 26 to 58 years is shown in Fig. 3 and this yielded a mean deviation of 15.4% giving a standard deviation of 19% from equation (3). In this case two years of catches are grouped together. The four years' catches off the coast of Japan of male sperm whales of ages 13 to 30 years gave a mean deviation of 12.4% (a standard deviation of 16%), and the females from the same location over the four years and from age 13 to 48 had a mean deviation of 16.2% (a standard deviation of 20%). All figures are similar to those from the minke whale analysis.

Lett and Benjaminsen (1977) present catch at age data for the northwestern Atlantic harp seal population for twenty years but in some years the data have been smoothed. No grouping of years is done. An analysis of the six years 1953–54 and 1961–63 gave mean deviations of 23.4 to 43.8%; standard deviations of 29 to 55%.

Best (pers. comm.) has obtained direct counts of South African right whale adults and calves. Over the period 1969 to 1977 the population appears to have been increasing substantially and the mean ratio of calves to adults he gives as 0.28. The mean deviation is 24.5% giving a standard deviation of 30.7%. The sample standard deviation was 20.4%. (These two values do not differ significantly at the 20% level with 8 and 8 degrees of freedom in an F test, but

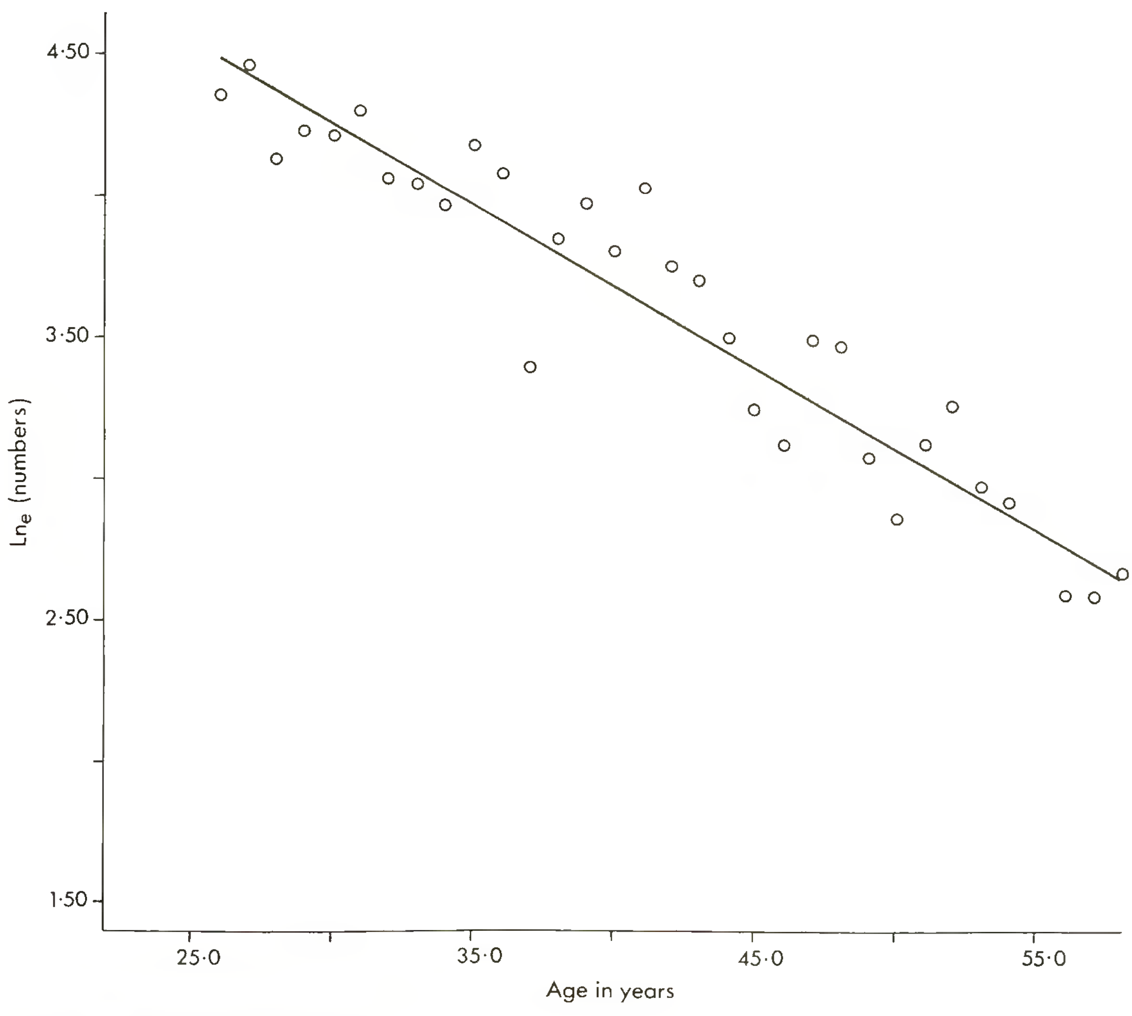

Fig. 3. Ages of Aleutian males 1961/62.

it must be remembered that equation (3) assumes that the variables are random normally distributed.)

Notwithstanding the simplicity of the approach, the whales all show standard deviations between 15% and 30% with the seals somewhat higher. A large proportion of this is likely to be due to sampling but the observed ranges of standard deviations have been used in the simulations.

Table 3

Proportion of MSY to be taken = 0.9 (2σ = 50%).

Run	% of equilibrium catch	Years to reach 0.9 x MSYL if cut-off used	Years to reach 0.9 x MSYL if fixed quota used
1	100	*	*
2	100	*	*
3	100	*	1,092
4	100	*	*
5	100	*	591
6	100	*	977
7	100	*	*
8	100	*	*
9	100	*	*
10	100	*	*
11	100	*	*
12	100	*	*
13	100	*	*
14	100	*	*
15	100	*	*
16	100	*	*
17	100	*	*
18	100	*	*
19	100	*	*
20	100	*	*
21	100	*	*
22	100	*	468

* – not below 0.9 x MSYL in 2,000 years.

RESULTS

The first series of simulations introduced a variation in recruitment of $2\sigma = 50\%$ at MSYL. Table 1 shows the results of harvesting the full MSY when the population is fluctuating because of this recruitment. If a fixed, permanent, quota of MSY is taken then each of the 22 simulations show the population falling into the protected category. The average time to reach 0.9 x MSYL is 160 years. However, if the cut-off mechanism is used, only twice does the population fall into the protected category, and in both of those cases after 1,000 years. The cut-off mechanism means that a smaller catch is taken if the population falls below MSYL and hence an average catch of less than MSY is to be expected over the 2,000 years. The catch however is still between 96% and 98% of the potential equilibrium catch.

Table 2 shows the results of taking 0.95 of MSY. It now takes, on average, over 1,000 years for the population to fall into the protected category when a fixed quota is used, and when the cut-off mechanism is used the populations always remain above 0.9 x MSYL with between 99% and 100% of the equilibrium yield being taken.

The trend is extended to the series where 0.9 of MSY is harvested; the present IWC strategy. When a fixed quota is used, in only 4 of the 22 simulations does the population fall below 0.9 x MSY, and if the cut-off is used the population remains above the protected category level, with 100% of the potential yield having been taken. The trend is continued for yields of 0.8 and 0.7 of MSY with the stocks remaining above the protected level even with a fixed quota system.

In the second series the variation in recruitment has been halved and in all cases when 0.95 or less of MSY is taken even the fixed quota system does not cause the population to fall into the protected category. Table 4 gives the results for the 5 simulations taking the full MSY: if a fixed quota is used then it takes, on average, 524 years before the population falls below 0.9 x MSYL, but this level is not reached if the cut-off mechanism is used and between 95% and 99% of the equilibrium yield is achieved.

Table 4

Proportion of MSY to be taken = 1.0 (2σ = 25%).

Run	% of equilibrium catch	Years to reach 0.9 x MSY if cut-off used	Years to reach 0.9 x MSY if fixed quota used
1	99	*	159
2	98	*	207
3	99	*	224
4	95	*	914
5	99	*	1,114
Average			524

* – not below 0.9 x MSYL in 2,000 years.

In the third series variation in recruitment is double that of the first with $2\sigma = 100\%$ and the average time for the stock to reach the protected category is given in Table 5 for the 22 simulations. As before and as expected, the quota system is always worse than the cut-off scheme. For the quota system the average time increases from 47 to 1,300 years as 1.0 to 0.8 of MSY is taken, with 530 years at 0.9 of MSY. For the cut-off scheme the range is extended to 110 to 1,550 years with 615 years at 0.9 of MSY. The standard deviations can be seen to be high, very generally of the order of the mean, and the distribution is highly skewed (e.g. Beddington and Grenfell, 1979; and Kirkwood, 1978).

A MARKOV APPROXIMATION

An approximation to the simulations can be given as a simple Markovian random walk if density dependent feed back mechanisms and age structure effects are neglected. With a given probability distribution for recruitment the time for these sequential recruitments to "walk" to some specified level may be determined. For instance, a normal

Table 5

Average and standard deviation of time in years to reach the protected category from 22 simulations (2σ = 100%).

Proportion of MSY	Cut-off scheme	Quota	
1.0	113	47	$\bar{x}$
	129	51	σ
0.95	294	248	$\bar{x}$
	219	200	σ
0.9	615	531	$\bar{x}$
	475	473	σ
0.8	*1,553	*1,297	$\bar{x}$
	*550	*521	σ

* Taking value of 2,000 years if protected category not reached by then.

distribution with a mean value of zero and standard deviation of 250 reflects the nature of the first simulation with a constant quota of the MSY. The time taken for this system to walk to 1,000 would approximate to the time taken for the stock to decrease from its equilibrium of 10,000 to the protected level of 9,000.

For such a random walk the probability that the stock is at a level x at time t P(x, t) can be given by

$$P(x, t) = (1/\sigma\sqrt{2\pi}) \exp(-x^2/2\sigma^2),$$

where

$$\sigma^2 = kt,$$

a solution of the Fokker-Planck equation.

Table 6

The probabilities of the stock reaching a level (x) within a period of t_0 years with a random walk model as described in the text and compared with the probabilities derived from the simulations (Tables 1 and 3 – constant quota).

x	Random walk		Simulations	
t_0	1,000	4,000	1,000	4,000
10	0.20	0.01	0.14	0.0
50	0.40	0.02	0.27	0.0
100	0.75	0.12	0.64	0.0

The probability that the stock will, *for the first time*, reach a level x at time t, $\bar{p}(x, t)$, can be given by:

$$\bar{p}(x, t) = (x/t)(4\pi kt)^{-1} \exp(-x^2/4kt),$$

(Feller, 1957; Bailey, 1964) and the integration of $\bar{p}$ from $t = 0$ to t_0 yields the probability that the stock level x will be encountered for the first time within t_0 years.

Table 6 gives these probabilities for two stock levels:

(1) for x = 1,000, corresponding to a stock at the MSYL falling to the protected level,
(2) for x = 4,000, corresponding to a stock at the equilibrium level when 0.9 of MSY is taken falling to the protected level.

In each case values for t_0 of 10, 50 and 100 years are calculated and compared with the proportions obtained from the simulations (Tables 1 and 3).

The results indicate a fairly high probability of the stocks falling into the protected category within 50 years if they are maintained at MSYL (p = 0.4), but only a 12% probability in 100 years if the stock is maintained at the size equivalent to taking 0.9 of MSY. The correlation with the simulations does not show substantial discrepancies, although the probabilities from the random walk should be always higher.

DISCUSSION

Provided population variation is not greater than considered in this study, the results clearly show that the present IWC management strategy of harvesting at 90% of MSY with the reduction of quotas as the stock falls does not endanger the stocks of whales with respect to random fluctuations in density. Even if a constant quota regime existed, the practical effects would on average not be noticed over a period of several hundred years, and consequently a reduction of the 90% to a smaller figure cannot be justified on this basis. This is especially the case if it is borne in mind that, if MSY is over-estimated by 30% then the stock could be reduced to a protected stock over only 20 years, if the cut-off were not applied. This latter problem is not insignificant and it was as a precaution against over-estimation that the 90% scheme was introduced. The reasons why the inherent variability is so insignificant a feature are (a) the very flat nature of the yield curve, allowing only a small percentage of the stock to be taken in any one year (b) the damping effect of the potential stock size. These results are, however, an order of magnitude greater than those found by Beddington (1977) for the times for a given harvesting strategy to drive the population into the protected category, but a much larger variability was used to derive those results (pers. comm.).

A criticism of this present study may be that the cut-off scheme applied is one which responds immediately, that is, the change in stock size is immediately detectable and the quotas are changed accordingly. In practice, there will be some time lags in making this change; at least one year for the Northern Hemisphere stocks. However the fact that a constant quota, with no cut-off, produced no significant effect for the 90% scheme indicates that the criticism is not a serious one in practical terms.

Finally, it can be concluded from this study that the effects of variability combined with the harvesting strategy of the IWC as discussed by Beddington (1977) do not warrant a change in the present management practice. However, this conclusion should not detract from the more major problem of ensuring that the MSY is not over-estimated.

SUMMARY

The quantitative effects of harvesting baleen whale populations subject to stochastic variability are considered. The results show that for the present IWC harvesting strategy adverse affects do not appear over time scales of several hundreds of years and that yields are negligibly reduced. It is concluded that the effects of natural population variability do not warrant a change in the present management strategy. This does not however reduce the need to ensure that MSY is not over-estimated.

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SC/30/Doc 26

Japanese Pelagic Whaling and Whale Sightings in the 1977/78 Antarctic Season

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ABSTRACT

The yearly change in relative abundance of sei and minke whales using CPUE data is examined for the Antarctic seasons from 1957/58 to 1977/78. Further, the yearly change of indices of abundance of the Antarctic sei and minke whales from sightings data of operating catcher boats and that of the Antarctic blue, right, fin, sei, sperm and minke whales from scouting boat sightings data are also investigated and the abundance of these seven species of whales in 1977/78 season estimated using Doi's (1971) theory.

1. SUMMARY OF EXPLOITATION IN THE 1977/78 SEASON

Japanese whaling was reduced to only one expedition in the 1977/78 Antarctic season, and therefore three whaling expeditions (one Japanese and two Soviet) operated in the Antarctic during this season.

During the 1977/78 season, the catching of sei whales was prohibited in Areas II, III, V and VI, of male and female sperm whales in Division 9 (100° W–60° W) and of female sperm whales in Division 4 (60° E–90° E).

Only the Japanese whaling expedition did not fill its male and female sperm whale and sei whale quotas in this Antarctic season. Many factors are thought to have brought this about, the main reason possibly being that the oceanographic and weather conditions were not normal. Furthermore, it is possible that the areal catch limit system affected the whaling operations.

Table 1 shows the catch and effort by pelagic whaling country based on the information from BIWS.*

Table 2 (Ohsumi, 1979) and Table 3 (Ohsumi and Yamamura, 1978) show the yearly change in CPUE by Area for the sei and minke whales, based on Japanese catch and effort data alone. These two tables indicate that the Japanese whaling grounds have changed from year to year, however, in Area IV, the CPUE of sei whales shows an almost constant value since 1967/68 except for the 1977/78 season. Yearly changes in the CPUE of minke whales were shown by Ohsumi (1979): there are not enough data for Areas I, II, V and VI to estimate any yearly trend in CPUE, but in Area III, the CPUE based on corrected CSW shows an increasing trend after the 1974/75 season, and in Area IV, the CPUE for female minke whales based on corrected CSW is estimated to have been increasing in recent years but has remained constant for males.

Table 1

Results of pelagic whaling in the 1977/78 Antarctic season

		I	II	III	IV	V	VI	Total
JAPAN								
CDW		–	–	103	524	218	78	923
Sei		–	–	–	254	–	–	254
Minke		–	–	1,012	481	668	239	2,400
Sperm	Male	–	–	–	29	111	45	185
	Female	–	–	–	–	75	36	111
USSR								
CDW		552	624	1,347	333	273	660	3,789
Sei		311	–	–	–	–	–	311
Minke		463	362	789	482	216	288	2,600
Sperm	Male	153	517	1,581	257	198	585	3,291
	Female	–	132	537	–	26	255	950

The CDW of the Soviet expeditions is based on their effort for all species in the baleen whale season. On the other hand, in the case of the Japanese expedition, most of the effort was directed towards sei and minke whales. Therefore, it is more satisfactory to only use the Japanese catch and effort data for calculating the CPUE for sei and minke whales. Fishing effort has been examined by Ohsumi (1979) for the minke whale and Ohsumi and Yamamura (1978) for the sei whale.

* BIWS: The Bureau of International Whaling Statistics, Sandefjord, Norway.

2. WHALE SIGHTING

The number of Protection Stocks in the Antarctic has been increased year by year, and at present six species have at least some of their Antarctic stocks protected (blue, humpback, right, fin, sei and sperm whales). Although the Bryde's whale population was classified as an Initial Management Stock at the 29th IWC Meeting, no quota was set because there was no satisfactory estimate of stock size.

Estimation of abundance and yearly changes in abundance is not only necessary for exploitable stocks but also for protected populations. Many approaches can be used to estimate the population sizes of exploitable whale species, e.g. a modified DeLury method, a least squares method, a modified Russell equation, cohort analysis, population

Table 2

CPUE of the minke whales caught by Japanese whaling expeditions

Year	Corrected CSW Males	Corrected CSW Females
Area I		
1975/76	337.5	319.1
1976/77	218.5	238.4
1977/78	–	–
Area II		
1973/74	74.3	90.3
1974/75	263.0	343.4
1975/76	424.1	465.8
1976/77	–	–
1977/78	–	–
Area III		
1971/72	157.7	183.4
1972/73	–	–
1973/74	837.7	1,488.0
1974/75	976.8	1,612.9
1975/76	185.2	184.7
1976/77	212.9	237.6
1977/78	122.5	132.5
Area IV		
1971/72	1,071.5	1,663.5
1972/73	729.3	1,115.8
1973/74	973.8	1,078.0
1974/75	734.1	599.5
1975/76	151.2	147.2
1976/77	400.6	373.9
1977/78	116.2	150.9
Area V		
1974/75	158.7	138.6
1975/76	234.8	191.4
1976/77	197.1	138.3
1977/78	693.1	840.1
Area VI		
1973/74	29.2	30.3
1974/75	–	–
1975/76	324.9	429.4
1976/77	37.1	40.0
1977/78	296.0	254.5

CSW: Catcher's searching hour's work (Ohsumi, 1979).

models based on age structure, the population model used in the Rome meeting, 1968, the population model used by Ohsumi and Fukuda (1972), the matrix model (Smith, 1977). However, the whale sighting method is the only approach which can be used to estimate the abundance of prohibited species of whales at present.

Two kinds of whale sighting schemes in the Antarctic have been systematically assigned to the Japanese expeditions as one of the basic records submitted to the government since the 1965/66 season as discussed by Masaki and Yamamura (1978). One is sightings by operating catcher boats and the other is sightings by scouting boats.

Table 3a

CPUE of the sei whales caught by Japanese whaling expeditions in Area IV in the Antarctic

Year	CPUE	CPUE-I	CPUE-II
1957/58	0.0096	0.0109	0.0448
1958/59	0.0062	0.0063	0.0367
1959/60	0.0080	0.0098	0.0100
1960/61	0.0052	0.0079	0.0081
1961/62	0.0165	0.0244	0.0231
1962/63	0.0102	0.0132	0.0368
1963/64	0.0000	0.0000	–
1964/65	–	–	–
1965/66	–	–	–
1966/67	0.1626	0.2088	0.1078
1967/68	0.0838	0.1314	0.0598
1968/69	0.0462	0.0483	0.0354
1969/70	0.1000	0.1116	0.0352
1970/71	0.1190	0.1232	0.0405
1971/72	0.1129	0.1083	0.0393
1972/73	0.0920	0.0987	0.0373
1973/74	0.0920	0.1056	0.0517
1974/75	0.0732	0.0683	0.0257
1975/76	0.1418	0.1115	0.0366
1976/77	0.1411	0.1147	0.0406
1977/78	0.0326	0.0312	0.0137

CPUE: Catch/catcher's day's work; CPUE-I: Catch/CHW-I; CPUE-II: Catch/CHW-II, CHW-I: Catcher's hour's work which is corrected by weather coefficient (Ohsumi and Yamamura, 1978); CHW-II: Catcher's hour's work which is corrected by weather and distribution coefficients (Ohsumi and Yamamura, 1978).

The total scouting distance in the 1977/78 season was 73,758 miles, about 50% of scouting distance in the 1976/77 season and the research by scouting boats was centred around Areas III, IV, V and VI (Table 4A).

2.1. Whale sighting by operating catcher boats

Table 4 shows the number of sei and minke whales sighted per day per catcher boat by Sector from the 1972/73 to 1977/78 Antarctic whaling seasons.

The indices of abundance show a decreasing trend since the 1972/73 season. In Sectors IV-D and V-D, large yearly fluctuations are observed.

Indices of abundance of the Antarctic minke whales in Areas I–VI in Zone B (60° S–70° S) show large annual variations and thus on the whole no trend has been observed. These tendencies parallel the changes of CPUE of minke whales shown in Table 2.

2.2. Whale sighting by scouting boats

Tables 5, 8, 11, 14, 17, 20 and 23 show the number of seven species of whale sighted (blue, fin, humpback, right, sei, minke and sperm whales) per 10,000 miles scouting distance from October to April during the 1965/66 to 1977/78 Antarctic whaling seasons.

Table 3b

Research distance (miles) covered by scouting boats in the Antarctic in the 1977/78 season

Area	I	II	III	IV	V	VI	Total
0° S–10° S	–	–	609	–	278	169	1,056
10° S–20° S	–	–	–	1,178	1,913	3,562	8,019
20° S–30° S	–	–	2,824	2,819	6,075	4,112	15,830
30° S–40° S	–	–	2,127	4,108	1,280	–	7,515
40° S–50° S	379	147	5,134	16,921	2,975	2,155	27,711
50° S–60° S	494	–	443	2,378	1,651	1,800	6,766
60° S–70° S	315	442	68	1,970	3,407	659	6,861
Total	1,188	589	12,571	29,374	17,579	12,457	73,758

(A) *Sei whales:* the indices of abundance in Sectors III-E, III-D, IV-E, IV-D, IV-A and VI-A show a decreasing trend as seen in Table 5. It has remained almost constant in Sector III-D since 1968/69, but has shown an increasing trend in Sector V-D in recent years.

It has been presumed that baleen whales migrate southwards and northwards every year between the breeding and feeding grounds. Thus any examination of the yearly change in the abundance indices, especially of baleen whales, must examine the annual changes in given months and latitudinal Zones.

Tables 6–7 show the number of sei whales sighted per 10,000 miles scouting distance by Sector in December and January. These tables clearly indicate that the abundance in Sector V-D has been decreasing each year since the 1966/67 season.

From these results, it is possible that the abundance of sei whales in Areas III, IV and V has been decreasing in the Antarctic.

(B) *Minke whales:* Tables 8–10 show annual indices of abundance of minke whales from October to April, in December and in January, respectively. Because of the large yearly fluctuation in the sighting index, no definite trend in density has been observed.

(C) *Sperm whales:* no trend in the density of sperm whales has been observed (Tables 11–13).

(D) *Prohibited species:* the annual change in density of prohibited species (blue, right, humpback and fin whales) in each sector shows large variations. No definite trend has been observed in the density of most of the prohibited species mentioned above in the greater part of sectors in the Antarctic (Tables 14–25). However, it is noteworthy that the density of blue and right whales in Sector IV-D has been increasing since the 1974/75 season (Tables 14–16, 20–22). Furthermore, a high density of fin whales in Areas I and II has been observed in recent years (Tables 23–25).

3. ESTIMATION OF ABUNDANCE OF WHALES BY MEANS OF WHALE SIGHTING

Using areal dimensions (S), scouting distance (D), number of whales sighted (N), sighting rate by species of whales (p), and sighting rate (R), the abundance of whales by year, by sector, by 10° square and by species have been calculated for the 1965/66 to 1977/78 seasons as shown in Tables 26–42, on the basis of Doi's (1971) theory which is expressed as follows:

$$\text{Abundance} = \frac{S \cdot N}{D \cdot p \cdot R}$$

where, R = 9.8 miles, p = blue (0.141), humpback (0.221), right (0.221), fin (0.211), sei (0.197), sperm (0.138), minke (0.112).

In particular, the estimations of abundance of minke whales were calculated using three approaches: in Approach I based on Doi's (1971) theory, the abundance in the sectors not covered was estimated using the yearly average value for each sector; Approach II is basically the same as Approach I, but the maximum and minimum values are excluded in calculating the average value for each sector; Approach III deals only with the actual data in each unit area (Sector and 10° square).

3.1. Sei whales

A decreasing trend in abundance in Area IV has been observed since the 1970/71 season, but an increasing tendency has been observed in the abundance of sei whales in Areas III, V and VI in recent years (Table 26).

The population in the 1977/78 season is estimated to be 100,450 whales (Table 27).

3.2. Sperm whales

Table 28 shows the abundance of sperm whales by years and by Sector. The annual change in abundance of sperm whales in each Sector shows large variations, especially in the Sectors of Zones E and D, and thus no definite trend in abundance has been observed. The total population of the sperm whale varies from 148,180 to 441,480 whales (Table 27). The abundance in the 1977/78 season is estimated to be 192,120 whales. This figure does not indicate the total sperm whale population in the Antarctic, but the average number of whales observed in the summer season in the waters south of 30° S (from October to April). Sperm whales are found in the waters of lower latitudes even in summer and therefore, to estimate the total abundance of sperm whales from sightings data, the waters north of 30° S must be investigated.

3.3. Minke whales

The abundance of minke whales has been calculated for each sector up to 1976/77 (Masaki and Yamamura, 1978). Minke whales are most abundant in the waters near the pack-ice edge in the summer season, i.e. there are large differences in abundance by latitudinal Zone as shown in Tables 29–32. Therefore, in this section, I estimate the minke whale abundance for each sector (Case I) [Tables 33–34] and each 5° square (Case II) [Tables 35–36].

Approach I

The yearly total abundance of minke whale varies from 422,320 to 1,305,580 (Table 27) during the seasons of 1965/66 to 1977/78, and the average abundance is estimated to be 646,780. The abundance for the 1977/78 season is estimated to be 917,940 whales in Case I. On the other hand, in Case II, the total abundance of minke whales varies from 486,100 to 571,940, and the average abundance is estimated to be 502,980. The abundance for the 1977/78 season is estimated to be 520,540 whales. The variations in areal abundance are not as large as those in Case I.

Approach II

The total abundance in each year in Case I varies from 371,030 to 1,311,190 and in Case II from 431,610 to 533,340. The average abundance is estimated to be 559,400 in Case I and 488,400 whales in Case II, and the abundance in the 1977/78 season is estimated to be 910,830 in Case I and 512, 620 whales in Case II.

Approach III

Tables 37–38 show the abundance by Area and by year using only the values for those Sectors and 5° squares actually investigated, and the average abundance is estimated to be 391,170 in Case I and 113,160 in Case II (Table 27). No definite trends have been observed in the yearly total and average abundances of the Antarctic minke whale.

3.4. Prohibited species

The abundance in each year and the average abundance by Sector of the prohibited species during the seasons of 1965/66 to 1977/78 are shown in Tables 39–42, and it can be seen that no yearly changes in the abundance of prohibited species (blue, right, humpback and fin whales) have been observed.

The average abundances of blue, fin, humpback and right whales in the Antarctic south of 30° S in the summer season are estimated to be 8,442, 69,680, 4,000 and 3,007 whales, respectively.

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Table 4

Number of minke and sei whales sighted per one CDW in the Antarctic

Area	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Zone D (49° S–50° S), Sei whale						
I		–	–	1.660	–	–
II	–	–	0.300	1.755	–	–
III	1.974	0.781	0.306	–	–	–
IV	4.195	3.425	3.374	6.179	5.790	0.988
V	6.934	3.657	6.973	3.048	5.317	6.333
VI	–	–	5.006	0.100	2.952	–
Zone A (50° S–60° S), Sei whale						
I	–	–	–	4.520	3.417	–
II	–	–	–	1.074	–	–
III	–	–	0.000	–	–	–
IV	2.160	0.712	0.341	–	–	0.000
V	–	0.000	–	0.556	–	–
VI	2.776	3.600	2.442	1.108	2.625	–
Zone B (60° S–70° S), Sei whale						
I	–	–	–	–	–	–
II	–	–	–	–	2.542	–
III	–	–	–	–	–	0.000
IV	–	–	–	–	–	0.036
V	–	–	–	–	–	0.000
VI	14.524	1.487	3.667	0.400	–	0.000
Zone C (70° S–80° S), Minke whale						
I	–	–	–	–	–	–
II	–	–	–	9.800	–	–
III	–	–	–	–	–	–
IV	–	7.560	8.360	–	–	0.147
V	–	–	–	–	–	–
VI	–	–	–	–	–	–
Zone B (60° S–70° S), Minke whale						
I	–	–	–	16.050	51.580	–
II	–	84.890	52.130	5.450	–	–
III	–	49.797	38.973	54.043	66.884	92.291
IV	24.990	30.075	15.813	31.900	20.740	63.080
V	–	–	18.437	28.360	31.378	14.983
VI	–	–	–	21.571	–	14.983
Zone C (70° S–80° S), Minke whale						
I	–	–	–	–	67.400	–
II	–	16.440	49.080	65.130	–	–
III	–	–	–	–	–	–
IV	–	–	–	–	–	–
V	–	–	–	–	–	–
VI	–	–	–	–	55.440	–

Table 5

Number of sei whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	0	–	–	–	–	–	–	–	–	192	–	53
	A	11	861	–	–	0	–	–	–	–	0	35	95	0
	B	–	–	–	–	–	–	–	–	0	0	15	15	32
II	E	0	502	–	–	83	–	–	–	–	–	0	–	–
	D	509	31	–	–	146	–	–	–	–	0	178	0	0
	A	31	–	–	–	9	–	–	–	0	0	29	133	–
	B	1,481	–	–	–	–	–	–	–	0	0	136	182	0
III	E	0	1,143	290	260	128	52	48	117	42	35	–	3	9
	D	337	532	540	193	100	111	82	139	67	23	–	98	160
	A	14	–	12	0	9	98	3	0	6	9	0	2	203
	B	–	–	–	–	–	–	0	0	0	–	0	3	0
IV	E	–	88	358	307	360	434	163	165	59	71	46	20	7
	D	–	404	320	174	649	421	231	229	139	106	175	112	59
	A	–	657	265	87	51	4	74	41	2	20	11	4	80
	B	–	–	20	–	13	–	0	0	0	0	0	0	0
V	E	–	–	620	288	–	157	616	157	188	34	72	0	156
	D	–	1,309	312	362	–	271	731	436	231	133	100	136	168
	A	–	161	75	103	–	–	–	2	17	111	0	7	79
	B	–	–	45	–	–	–	–	36	–	73	–	0	0
VI	E	–	–	–	–	–	0	–	0	–	–	–	0	–
	D	–	56	1,104	177	–	47	–	56	445	145	29	112	204
	A	–	506	413	232	–	7	–	248	163	130	114	46	0
	B	–	–	7	154	–	–	–	331	83	49	23	99	0
												C = 0		

Table 6

Number of sei whales sighted per 10,000 miles scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	50	–	–
	A	8	861	–	–	0	–	–	–	–	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	11	–	32
II	E	0	502	–	–	94	–	–	–	–	–	–	–	–
	D	564	0	–	–	181	–	–	–	–	–	174	–	–
	A	0	–	–	–	0	–	–	–	0	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	0	–	–
III	E	–	806	150	317	13	–	31	191	–	–	–	–	–
	D	272	425	339	292	112	139	91	109	29	–	–	–	–
	A	0	–	–	–	7	0	–	0	–	–	–	–	–
	B	–	–	–	–	–	–	–	0	–	–	–	–	–
IV	E	–	88	82	409	178	305	185	245	21	–	–	–	0
	D	–	212	388	244	940	591	303	230	174	122	3,729	107	22
	A	–	0	7	12	0	0	–	–	–	0	0	10	–
	B	–	–	38	–	–	–	–	–	–	0	–	–	–
V	E	–	–	0	725	–	0	1,176	18	292	94	172	–	156
	D	–	559	246	631	–	224	831	498	317	231	119	155	122
	A	–	0	38	–	–	–	–	–	–	–	0	9	0
	B	–	–	0	–	–	–	–	–	–	–	–	0	0
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	537	232	–	47	–	0	–	274	–	–	–
	A	–	–	0	–	–	7	–	–	–	–	–	0	30
	B	–	–	0	–	–	–	–	–	–	–	–	–	–

Table 7

Number of sei whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	14	–	–	–	–	–	–	–	–	0	0	45	–
	B	–	–	–	–	–	–	–	–	–	–	0	0	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	458	–	–	–	92	–	–	–	–	–	165	–	–
	A	40	–	–	–	12	–	–	–	–	–	70	368	–
	B	–	–	–	–	–	–	–	–	0	–	–	182	–
III	E	0	3,505	–	–	175	–	–	–	–	–	–	0	–
	D	746	544	1,113	231	99	45	149	96	89	0	–	215	133
	A	54	–	0	0	13	0	–	–	–	–	–	0	–
	B	–	–	–	–	–	–	–	0	0	–	–	–	–
IV	E	–	–	–	–	–	0	150	–	–	–	0	35	9
	D	–	604	107	168	480	233	215	202	103	135	175	150	123
	A	–	–	167	86	27	1	1	0	–	–	83	6	90
	B	–	–	–	–	0	–	0	0	–	–	–	0	–
V	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	2,242	592	556	–	186	477	369	106	0	42	44	0
	A	–	67	38	74	–	–	–	4	0	–	0	–	86
	B	–	–	115	–	–	–	–	6	–	–	–	–	0
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	96	1,918	168	–	–	–	452	445	59	24	210	–
	A	–	–	858	339	–	–	–	379	111	159	45	14	–
	B	–	–	–	272	–	–	–	171	14	43	0	78	–

Table 8

Number of minke whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	7	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	211
	A	0	0	–	–	15	–	–	–	–	32	14	28	81
	B	–	–	–	–	–	–	–	–	3,141	0	292	259	889
II	E	0	9	–	–	15	–	–	–	–	–	0	–	–
	D	0	7	–	–	11	–	–	–	–	0	5	0	–
	A	0	–	–	–	35	–	–	–	1,393	695	71	141	0
	B	–	–	–	–	–	–	–	–	1,885	1,259	472	1,212	3,643
III	E	0	0	3	22	8	43	19	10	24	52	–	36	28
	D	0	37	26	28	14	22	27	42	12	48	–	16	21
	A	0	–	93	202	50	13	35	130	44	2	0	92	90
	B	–	–	–	–	–	–	193	2,226	8,511	–	3,872	998	2,647
IV	E	–	0	16	17	7	76	22	30	48	59	19	14	17
	D	–	8	12	26	14	17	36	23	25	32	16	11	26
	A	–	32	359	459	192	109	182	169	41	101	32	86	168
	B	–	–	1,281	–	319	–	1,606	794	383	1,560	1,104	1,899	4,147
V	E	–	–	0	0	–	5	13	9	79	8	16	0	0
	D	–	9	9	6	–	6	12	11	34	21	15	15	34
	A	–	0	26	0	–	–	–	27	6	132	12	43	49
	B	–	–	317	–	–	–	–	379	–	637	–	523	5,812
VI	E	–	–	–	–	–	0	–	0	–	–	–	0	–
	D	–	0	0	1	–	0	–	0	0	26	52	20	33
	A	–	4	43	11	–	0	–	226	50	131	34	95	117
	B	–	–	164	16	–	–	–	299	113	198	386	154	379

Table 9

Number of minke whales sighted per 10,000 mile scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	–
	A	0	0	–	–	23	–	–	–	–	–	7	–	–
	B	–	–	–	–	–	–	–	–	3,141	–	261	–	889
II	E	0	9	–	–	19	–	–	–	–	–	–	–	–
	D	0	6	–	–	6	–	–	–	–	–	5	–	–
	A	0	–	–	–	79	–	–	–	1,393	–	139	–	–
	B	–	–	–	–	–	–	–	–	1,332	–	44	–	–
III	E	–	0	6	28	6	–	0	0	–	–	–	–	–
	D	0	98	21	26	27	48	10	7	14	–	–	–	–
	A	0	–	–	–	48	12	–	160	–	–	–	–	–
	B	–	–	–	–	–	–	–	1,742	–	–	–	–	–
IV	E	–	0	0	18	12	275	31	21	5	–	–	–	15
	D	–	30	15	35	22	20	60	25	16	8	0	8	52
	A	–	0	491	29	72	36	–	–	–	0	15	103	–
	B	–	–	1,621	–	–	–	–	–	–	2,532	–	–	–
V	E	–	–	0	0	–	0	6	22	0	0	51	–	0
	D	–	22	10	2	–	2	14	10	49	39	14	16	32
	A	–	0	44	–	–	–	–	–	–	–	0	28	0
	B	–	–	330	–	–	–	–	–	–	–	–	34	171
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	0	0	–	0	–	0	–	39	–	–	–
	A	–	–	193	–	–	0	–	–	–	–	–	0	256
	B	–	–	142	–	–	–	–	–	–	–	–	–	–

Table 10

Number of minke whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	0	–	–	–	–	–	–	–	–	0	120	0	–
	B	–	–	–	–	–	–	–	–	–	–	689	0	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	–	–	–	10	–	–	–	–	–	6	–	–
	A	0	–	–	–	17	–	–	–	–	–	0	263	–
	B	–	–	–	–	–	–	–	–	2,660	–	–	1,212	–
III	E	0	0	–	–	0	–	–	–	–	–	–	0	–
	D	0	17	54	42	12	19	40	34	4	15	–	13	0
	A	0	–	299	252	69	0	–	–	–	–	–	316	–
	B	–	–	–	–	–	–	–	4,039	8,511	–	–	–	–
IV	E	–	–	–	–	–	0	0	–	–	–	0	0	0
	D	–	0	0	10	0	15	20	22	53	23	19	13	7
	A	–	–	462	439	236	160	302	66	–	–	0	90	190
	B	–	–	1,053	–	349	–	2,511	1,562	–	–	–	2,709	–
V	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	6	9	31	–	0	8	6	15	0	15	9	0
	A	–	0	0	0	–	–	–	35	0	–	0	–	53
	B	–	–	230	–	–	–	–	303	–	–	–	–	208
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	0	0	0	–	–	–	0	0	20	0	39	–
	A	–	–	39	3	–	–	–	348	38	173	83	125	–
	B	–	–	–	30	–	–	–	460	110	271	601	181	–

Table 11

Number of sperm whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	82	–	–
	D	0	0	–	–	–	–	–	–	–	–	59	–	53
	A	0	0	–	–	0	–	–	–	–	0	11	53	122
	B	–	–	–	–	–	–	–	–	16	43	21	114	64
II	E	0	0	–	–	36	–	–	–	–	–	0	–	–
	D	24	3	–	–	79	–	–	–	–	0	191	40	0
	A	10	–	–	–	20	–	–	–	42	6	22	25	–
	B	0	–	–	–	–	–	–	–	44	0	15	0	0
III	E	0	74	213	507	158	249	125	146	122	974	–	226	569
	D	42	53	113	85	59	123	115	161	203	54	–	70	68
	A	9	–	19	18	8	47	31	120	6	7	28	23	0
	B	–	–	–	–	–	–	0	134	0	–	13	35	0
IV	E	–	221	302	240	540	194	390	171	174	269	373	62	229
	D	–	31	38	101	87	137	165	87	52	146	170	80	42
	A	–	23	34	21	15	16	12	31	43	10	1	15	42
	B	–	–	36	–	13	–	0	143	0	30	34	44	51
V	E	–	–	178	101	–	274	563	540	354	482	433	260	0
	D	–	356	178	79	–	284	92	109	58	128	133	125	17
	A	–	0	14	3	–	–	–	2	23	17	0	22	18
	B	–	–	29	–	–	–	–	59	–	82	–	20	76
VI	E	–	–	–	–	–	0	–	0	–	–	–	286	–
	D	–	1,553	149	64	–	61	–	111	12	148	266	0	167
	A	–	40	18	16	–	7	–	13	18	16	17	32	17
	B	–	–	0	16	–	–	–	29	9	32	36	44	46
													C = 0	

Table 12

Number of sperm whales sighted per 10,000 miles scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	–
	A	0	0	–	–	0	–	–	–	–	–	10	–	–
	B	–	–	–	–	–	–	–	–	16	–	6	–	64
II	E	0	0	–	–	43	–	–	–	–	–	–	–	–
	D	35	0	–	–	103	–	–	–	–	–	339	–	–
	A	7	–	–	–	26	–	–	–	42	–	0	–	–
	B	–	–	–	–	–	–	–	–	58	–	0	–	–
III	E	–	49	220	913	64	–	0	70	–	–	–	–	–
	D	19	60	92	96	19	488	262	61	14	–	–	–	–
	A	5	–	–	–	0	0	–	231	–	–	–	–	–
	B	–	–	–	–	–	–	–	170	–	–	–	–	–
IV	E	–	221	164	296	6	20	64	238	43	–	–	–	0
	D	–	0	43	116	134	147	187	49	30	19	119	8	49
	A	–	0	9	4	29	13	–	–	–	0	0	36	–
	B	–	–	45	–	–	–	–	–	–	0	–	–	–
V	E	–	–	0	242	–	57	385	224	552	869	395	–	0
	D	–	98	80	108	–	290	117	119	76	130	142	148	21
	A	–	0	13	–	–	–	–	–	–	–	0	17	0
	B	–	–	110	–	–	–	–	–	–	–	–	0	40
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	318	110	–	61	–	546	–	218	–	–	–
	A	–	–	0	–	–	7	–	–	–	–	–	0	15
	B	–	–	0	–	–	–	–	–	–	–	–	–	–

Table 13

Number of sperm whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	0	–	–	–	–	–	–	–	–	0	0	0	–
	B	–	–	–	–	–	–	–	–	23	–	32	0	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	34	–	–	–	15	–	–	–	529	–	110	–	–
	A	6	–	–	–	15	–	–	–	–	–	52	0	–
	B	–	–	–	–	–	–	–	–	0	–	–	0	–
III	E	0	45	–	–	114	–	–	–	–	–	–	854	–
	D	58	31	130	137	44	117	97	281	125	162	–	169	61
	A	33	–	0	11	7	0	–	–	–	–	–	24	–
	B	–	–	–	–	–	–	–	0	–	–	–	–	–
IV	E	–	–	–	–	–	0	0	–	–	–	0	23	35
	D	–	42	9	26	41	145	100	148	39	250	86	97	49
	A	–	–	33	21	21	20	6	0	0	–	8	14	19
	B	–	–	31	–	15	–	0	90	–	–	–	21	–
V	E	–	–	–	–	–	148	–	–	–	–	–	–	–
	D	–	252	0	78	–	20	35	24	12	0	83	3	0
	A	–	0	0	25	–	–	–	4	28	–	0	–	20
	B	–	–	0	–	–	–	–	73	14	–	–	–	42
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	2,867	9	20	–	–	–	50	–	103	548	0	–
	A	–	–	39	16	–	–	–	0	–	15	19	40	–
	B	–	–	–	10	–	–	–	25	–	43	19	52	–

Table 14

Number of blue whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	0
	A	0	0	–	–	0	–	–	–	–	0	0	0	0
	B	–	–	–	–	–	–	–	–	0	0	0	0	0
II	E	0	0	–	–	0	–	–	–	–	–	0	–	–
	D	0	0	–	–	0	–	–	–	–	0	0	0	204
	A	0	–	–	–	0	–	–	–	0	0	0	0	–
	B	0	–	–	–	–	–	–	–	5	0	0	0	0
III	E	0	6	3	0	20	0	2	2	0	0	–	0	0
	D	16	19	51	64	48	41	5	22	3	14	–	5	14
	A	7	–	6	9	0	13	9	0	0	0	0	0	113
	B	–	–	–	–	–	–	0	0	0	–	0	6	0
IV	E	–	0	0	0	2	4	5	2	6	0	2	2	5
	D	–	11	0	15	10	9	8	10	10	23	18	16	23
	A	–	0	4	3	4	4	4	18	5	0	0	2	21
	B	–	–	7	–	0	–	0	0	0	0	0	35	0
V	E	–	–	25	–	–	20	1	0	0	4	0	0	469
	D	–	7	1	0	–	19	2	0	1	8	2	7	17
	A	–	0	0	0	–	–	–	0	0	2	0	0	0
	B	–	–	14	–	–	–	–	0	–	0	–	8	9
VI	E	–	–	–	–	–	0	–	0	–	–	–	0	–
	D	–	0	0	0	–	0	–	0	0	0	0	0	0
	A	–	0	0	1	–	7	–	0	0	0	0	0	0
	B	–	–	0	11	–	–	–	0	0	0	0	0 C = 0	0

Table 15

Number of blue whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	0	–	–	–	–	–	–	–	–	0	0	0	–
	B	–	–	–	–	–	–	–	–	–	–	0	0	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	–	–	–	0	–	–	–	–	–	0	–	–
	A	0	–	–	–	0	–	–	–	–	–	0	0	–
	B	–	–	–	–	–	–	–	–	0	–	–	0	–
III	E	0	45	–	–	46	–	–	–	–	–	–	0	–
	D	0	6	99	28	13	4	3	7	4	12	–	7	14
	A	0	–	22	0	0	0	–	–	–	–	–	0	–
	B	–	–	–	–	–	–	–	0	0	–	–	–	–
IV	E	–	–	–	–	–	0	0	–	–	–	0	12	0
	D	–	0	0	19	0	18	7	21	18	28	26	16	7
	A	–	–	2	1	0	6	0	0	–	–	0	0	24
	B	–	–	0	–	0	–	0	0	–	–	–	169	–
V	E	–	–	–	–	–	56	–	–	–	–	–	–	–
	D	–	15	0	0	–	0	7	0	0	67	12	44	0
	A	–	0	0	0	–	–	–	0	0	–	0	–	0
	B	–	–	0	–	–	–	–	0	–	–	–	–	0
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	0	0	0	–	–	–	0	0	0	0	0	–
	A	–	–	0	1	–	–	–	0	0	0	0	0	–
	B	–	–	–	25	–	–	–	0	0	0	0	0	–

Table 16

Number of blue whales sighted per 10,000 miles scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	–
	A	0	0	–	–	0	–	–	–	–	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	0	–	0
II	E	0	0	–	–	0	–	–	–	–	–	–	–	–
	D	0	0	–	–	0	–	–	–	–	–	0	–	–
	A	0	–	–	–	0	–	–	–	0	–	0	–	–
	B	–	–	–	–	–	–	–	–	8	–	0	–	–
III	E	–	0	0	0	0	–	0	17	–	–	–	–	–
	D	0	1	0	0	8	0	0	0	0	–	–	–	–
	A	16	–	–	–	0	0	–	0	–	–	–	–	–
	B	–	–	–	–	–	–	–	0	–	–	–	–	–
IV	E	–	0	0	0	0	7	9	2	0	–	–	–	31
	D	–	0	0	3	12	2	11	7	9	4	0	38	39
	A	–	0	2	33	0	0	–	–	–	0	0	10	–
	B	–	–	13	–	–	–	–	–	–	0	–	–	–
V	E	–	–	0	0	–	199	0	0	0	0	0	–	469
	D	–	0	3	0	–	18	0	0	1	14	0	1	11
	A	–	0	0	–	–	–	–	–	–	–	0	0	0
	B	–	–	83	–	–	–	–	–	–	–	–	0	10
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	0	0	–	0	–	0	–	0	–	–	–
	A	–	–	0	–	–	7	–	–	–	–	–	0	0
	B	–	–	0	–	–	–	–	–	–	–	–	–	–

Table 17

Number of humpback whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	0
	A	0	0	–	–	0	–	–	–	–	0	0	0	0
	B	–	–	–	–	–	–	–	–	8	0	1	0	0
II	E	0	0	–	–	0	–	–	–	–	–	0	–	–
	D	2	10	–	–	1	–	–	–	–	0	0	0	0
	A	0	–	–	–	9	–	–	–	5	0	0	0	–
	B	0	–	–	–	–	–	–	–	0	0	15	0	91
III	E	0	0	0	0	3	2	0	0	7	0	–	1	0
	D	1	0	1	0	1	1	1	3	1	0	–	5	4
	A	2	–	0	0	5	0	8	0	0	0	0	0	23
	B	–	–	–	–	–	–	0	3	0	–	56	0	0
IV	E	–	0	0	1	7	1	1	4	5	1	0	4	0
	D	–	0	0	1	2	2	1	1	1	1	0	1	0
	A	–	1	3	11	2	3	1	0	0	10	0	0	21
	B	–	–	3	–	7	–	0	16	0	10	3	26	0
V	E	–	–	0	0	–	0	0	0	3	0	7	0	0
	D	–	5	0	0	–	0	0	0	3	6	1	1	3
	A	–	0	0	0	–	–	–	0	0	0	0	0	0
	B	–	–	2	–	–	–	–	4	–	16	–	0	9
VI	E	–	–	–	–	–	0	–	0	–	–	–	0	–
	D	–	0	0	1	–	0	–	0	0	0	0	0	0
	A	–	0	1	0	–	14	–	15	14	17	2	0	0
	B	–	–	15	9	–	–	–	21	16	15	5	0	0
													C = 0	

Table 18

Number of humpback whales sighted per 10,000 miles scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	–
	A	0	0	–	–	0	–	–	–	–	–	0	–	–
	B	–	–	–	–	–	–	–	–	8	–	0	–	0
II	E	0	0	–	–	0	–	–	–	–	–	–	–	–
	D	3	0	–	–	1	–	–	–	–	–	0	–	–
	A	0	–	–	–	18	–	–	–	5	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	0	–	–
III	E	–	0	0	0	0	–	0	0	–	–	–	–	–
	D	10	0	0	0	8	0	0	0	0	–	–	–	–
	A	0	–	–	–	0	0	–	0	–	–	–	–	–
	B	–	–	–	–	–	–	–	4	–	–	–	–	–
IV	E	–	0	0	2	12	0	0	5	0	–	–	–	0
	D	–	0	0	1	0	1	0	2	1	2	0	0	0
	A	–	0	2	0	0	0	–	–	–	0	0	0	–
	B	–	–	0	–	–	–	–	–	–	0	–	–	–
V	E	–	–	0	0	–	0	0	0	0	0	0	–	0
	D	–	0	0	0	–	0	0	0	2	13	0	1	5
	A	–	0	0	–	–	–	–	–	–	–	0	0	0
	B	–	–	0	–	–	–	–	–	–	–	–	0	10
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	0	4	–	0	–	0	–	0	–	–	–
	A	–	–	16	–	–	14	–	–	–	–	–	0	0
	B	–	–	22	–	–	–	–	–	–	–	–	–	–

Table 19

Number of humpback whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	0	–	–	–	–	–	–	–	–	0	0	0	–
	B	–	–	–	–	–	–	–	–	–	–	0	0	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	1	–	–	–	0	–	–	–	–	–	0	–	–
	A	0	–	–	–	7	–	–	–	–	–	0	0	–
	B	–	–	–	–	–	–	–	–	0	–	–	0	–
III	E	0	0	–	–	4	–	–	–	–	–	–	0	–
	D	0	0	2	0	0	0	2	3	0	0	–	0	3
	A	0	–	0	0	10	0	–	–	–	–	–	0	–
	B	–	–	–	–	–	–	–	0	0	–	–	–	–
IV	E	–	–	–	–	–	0	0	–	–	–	0	0	0
	D	–	0	3	0	0	2	1	0	0	2	1	2	0
	A	–	–	3	13	1	5	0	0	–	–	0	0	24
	B	–	–	8	–	0	–	0	0	–	–	–	106	–
V	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	6	0	0	–	0	2	0	2	0	0	0	0
	A	–	0	0	0	–	–	–	0	0	–	0	–	0
	B	–	–	0	–	–	–	–	6	–	–	–	–	0
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	0	0	0	–	–	–	0	0	0	0	0	–
	A	–	–	0	0	–	–	–	0	12	16	6	0	–
	B	–	–	–	10	–	–	–	20	25	23	13	0	–

Table 20

Number of right whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1972/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	0	–	–	–	–	–	–	–	–	5	–	0
	A	0	0	–	–	0	–	–	–	–	0	0	0	0
	B	–	–	–	–	–	–	–	–	0	0	0	0	0
II	E	0	19	–	–	8	–	–	–	–	–	0	–	–
	D	1	17	–	–	5	–	–	–	–	0	55	0	0
	A	0	–	–	–	1	–	–	–	0	0	0	0	–
	B	0	–	–	–	–	–	–	–	0	0	0	0	0
III	E	0	0	0	0	1	0	0	1	2	0	–	0	0
	D	2	1	1	0	1	0	1	4	1	1	–	0	2
	A	0	–	0	0	0	0	0	0	0	0	0	0	0
	B	–	–	–	–	–	–	0	0	0	–	0	0	0
IV	E	–	0	0	0	0	10	1	0	2	2	0	0	0
	D	–	0	4	0	26	4	10	22	23	18	24	9	44
	A	–	3	0	0	1	0	0	0	0	0	10	0	0
	B	–	–	0	–	0	–	0	0	0	0	0	0	0
V	E	-	–	0	0	–	0	1	0	0	1	0	0	0
	D	–	1	4	0	–	1	1	1	7	2	1	4	44
	A	–	0	0	0	–	–	–	0	0	0	0	0	0
	B	–	–	0	–	–	–	–	0	–	0	–	0	0
VI	E	–	–	–	–	–	0	–	0	–	–	–	0	–
	D	–	0	1	0	–	0	–	0	0	0	0	0	0
	A	–	0	2	4	–	0	–	0	0	0	0	0	0
	B	–	–	0	0	–	–	–	1	0	0	0	0	0
													C = 0	

Table 21

Number of right whales sighted per 10,000 miles scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	–
	A	0	0	–	–	0	–	–	–	–	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	0	–	0
II	E	0	19	–	–	10	–	–	–	–	–	–	–	–
	D	2	13	–	–	7	–	–	–	–	–	62	–	–
	A	0	–	–	–	0	–	–	–	0	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	0	–	–
III	E	–	0	0	0	0	–	0	0	–	–	–	–	–
	D	0	2	0	3	8	0	0	0	0	–	–	–	–
	A	0	–	–	–	0	0	–	0	–	–	–	–	–
	B	–	–	–	–	–	–	–	0	–	–	–	–	–
IV	E	–	0	0	0	0	0	2	0	0	–	–	–	0
	D	–	0	5	0	16	7	2	18	32	51	71	42	45
	A	–	0	0	0	0	0	–	–	–	0	0	0	–
	B	–	–	0	–	–	–	–	–	–	0	–	–	–
V	E	–	–	0	0	–	0	0	0	0	0	0	–	0
	D	–	0	0	0	–	0	0	0	2	0	0	4	0
	A	–	0	0	–	–	–	–	–	–	–	0	0	0
	B	–	–	0	–	–	–	–	–	–	–	–	0	0
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	3	0	–	0	–	0	–	0	–	–	–
	A	–	–	0	–	–	0	–	–	–	–	–	0	0
	B	–	–	0	–	–	–	–	–	–	–	–	–	–

Table 22

Number of right whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	0	–	–	–	–	–	–	–	–	0	0	0	–
	B	–	–	–	–	–	–	–	–	–	–	0	0	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	–	–	–	3	–	–	–	–	–	69	–	–
	A	0	–	–	–	2	–	–	–	–	–	0	0	–
	B	–	–	–	–	–	–	–	–	0	–	–	0	–
III	E	0	0	–	–	0	–	–	–	–	–	–	0	–
	D	10	1	4	0	1	0	1	5	1	0	–	0	0
	A	0	–	0	0	0	0	–	–	–	–	–	0	–
	B	–	–	–	–	–	–	–	0	0	–	–	–	–
IV	E	–	–	–	–	–	0	0	–	–	–	0	0	0
	D	–	0	0	0	0	1	19	9	0	2	37	5	61
	A	–	–	0	0	0	0	0	0	–	–	75	0	0
	B	–	–	0	–	0	–	0	0	–	–	–	0	–
V	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	0	14	2	–	0	3	0	2	0	12	6	0
	A	–	0	0	0	–	–	–	0	0	–	0	–	0
	B	–	–	0	–	–	–	–	0	–	–	–	–	0
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	0	0	0	–	–	–	0	0	0	0	0	–
	A	–	–	0	6	–	–	–	0	0	0	0	0	–
	B	–	–	–	0	–	–	–	0	0	0	0	0	–

Table 23

Number of fin whales sighted per 10,000 miles scouting distance from October to April

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	0
	A	0	0	–	–	0	–	–	–	–	0	49	63	20
	B	–	–	–	–	–	–	–	–	0	21	27	213	159
II	E	0	0	–	–	4	–	–	–	–	–	0	–	–
	D	10	0	–	–	10	–	–	–	–	0	0	20	136
	A	26	–	–	–	76	–	–	–	14	54	156	141	–
	B	0	–	–	–	–	–	–	–	0	0	0	545	0
III	E	0	10	20	0	23	7	0	25	0	0	–	0	9
	D	80	59	94	208	134	191	64	218	63	31	–	82	66
	A	273	–	37	101	97	547	111	167	0	24	0	21	45
	B	–	–	–	–	–	–	0	29	0	–	3	3	0
IV	E	–	0	2	6	0	7	3	3	3	1	2	1	0
	D	–	14	38	73	22	27	10	11	8	15	3	13	5
	A	–	904	662	296	425	132	141	133	7	244	5	46	189
	B	–	–	13	–	13	–	0	8	9	13	0	3	0
V	E	–	–	12	0	–	5	0	0	0	2	0	0	0
	D	–	29	6	17	–	1	2	3	3	9	2	3	34
	A	–	0	12	14	–	–	–	0	0	502	0	46	158
	B	–	–	0	–	–	–	–	76	–	98	–	16	6
VI	E	–	–	–	–	–	0	–	0	–	–	–	0	–
	D	–	0	8	0	–	9	–	51	0	0	0	0	28
	A	–	0	40	12	–	0	–	272	34	66	9	53	67
	B	–	–	0	138	–	–	–	313	65	17	25	0	0
													C = 0	

Table 24

Number of fin whales sighted per 10,000 miles scouting distance in December

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	0	0	–	–	–	–	–	–	–	–	0	–	–
	A	0	0	–	–	0	–	–	–	–	–	17	–	–
	B	–	–	–	–	–	–	–	–	0	–	33	–	169
II	E	0	0	–	–	5	–	–	–	–	–	–	–	–
	D	21	0	–	–	3	–	–	–	–	–	0	–	–
	A	0	–	–	–	176	–	–	–	14	–	0	–	–
	B	–	–	–	–	–	–	–	–	0	–	0	–	–
III	E	–	6	29	0	0	–	0	44	–	–	–	–	–
	D	237	12	54	19	4	0	0	27	7	–	–	–	–
	A	531	–	–	–	75	36	–	0	–	–	–	–	–
	B	–	–	–	–	–	–	–	36	–	–	–	–	–
IV	E	–	0	0	10	0	0	6	1	0	–	–	–	0
	D	–	0	41	42	2	12	4	8	3	6	0	27	1
	A	–	0	452	16	272	53	–	–	–	0	0	108	–
	B	–	–	26	–	–	–	–	–	–	0	–	–	–
V	E	–	–	0	0	–	0	0	0	0	8	0	–	0
	D	–	9	2	3	–	2	2	1	1	7	1	2	42
	A	–	–	25	–	–	–	–	–	–	–	0	41	0
	B	–	–	0	–	–	–	–	–	–	–	–	0	0
VI	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	–	0	0	–	9	–	0	–	0	–	–	–
	A	–	–	16	–	–	0	–	–	–	–	–	0	90
	B	–	–	0	–	–	–	–	–	–	–	–	–	–

Table 25

Number of fin whales sighted per 10,000 miles scouting distance in January

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	0	–	–	–	–	–	–	–	–	0	40	136	–
	B	–	–	–	–	–	–	–	–	–	–	41	182	–
II	E	–	–	–	–	–	–	–	–	–	–	0	–	–
	D	4	–	–	–	33	–	–	–	–	–	0	–	–
	A	44	–	–	–	15	–	–	–	–	–	0	158	–
	B	–	–	–	–	–	–	–	–	0	–	–	545	–
III	E	0	45	–	–	50	–	–	–	–	–	–	0	–
	D	103	54	160	176	116	108	65	101	18	35	–	124	51
	A	250	–	67	29	150	–	–	–	–	–	–	0	–
	B	–	–	–	–	–	–	–	0	0	–	–	–	–
IV	E	–	–	–	–	–	0	0	–	–	–	0	0	0
	D	–	0	29	87	0	47	17	25	7	3	5	15	0
	A	–	–	533	342	267	189	28	98	–	–	0	25	24
	B	–	–	0	–	0	–	0	20	–	–	–	21	–
V	E	–	–	–	–	–	0	–	–	–	–	–	–	–
	D	–	53	21	3	–	0	2	0	2	0	6	9	0
	A	–	0	0	99	–	–	–	0	0	–	0	–	0
	B	–	–	0	–	–	–	–	118	–	–	–	–	0
VI	E	–	–	–	–	–	–	–	–	–	–	–	–	–
	D	–	0	19	0	–	–	–	553	0	0	0	0	–
	A	–	–	39	11	–	–	–	123	30	96	13	71	–
	B	–	–	–	124	–	–	–	512	64	0	51	0	–

Table 26

Abundance of sei whales using sightings data from the waters south of 30° S

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	D	0	0	(9,790)	(9,790)	(9,790)	(9,790)	(9,790)	(9,790)	(9,790)	(9,790)	13,880	(9,790)	3,810
	A	650	53,110	3,060	(3,060)	0	(3,060)	(3,060)	(3,060)	(3,060)	0	2,170	5,830	0
	B	(570)	(570)	(570)	(570)	(570)	(570)	(570)	(570)	0	0	640	670	1,390
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		1,220+	53,670+	13,420+	13,420+	10,360+	13,420+	13,420+	13,420+	12,850+	9,790+	16,690+	6,290+	5,200+
II	E	0	42,190	(10,370)	(10,370)	6,970	(10,370)	(10,370)	(10,370)	(10,370)	(10,370)	0	(10,370)	(10,370)
	D	40,390	2,440	(29,800)	(29,800)	11,540	(29,800)	(29,800)	(29,800)	(29,800)	(29,800)	14,120	0	0
	A	2,010	(1,540)	(1,540)	(1,540)	560	(1,540)	(1,540)	(1,540)	0	0	1,870	8,520	(1,540)
	B	47,580	(3,670)	(3,670)	(3,670)	(3,670)	(3,670)	(3,670)	(3,670)	0	0	4,370	5,840	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		89,980+	49,840+	45,380+	45,380+	22,740+	45,380+	45,380+	45,380+	40,170+	40,170+	20,360+	24,730+	11,910+
III	E	0	113,830	28,860	28,870	12,780	5,130	4,770	11,660	4,210	3,460	(18,410)	320	940
	D	31,140	56,910	49,980	17,810	9,250	10,230	7,650	12,810	6,170	4,190	(20,030)	9,080	14,770
	A	1,050	(1,130)	1,200	0	680	7,360	250	0	470	670	0	170	15,280
	B	(30)	(30)	(30)	(30)	(30)	(30)	0	0	0	(30)	0	140	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		32,220	171,900	80,070	46,710	22,740	22,750	12,670	24,470	10,850	5,650	38,440	9,710	30,990
IV	E	(17,140)	7,380	29,880	25,630	30,100	36,250	13,630	13,770	4,890	5,950	3,820	230	610
	D	(20,580)	32,030	25,390	13,830	51,130	33,350	18,350	18,130	11,060	8,820	13,840	8,900	4,690
	A	(7,800)	(42,380)	17,080	5,620	3,270	250	4,780	2,640	150	1,300	730	270	5,150
	B	(90)	(90)	560	(90)	370	(90)	0	0	0	0	0	0	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		45,610	81,880	72,910	45,170	84,870	69,940	36,760	34,540	16,100	16,070	18,390	9,400	10,450
V	E	(13,360)	(13,360)	(42,000)	5,490	(13,360)	10,890	42,420	10,890	13,000	2,370	4,970	0	10,820
	D	(23,870)	97,480	23,220	26,960	(23,870)	20,170	54,410	32,490	16,300	9,650	7,480	10,110	12,510
	A	(3,510)	10,350	4,840	6,630	(3,510)	(3,510)	(3,510)	150	1,110	7,170	0	450	5,080
	B	(1,180)	(1,180)	1,770	(1,180)	(1,180)	(1,180)	(1,180)	1,420	(1,180)	2,860	(1,180)	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		41,920+	122,370+	71,830+	40,260+	41,920+	35,750+	101,520+	44,950+	31,590+	22,050+	13,630+	10,560+	28,410+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	0	(0)	(0)	0	(0)
	D	(20,030)	3,680	72,930	11,700	(20,030)	3,120	(20,030)	3,680	29,380	9,580	1,910	7,420	13,490
	A	(11,430)	27,190	22,190	12,450	(11,430)	370	(11,430)	13,330	8,650	6,990	6,100	2,480	0
	B	(5,640)	(5,640)	300	6,140	(5,640)	(5,640)	(5,640)	13,210	3,300	1,970	900	3,940	0
	C	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Total		37,100	36,510	95,420	30,290	37,100	9,130	37,100	30,220	41,330	18,540	8,910	13,840	13,490

Table 27

Abundance of sei, sperm, fin, blue, humpback, right and minke whales using sightings data from the Antarctic south of 30° S

Season	Sei	Sperm	Fin	Blue	Hump.	Right	Minke whale					
							I*	I**	II*	II**	III*	III**
1965/66	248,050	148,180	70,790	6,684	3,630	1,688	524,350	486,100	453,170	472,150	0	0
1966/67	516,170	306,050	86,350	6,856	3,980	3,014	596,360	489,730	517,170	479,400	15,790	7,100
1967/68	379,030	182,050	70,510	11,959	2,795	2,281	629,330	499,040	552,850	495,630	170,540	95,500
1968/69	221,230	441,480	67,730	12,721	3,247	1,715	662,230	502,640	584,090	496,130	87,910	39,390
1969/70	219,730	218,940	87,670	12,031	4,714	3,565	554,020	480,170	486,070	476,240	60,160	31,680
1970/71	196,370	199,360	90,660	13,998	3,860	2,549	618,770	490,440	538,500	483,500	33,440	23,050
1971/72	246,850	211,000	49,430	4,563	2,674	2,484	383,220	489,350	371,030	483,750	139,130	45,360
1972/73	192,980	257,850	83,900	6,075	3,552	3,445	522,360	571,940	508,290	533,340	335,540	197,370
1973/74	152,890	159,000	16,510	3,542	3,319	3,497	1,305,580	527,480	1,311,190	521,590	1,228,690	296,910
1974/75	112,270	311,740	63,660	5,378	4,321	3,102	678,850	521,240	616,440	515,510	361,350	126,050
1975/76	116,390	205,030	28,090	6,714	3,459	6,689	536,860	429,250	542,350	431,610	461,050	147,330
1976/77	84,530	169,530	57,700	5,809	1,643	1,746	422,320	491,660	423,320	490,020	416,830	165,210
1977/78	100,450	192,120	60,650	43,925	6,341	6,505	917,940	520,540	910,830	512,620	854,840	86,090
Average	223,030	202,680	69,680	8,442	4,000	3,007	646,780	502,980	559,400	488,400	391,170	113,160

I*: Approach-I, Case-I (Area – Zone = Sector), I**: Approach-I, Case-II (5° square), II*: Approach-II, Case-I, II**: Approach-II, Case-II, III*: Approach-III, Case-I, III**: Approach-III, Case-II.

Table 28

Abundance of sperm whales using sightings data from the waters south of 30° S

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)	(8,570)
	D	0	0	(4,770)	(4,770)	(4,770)	(4,770)	(4,770)	(4,770)	(4,770)	(4,770)	6,100	(4,770)	5,430
	A	0	0	(1,740)	(1,740)	0	(1,740)	(1,740)	(1,740)	(1,740)	0	930	4,620	10,690
	B	(1,940)	(1,940)	(1,940)	(1,940)	(1,940)	(1,940)	(1,940)	(1,940)	1,030	2,670	1,340	7,140	3,970
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		10,510+	10,510+	17,020+	17,020+	15,280+	17,020+	17,020+	17,020+	16,110+	16,010+	16,940+	14,500+	28,660+
II	E	0	0	(3,580)	(3,580)	4,370	(3,580)	(3,580)	(3,580)	(3,580)	(3,580)	0	(3,580)	(3,580)
	D	2,760	390	(6,160)	(6,160)	8,940	(6,160)	(6,160)	(6,160)	(6.160)	(6.160)	21,640	4,570	0
	A	960	(1,670)	(1,670)	(1,670)	1,820	(1,670)	(1,670)	(1,670)	3,850	550	2,010	2,280	(1,670)
	B	0	(1,070)	(1,070)	(1,070)	(1,070)	(1,070)	(1,070)	(1,070)	2,010	0	670	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		3,720+	3,130+	12,480+	12,480+	16,200+	12,480+	12,480+	12,480+	15,600+	10,290+	24,320+	10,430+	5,250+
III	E	0	10,480	30,290	72,090	22,460	35,340	17,710	20,770	17,290	138,400	(30,220)	32,070	80,840
	D	5,560	8,070	14,880	11,190	7,840	16,180	15,320	21,320	26,800	5,040	(13,320)	9,260	9,000
	A	1,000	(2,250)	2,560	1,970	870	5,070	3,300	12,940	670	720	2,990	2,470	0
	B	(2,360)	(2,360)	(2,360)	(2,360)	(2,360)	(2,360)	0	52,780	0	(2,360)	780	2,150	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		8,920	23,160	50,090	87,610	33,530	58,950	26,330	107,810	44,760	146,520	47,310	45,950	89,840
IV	E	(31,090)	26,330	35,990	286,750	64,440	23,170	46,500	20,440	20,770	32,040	44,530	8,250	27,310
	D	(12,420)	3,490	4,280	11,430	9,770	15,550	18,700	9,840	5,850	17,240	19,190	9,060	4,750
	A	(1,950)	2,140	3,110	1,930	1,400	1,450	1,120	2,820	3,990	930	110	1,420	3,870
	B	(1,780)	(1,780)	1,460	(1,780)	530	(1,780)	0	5,760	0	1,220	1,380	1,770	2,050
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		47,240	33,740	44,840	301,890	76,140	41,950	66,320	38,860	30,610	51,430	65,210	20,500	37,980
V	E	(40,850)	(40,850)	17,220	2,740	(40,850)	27,050	55,360	53,410	35,020	47,680	42,760	25,700	0
	D	(13,190)	37,890	18,970	8,400	(13,190)	30,200	9,740	11,640	5,800	13,650	14,130	13,260	1,790
	A	(1,220)	0	1,330	260	(1,220)	(1,220)	(1,220)	210	2,100	1,520	0	2,030	1,670
	B	(2,910)	(2,910)	1,590	(2,910)	(2,910)	(2,910)	(2,910)	3,250	(2,910)	4,540	(2,910)	1,090	4,240
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		58,170+	81,650+	39,110+	14,310+	58,170+	61,380+	69,230+	68,510+	45,830+	67,390+	19,800+	42,080+	7,700+
VI	E	(3,060)	(3,060)	(3,060)	0	(3,060)	0	(3,060)	0	(3,060)	(3,060)	(3,060)	31,150	(3,060)
	D	(13,930)	146,440	14,040	6,070	(13,930)	5,800	(13,930)	10,500	1,130	13,950	25,060	0	15,760
	A	(1,380)	3,110	1,410	1,200	(1,380)	530	(1,380)	990	1,380	1,260	1,270	2,420	1,280
	B	(1,250)	(1,250)	0	900	(1,250)	(1,250)	(1,250)	1,680	520	1,830	2,060	2,500	2,590
	C	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Total		19,620	153,860	18,510	8,170	19,620	7,580	19,620	13,170	6,090	20,100	31,450	36,070	22,690

E: 30° S–40° S, D: 40° 2–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: average abundance in each sector during seasons 1965/66 to 1977/78.

Table 29

Average abundance of blue, fin, humpback, right, sei, minke and sperm whales during seasons 1965/66 to 1977/78 (Approach-I)

Area	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
Blue							
30° S–40° S	0	0	523	350	489	0	1,362
40° S–50° S	0	28	3,568	1,317	366	0	5,279
50° S–60° S	0	0	449	340	116	17	922
60° S–70° S	0	87	76	442	200	74	879
70° S–	+	+	–	–	+	0	0+
TOTAL	0+	115+	4,616	2,449	1,171+	91	8,442+
Fin							
30° S–40° S	0	242	948	277	87	0	1,554
40° S–50° S	0	639	9,943	1,646	471	340	13,039
50° S–60° S	1,977	4,091	8,875	20,481	7,789	2,941	46,154
60° S–70° S	1,744	523	304	154	1,619	4,589	8,933
70° S–	+	+	–	–	+	0	0+
TOTAL	3,721+	5,495+	20,070	22,558	9,966+	7,870	69,680+
Humpback							
30° S–40° S	0	0	127	142	52	0	321
40° S–50° S	0	117	73	83	103	26	402
50° S–60° S	0	178	226	205	0	376	985
60° S–70° S	509	50	388	894	292	159	2,292
70° S–	+	+	–	–	+	0	0+
TOTAL	509+	345+	814	1,324	447+	561	4,000+
Right							
30° S–40° S	0	616	48	152	31	0	847
40° S–50° S	213	586	93	973	167	13	2,045
50° S–60° S	0	22	0	40	0	44	106
60° S–70° S	0	0	0	0	0	9	9
70° S–	+	+	–	–	+	0	0+
TOTAL	213+	1,224+	141	1,165	198+	66	3,007+
Sei							
30° S–40° S	0	10,370	18,410	17,140	13,360	0	59,280
40° S–50° S	9,790	29,800	20,030	20,580	23,870	20,030	124,100
50° S–60° S	3,060	1,540	1,130	7,800	3,510	11,430	28,470
60° S–70° S	570	3,670	30	90	1,180	5,640	11,180
70° S–	+	+	–	–	+	0	0+
TOTAL	13,420+	45,380+	39,600	45,610	41,920+	37,100	223,030+
Minke							
30° S–40° S	960	1,980	3,450	5,050	1,560	0	13,000
40° S–50° S	3,360	440	4,110	3,220	1,930	1,310	14,370
50° S–60° S	1,900	21,370	6,870	26,900	5,510	7,050	69,600
60° S–70° S	39,070	78,950	271,970	77,630	29,460	13,940	511,020
70° S–	+	+	–	–	+	38,790	38,790+
TOTAL	45,290+	102,740+	286,400	112,800	38,460+	61,090	646,780+
Sperm							
30° S–40° S	8,570	3,580	30,220	31,090	40,850	3,060	117,370
40° S–50° S	4,770	6,160	13,320	12,420	13,190	13,930	63,790
50° S–60° S	1,740	1,670	2,250	1,950	1,220	1,380	10,210
60° S–70° S	1,940	170	2,360	1,780	2,910	1,250	11,310
70° S–	+	+	–	–	+	0	0+
TOTAL	17,020+	12,480+	48,150	47,240	58,170+	19,620	202,680+

Table 30

Average abundance of minke whales during seasons 1965/66 to 1977/78 in the Antarctic (Approach-I)

Area	I	II	III	IV	V	VI	Total
30° S–35° S	+	+	1,750	2,670	510	0+	4,930+
35° S–40° S	250+	1,120+	1,160	1,930	650	0+	5,110
40° S–45° S	0+	300	2,520	1,770	860	900	6,350+
45° S–50° S	2,400+	100	1,550	1,040	620	550	6,260+
50° S–55° S	1,380+	3,150	1,740	3,550	1,200	870	11,890+
55° S–60° S	950+	41,850	8,540+	20,510	5,270	4,270	81,390+
60° S–65° S	6,870	15,580+	55,620+	55,340	17,570	8,320	159,300+
65° S–70° S	29,680+	36,000+	140,450+	6,400+	9,810+	4,100+	226,440+
70° S–	+	+	–	–	+	1,310	1,310+
TOTAL	41,530+	98,100+	213,330+	93,210+	36,490+	20,320+	502,980+

Table 31

Average abundance of minke whales during seasons 1965/66 to 1977/78 in the Antarctic (Approach-II)

Area	I	II	III	IV	V	VI	Total
30° S–35° S	+	+	1,590	2,300	510+	0+	4,400+
35° S–40° S	250+	1,120+	1,120	1,240	650+	0+	4,380+
40° S–45° S	0+	300	2,190	1,490	720+	900	5,600+
45° S–50° S	2,400+	100	1,280	950	590	550	5,870+
50° S–55° S	1,380+	3,150	1,710	2,830	1,200	700	10,970+
55° S–60° S	950+	41,850+	8,450+	15,960	5,270	3,690	76,170+
60° S–65° S	6,870	15,580+	55,620+	50.060	17,420	7,750	153,300+
65° S–70° S	29,680	36,000+	140,450+	6,400+	9,810+	4,100+	226,440+
70° S–	+	+	–	–	+	1,310+	1,310+
TOTAL	41,530+	98,100+	212,410+	81,230+	36,170+	19,000+	488,440+

Table 32

Average abundance of minke whales during seasons of 1965/66 to 1977/78 in the Antarctic (Approach–II)

Area	I	II	III	IV	V	VI	Total
30° S–40° S	960	1,980	3,720	3,940	1,120	0	11,720
40° S–50° S	3,360	440	3,960	2,930	2,110	1,350	14,150
50° S–60° S	2,100	14,270	6,520	23,070	3,430	5,610	55,000
60° S–70° S	40,990	69,870	209,560	70,550	34,880	13,890	439,740
70° S–	+	+	–	–	+	38,790	38,790+
TOTAL	47,410+	86,560+	223,760	100,490	41,540+	59,640	559,400+

Table 33

Abundance of minke whales using sightings data from the waters south of 30° S (Approach-I)

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)
	D	0	0	(3,360)	(3,360)	(3,360)	(3,360)	(3,360)	(3,360)	(3,360)	(3,360)	0	(3,360)	26,770
	A	0	0	(1,900)	(1,900)	1,660	(1,900)	(1,900)	(1,900)	(1,900)	3,480	1,530	3,040	8,780
	B	(39,070)	(39,070)	(39,070)	(39,070)	(39,070)	(39,070)	(39,070)	(39,070)	241,940	0	22.460	19,930	68,460
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		40,030	40,030	45,290	45,290	45,050	45,290	45,290	45,290	248,160	7,800	24,950	27,290	104,970
II	E	0	1,370	(1,980)	(1,980)	2,230	(1,980)	(1,980)	(1,980)	(1,980)	(1,980)	0	(1,980)	(1,980)
	D	0	950	(440)	(440)	1,460	(440)	(440)	(440)	(440)	(440)	750	0	0
	A	0	(21,370)	(21,370)	(21,370)	3,930	(21,370)	(21,370)	(21,370)	157,190	78,460	7,960	15,930	(21,370)
	B	0	(78,950)	(78,950)	(78,950)	(78,950)	(78,950)	(78,950)	(78,950)	106,510	71,100	26,640	68,480	205,770
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	102,640+	102,740+	102,740+	86,570+	102,740+	102,740+	102,740+	266,120+	151,980+	35,350+	86,390+	229,120+
III	E	0	0	580	3,900	1,480	750	3,360	1,250	4,140	9,140	(3,350)	6,310	4,940
	D	0	7,040	4,240	4,540	2,280	3,630	4,420	6,870	1,990	5,490	(4,110)	2,570	3,490
	A	0	(6,870)	15,800	26,660	6,580	1,790	4,650	17,160	5,790	290	0	12,190	11,940
	B	(271,970)	(271,970)	(271,970)	(271,970)	(271,970)	(271,970)	14,740	170,000	649,660	(271,970)	295,530	76,160	202,060
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		271,970	285,880	292,590	307,070	282,310	278,140	27,170	195,280	661,580	286,890	303,090	97,230	222,430
IV	E	(5,050)	0	2,300	2,540	960	11,160	3,180	4,420	7,060	8,700	2,830	2,240	2,500
	D	(3,220)	1,170	1,730	3,640	1,970	2,340	5,040	3,170	3,460	4,630	2,190	1,580	3,630
	A	(26,900)	3,650	40,710	52,070	21,750	12,400	20,660	19,220	4,660	11,420	3,620	9,700	19,070
	B	(77,630)	(77,630)	63,710	(77,630)	15,860	(77,630)	79,870	39,510	19,050	77,580	54,910	94,490	206,300
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		112,800	82,450	108,450	135,880	40,540	103,530	108,750	66,320	34,230	102,330	63,550	108,010	231,500
V	E	(1,560)	(1,560)	0	0	(1,560)	550	1,630	1,110	9,660	970	1,970	0	0
	D	(1,930)	1,230	1,200	720	(1,930)	820	1,580	1,490	4,250	2,190	1,950	1,940	4,400
	A	(5,510)	0	2,950	0	(5,510)	(5,510)	(5,510)	(5,510)	3,080	650	15,000	1,360	4,850
	B	(29,460)	(29,460)	21,740	(29,460)	(29,460)	(29,460)	(29,460)	25,960	(29,460)	43,610	(29,460)	(35,800)	39,810
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		38,460+	32,250+	25,890+	30,180+	38,460+	36,340	38,180+	31,640+	44,020+	61,770+	34,740+	42,590+	49,710+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	(0)	(0)	(0)	0	(0)
	D	(1,310)	0	0	160	(1,310)	0	(1,310)	0	0	3,070	6,040	2,310	3,780
	A	(7,050)	380	4,060	1,010	(7,050)	0	(7,050)	21,350	4,730	12,360	3,240	8,940	11,020
	B	(13,940)	(13,940)	11,520	1,110	(13,940)	(13,940)	(13,940)	20,950	7,950	13,860	27,110	10,770	26,620
	C	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	38,790	(38,790)
Total		61,090	53,110	54,370	41,070	61,090	52,730	61,090	81,090	51,470	68,080	75,180	60,810	80,210

E: 30° S–40° S, D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: Average abundance in each sector during seasons 1965/66 to 1977/78.

Table 34

Abundance of minke whales using sightings data from the Antarctic (Approach-I)

		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	30° S–35° S													
	35° S–40° S	254+	254+	254+	254+	254+	254+	254+	254+	254+	254+	254+	254+	254+
	40° S–45° S	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
	45° S–50° S	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+
	50° S–55° S	1,368+	1,368+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+
	55° S–60° S	736+	946+	946+	946+	946+	946+	946+	946+	946+	946+	775+	1,144+	1,254+
	60° S–65° S	6,866	6,866	6,866	6,866	6,866	6,866	6,866	6,866	8,240	5,994	6,006	6,725	12,529
	65° S–70° S	29,676+	29,676+	29,676+	29,676+	29,676+	29,676+	29,676+	29,676+	54,548+	26,014+	20,986+	20,469+	29,676+
	70° S–75° S	+	+	+	+	+	+	+	+	+	+	+	+	+
TOTAL		41,302+	41,512+	41,528+	41,528+	41,586+	41,528+	41,528+	41,528+	67,774+	36,986+	31,807+	32,378+	47,499+
II	30° S–35° S													
	35° S–40° S	1,076+	1,182+	1,115+	1,115+	1,172+	1,115+	1,115+	1,115+	1,115+	1,115+	1,115+	1,115+	1,115+
	40° S–45° S	0	577	301	301	744	301	301	301	301	301	329	301	301
	45° S–50° S	0	78	104	104	735	104	104	104	104	66	117	66	104
	50° S–55° S	430	3,151	3,151	3,151	1,395	3,151	3,151	3,151	3,151	7,727	3,208	2,363	3,151
	55° S–60° S	36,336+	41,849+	41,849+	41,849+	41,509+	41,849+	41,849+	41,849+	43,946+	41,382+	41,822+	41,867+	41,849+
	60° S–65° S	15,584+	15,584+	15,584+	15,584+	15,584+	15,584+	15,584+	15,584+	17,376+	15,566+	14,500+	16,775+	15,584+
	65° S–70° S	33,058+	35,995+	35,995+	35,995+	35,995+	35,995+	35,995+	35,995+	35,995+	38,452+	35,995+	35,995+	35,995+
	70° S–75° S	+	+	+	+	+	+	+	+	+	+	+	+	+
TOTAL		86,484+	98,416+	98,099+	98,099+	97,134+	98,099+	98,099+	98,099+	101,988+	104,609+	97,086+	98,482+	98,099+
III	30° S–35° S	1,745	1,745	1,555	1,593	3,192	2,516	2,334	961	991	1,988	1,745	861	1,400
	35° S–40° S	1,162	533	726	1,421	562	2,398	1,467	473	2,443	1,162	1,162	602	1,714
	40° S–45° S	0	3,912	1,142	1,317	659	1,596	2,945	2,729	1,266	3,542	2,523	1,137	3,083
	45° S–50° S	278	940	1,438	1,612	926	1,875	1,119	4,343	630	244	1,545	2,070	7,520
	50° S–55° S	501	1,737	1,655	2,062	2,435	2,969	3,979	2,510	2,469	187	1,737	1,798	2,314
	55° S–60° S	8,541+	8,541+	11,437+	9,911+	9,206+	6,601+	7,817+	8,541+	8,541+	7,404+	8,020+	8,654+	8,541+
	60° S–65° S	55,623+	55,623+	55,623+	55,623+	55,623+	55,623+	36,972+	92,416+	55,623+	55,623+	51,872+	47,914+	55,623+
	65° S–70° S		140,448+	140,448+	140,448+	140,448+	140,448+	140,448+	167,731+	168,431+	140,448+	104,984+	140,217+	140,130+
	70° S–75° S	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL		208,298+	213,479+	214,024+	213,987+	213,051+	214,026+	197,081+	279,704+	240,394+	210,598+	173,588+	203,253+	220,325+
IV	30° S–35° S	2,672+	2,316+	2,910+	2,196+	1,034+	2,346+	1,707+	2,573+	3,018+	4,649+	2,418+	2,176+	1,966+
	35° S–40° S	1,930	1,039	959	851	506	4,562	1,753	1,402	2,140	1,331	873	770	938
	40° S–45° S	1,774	1,204	804	1,083	609	1,142	2,710	1,901	2,130	2,506	1,407	1,302	1,645
	45° S–50° S	1,042	938	789	1,089	759	1,710	1,157	679	662	1,936	425	1,271	596
	50° S–55° S	3,545	1,575	3,171	6,377	2,725	2,168	4,818	3,299	1,301	1,906	1,520	2,210	2,429
	55° S–60° S	20,509	14,667	25,808	28,320	18,171	9,130	18,928	23,769	9,346	15,747	8,893	5,586	19,891
	60° S–65° S	55,342	55,342	59,188	55,342	41,397	55,342	58,145	53,954	40,246	66,696	49,197	87,278	50,776
	65° S–70° S	6,403+	6,403+	3,049+	6,403+	6,403+	6,403+	6,403+	6,403+	6,403+	6,403+	5,464+	6,403+	6,562+
	70° S–75° S	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL		93,217+	83,484+	96,678+	101,661+	71,604+	82,803+	95,621+	93,979+	65,246+	101,174+	70,197+	106,996+	84,803+
V	30° S–35° S	509+	509+	509+	509+	509+	336+	966+	436+	336+	399+	378+	222+	509+
	35° S–40° S	648+	648+	292+	257+	648+	294+	356+	390+	2,794+	658+	1,112+	543+	531+
	40° S–45° S	858	557	906	377	858	475	493	714	1,134	1,435	653	712	671
	45° S–50° S	615	698	326	294	615	234	1,045	685	830	449	1,686	2,438	2,131
	50° S–55° S	1,201	924	1,039	880	1,201	1,201	1,201	1,300	1,288	932	714	2,688	1,035
	55° S–60° S	5,268	5,268	4,771	5,268	5,268	5,268	5,268	2,471	5,228	6,812	5,268	1,496	3,697
	60° S–65° S	17,566	17,566	12,050	17,566	17,566	17,566	17,566	21,428	17,566	27,328	17,566	13,064	23,265
	65° S–70° S	9.806+	9.806+	10.099+	9,806+	9.806+	9,806+	9,806+	8,755+	9,806+	9,806+	9,806+	9,806+	10,213+
	70° S–75° S	+	+	+	+	+	+	+	+	+	+	+	+	+
TOTAL		36,471+	35,976+	29,992+	34,957+	36,471+	35,180+	36,701+	36,179+	38,982+	47,819+	37,183+	30,969+	42,052+
VI	30° S–35° S	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
	35° S–40° S	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
	40° S–45° S	901+	787+	512+	422+	901+	464+	901+	584+	901+	1,506+	4,577+	426+	994+
	45° S–50° S	553	426	393	17	553	323	553	533	240	622	430	1,007	823
	50° S–55° S	866	162	753	39	866	395	866	536	581	1,710	1,552	403	901
	55° S–60° S	4,273	1,761	3,378	1,596	4,273	3,889	4,273	5,190	2,222	4,269	2,163	4,786	10,245
	60° S–65° S	8,316	8,316	8,273	•6,019	8,316	8,316	8,316	10,064	5,628	6,535	3,879	7,796	8,636
	65° S–70° S	4,104+	4,104+	4,104+	3,001+	4,104+	4,104+	4,104+	4,238+	2,211+	4,104+	5,474+	3,851+	4,856+
	70° S–75° S	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+
TOTAL		20,323+	16,866+	18,723+	12,404+	20,323+	18,801+	20,323+	22,455+	13,093+	20,056+	19,385+	19,579+	27,765+
		486,095+	489,733+	499,044+	502,636+	480,169+	490,437+	489,353+	571,944+	527,477+	521,242+	429,246+	491,657+	520,543+

Table 35

Abundance of minke whales using sightings data from the waters south of 30° S (Approach-II)

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	(960)	960	(960)	(960)
	D	0	0	(3,359)	(3,359)	(3,359)	(3,359)	(3,359)	(3,359)	(3,359)	(3,359)	0	(3,359)	26,770
	A	0	0	(2,098)	(2,098)	1,660	(2,098)	(2,098)	(2,098)	(2,098)	3,480	1,530	3,040	8,780
	B	(40,990)	(40,990)	(40,990)	(40,990)	(40,990)	(40,990)	(40,990)	(40,990)	241,940	0	22,460	19,930	68,460
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		41,950+	41,950+	47,407+	47,407+	46,969+	47,407+	47,407+	47,407+	248,357+	7,799+	24,950+	27,289+	104,970+
II	E	0	1,370	(1,976)	(1,976)	2,230	(1,976)	(1,976)	(1,976)	(1,976)	(1,976)	0	(1,976)	(1,976)
	D	0	950	(440)	(440)	1,460	(440)	(440)	(440)	(440)	(440)	750	0	0
	A	0	(14,267)	(14,267)	(14,267)	3,930	(14,267)	(14,267)	(14,267)	157,190	78,460	7,960	15,930	(14,267)
	B	0	(69,867)	(69,867)	(69,867)	(69,867)	(69,867)	(69,867)	(69,867)	106,510	71,100	26,640	68,480	205,770
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	86,454+	86,550+	86,550+	77,487+	86,550+	86,550+	86,550+	266,116+	151,976+	35,350+	86,386+	222,013+
III	E	0	0	580	3,900	1,480	750	3,360	1,250	4,140	9,140	(3,716)	6,310	4,940
	D	0	7,040	4,240	4,540	2,280	3,630	4,420	6,870	1,990	5,490	(3,961)	2,570	3,490
	A	0	(6,516)	15,800	26,660	6,580	1,790	4,650	17,160	5,790	290	0	12,190	11,940
	B	(209,560)	(209,560)	(209,560)	(209,560)	(209,560)	(209,560)	14,740	170,000	649,660	(209,560)	295,530	76,160	202,060
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		209,560	223,116	230,180	244,660	219,900	215,730	27,170	195,280	661,580	224,480	303,207	97,230	222,430
IV	E	(3,936)	0	2,300	2,540	960	11,160	3,180	4,420	7,060	8,700	2,830	2,240	2,500
	D	(2,927)	1,170	1,730	3,640	1,970	2,340	5,040	3,170	3,460	4,630	2,190	1,580	3,630
	A	(23,068)	3,650	40,710	52,070	21,750	12,400	20,660	19,220	4,660	11,420	3,620	9,700	19,070
	B	(70,554)	(70,554)	63,710	(70,554)	15,860	(70,554)	79,870	39,510	19,050	77,580	54,910	94,490	206,300
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		100,485	75,374	108,450	128,804	40,540	96,454	108,750	66,320	34,230	102,330	63,550	108,010	231,500
V	E	(1,117)	(1,117)	0	0	(1,117)	550	1,630	1,110	9,660	970	1,970	0	0
	D	(2,111)	1,230	1,200	720	(2,111)	820	1,580	1,490	4,250	2,190	1,950	1,940	4,400
	A	(3,432)	0	2,950	0	(3,432)	(3,432)	(3,432)	3,080	650	15,000	1,360	4,850	5,500
	B	(34,875)	(34,875)	21,740	(34,875)	(34,875)	(34,875)	(34,875)	25,960	(34,875)	43,610	(34,875)	35,800	39,810
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		41,535+	37,222+	25,890+	35,595+	41,535+	39,677+	41,517+	31,640+	49,435+	61,770+	40,155+	42,590+	49,710+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	(0)	(0)	(0)	0	(0)
	D	(1,348)	0	0	160	(1,348)	0	(1,348)	0	0	3,070	6,040	2,310	3,780
	A	(5,609)	380	4,060	1,010	(5,069)	0	(5,069)	21,350	4,730	12,360	3,240	8,940	11,020
	B	(13,888)	(13,888)	11,520	1,110	(13,888)	(13,888)	(13,888)	20,950	7,950	13,860	27,110	10,770	26,620
	C	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	(38,790)	38,790	(38,790)
Total		59,635	53,058	54,370	41,070	59,635	52,678	59,635	81,090	51,470	68,080	75,180	60,810	80,210

E: 30° S–40° S, D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: average abundance in each sector during seasons 1965/66 to 1977/78.

Table 36

Abundance of minke whales using sightings data from the waters south of 30° S (Approach-II)

		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	30° S–35° S	+	+	+	+	+	+	+	+	+	+	+	+	+
	35° S–40° S	254+	254+	254+	254+	254+	254+	254+	254+	254+	255+	254+	254+	254+
	40° S–45° S	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
	45° S–50° S	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+	2,402+
	50° S–55° S	1,368+	1,368+	1,384+	1,384+	1,442+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+	1,384+
	55° S–60° S	736+	946+	946+	946+	946+	946+	946+	946+	946+	938+	775+	1,144+	1,254+
	60° S–65° S	6,866	6,866	6,866	6,866	6,866	6,866	6,866	6,866	8,240	5,994	6,006	6,725	12,529
	65° S–70° S	29,676+	29,676+	29,676+	29,676+	29,676+	29,676	29,676	29,676+	54,548+	26,014+	20,986+	20,469+	29,676+
	70° S–75° S	+	+	+	+	+	+	+	+	+	+	+	+	+
TOTAL		41,302+	41,512+	41,512+	41,512+	41,570	41,512+	41,512+	41,512+	67,774+	36,986+	31,808+	32,378+	34,970+
II	30° S–35° S	+	+	+	+	+	+	+	+	+	+	+	+	+
	35° S–40° S	1,076+	1,182+	1,115+	1,115+	1,172+	1,115+	1,115+	1,115+	1,115+	1,115+	1,115+	1,115+	1,115+
	40° S–45° S	0	577	301	301	744	301	301	301	301	301	329	301	301
	45° S–50° S	0	78	104	104	735	104	104	104	104	66	117	66	104
	50° S–55° S	430	3,151	3,151	3,151	1,395	3,151	3,151	3,151	3,151	7,727	3,208	2,363	3,151
	55° S–60° S	36,336+	41,849+	41,849+	41,849+	41,509+	41,849+	41,849+	41,849+	43,946+	41,382+	41,822+	41,867+	41,849
	60° S–65° S	15,584+	15,584+	15,584+	15,584+	15,584+	15,584+	15,584+	15,584+	17,376+	15,566+	14,500+	16,775+	15,584+
	65° S–70° S	33,058+	35,995+	35,995+	35,995+	35,995+	35,995+	35,995+	35,995+	35,995+	38,452+	35,995+	35,995+	35,995+
	70° S–75° S	+	+	+	+	+	+	+	+	+	+	+	+	+
TOTAL		86,484+	98,416+	98,099+	98,099+	97,134+	98,099+	98,099+	98,099+	101,988+	104,609+	97,086+	98,482+	98,099+
III	30° S–35° S	1,587	1,587	1,397	1,398	3,019	2,516	2,371	998	991	1,830	1,587	861	1,205
	35° S–40° S	1,116	533	680	1,421	562	2,398	1,421	473	2,443	1,116	1,116	602	1,714
	40° S–45° S	0	3,912	1,136	1,355	659	1,634	2,989	2,729	1,266	3,526	2,186	888	3,077
	45° S–50° S	239	774	1,272	1,446	926	1,702	1,119	4,373	630	244	1,278	2,032	7,520
	50° S–55° S	501	1,714	1,632	2,039	2,435	2,946	3,979	2,487	2,469	164	1,714	1,798	2,314
	55° S–60° S	8,453+	8,453+	11,437+	9,911+	9,206+	6,601+	7,817+	8,453+	8,453+	7,404+	7,932+	8,654+	8,453+
	60° S–65° S	55,623+	55,623+	55,623+	55,623+	55,623+	55,623+	36,972+	92,416+	55,623+	55,623+	51,872+	47,914+	55,623+
	65° S–70° S	140,448+	140,448+	140,448+	140,448+	140,448+	140,448+	140,488+	131,283+	168,431+	140,448+	104,984+	140,219+	140,130+
	70° S–75° S	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL		207,967+	213,044+	213,625+	213,641+	212,878+	213,868+	197,116+	243,212+	240,306+	210,355+	172,669+	202,959+	220,036+
IV	30° S–35° S	2,301+	2,038+	2,539+	1,825+	963+	2,346+	1,707+	2,572+	3,016+	4,649+	2,436+	2,366+	1,873+
	35° S–40° S	1,242	972	347	851	506	4,562	1,753	1,402	2,093	1,320	853	770	922
	40° S–45° S	1,489	979	803	1,068	609	1,142	2,710	1,901	2,130	2,506	1,596	1,302	1,634
	45° S–50° S	952	899	765	1,058	735	1,710	1,157	734	638	1,936	414	1,231	545
	50° S–55° S	2,829	1,353	3,096	6,302	2,801	2,093	4,818	3,143	1,154	1,906	1,358	2,210	2,191
	55° S–60° S	15,961	11,837	25,784	28,242	17,653	9,052	18,928	21,957	8,462	13,980	8,612	5,586	15,421
	60° S–65° S	50,059	50,059	57,946	50,059	39,983	50,059	53,950	53,954	35,823	63,504	48,337	86,010	48,828
	65° S–70° S	6,403+	6,403+	3,049+	6,403+	6.403	6,403	6,403	6,403	6,403	6,403	5,464	6,403	6,562
	70° S–75° S	–	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL		81,236+	74,540+	94,329+	95,808+	69,653+	77,367+	91,426+	92,066+	59,719+	96,204+	69,070+	105,878+	77,976+
V	30° S–35° S	509+	509+	509+	509+	509+	336+	966+	438+	336+	399+	378+	222+	509+
	35° S–40° S	648+	648+	292+	210+	648+	294+	356	390+	2,794	658+	1,112+	543+	531+
	40° S–45° S	716	550	906	370	716	475	514	714	1,134	1,435	653	733	649
	45° S–50° S	591	698	326	294	591	203	1,045	685	830	449	1,686	2,438	2,137
	50° S–55° S	1,201	924	1,039	880	1,201	1,201	1,201	1,300	1,288	932	714	2,725	1,035
	55° S–60° S	5,268	5,268	4,771	5,268	5,268	5,268	5,268	2,471	5,228	6,812	5,268	1,496	3,697
	60° S–65° S	17,418	17,418	12,050	17,418	17,418	17,418	17,418	21,428	17,418	27,328	17,418	12,916	23,265
	65° S–70° S	9.806+	9,806+	10,099+	9,806+	9,806+	9,806+	9,806+	8,755	9,806+	9,806+	9,806+	9,806+	10,213+
	70° S–75° S	+	+	+	+	+	+	+	+	+	+	+	+	+
TOTAL		36,157+	35,821+	29,992+	34,755+	36,157+	35,001+	36,574+	36,181+	38,834+	47,819+	37,035+	30,879+	42,036+
IV	30° S–35° S	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
	35° S–40° S	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
	40° S–45° S	901+	787+	512+	422+	901+	464+	901+	584+	901+	1,506	4,577+	426+	994+
	45° S–50° S	553	426	393	17	553	323	553	533	240	622	430	1,007	813
	50° S–55° S	702	162	753	39	702	317	702	398	521	1,710	1,552	377	823
	55° S–60° S	3,691	1,529	3,315	1,533	3,691	3,375	3,691	5,127	2,159	4,269	2,163	4,718	10,155
	60° S–65° S	7,747	7,747	7,673	5,980	7,747	7,747	7,747	10,064	5,628	6,020	8,439	7,742	8,021
	65° S–70° S	4,104+	4,104+	4,104+	3,001+	4,104+	4,104+	4,104+	4,238+	2,211+	4,104+	5,474+	3,851	4,856+
	70° S–75° S	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+	1,310+
TOTAL		19,008+	16,065+	18,060+	12,302+	19,008+	17,640+	19,008+	22,254+	12,970+	19,541+	23,945+	19,431+	26,972+

Table 37

Abundance of minke whales using sightings data in the waters south of 30° S (Approach-III)

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E											960		
	D	0	0									0		26,770
	A	0	0			1,660					3,480	1,530	3,040	8,780
	B									241,940	0	22,460	19,930	68,460
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	0+	+	+	1,660+	+	+	+	241,940+	3,480+	24,950+	22,970+	104,010+
II	E	0	1,370			2,230						0		
	D	0	950			1,460						750	0	0
	A	0				3,930				157,190	78,460	7,960	15,930	
	B	0								106,510	71,100	26,640	68,480	205,770
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	2,320+	+	+	7,620+	+	+	+	263,700+	149,560+	35,350+	84,410+	205,770+
III	E	0	0	580	3,900	1,480	750	3,360	1,250	4,140	9,140		6,310	4,940
	D	0	7,040	4,240	4,540	2,280	3,630	4,420	6,870	1,990	5,490		2,570	3,490
	A	0		15,800	26,660	6,580	1,790	4,650	17,160	5,790	290	0	12,190	11,940
	B							14,740	170,000	649,660		295,530	76,160	202,060
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		0	7,040	20,620	35,100	10,340	6,170	27,170	195,280	661,580	14,920	295,530	97,230	222,430
IV	E		0	2,300	2,540	960	11,160	3,180	4,420	7,060	8,700	2,830	2,240	2,500
	D		1,170	1,730	3,640	1,970	2,340	5,040	3,170	3,460	4,630	2,190	1,580	3,630
	A		3,650	40,710	52,070	21,750	12,400	20,660	19,220	4,660	11,420	3,620	9,700	19,070
	B			63,710		15,860		79,870	39,510	19,050	77,580	54,910	94,490	206,300
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total			4,820	108,450	58,250	40,540	25,900	108,750	66,320	34,230	102,330	63,550	108,010	231,500
V	E			0	0		550	1,630	1,110	9,660	970	1,970	0	0
	D		1,230	1,200	720		820	1,580	1,490	4,250	2,190	1,950	1,940	4,400
	A		0	2,950	0				3,080	650	15,000	1,360	4,850	5,500
	B			21,740					25,960		43,610		35,800	39,810
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		+	1,230+	25,890+	720+	+	1,370+	3,210+	31,640+	14,560+	61,770+	5,280+	42,590+	49,710+
VI	E				0		0		0				0	
	D		0	0	160		0		0	0	3,070	6,040	2,310	3,780
	A		380	4,060	1,010		0		21,350	4,730	12,360	3,240	8,940	11,020
	B			11,520	1,110				20,950	7,950	13,860	27,110	10,770	26,620
	C												38,790	
Total			380	15,580	2,280		0		42,300	12,680	29,290	36,390	60,810	41,420

E: 30° S–40° S, D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S.

Table 38

Abundance of minke whales using sightings data for the Antarctic (Approach-III)

	1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I 30° S–35° S													
35° S–40° S											255		
40° S–45° S											0		
45° S–50° S	0	0									0		2,402
50° S–55° S	0	0			74						0	1,368	0
55° S–60° S	0									685	340	886	817
60° S–65° S									3,293	0	6,006	1,577	6,963
65° S–70° S									42,960	0	19,462	2,941	
70° S–75° S													
TOTAL	0	0			74				46,253	685	26,063	6,772	10,182
II 30° S–35° S													
35° S–40° S	0	126			1,172						0		
40° S–45° S	0	484			744						205	0	0
45° S–50° S	0	0			735					0	79	0	
50° S–55° S	0				1,395					6,956	149	1,824	
55° S–60° S	0				985				42,621	7,351	1,298	1,343	
60° S–65° S									14,636	2,722	1,542	2,588	
65° S–70° S	0								20,919	5,394			
70° S–75° S													
TOTAL	0	610			5,031				78,176	22,423	3,273	5,755	0
III 30° S–35° S		0	0	328	1,907	2,032	2,022	597	686	548		861	511
35° S–40° S	0	0	112	1,301	196	2,032	665	473	1,655			0	1,221
40° S–45° S	0	3,912	1,007	1,122	659	772	2,840	2,729	1,266	3,458		0	2,993
45° S–50° S	0	225	723	897	926	1,265	1,035	4,373	630	244		1,667	7,520
50° S–55° S	0		71	825	2,096	1,418	3,687	1,441	1,937	0	0	912	766
55° S–60° S			4,813	3,107	2,656	184	1,451	2,233		259	0	5,466	
60° S–65° S							1,173	78,643			26,333	30,159	
65° S–70° S								7,715			51,258	669	1,293
70° S–75° S									143,757				
TOTAL	0	4,137	6,726	7,580	8,440	7,703	12,873	98,204	149,931	4,509	77,591	39,734	14,304
IV 30° S–35° S		0	1,045	0	0	2,190	900	1,879	2,053	4,630	1,081	2,347	938
35° S–40° S		0	244	744	408	4,548	1,356	1,402	1,406	956	255	663	270
40° S–45° S		183	740	953	609	1,142	2,710	1,901	2,130	2,506	1,407	1,302	1,486
45° S–50° S		228	407	466	272	1,599	1,078	350	143	1,795	151	956	136
50° S–55° S		0	1,989	5,408	2,058	1,516	4,288	1,962	241	1,239	0	2,210	525
55° S–60° S		616	24,773	22,742	9,868	3,552	13,803	11,767	1,356	5,100	1,551	5,586	4,960
60° S–65° S			39,934		4,924		6,188	35,273	5,271	42,468	14,095	80,687	6,067
65° S–70° S			478							667	1,712		5,895
70° S–75° S													
TOTAL		1,027	69,610	30,313	18,139	14,547	30,323	54,534	12,600	59,361	20,252	93,751	20,277
V 30° S–35° S						0	787	259	0	399	205	0	
35° S–40° S			0	0		225	287	390	2,584	658	616	0	0
40° S–45° S		513	906	305		475	259	714	1,134	1,435	653	478	163
45° S–50° S		646	196	141		99	832	566	716	429	1,673	2,305	1,747
50° S–55° S		0	170	0				653	353	200	163	2,688	0
55° S–60° S			711					1,293	0	5,785		1,027	3,181
60° S–65° S			7,803					21,428		16,986		2,551	18,374
65° S–70° S			3,783					6,444					4,714
70° S–75° S													
TOTAL		1,159	13,569	446		799	2,165	31,747	4,787	25,892	3,310	9,049	28,179
VI 30° S–35° S												0	
35° S–40° S						0		0				0	
40° S–40° S		0	0	21		0		0		1,105	3,993	0	760
45° S–50° S		0	0	17		0		0	0	622	0	727	696
50° S–55° S		0	753	39		0		0	406	1,582	1,552	268	506
55° S–60° S		169	2,401	801		0		3,598	1,427	4,269	1,742	4,402	8,371
60° S–65° S			2,441	168				8,829	3,959	5,598	5,349	697	1,276
65° S–70° S				0				454	0		4,204	2,748	1,535
70° S–75° S												1,310	
TOTAL		169	5,595	1,046		0		12,881	5,792	13,176	16,840	10,152	13,144

Table 39

Abundance of blue whales using sightings data from the waters south of 30° S

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	(0)
	D	0	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	0
	A	0	0	(0)	(0)	0	(0)	(0)	(0)	(0)	0	0	0	0
	B	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	0	0	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+	0+
II	E	0	0	(0)	(0)	0	(0)	(0)	(0)	(0)	(0)	0	(0)	(0)
	D	0	0	(28)	(28)	0	(28)	(28)	(28)	(28)	(28)	0	0	22,607
	A	0	(0)	(0)	(0)	0	(0)	(0)	(0)	0	0	0	0	(0)
	B	0	(87)	(87)	(87)	(87)	(87)	(87)	(87)	218	0	0	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	87+	115+	115+	87+	115+	115+	115+	246+	28+	0+	0+	22,607+
III	E	0	285	463	0	2,748	0	334	278	0	0	(523)	0	0
	D	2,167	2,815	6,631	8,265	6,138	5,301	681	2,795	402	1,273	(3,568)	680	1,762
	A	730	(449)	836	962	0	1,418	923	0	0	0	0	0	11,860
	B	(76)	(76)	(76)	(76)	(76)	(76)	0	0	0	(76)	0	382	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		2,973	3,625	8,006	9,303	8,962	6,795	1,938	3,073	402	1,349	4,091	1,062	13,622
IV	E	(350)	0	0	0	253	510	622	194	1,052	0	281	323	568
	D	(1,317)	1,242	0	1,660	1,124	991	878	1,114	1,162	2,716	1,970	1,731	2,553
	A	(340)	0	371	305	343	384	322	1,579	412	0	0	186	1,894
	B	(442)	(442)	259	(442)	0	(442)	0	0	0	0	0	1,375	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		2,449	1,684	630	2,410	1,720	2,327	1,822	2,887	2,626	2,716	2,251	3,615	5,015
V	E	(489)	(489)	2,324	0	(489)	1,902	108	0	0	423	0	0	453
	D	(366)	697	105	0	(366)	1,952	173	0	68	862	172	704	1,749
	A	(116)	0	0	0	(116)	(116)	(116)	0	0	0	0	0	0
	B	(200)	(200)	779	(200)	(200)	(200)	(200)	0	(200)	0	(200)	428	479
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		1,171+	1,386+	3,208	200+	1,171+	4,170+	597	0+	268+	1,285+	372+	1,132+	2,681+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	(0)	(0)	(0)	0	(0)
	D	(0)	0	0	0	(0)	0	(0)	0	0	0	0	0	0
	A	(17)	0	0	62	(17)	517	(17)	0	0	0	0	0	0
	B	(74)	(74)	0	631	(74)	(74)	(74)	0	0	0	0	0	0
	C	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)
Total		91	74	0	693	91	591	91	0	0	0	0	0	0

E: 30° S–40° S. D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: average abundance in each sector during seasons 1965/66 to 1977/78.

Table 40

Abundance of fin whales using sightings data from the waters south of 30° S

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	D	0	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
	A			(1,980)	(1,980)	0	(1,980)	(1,980)	(1,980)	(1,980)	0	2,840	3,630	1,170
	B	(1,740)	(1,740)	(1,740)	(1,740)	(1,740)	(1,740)	(1,740)	(1,740)	0	870	1,080	8,710	6,490
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		1,740+	1,740+	3,720+	3,720+	1,740+	3,720+	3,720+	3,720+	1,980+	870+	3,920+	12,340+	7,660+
II	E	0	0	(240)	(240)	300	(240)	(240)	(240)	(240)	(240)	0	(240)	(240)
	D	720	0	(640)	(640)	720	(640)	(640)	(640)	(640)	(640)	0	1,500	10,070
	A	1,530	(4,090)	(4,090)	(4,090)	4,540	(4,090)	(4,090)	(4,090)	840	3,230	9,330	8,450	(4,090)
	B	0	(520)	(520)	(520)	(520)	(520)	(520)	(520)	0	0	0	16,360	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		2,250+	4,610+	5,490+	5,490+	6,080+	5,490+	5,490+	5,490+	1,720+	4,110+	9,330+	26,550+	14,400+
III	E	0	950	1,860	0	2,100	630	0	2,330	0	0	(950)	0	870
	D	6,900	5,940	8,160	17,940	11,530	16,510	5,570	18,820	5,410	1,880	(9,940)	7,110	5,720
	A	19,200	(8,880)	3,350	7,080	44,290	38,380	7,780	11,710	0	1,720	0	1,460	3,170
	B	(300)	(300)	(300)	(300)	(300)	(300)	0	1,160	0	(300)	130	130	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		26,400	16,070	13,670	25,320	58,220	55,820	13,350	34,020	5.410	3,900	11,020	8,700	9,760
IV	E	(280)	0	180	430	0	580	260	230	230	70	190	110	0
	D	(1,650)	1,040	2,840	5,420	1,710	1,990	720	850	590	1,190	210	980	350
	A	(20,480)	54,390	39,830	17,820	1,740	7,940	8,490	8,000	410	14,670	270	2,790	11,390
	B	(150)	(150)	350	(150)	340	(150)	0	220	230	350	0	70	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		22,560	55,580	43,200	23,820	3,790	10,660	9,470	9,300	1,460	16,280	670	3,950	11,740
V	E	(90)	(90)	780	0	(90)	290	0	0	0	140	0	0	0
	D	(470)	2,050	420	1,200	(470)	100	120	190	200	620	130	210	2,340
	A	(7,790)	0	700	840	(7,790)	(7,790)	(7,790)	0	0	30,210	0	2,740	9,480
	B	(1,620)	(1,620)	0	(1,620)	(1,620)	(1,620)	(1,620)	2,760	(1,620)	3,560	(1,620)	570	210
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		9,970+	3,760+	1,900+	3,660+	9,970+	9,800+	9,530+	2,950+	1,820+	34,530+	1,750+	3.520+	12,030+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	(0)	(0)	(0)	0	(0)
	D	(340)	0	500	0	(340)	580	(340)	3,150	0	0	0	0	1,720
	A	(2,940)	0	2,030	580	(2,940)	0	(2,940)	13,620	1,720	3,330	470	2,640	3,340
	B	(4,590)	(4,590)	0	5,140	(4,590)	(4,590)	(4,590)	11,650	2,400	640	930	0	0
	C	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)
Total		7,870	4,590	2,530	5,720	7,870	5,170	7,870	28,420	4,120	3,970	1,400	2,640	5,060

E: 30° S–40° S, D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: average abundance in each sector during seasons 1965/66 to 1977/78.

Table 41

Abundance of humpback whales using sightings data in the waters south of 30°S

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	(0)
	D	0	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	0
	A	0	0	(0)	(0)	0	(0)	(0)	(0)	(0)	0	0	0	0
	B	(50)	(50)	(50)	(50)	(50)	(50)	(50)	(50)	320	0	34	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		50+	50+	50+	50+	50+	50+	50+	50+	320+	0+	34+	0+	0+
II	E	0	0	(0)	(0)	0	(0)	(0)	(0)	(0)	(0)	0	(0)	(0)
	D	120	724	(117)	(117)	102	(117)	(117)	(117)	(117)	(117)	0	0	0
	A	0	(178)	(178)	(178)	497	(178)	(178)	(178)	267	0	0	0	(178)
	B	(388)	(388)	(388)	(388)	(388)	(388)	(388)	(388)	0	0	417	0	2,591
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		508+	1,290+	683+	683+	987+	683+	683+	683+	384+	117+	417+	0+	2,769+
III	E	0	0	0	0	250	199	0	0	560	0	(127)	94	0
	D	75	26	123	0	47	59	67	283	48	0	(73)	434	322
	A	156	(226)	0	0	364	0	515	0	0	0	0	0	1,513
	B	(894)	(894)	(894)	(894)	(894)	(894)	0	123	0	(894)	2,181	0	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		1,125	1,146	1,107	894	1,555	1,152	582	406	608	894	2,381	528	1,835
IV	E	(142)	0	0	103	485	65	116	296	335	64	0	309	0
	D	(83)	0	35	44	160	120	105	86	54	89	29	100	0
	A	(205)	126	162	619	88	171	41	0	0	579	0	0	1,208
	B	(292)	(292)	83	(292)	164	(292)	0	410	0	253	66	650	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		722	418	280	1,058	897	648	262	792	389	985	95	1,059	1,208
V	E	(52)	(52)	0	0	(52)	0	0	0	16	0	44	0	0
	D	(103)	356	0	0	(103)	0	27	0	216	412	55	56	223
	A	(0)	0	0	0	(0)	(0)	(0)	0	0	0	0	0	0
	B	(159)	(159)	83	(159)	(159)	(159)	(159)	133	(159)	567	(159)	0	306
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		314+	567+	83+	159+	314+	159+	186+	133+	391+	979+	258+	56+	529+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	(0)	(0)	(0)	0	(0)
	D	(26)	0	0	81	(26)	0	(26)	0	0	0	0	0	0
	A	(376)	0	61	0	(376)	659	(376)	729	668	819	113	0	0
	B	(509)	(509)	531	322	(509)	(509)	(509)	759	559	527	161	0	0
	C	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)
Total		911	509	592	403	911	1,168	911	1,488	1,227	1,346	274	0	0

E: 30° S–40° S, D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: average abundance in each sector during seasons 1965/66 to 1977/78.

Table 42

Abundance of right whales using sightings data from the waters south of 30° S

Sector		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
I	E	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	(0)
	D	0	0	(213)	(213)	(213)	(213)	(213)	(213)	(213)	(213)	317	(213)	0
	A	0	0	(0)	(0)	0	(0)	(0)	(0)	(0)	0	0	0	0
	B	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	0	0	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		0+	0+	213+	213+	213+	213+	213+	213+	213+	213+	317+	213+	0+
II	E	0	1,393	(616)	(616)	565	(616)	(616)	(616)	(616)	(616)	0	(616)	(616)
	D	83	1,206	(586)	(586)	384	(586)	(586)	(586)	(586)	(586)	3,853	0	0
	A	0	(22)	(22)	(22)	71	(22)	(22)	(22)	0	0	0	0	(22)
	B	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	0	0	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		83+	2,621+	1,224+	1,224+	1,020+	1,224+	1,224+	1,224+	1,202+	1,202+	3,853+	616+	638+
III	E	0	0	0	0	125	0	0	89	0	0	(48)	0	0
	D	176	116	123	35	63	15	50	304	80	0	(93)	0	161
	A	0	(0)	0	0	0	0	0	0	0	0	0	0	0
	B	(0)	(0)	(0)	(0)	(0)	(0)	0	0	0	(0)	0	0	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		176	116	123	35	188	15	50	393	80	0	141	0	161
IV	E	(152)	0	0	0	0	715	104	22	0	128	0	0	0
	D	(973)	0	315	29	1,814	281	703	1,521	1,592	1,351	1,695	636	3,132
	A	(40)	148	0	0	66	0	0	0	0	0	589	0	0
	B	(0)	(0)	0	(0)	0	(0)	0	0	0	0	0	0	0
	C	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		1,165	148	315	29	1,880	996	807	1,543	1,592	1,479	2,284	636	3,132
V	E	(31)	(31)	0	0	(31)	0	69	0	0	90	0	0	0
	D	(167)	89	236	17	(167)	92	55	36	410	118	92	281	2,574
	A	(0)	0	0	0	(0)	(0)	(0)	0	0	0	0	0	0
	B	(0)	(0)	0	(0)	(0)	(0)	(0)	0	(0)	0	(0)	0	0
	C	+	+	+	+	+	+	+	+	+	+	+	+	+
Total		198+	120+	236+	17+	198+	92+	124+	36+	410+	208+	92+	281+	2,574+
VI	E	(0)	(0)	(0)	0	(0)	0	(0)	0	(0)	(0)	(0)	0	(0)
	D	(13)	0	79	0	(13)	0	(13)	0	0	0	0	0	0
	A	(44)	0	91	197	(44)	0	(44)	0	0	0	0	0	0
	B	(9)	(9)	0	0	(9)	(9)	(9)	36	0	0	0	0	0
	C	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)
Total		66	9	170	197	66	9	66	36	0	0	0	0	0

E: 30° S–40° S, D: 40° S–50° S, A: 50° S–60° S, B: 60° S–70° S, C: south of 70° S. Figures in parentheses: average abundance in each sector during seasons 1965/66 to 1977/78.

SC/30/Doc 27

Indices of Abundance of Large Sized Whales in the North Pacific in the 1977 Whaling Season

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1. EFFORT AND CATCH IN 1977

In the 1977 whaling season, one Japanese expedition (*Kyokuyo maru No. 3*), two Soviet expeditions and four Japanese Pacific coastal whaling land stations (Osawa, Ayukawa, Wadaura and Taiji) operated in the North Pacific. The number of catcher boats attached to the Japanese expedition was reduced from nine to eight. For the first time the exploitation of Square L22 was carried out by the Japanese pelagic expedition because the domestic legal limit for Japanese pelagic whaling had been shifted westward from 165° E to 159° E (Fig. 1b). It is noteworthy that the Japanese expedition operated in a very small area of eight 10° squares, especially in Square L23, which was first exploited last season, where 97% of the Bryde's and 59% of the sperm whale quotas were taken for 55% of the effort. On the other hand, the two Soviet expeditions hunted extensively in the North Pacific and divided their effort equally between all Areas except Area V. Table 1 shows the combined effort and catch of Japanese and Soviet whaling.

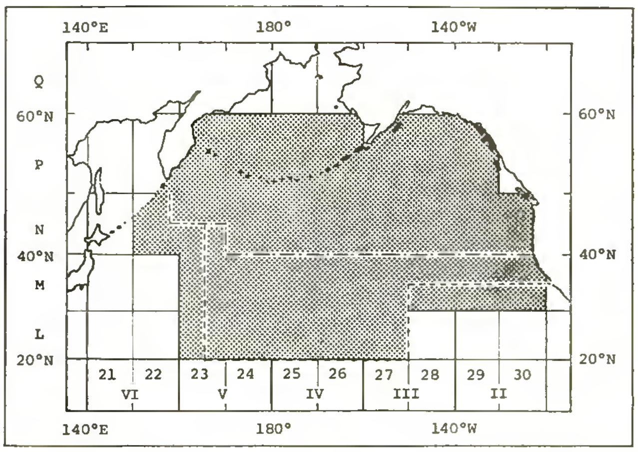


Fig. 1a. Range of operating area of Japanese pelagic whaling during the years 1966–76 used for the calculation of the index of abundance from CPUE data. —·—·—: Southern range for 1967–71. - - - - - -: Southern range for 1972–76.

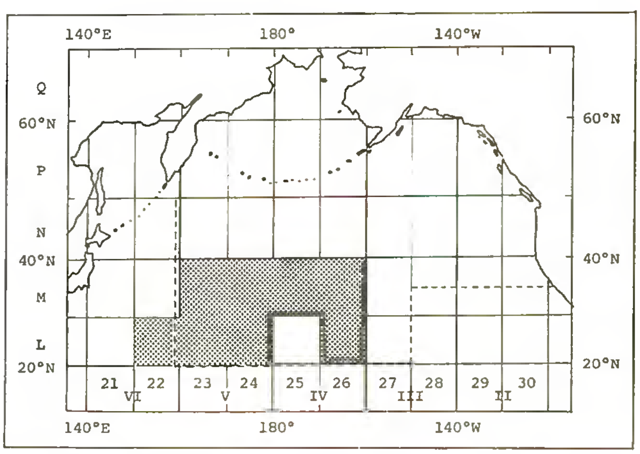


Fig. 1b. Range of operating area in 1977. - - - - - -: Southern range after 1977.

Table 1

Effort and catch of whales in the North Pacific, 1977

			Sperm		
Area	CDW	Bryde's	Male	Female	Total
Area II	669	0	374	526	900
Area III	572	2	202	140	342
Area IV	695	7	430	16	446
Area V	1,700	563	1,112	724	1,836
Area VI	648	127	419	384	803
Asian coast	1,282	76	1,091	926	2,017
Total	5,566	775	3,628	2,716	6,344

The total effort decreased to 92% of that in 1976. The main pelagic whaling ground last season was Area VI (CDW: 31%; Bryde's: 46%; sperm: 25%), however this season it moved to Area V (CDW: 40%; Bryde's: 81%; sperm: 42%). Japanese whalers achieved their quotas for both Bryde's and sperm whales, but the Soviet whalers only took 55% of their Bryde's whale quota and 79% (Male: 72%; Female: 90%) of their sperm whale quota.

2. CPUE

Fishing effort data (CDW) separated for the two whale species were adjusted by the average tonnage of the eight catcher boats (791 tons) attached to the Japanese expedition (Appendix Table 1). The yearly change in CPUE is shown in Table 2. The CPUE value for Bryde's whales is almost the same as for last season, and the value for sperm whales decreased very slightly.

Wada (1978) calculated indices of abundance of whales using CPUE data by 10° squares using average indices of abundance from two periods (1966–71 and 1972–76) as the estimated values for the squares where no whaling took place. However, yearly changes of indices of abundance obtained using this method often showed a gap between 1971 and 1972, especially for female sperm whales. Therefore, for the sake of better comparison of yearly changes of indices of abundance through the period, three distinct indices of abundance are given in this paper in the manner described below.

(1) Case-I
Only actual data are used for the calculation (uncorrected).

Table 2

Effort, catch and CPUE of Japanese pelagic whaling

Year	Corrected CDW				Catch				CPUE			
	Fin	Sei (baleen)	Br.	Sperm	Fin	Sei	Br.	Sperm	Fin	Sei	Br.	Sperm
1966	–	1,194	–	952	1,266	2,208	–	3,000	1.06	1.85	–	3.15
1967	–	1,245	–	813	844	3,474	–	3,000	0.68	2.79	–	3.69
1968	–	1,211	–	755	729	3,819	–	3,000	0.60	3.15	–	3.97
1969	–	1,523	–	1,059	576	3,591	–	3,000	0.38	2.36	–	2.83
1970	–	2,008	–	798	518	3,235	–	2,700	0.26	1.62	–	3.38
1971	–	1,896	98	847	542	2,419	109	1,803	0.29	1.27	1.11	2.13
1972	–	1,706	323	664	426	2,041	5	1,567	0.25	1.20	0.02	2.36
1973	1,166	1,395	353	567	256	1,710	2	1,803	0.22	1.23	0.01	3.18
1974	851	1,552	564	482	216	1,190	522	1,803	0.25	0.77	0.93	3.74
1975	394	819	785	434	118	454	688	1,803	0.30	0.55	0.88	4.15
1976	–	–	333	437	–	–	578	1,053	–	–	1.74	2.41
1977	–	–	247	468	–	–	424	1,061	–	–	1.72	2.27

(2) Case-II
Average indices of abundance are calculated using total catch and effort data for each 10° square for the twelve years from 1966 to 1977.

(3) Case-III
Average indices of abundance for the years after 1971 are calculated using data from a moving five year average, but for the years before 1970 data from a fixed five year average (1966–70)) are commonly used.

Figs 3a–c show the yearly changes of indices of abundance thus calculated. In Fig. 3a, the values for indices of abundance for Bryde's whales in 1977 showed a considerable decrease, especially in Case-I, but the CPUE in Table 2 shows almost the same level as in 1976. Therefore, this can be mainly attributed to the decrease in the number of whaling squares from six to three. The yearly changes of indices of abundance of the sperm whale, which showed a very similar pattern between male and female whales, seem to be on the decrease after 1974 (Figs 3b and 3c). Here again the effect of a reduction in the whaling ground should be considered because the number of whaling squares decreased from eighteen in 1974 to eight in 1977.

3. WHALE SIGHTING

In 1977, whale sighting was carried out by two scouting boats in the areas shown in Fig. 2b. The scouting distance

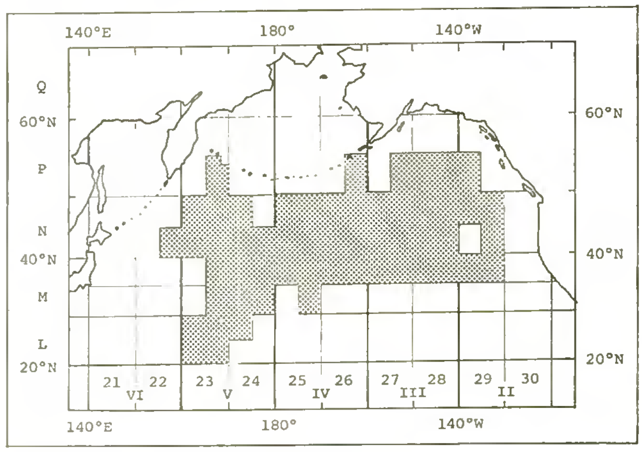


Fig. 2b. Range of research area in 1977.

in 1977, 22,143 miles, showed an increase to 119% of the previous year although it is still at a low level. As shown in Fig. 2b, the research area was not limited to the operating area (Fig. 1b), and 52% of the navigation (11,466 miles) was made north of 40° N where the Japanese expedition did not operate. Sighting in the lower latitudinal waters of the western Pacific is still insufficient.

Indices of abundance using whale sighting data were calculated by 5° squares in the same manner as those for CPUE. The fixed five years for Case-III was set as 1965–69 except for Bryde's whales (1972–76) and minke whales (1966–70). Figs 4a–h show the result of the calculations. The indices of abundance of the Bryde's whale which

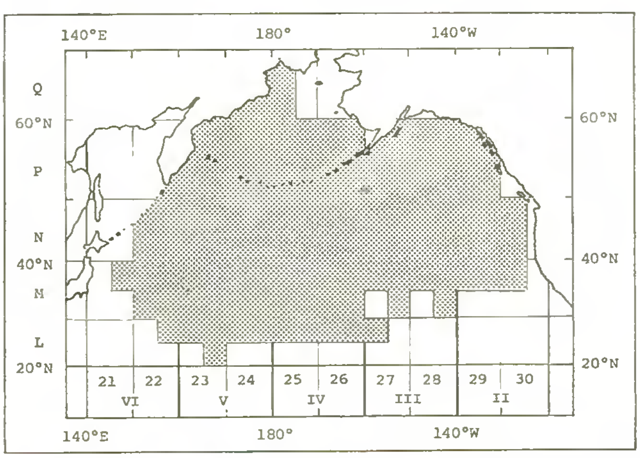


Fig. 2a. Range of research area by Japanese scouting boats during the years 1965–76 used for the calculation of the index of abundance from whale sighting data.

Fig. 3a. Yearly changes of indices of abundance by means of CPUE for Bryde's whales. ●–●: Case-I; ○–○: Case-II; ○- - -○: Case-III.

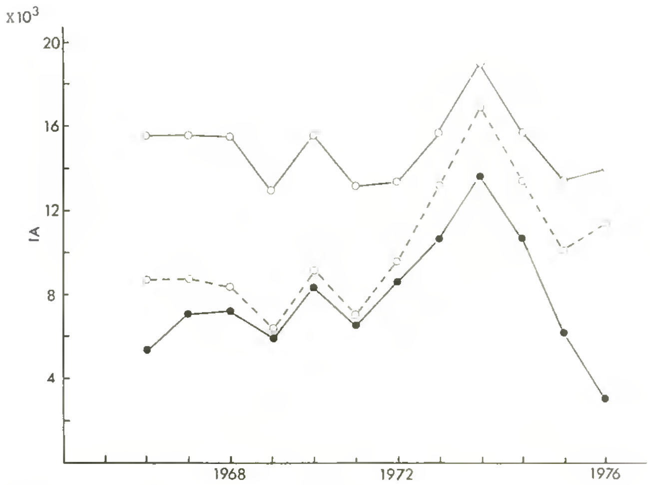


Fig. 3b. Male sperm whales.

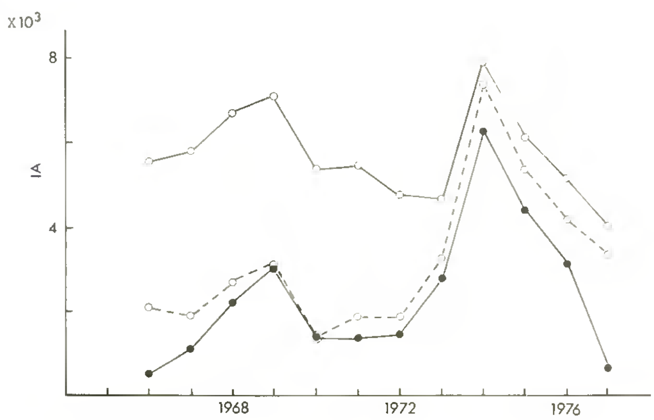


Fig. 3c. Female sperm whales.

showed a rapid increase until 1976, decreased in 1977 although only slightly (Fig. 4a). It is important to watch the future trend for this whale species. Patterns in the early changes of indices of abundance for the sperm whale differ among the three Cases. Large yearly fluctuations are found in Case-I and therefore no particular trend can be observed. Values for the last three years are near to the lowest level in Case-I but are at a relatively high level in Case-III. On the other hand, Case-II clearly shows a decreasing trend. Indices of abundance of minke whales which showed a gradual increase until 1975 along with the increase of interest in this whale species decreased remarkably after 1976 (Fig. 4c). Yearly changes of indices of abundance for fin whales in all three cases showed a very gradual decrease throughout the period (Fig. 4d). In sei whales, the decreasing trend is seen more clearly and more rapidly after 1969 (Fig. 4e). For the other prohibited species such as blue, humpback and right whales, no particular trend was observed (Figs 4f–h).

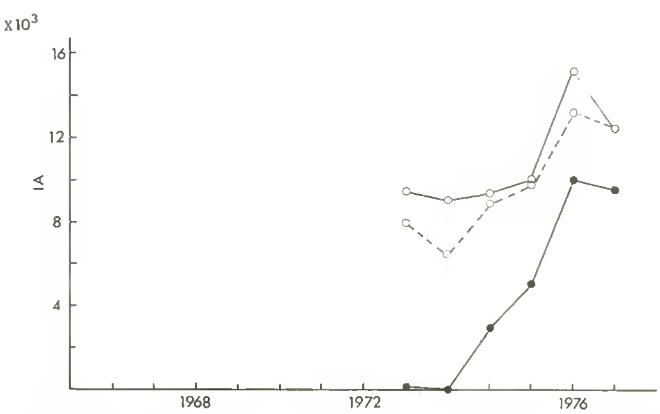


Fig. 4a. Yearly changes of indices of abundance from whale sighting data for Bryde's whales. ●–●: Case-I; ○–○: Case-II: ○- - -○: Case-III.

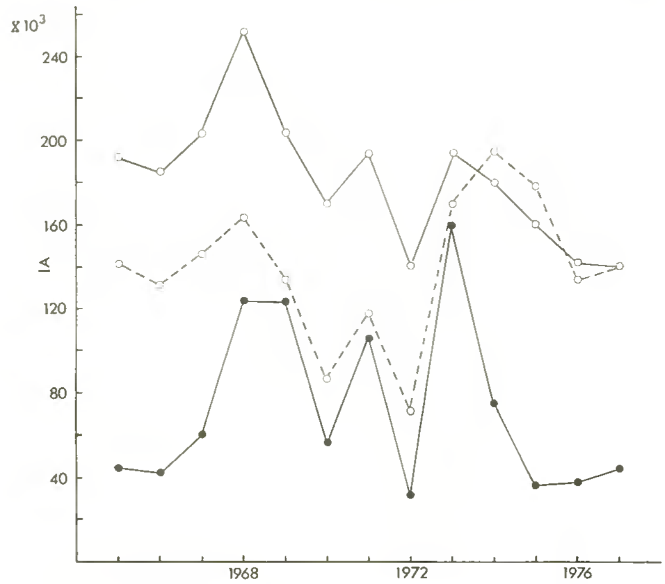


Fig. 4b. Sperm whales.

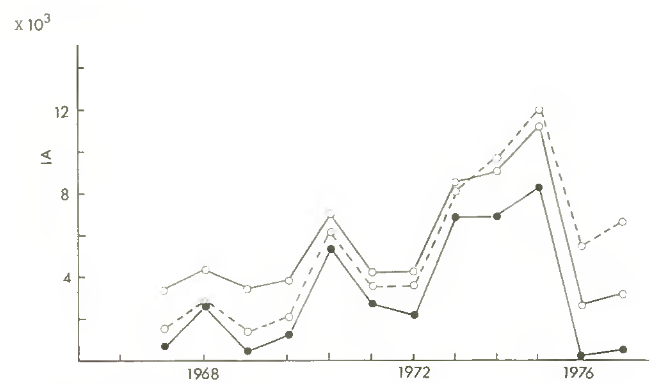


Fig. 4c. Minke whales.

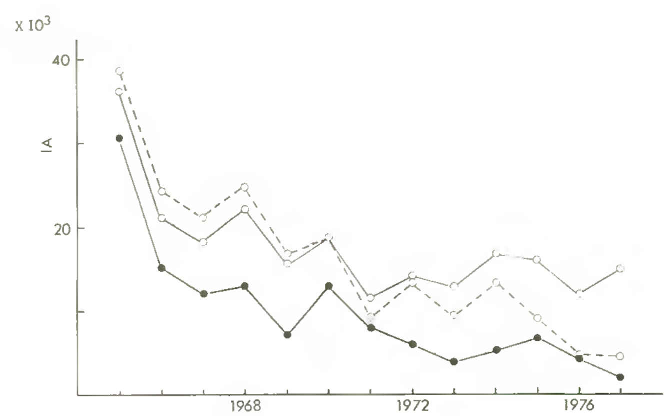


Fig. 4d. Fin whales.

REFERENCE

Wada, S. 1978. Indices of abundance of large-sized whales in the North Pacific in the 1976 whaling season. *Rep. int. Whal. Commn* 28: 319–24.

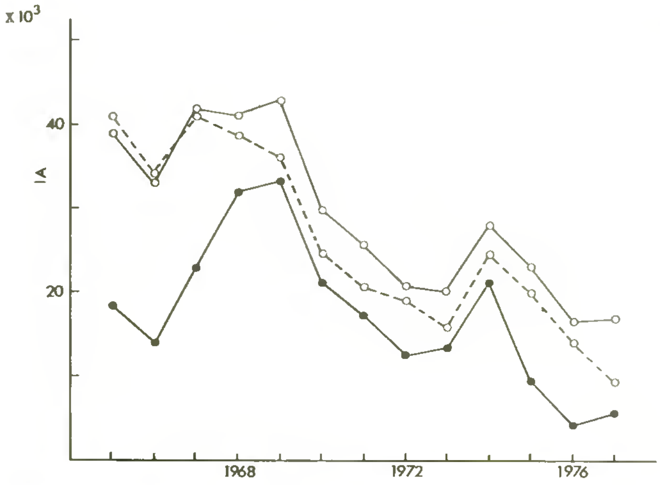


Fig. 4e. Sei whales.

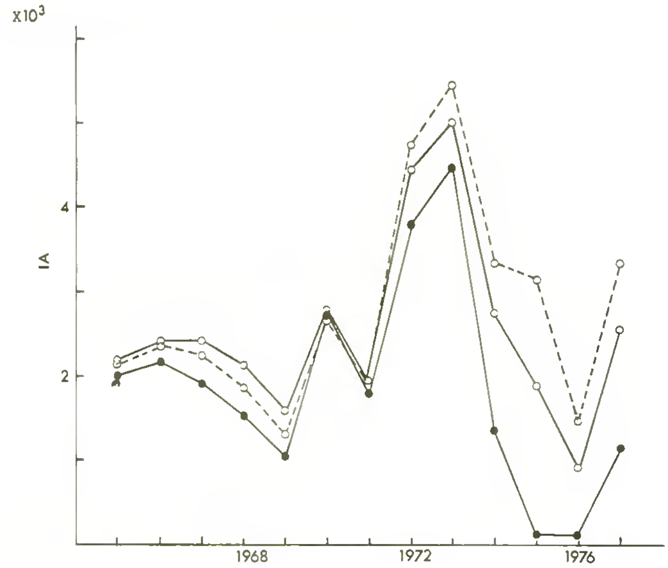


Fig. 4g. Humpback whales.

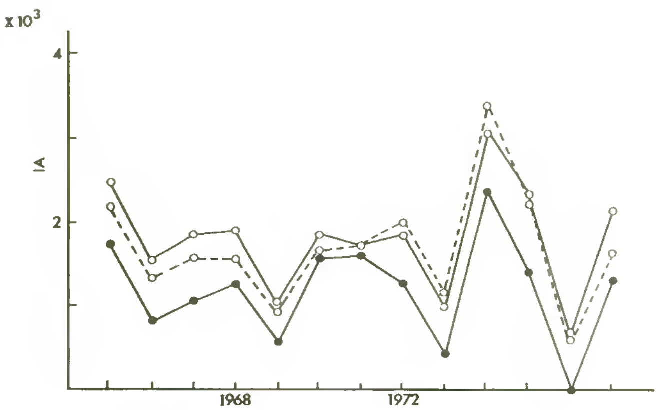


Fig. 4f. Blue whales.

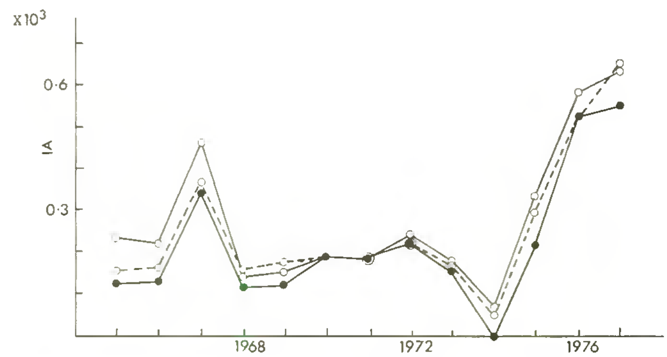


Fig. 4h. Right whales.

Appendix Table 1

Corrected CDW and catch of whales by Japanese pelagic whaling in the North Pacific, 1977

	Corrected CDW		Number of whales caught			
				Sperm		
10° square	Bryde's	Sperm	Bryde's	Male	Female	Total
L 22 (Area VI)	6.3	6.3	12	15	0	15
M 23	–	75.9	–	101	0	101
M 24	–	75.9	–	143	28	171
L 23	227.8	196.2	412	367	262	629
L 24	12.7	44.3	0	58	15	73
Area V total	240.5	392.3	412	669	305	974
M 25	–	38.0	–	38	0	38
M 26	–	12.7	–	11	0	11
L 26	–	19.0	–	23	0	23
Area IV total	–	69.7	–	72	0	72
All Area total	246.8	468.3	424	756	305	1,061

Appendix Table 2

Scouting distance (miles) and number of whales sighted by Japanese scouting boats in the North Pacific, 1977

5° square	Scouting distance (miles)	Number of whales sighted							
		Bryde's	Sperm	Minke	Fin	Sei	Blue	Humpback	Right
N 22 S–E (Area VI)	142	0	0	0	0	0	0	0	0
P 23 S–E	183	0	0	0	2	0	0	0	0
N 23 N–W	344	0	0	0	1	0	0	0	0
N 23 N–E	168	0	0	0	0	0	0	0	0
N 24 N–W	502	0	0	0	0	0	0	0	0
N 23 S–W	679	0	8	1	0	1	1	0	0
N 23 S–E	845	0	18	0	0	4	2	0	0
N 24 S–W	490	0	.0	0	2	0	0	0	0
N 24 S–E	169	0	0	0	0	1	0	0	0
M 23 N–E	174	0	0	0	0	0	0	0	0
M 24 N–W	251	0	0	0	0	0	0	0	0
M 24 N–E	841	0	0	0	0	0	0	0	0
M 23 S–E	175	2	0	0	0	0	0	0	0
M 24 S–W	859	4	0	0	0	0	0	0	0
M 24 S–E	362	1	0	0	0	0	0	0	0
L 23 N–W	465	15	0	0	0	0	0	0	0
L 23 N–E	851	20	0	0	0	0	0	0	0
L 24 N–W	278	8	20	0	0	0	0	0	0
L 23 S–W	361	6	6	0	0	0	0	0	0
L 23 S–E	389	0	0	0	0	0	0	0	0
Area V total	8,386	56	52	1	5	6	3	0	0
P 26 S–E	172	0	5	0	0	0	0	0	0
N 25 N–W	190	0	0	0	0	2	1	0	0
N 25 N–E	348	0	0	0	2	0	0	0	0
N 26 N–W	181	0	0	0	1	0	0	0	0
N 26 N–E	160	0	0	0	0	0	0	0	0
N 25 S–W	341	0	0	0	0	0	0	0	0
N 25 S–E	180	0	20	0	0	0	0	0	0
N 26 S–W	523	0	3	2	0	2	0	0	0
N 26 S–E	696	0	0	0	0	0	0	0	0
M 25 N–W	368	0	0	0	0	0	0	0	0
M 25 N–E	541	0	0	0	0	0	0	0	0
M 26 N–W	848	0	19	0	0	0	0	0	0
M 26 N–E	1,033	0	21	0	0	0	0	0	0
M 25 S–E	165	0	0	0	0	0	0	0	0
Area IV total	5,746	0	68	2	3	6	1	0	0
P 27 S–E	176	0	0	0	0	0	0	0	0
P 28 S–W	196	0	0	0	0	0	0	1	0
P 28 S–E	575	0	10	0	1	2	0	2	0
N 27 N–W	345	0	0	0	0	0	0	0	0
N 27 N–E	370	0	0	0	0	4	0	0	1
N 28 N–W	183	0	0	0	0	0	0	0	0
N 28 N–E	378	0	0	0	0	3	0	0	1
N 27 S–W	375	0	0	0	0	0	0	0	0
N 27 S–E	353	0	0	0	0	0	0	0	0
N 28 S–W	359	0	0	0	0	1	0	0	0
N 28 S–E	354	0	0	0	0	2	0	0	0
M 27 N–W	1,063	0	20	0	0	0	0	0	0
M 27 N–E	391	0	3	0	0	0	0	0	0
M 28 N–W	369	0	0	0	0	0	0	0	0
M 28 N–E	527	0	30	0	0	0	0	0	0
Area III total	6,014	0	63	0	1	12	0	3	2
P 29 S–W	194	0	2	0	0	3	0	2	0
N 29 N–W	563	0	30	1	2	1	1	1	2
N 29 N–E	190	0	3	0	0	1	2	0	0
N 29 S–E	542	0	17	0	0	2	0	0	0
M 29 N–W	187	0	0	0	0	1	0	0	0
M 29 N–E	179	0	23	0	0	0	0	0	0
Area II total	1,855	0	75	1	2	8	3	3	2
All Area total	22,143	56	258	4	11	33	7	6	4

Appendix Table 3

Indices of abundance of the commercial whales by use of catch and effort data of the Japanese expeditions in the North Pacific

	VI	V	IV	III	II	Total
			A. Bryde's whales			
Case-I						
1971	–	40	–	–	–	40
1972	–	10	–	–	–	10
1973	–	0	–	–	–	0
1974	–	400	1,210	0	–	1,610
1975	–	1,050	1,230	0	70	2,350
1976	–	1,920	980	–	–	2,900
1977	620	590	–	–	–	1,210
Case-II						
1971	620	1,350	1,240	0	70	3,280
1972	620	1,120	1,240	0	70	3,050
1973	620	1,180	1,240	0	70	3,110
1974	620	1,510	1,210	0	70	3,410
1975	620	1,640	1,230	0	70	3,560
1976	620	1,960	1,270	0	70	3,920
1977	620	870	1,240	0	70	2,800
Case-III						
1971	–	880	1,250	0	70	2,200
1972	–	700	1,250	0	70	2,020
1973	–	750	1,250	0	70	2,070
1974	–	1,090	1,210	0	70	2,370
1975	–	1,050	1,230	0	70	2,350
1976	–	1,920	1,270	0	70	3,260
1977	620	960	1,240	0	70	2,890

	VI	V	IV	III	II	Total
			B. Male sperm whales			
Case-I						
1966	–	1,230	3,740	500	–	5,470
1967	20	1,330	2,960	2,750	–	7,060
1968	–	2,000	2,000	2,580	700	7,280
1969	–	2,310	870	1,640	1,120	5,940
1970	–	3,410	1,730	2,360	830	8,330
1971	0	1,290	1,580	1,920	1,720	6,510
1972	50	1,550	1,890	2,810	2,360	8,660
1973	30	3,440	1,760	3,330	2,220	10,780
1974	–	3,910	4,020	4,620	1,170	13,720
1975	–	1,700	5,060	3,380	510	10,650
1976	–	1,930	720	3,490	–	6,140
1977	80	1,980	940	–	–	3,000
Case-II						
1966	810	3,960	5,910	2,960	1,840	15,480
1967	800	3,490	5,130	4,340	1,840	15,600
1968	810	4,390	4,470	3,840	1,740	15,250
1969	810	4,470	3,340	2,410	1,860	12,890
1970	810	5,570	4,610	3,130	1,570	15,690
1971	810	3,680	4,170	2,690	1,830	13,180
1972	820	3,200	3,940	3,060	2,470	13,490
1973	800	5,460	3,490	3,800	2,220	15,770
1974	810	5,930	5,080	5,340	1,910	19,070
1975	810	4,310	6,120	3,630	930	15,800
1976	810	3,850	2,430	4,460	1,840	13,390
1977	810	3,910	4,010	3,420	1,840	13,990
Case-III						
1966	20	1,790	3,740	2,210	1,050	8,810
1967	20	1,330	2,960	3,470	1,050	8,830
1968	20	2,230	2,300	2,900	910	8,360
1969	20	2,310	1,170	1,640	1,120	6,260
1970	20	3,410	2,440	2,360	830	9,040
1971	20	1,560	1,820	1,920	1,720	7,040
1972	10	2,340	2,170	2,810	2,360	9,690
1973	0	5,200	2,100	3,730	2,220	13,250
1974	40	5,380	4,670	4,810	1,940	16,840
1975	40	2,920	5,620	3,760	1,070	13,410
1976	40	2,980	1,220	4,530	1,350	10,120
1977	800	2,560	2,510	3,590	2,000	11,460

Appendix Table 3 (*continued*)

	VI	V	IV	III	II	Total
			C. Female sperm whales			
Case-I						
1966	–	270	10	250	–	530
1967	0	330	60	750	–	1,140
1968	–	940	20	660	630	2,250
1969	–	1,250	30	520	1,330	3,130
1970	–	780	100	280	220	1,380
1971	0	500	0	260	630	1,390
1972	30	200	340	490	370	1,430
1973	0	1,200	290	270	1,080	2,840
1974	–	1,620	4,050	30	680	6,380
1975	–	1,550	2,240	550	160	4,500
1976	–	690	2,460	0	–	3,150
1977	0	650	0	–	–	650
Case-II						
1966	10	1,650	2,250	550	1,170	5,630
1967	0	1,400	2,320	990	1,170	5,880
1968	10	2,170	2,270	980	1,300	6,720
1969	10	2,320	2,280	640	1,870	7,120
1970	10	1,850	2,350	400	760	5,370
1971	10	1,730	2,260	390	1,170	5,560
1972	30	1,210	2,280	610	670	4,800
1973	0	2,000	1,330	330	1,080	4,740
1974	10	2,420	4,060	280	1,220	7,990
1975	10	2,660	2,250	670	580	6,170
1976	10	1,370	2,490	330	1,170	5,370
1977	10	1,340	950	630	1,170	4,100
Case-III						
1966	0	700	10	580	850	2,140
1967	0	320	60	750	850	1,980
1968	0	1,090	20	840	720	2,670
1969	0	1,250	30	520	1,330	3,130
1970	0	780	100	280	220	1,380
1971	0	710	0	560	630	1,900
1972	30	660	340	490	370	1,890
1973	0	1,870	290	270	1,080	3,510
1974	20	2,010	4,050	120	1,260	7,460
1975	20	1,830	2,240	730	630	5,450
1976	20	800	2,460	490	510	4,280
1977	0	820	900	690	980	3,390

Appendix Table 4

Indices of abundance of whales by means of whale sighting by Japanese scouting boats in the North Pacific

	VI	V	IV	III	II	Total
			A. Bryde's whales			
Case-I						
1972	0	130	0	0	0	130
1973	0	0	0	0	0	0
1974	0	1,390	1,580	0	0	2,970
1975	300	2,200	2,510	0	0	5,010
1976	0	7,920	2,650	0	0	10,570
1977	0	9,560	0	0	0	9,560
Case-II						
1972	0	6,080	3,460	0	0	9,540
1973	0	5,950	2,120	0	0	8,070
1974	0	5,670	3,690	0	0	9,360
1975	300	6,520	3,320	0	0	10,140
1976	0	9,330	5,270	0	0	14,600
1977	40	9,670	2,690	0	0	12,400
Case-III						
1972	0	4,460	3,560	0	0	8,020
1973	0	4,330	2,120	0	0	6,450
1974	0	5,210	3,690	0	0	8,900
1975	300	6.060	3,430	0	0	9,790
1976	0	7,950	5,270	0	0	13,220
1977	50	9,680	2,690	0	0	12,420

Appendix Table 4 (*continued*)

	VI	V	IV	III	II	Total
			B. Sperm whales			
Case-I						
1965	0	12,250	19,070	10,140	3,760	45,220
1966	1,500	21,200	14,850	4,260	1,030	42,840
1967	300	32,040	21,140	6,580	0	60,060
1968	2,090	36,000	15,770	53,200	17,160	124,220
1969	1,730	25,340	9,380	12,570	71,960	120,980
1970	410	7,210	13,890	13,580	21,010	56,100
1971	1,880	9,190	6,420	15,360	73,980	106,830
1972	170	6,300	4,070	21,220	540	32,300
1973	4,850	47,770	19,720	11,500	76,000	159,840
1974	10,850	26,540	6,360	13,960	17,690	75,400
1975	550	27,300	4,880	3,380	80	36,190
1976	12,440	10,000	8,390	6,880	180	37,890
1977	0	9,320	12,380	6,920	16,060	44,680
Case-II						
1965	5,940	57,400	30,450	30,220	68,810	192,820
1966	7,430	64,500	26,230	23,090	64,070	185,320
1967	6,580	73,430	28,000	27,090	67,360	202,460
1968	7,350	81,410	25,760	65,480	72,480	252,480
1969	7,060	69,960	17,660	25,110	84,520	204,310
1970	6,010	52,760	20,420	25,480	65,140	169,810
1971	7,140	53,390	15,550	27,640	89,400	193,120
1972	1,620	44,430	13,640	30,250	50,050	139,990
1973	6,130	72,360	25,730	13,480	76,490	194,190
1974	12,130	59,020	14,470	20,630	73,560	179,810
1975	1,110	65,210	17,750	14,880	62,660	161,610
1976	13,660	24,590	20,550	19,600	64,150	142,550
1977	6,300	46,810	21,550	14,930	51,960	141,550
Case-III						
1965	2,000	27,810	24,080	24,220	63,730	141,840
1966	3,500	33,700	19,850	16,040	58,790	131,880
1967	1,710	39,640	21,810	21,450	61,770	146,380
1968	2,430	44,240	19,810	53,950	42,780	163,210
1969	2,660	32,760	13,320	13,400	72,530	134,670
1970	1,670	14,990	14,560	13,580	41,140	85,940
1971	2,210	12,760	8,200	13,560	81,790	118,520
1972	500	6,350	5,470	25,030	34,290	71,640
1973	5,770	53,210	20,520	15,020	76,270	170,790
1974	11,880	67,110	7,490	20,510	88,440	195,430
1975	580	72,480	10,230	16,430	78,360	178,080
1976	13,650	12,470	12,230	18,050	76,710	133,110
1977	6,110	32,660	15,300	13,680	74,950	142,700
			C. Minke whales			
Case-I						
1966	0	330	230	80	0	640
1967	0	1,000	1,090	220	300	2,610
1968	0	120	310	30	0	460
1969	0	340	500	360	0	1,200
1970	0	2,150	1,660	860	700	5,370
1971	0	500	580	600	930	2,610
1972	0	1,580	160	300	200	2,240
1973	0	1,460	4,170	1,280	30	6,940
1974	220	4,520	2,050	100	0	6,890
1975	950	1,010	1,810	3,650	960	8,380
1976	0	200	0	0	0	200
1977	0	100	250	0	110	460
Case-II						
1966	130	1,600	720	550	350	3,350
1967	170	1,570	1,430	730	510	4,410
1968	110	1,600	1,190	90	370	3,360
1969	90	1,950	1,260	470	20	3,790
1970	130	3,530	1,860	880	700	7,100
1971	110	1,690	810	650	930	4,190
1972	40	2,390	920	400	450	4,200
1973	80	2,720	4,390	1,380	50	8,620
1974	300	5,640	2,870	210	20	9,040
1975	950	2,480	2,850	3,770	1,230	11,280
1976	40	1,320	880	100	340	2,680
1977	190	1,380	1,030	120	410	3,130

Appendix Table 4 (*continued*)

	VI	V	IV	III	II	Total
Case-III						
1966	0	1,050	320	180	0	1,550
1967	0	1,010	1,090	320	300	2,720
1968	0	1,010	350	30	20	1,410
1969	0	1,180	580	380	0	2,140
1970	0	3,070	1,660	860	700	6,290
1971	0	1,420	620	680	930	3,650
1972	0	1,580	850	630	540	3,600
1973	0	2,090	4,390	1,630	90	8,200
1974	220	5,490	3,540	470	60	9,780
1975	950	2,320	3,450	3,790	1,500	12,010
1976	50	950	4,120	150	140	5,410
1977	570	1,850	4,090	100	110	6,720
D. Fin whales						
Case-I						
1965	0	2,520	11,430	4,140	12,550	30,640
1966	500	9,290	2,370	2,180	930	15,270
1967	2,210	3,060	3,540	2,240	1,210	12,260
1968	3,820	4,920	1,580	2,840	0	13,160
1969	240	2,760	1,470	1,070	1,430	6.970
1970	610	1,950	6,200	3,320	1,230	13,310
1971	110	900	4,550	2,090	810	8,460
1972	1,330	2,960	700	940	420	6,350
1973	90	560	550	1,650	1,480	4,330
1974	0	610	100	1,510	3,560	5,780
1975	510	60	230	2,620	3,410	6,830
1976	690	0	0	1,410	2,260	4,360
1977	0	1,000	690	100	220	2,010
Case-II						
1965	1,550	3,740	12,000	4,830	13,840	35,960
1966	2,050	10,140	4,560	2,850	2,010	21,610
1967	2,570	3,810	5,580	3,180	3,630	18,770
1968	3,980	6,310	5,970	3,100	3,000	22,360
1969	1,690	4,310	6,030	1,740	1,880	15,650
1970	2,070	3,760	7,940	3,320	1,900	18,990
1971	160	1,730	6,590	2,350	810	11,640
1972	1,440	3,790	5,680	2,220	1,660	14,790
1973	1,730	3,250	3,320	2,930	1,920	13,150
1974	1,640	3,040	5,400	2,340	4,690	17,110
1975	720	3,420	6,320	4,070	1,930	16,460
1976	690	2,110	5,310	1,920	2,360	12,390
1977	1,690	3,820	5,830	1,550	2,130	15,020
Case-III						
1965	2,810	5,620	11,700	4,720	13,970	38,820
1966	3,310	11,530	4,260	3,070	2,350	24,520
1967	2,630	4,890	5,160	3,200	5,600	21,480
1968	3,820	6,590	4,890	3,160	6,040	24,500
1969	2,820	4,790	4,960	1,850	1,920	16,340
1970	3,190	3,830	6,200	3,320	2,170	18,710
1971	110	970	5,010	2,340	810	9,240
1972	1,330	2,960	6,500	1,620	1,530	13,940
1973	1,120	1,150	3,080	2,390	1,810	9,550
1974	1,050	1,050	5,310	1,910	4,160	13,480
1975	510	1,130	3,300	3,480	830	9,250
1976	690	290	410	1,700	1,680	4,770
1977	830	1,040	920	470	1,310	4,570
E. Sei whales						
Case-I						
1965	0	3,280	7,010	6,370	1,900	18,560
1966	0	6,620	2,590	3,670	1,310	14,190
1967	150	12,080	10,730	480	0	23,440
1968	2,170	10,810	4,940	13,090	1,110	32,120
1969	2,980	4,480	11,020	12,200	2,750	33,430
1970	130	4,640	2,630	4,980	9,130	21,510
1971	1,010	7,460	1,550	2,570	4,800	17,390
1972	130	7,690	2,560	2,280	270	12,930
1973	750	4,360	4,690	2,530	1,120	13,450
1974	6,080	12,050	2,130	1,230	100	21,590
1975	180	5,700	450	2,820	460	9,610
1976	580	2,240	120	820	400	4,160
1977	0	810	1,090	1,900	1,910	5,710

Appendix Table 4 (*continued*)

	VI	V	IV	III	II	Total
Case-II						
1965	1,610	10.970	10.180	10,130	6,000	38,890
1966	1,610	14,070	5,760	7,100	4,700	33,240
1967	1,720	18,850	11,980	4,530	5,090	42,170
1968	3,480	12,270	6,290	13,900	5,020	40,960
1969	3,930	9,960	11,990	13,640	3,420	42,940
1970	1,470	9,830	3,760	5,240	9,390	29,690
1971	2,260	12,520	2,720	3,380	4,900	25,780
1972	580	10,460	3,560	4,070	2,140	20,810
1973	1,060	7.940	5,170	4,240	1,790	20,200
1974	6,380	13,680	4,150	2,810	1,060	28,080
1975	510	10,550	4,360	5,080	2,730	23,230
1976	970	5,960	3,890	1,920	4,010	16,750
1977	1,560	3,750	2,980	3,940	4,700	16,930
Case-III						
1965	3,580	7,170	11,600	14,800	3,780	40,930
1966	3,580	10,100	7,180	10,360	2,850	34,070
1967	3,920	14,080	10,730	9,070	3,310	41,110
1968	5,150	10,940	5,110	13,860	3,890	38,950
1969	3,080	4,890	11,220	13,550	3,570	36,310
1970	3,200	4,710	2,630	4,980	9,130	24,650
1971	3,990	7,810	1,570	2,570	4,800	20,740
1972	3,290	7,690	2,760	3,550	1,720	19,010
1973	1,140	4,790	4,950	3,650	1,340	15,870
1974	6,500	12,880	2,500	2,110	810	24,800
1975	550	12,790	1,410	3,200	1,950	19,900
1976	620	8,730	1,820	1,700	1,180	14,050
1977	1,080	1,860	1,780	2,240	2,710	9,670

F. Blue whales

	VI	V	IV	III	II	Total
Case-I						
1965	0	390	600	560	190	1,740
1966	0	330	70	210	220	830
1967	40	30	740	230	0	1,040
1968	140	680	300	160	0	1,280
1969	0	240	190	70	70	570
1970	130	310	40	540	550	1,570
1971	170	390	190	0	860	1,610
1972	70	420	730	0	50	1,270
1973	0	120	70	250	0	440
1974	150	590	150	540	940	2,370
1975	0	280	0	1,110	0	1,390
1976	0	0	0	0	0	0
1977	0	260	320	0	750	1,330
Case-II						
1965	60	590	750	610	460	2,470
1966	60	500	220	260	500	1,540
1967	80	180	770	290	530	1,850
1968	140	760	340	160	510	1,910
1969	50	340	190	210	260	1,050
1970	170	380	60	540	710	1,860
1971	170	400	210	0	910	1,690
1972	70	420	750	220	380	1,840
1973	70	160	90	470	190	980
1974	220	620	210	740	1,260	3,050
1975	20	360	190	1,390	410	2,370
1976	0	30	140	10	480	660
1977	70	310	350	280	1,140	2,150
Case-III						
1965	70	600	680	610	250	2,210
1966	70	540	140	240	340	1,330
1967	40	200	740	280	320	1,580
1968	140	680	300	160	290	1.570
1969	70	240	190	150	250	900
1970	200	310	40	540	550	1,640
1971	170	400	190	0	860	1,620
1972	70	420	750	350	400	1,990
1973	80	190	90	630	170	1,160
1974	240	650	170	930	1,380	3,370
1975	40	460	140	1,270	310	2,220
1976	0	30	370	40	160	600
1977	0	260	320	300	750	1,630

Appendix Table 4 (*continued*)

	VI	V	IV	III	II	Total
			G. Humpback whales			
Case-I						
1965	0	60	370	780	780	1,990
1966	0	100	1,180	980	0	2,260
1967	0	20	640	1,310	0	1,970
1968	110	160	80	1,220	0	1,570
1969	0	190	360	550	0	1,100
1970	0	130	440	1,450	760	2,780
1971	0	80	790	970	0	1,840
1972	0	610	790	2,440	0	3,840
1973	100	140	710	3,290	290	4,530
1974	0	130	0	340	930	1,400
1975	0	110	0	0	0	110
1976	0	120	0	0	0	120
1977	0	0	0	470	680	1,150
Case-II						
1965	60	130	390	850	800	2,230
1966	60	160	1,200	1,060	0	2,480
1967	60	70	640	1,390	310	2,470
1968	150	180	260	1,300	300	2,190
1969	0	210	560	750	120	1.640
1970	40	140	440	1,450	760	2,830
1971	40	90	790	1,060	0	1,980
1972	40	610	1,030	2,720	120	4,520
1973	100	210	790	3,570	410	5,080
1974	0	170	680	910	1,050	2,810
1975	20	200	730	660	290	1,900
1976	40	190	330	80	290	930
1977	40	80	320	1,140	970	2,550
Case-III						
1965	50	180	370	780	780	2,160
1966	50	200	1,180	980	0	2,410
1967	50	110	640	1,310	190	2,300
1968	110	160	140	1,340	190	1,940
1969	0	210	430	750	0	1,390
1970	0	130	440	1,450	760	2,780
1971	0	90	790	1,100	0	1,980
1972	0	610	980	2,780	440	4,810
1973	100	260	820	3,640	730	5,550
1974	0	200	590	1,260	1,370	3,420
1975	0	360	790	1,740	270	3,160
1976	50	440	450	0	520	1,460
1977	50	40	450	1,500	1,320	3,360
			H. Right whales			
Case-I						
1965	0	0	120	10	0	130
1966	0	50	10	70	0	130
1967	0	60	200	80	0	340
1968	0	110	0	0	0	110
1969	0	100	20	0	0	120
1970	100	40	0	0	50	190
1971	40	140	0	0	0	180
1972	0	220	0	0	0	220
1973	0	0	130	20	0	150
1974	0	0	0	0	0	0
1975	0	0	0	220	0	220
1976	0	200	0	330	0	530
1977	0	0	0	330	220	550
Case-II						
1965	20	40	120	50	10	240
1966	20	80	10	100	0	210
1967	30	90	200	110	30	460
1968	0	110	10	0	20	140
1969	0	110	30	10	0	150
1970	100	40	0	0	50	190
1971	40	140	0	0	0	180
1972	0	220	10	10	0	240
1973	10	10	130	30	0	180
1974	10	10	30	20	0	70
1975	20	30	30	240	20	340
1976	0	210	20	330	20	580
1977	10	10	20	350	240	630

Appendix Table 4 (*continued*)

	VI	V	IV	III	II	Total
Case-III						
1965	0	30	120	10	0	160
1966	0	80	10	70	0	160
1967	0	90	200	80	0	370
1968	0	110	40	0	0	150
1969	0	100	60	10	0	170
1970	100	40	0	0	50	190
1971	40	140	0	0	0	180
1972	0	220	0	0	0	220
1973	20	0	130	20	0	170
1974	20	0	30	0	0	50
1975	0	30	50	220	0	300
1976	0	200	0	330	0	530
1977	0	0	0	430	220	650

SC/30/Doc 28

Bryde's Whales in the North Pacific in 1977

Seiji Ohsumi

Far Seas Fisheries Research Laboratory

The catch limit for Bryde's whales in the North Pacific was 1,000 in 1977 and this was allocated equally between the USSR and Japan.

Two Soviet expeditions and one Japanese expedition engaged in pelagic whaling, and 6 catcher boats engaged in coastal whaling in the waters adjacent to Japan.

WHALING GROUND

Fig. 1 shows the number of Bryde's whales caught in each 10° square in the North Pacific in 1977. The whaling ground of the Soviet expeditions was widespread and seemed to be affected by the 200 mile economic zones of the USA and Japan. The Japanese expedition only needed to operate in a smaller area because of the reduction in quota. The coastal whaling ground was off Sanriku, Kanto and Wakayama.

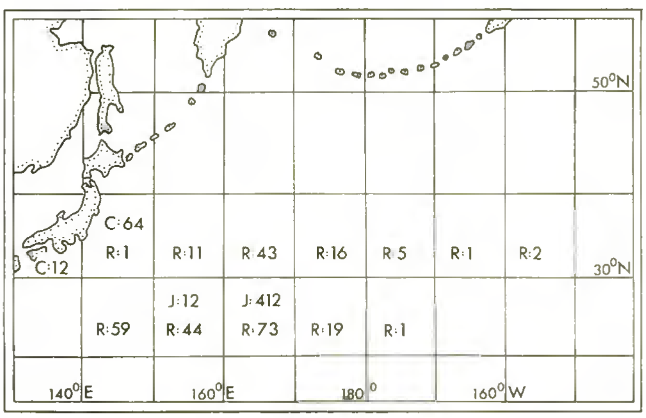


Fig. 1. Catch of Bryde's whales by 10° square in 1977. C: Japanese coastal whaling, J: Japanese pelagic whaling, R: Soviet pelagic whaling.

YEARLY TRENDS IN CATCH AND CPUE

Japanese whaling took its full quota, but as the USSR only took 275 Bryde's whales (55% of its quota), economic zones must have affected the Soviet catch. Table 1 shows the Bryde's whale catch since 1970.

Fig. 2 shows the yearly change in CPUE for Bryde's whales in the Sanriku area which is the main whaling ground of the species. Although the CPUE in 1977 was lower than the previous year, there is no overall trend of decrease.

Table 2 shows the yearly change in catch, effort and CPUE of the Bryde's whales by Japanese pelagic whaling. The CPUE in 1977 was almost the same as that in 1976, and there is no trend of decrease.

Table 3 shows the catch, effort and CPUE of Bryde's whales by Soviet expeditions in the L21–L25 area which is the main whaling ground of the Bryde's whale in the North Pacific. There had been no trend in CPUE until 1976, although the value was exceptionally high in 1973, but the value in 1977 was about half that of 1976. It must be

Table 1

Catch of Bryde's whales in the North Pacific in recent years

Year	Coastal Japan	Pelagic Japan	Pelagic USSR	Total
1970	73	–	66	139
1971	172	109	638	919
1972	125	5	71	201
1973	71	2	651	728
1974	187	522	654	1,363
1975	116	688	629	1,433
1976	83	578	679	1,340
1977	76	424	275	775

Table 2

Fishing effort, catch and CPUE of Bryde's whales taken by Japanese pelagic whaling

Year	CDW	Catch	CPUE
1971	139	109	0.784
1972	453	5	0.011
1973	343	2	0.006
1974	763	522	0.684
1975	1,061	688	0.648
1976	432	578	1.338
1977	312	424	1.359

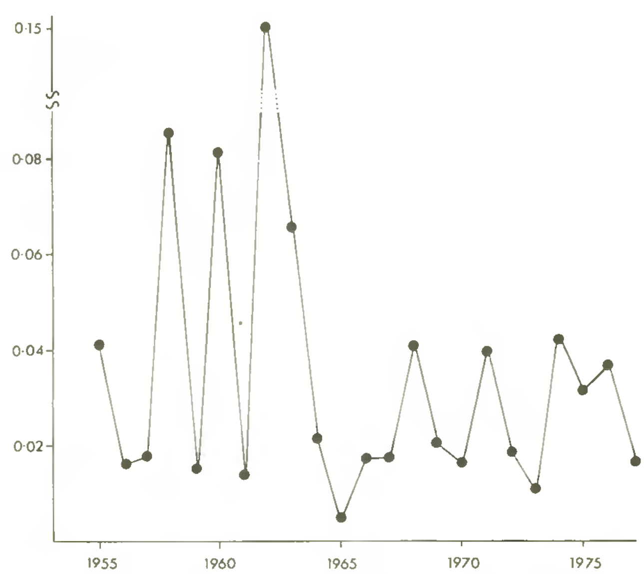


Fig. 2. Yearly change in CPUE for Bryde's whales caught in the Sanriku area by Japanese coastal whaling.

Table 3
Fishing effort, catch and CPUE of Bryde's whales taken by Soviet pelagic whaling in L21–L25

Year	CDW	Catch	CPUE
1973	566	518	0.915
1974	874	341	0.390
1975	1,460	561	0.384
1976	1,592	643	0.404
1977	945	195	0.206

considered whether this is due to operational changes or not. It is rather difficult to obtain fishing effort data from Russian catch statistics as the effort is not divided into each species.

Wada (1979) examined the yearly trend in density thoroughly using whale sighting data from scouting boats.

WHALE MARKING

In 1977, 15 Bryde's whales were effectively marked, and the number of surviving marked whales marked since 1972 was estimated to be 112.2, of these 3 were recaptured in 1977. Therefore the expedition rate was estimated to be 2.7% of the total population. Table 4 shows the estimated population sizes using whale marking data. The average population during the years 1975–77 is 40,800.

Fig. 3 shows the movements of recaptured Bryde's whales in 1977. The range of the North Pacific Bryde's whale is being gradually revealed.

REFERENCE

Wada, S. 1979. Indices of abundance of large sized whales in the North Pacific in 1977. Paper SC/30/Doc 27 (published in this volume).

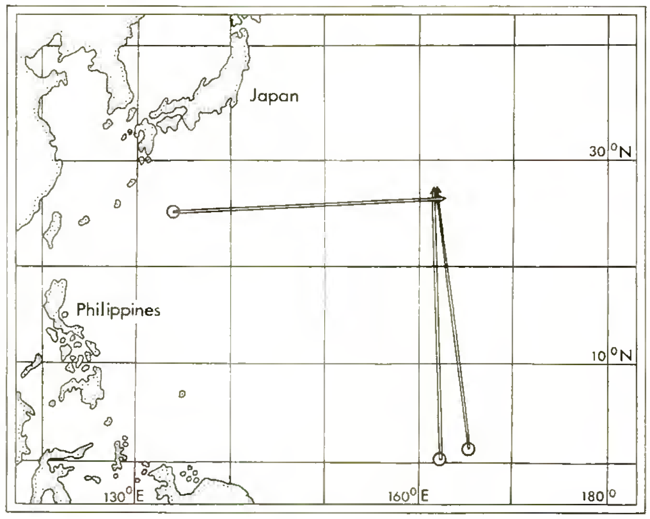


Fig. 3. Movements of marked Bryde's whales in 1977.

Table 4
Fishing rates and population sizes estimated from marking data during 1972–77

Year	Marked whales	Survived whales	Recaptured whales	Fishing rate	Catch	Population size
1972	8	8.0	–	0.000	201	–
1973	24	31.3	–	0.000	728	–
1974	9	37.7	–	0.000	1,363	–
1975	52	86.7	2	0.023	1,433	62,100
1976	32	109.8	4	0.036	1,340	36,800
1977	15	112.2	3	0.027	775	28,700
1975–1977	–	308.7	9	0.029	1,182.7	40,800

SC/30/Doc 30

Provisional Report of the Bryde's Whales Caught Under Special Permit in the Southern Hemisphere in 1977/78 and a Research Programme for 1978/79

Seiji Ohsumi

Far Seas Fisheries Research Laboratory

INTRODUCTION

The Far Seas Fisheries Research Laboratory planned to study the populations of the Bryde's whale in the Southern Hemisphere to follow the recommendation of the IWC Scientific Committee for the rational utilisation of whale stocks (IWC, 1977, p. 13). It was granted a permit on 7 October 1976 to take no more than 240 Bryde's whales by the Minister of Agriculture and Forestry in accordance with the provisions of Article VIII of the International Convention for the Regulation of Whaling.

This investigation was carried out with the co-operation of the Whales Research Institute, the Nippon Hogei Co. Ltd, and the Whaling Section of the Fisheries Agency. A provisional report was submitted to the IWC Scientific Committee in the 29th Annual Meeting of the IWC (Ohsumi, 1978), and a research programme for 1977/78 was offered in the report.

The IWC Scientific Committee adopted a new Rule of Procedure on Scientific Permits which required an advance review of proposed permits by the Committee at the 29th Meeting. The Far Seas Fisheries Research Laboratory re-examined the research programme for 1977/78 at the end of the Meeting, and applied to the Government. Mr K. Yonezawa, the Japanese Commissioner, sent the proposal to the Secretary of the IWC to be reviewed by the members of the Scientific Committee. Kind comments were sent by several members of the Committee, and the Minister of Agriculture and Forestry issued a permit to take no more than 120 Bryde's whales in the Southern Hemisphere in 1977/78 on 7 October 1977. Thus, a second investigation was carried out during that season.

This paper is a provisional report on the second investigation, as the data and materials collected are now being processed.

The research programme for 1978/79 is also attached to this paper, for review by the Scientific Committee (Appendix 1).

OUTLINE OF INVESTIGATION

The *Nissinmaru No. 3* expedition undertook the investigation using 10 catcher boats as shown in Table 1. Of these catcher boats, two worked as scouting boats, one worked mainly as a scouting boat, and the others all engaged in sighting as scouting boats before and during the experimental catch.

Three boats arrived in the research area in the western South Pacific on 19–21 October 1977, and began sighting. The remaining seven boats arrived on 26 October, and also engaged in sighting until the factory ship arrived and the experimental catch started on 29 October. The experimental operation by the expedition lasted until 21 November, and 114 Bryde's whales were caught during this period. In addition to this, 267 sperm whales and 22 minke whales were caught. Operational records for the experimental catch are shown in Table 2.

Table 1

Scale of the *Nissinmaru No. 3* Expedition for the experimental catch of Bryde's whales in 1977/78

Name of catcher	Gross tonnage	Engine (diesel) h.p.	Remarks
Shonanmaru	916.96	5,260	–
Shonanmaru No. 2	916.44	5,260	–
Kyomaru No. 1	812.02	3,290	–
Kyomaru No. 27	729.55	3,290	Mainly a scouting boat
Toshimaru No. 11	740.37	3,140	–
Toshimaru No. 12	647.31	3,480	Scouting boat
Toshimaru No. 16	758.33	3,500	–
Toshimaru No. 17	757.69	3,500	Scouting boat
Toshimaru No. 18	758.32	3,500	–
Toshimaru No. 25	739.92	3,600	–

Three scouting boats engaged in whale sighting and whale marking in the waters north of 40° S of the Indian Ocean from the middle decade of February to the middle of March 1978, mainly for a Bryde's whale investigation.

WHALE SIGHTING

Table 3 shows the sighting distance covered by scouting boats in the waters north of 40° S in the South Pacific and Indian Oceans in the 1977/78 season and the species and numbers of whales found. The whale sighting area and positions of Bryde's whales found are shown in Fig. 1.

The sighting was carried out to develop the research area eastwards from 180° longitude, and reached 137° W in 1977/78 in the South Pacific. In the Indian Ocean scouting boats tried to cover the central part of the Ocean.

Fig. 2 shows the number of Bryde's whales found per 10,000 miles steamed by scouting boats in 1977/78. Adding the results of the previous season (Ohsumi, 1978, p. 284), it can be seen that Bryde's whales are widely distributed in the South Pacific and Indian Oceans.

Whale sighting was also carried out by the operating catcher boats in the South Pacific. The whales found each day are shown in Table 2.

WHALE MARKING

Scouting boats tried to mark as many whales as possible in the waters north of 40° S in 1977/78. 423 Discovery marks were used in marking 3 blue, 1 fin, 3 humpback, 1 sei, 26 minke, 75 Bryde's and 63 sperm whales. Table 4 shows the marking results for the Bryde's whales – the effective hit ratio of marks for this species was 39.9%.

Fig. 3 shows that Bryde's whales were marked over a wide area in 1977/78.

Table 2

Operational records on the experimental catch of Bryde's whales by the *Nissinmaru No. 3* Expedition in the Southern Hemisphere in the 1977/78 season

Date	Noon position	Wind force	Visi-bility	Weather condition	Water temp. (°C)	CDW	CHW	CSW	Catch Br	Catch Sp	Catch Mi	Whales found B	Whales found F	Whales found H	Whales found Se	Whales found Br	Whales found Sp	Whales found Mi	Whales found R
1977																			
October																			
29	21° 03′ S, 179° 52′ E	3	9	bc	23.0	7	89.0	55.6	2	30	–	–	–	–	–	2	53	2	–
30	22° 21′ S, 179° 38′ E	4	9	bc	22.8	7	90.3	37.6	1	44	–	–	–	–	–	2	81	1	–
31	24° 02′ S, 179° 15′ W	3	9	bc	23.4	6	90.5	79.0	2	11	–	–	2	–	–	2	41	2	–
November																			
1	25° 16′ S, 177° 51′ W	2	9	bc	21.2	6	77.2	69.9	3	–	–	–	1	–	–	5	1	–	–
2	25° 30′ S, 174° 06′ W	4	9	bc	21.8	6	79.7	62.6	–	17	–	–	–	–	–	–	26	–	–
3	26° 27′ S, 172° 14′ W	4	9	bc	22.0	6	76.9	23.2	–	47	–	–	–	–	–	–	116	–	–
4	25° 15′ S, 169° 44′ W	2	9	bc	22.5	6	78.7	78.5	–	–	1	–	–	2	–	–	37	2	–
5	23° 41′ S, 166° 14′ W	3	9	b	22.4	5	65.4	52.7	–	12	3	–	–	–	–	–	13	5	–
6	25° 49′ S, 166° 10′ W	5	9	bc	22.0	6	79.6	76.4	–	–	2	–	–	–	–	–	–	2	–
7	26° 50′ S, 167° 50′ W	4	9	bc	21.6	6	82.0	69.3	–	22	–	–	–	2	–	–	40	–	–
8	26° 47′ S, 171° 12′ W	2	9	bc	20.8	6	80.5	75.9	2	–	3	–	–	3	–	2	–	3	–
9	28° 02′ S, 175° 06′ W	2	9	bc	20.8	6	78.8	56.0	20	9	–	–	–	–	–	24	62	1	–
10	28° 10′ S, 176° 48′ W	4	9	bc	21.0	6	81.4	75.3	4	1	–	–	–	–	–	5	6	–	–
11	27° 33′ S, 177° 16′ W	4	9	bc	20.8	6	80.1	63.1	7	8	2	2	–	2	–	7	16	2	–
12	26° 26′ S, 178° 19′ W	4	9	b	21.6	6	81.5	67.7	11	1	2	–	–	–	–	11	1	3	–
13	27° 38′ S, 179° 45′ W	2	9	c	20.8	6	80.4	73.6	5	–	–	–	–	–	–	5	2	1	–
14	28° 50′ S, 178° 48′ W	4	9	bc	20.2	6	95.7	79.2	10	7	2	–	–	–	–	11	12	2	–
15	27° 27′ S, 176° 22′ W	3	9	bc	20.8	8	106.1	89.8	16	1	4	–	–	2	–	18	2	4	–
16	28° 34′ S, 173° 33′ W	3	9	bc	20.6	7	95.4	85.2	9	2	–	–	–	–	–	9	2	–	–
17	27° 11′ S, 174° 08′ W	3	9	bc	22.0	7	94.0	82.7	15	1	1	–	–	–	–	17	2	1	–
18	29° 24′ S, 172° 01′ W	3	9	bc	20.6	7	95.4	89.1	7	–	2	–	–	–	–	8	1	2	–
19	32° 30′ S, 168° 55′ W	3	9	bc	18.2	7	97.1	65.9	–	26	–	–	–	–	–	–	89	–	–
20	36° 43′ S, 168° 43′ W	4	9	bc	16.6	6	84.7	60.8	–	21	–	–	–	–	1	–	251	–	–
21	40° 40′ S, 170° 02′ W	4	9	c	16.2	6	83.8	75.4	–	7	–	–	–	–	38	–	106	–	–

No marks have been recovered from the Bryde's whales in the Southern Hemisphere.

CATCH

A total of 114 Bryde's whales were caught experimentally in the South Pacific in the 1977/78 season. The positions of the whales caught are shown in Fig. 4. They were in the waters 21°–30° S, 179° E–170° W which developed the catch area eastwards from the previous season.

Many data were collected during the catching operations concerning the behaviour of the Bryde's whale and fishing effort and they are being analysed at present.

BIOLOGICAL INVESTIGATION OF WHALES CAUGHT

Measurements were made on each whale caught and biological materials collected which are now being examined in our laboratories.

Table 5 shows the size distribution of the whales caught. More males were taken than females as had happened in the previous season. Seven females were estimated to have been ovulating. Considering the wide range of the foetal lengths, it seems that this stock has a long breeding season.

Body proportions were measured for all the whales caught and the body weight was obtained for 13 whales. A complete skeleton was collected which was buried in sand in the campus of Hokkaido University for cleaning. Nasal bones were collected from 5 whales for taxonomic examination.

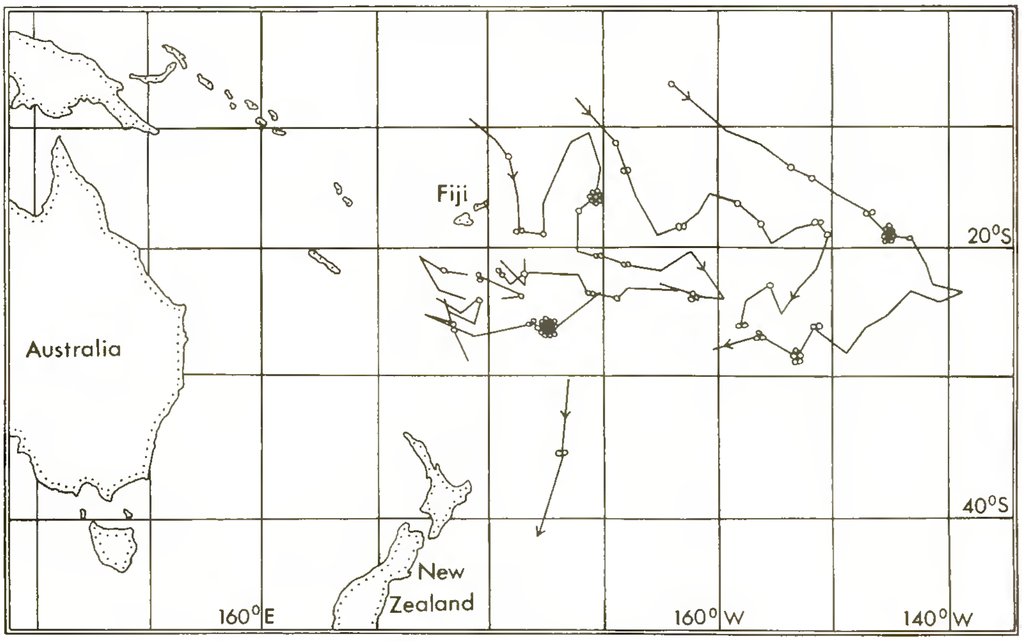
PRODUCTS

Table 6 shows amount of products from Bryde's whales caught in 1977/78. The total products were 1,128.1 metric tons, and 9.896 tons were produced on average per whale. The average body length of the whales caught was 12.98 m.

Table 3

Whales found during whale sighting by scouting boats in 1977/78

	Pacific	Indian	Total
Sighting distance (miles)	16,113	13,201	29,314
Blue whales	3	2	5
Fin whales	–	2	2
Humpback whales	6	–	6
Sei whales	–	3	3
Bryde's whales	89	44	133
Minke whales	50	26	76
Sperm whales	642	412	1,054
Cuvier's beaked whales	23	108	131
Killer whales	44	82	126
Pilot whales	205	38	243
Other small cetaceans	1,646	1,216	2,862



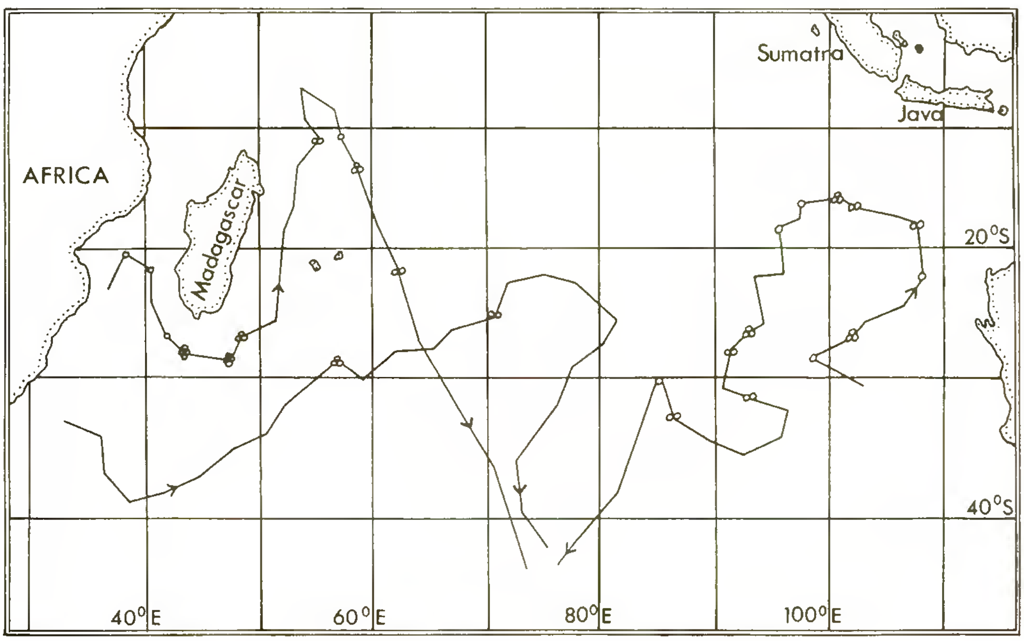


Fig. 1. Investigation ground of the scouting boats in the waters north of 40° S in 1977/78 and positions of Bryde's whales sighted by them. —: course of scouting boat; o: position of Bryde's whale.

Table 4

Whale marking results for Bryde's whales in 1977/78

	Hit	Hit, but protruding	Possible hit	No verdict	Ricochet	Miss	Total	Hit whale
South Pacific	50	–	4	3	1	68	126	47
Indian Ocean	28	–	3	–	1	30	62	28
Total	78	–	7	3	3	98	188	75

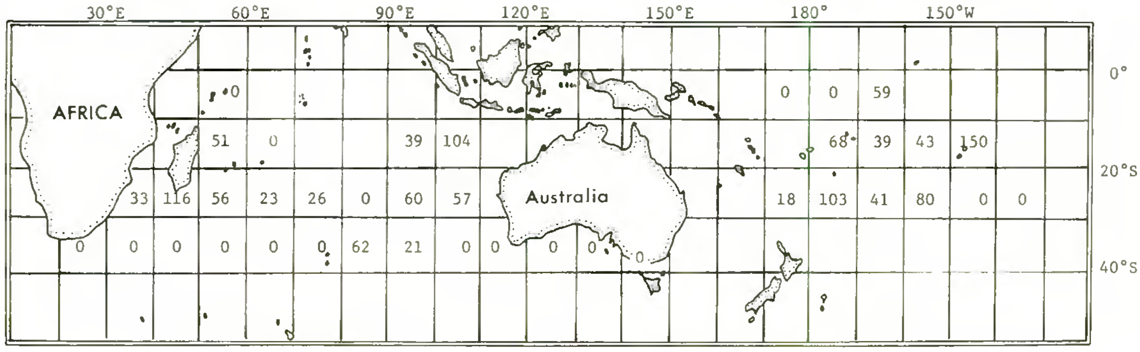


Fig. 2. Number of Bryde's whales sighted per 10,000 miles navigation by scouting boats in 1977/78.

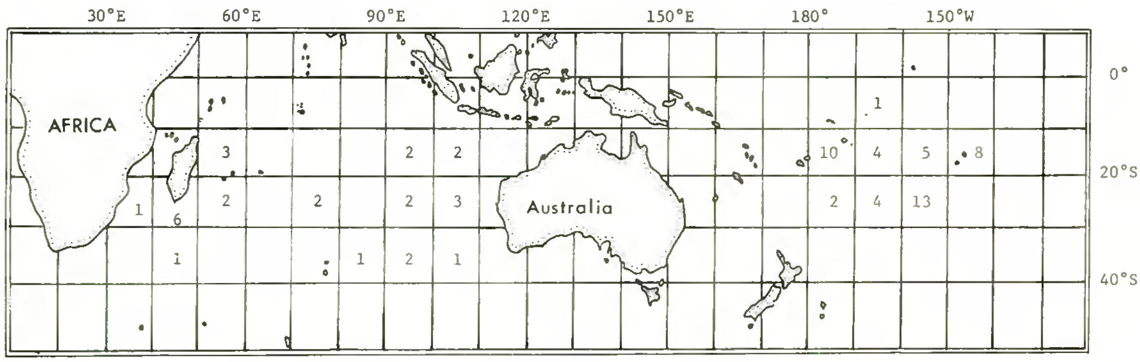


Fig. 3. Number of Bryde's whales effectively marked in 1977/78.

Table 5
Size distribution of Bryde's whales caught in 1977/78

Body length (feet)	Males			Females								
	Immat.	Mat.	Total	Immat.	Mat.	Total	P	P + L	O + L	L	O	R
24	–	–	–	1	–	1	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–
26	1	–	1	–	–	–	–	–	–	–	–	–
27	2	–	2	–	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	1	–	1	–	–	–	–	–	–
31	1	–	1	3	–	3	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	1	–	1	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	–	–
36	1	–	1	–	–	–	–	–	–	–	–	–
37	–	–	–	1	–	1	–	–	–	–	–	–
38	–	–	–	–	–	–	–	–	–	–	–	–
39	1	2	3	2	1	3	–	–	–	–	1	–
40	–	–	–	–	–	–	–	–	–	–	–	–
41	2	3	5	1	2	3	1	–	–	–	–	1
42	–	8	8	–	3	3	–	–	–	–	–	3
43	–	16	16	–	1	1	–	–	–	–	1	–
44	–	12	12	–	7	7	3	2	1	1	–	–
45	–	9	9	–	5	5	1	–	1	2	–	1
46	–	8	8	–	3	3	2	–	–	–	–	1
47	–	4	4	–	3	3	1	1	1	–	–	–
48	–	2	2	–	4	4	4	–	–	–	–	–
49	–	–	–	–	2	2	–	–	1	–	1	–
50	–	–	–	–	1	1	–	–	–	1	–	–
Total	8	64	72	10	32	42	12	3	4	4	3	6

P = pregnant. L = lactating. O = ovulating. R = resting.

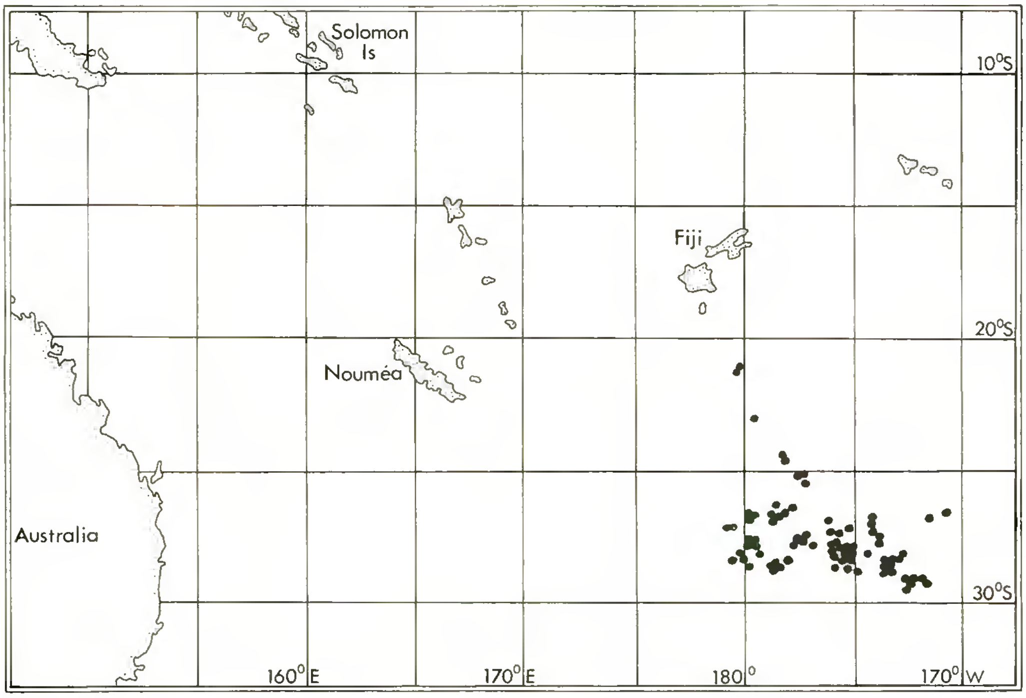


Fig. 4. Position of Bryde's whales caught in 1977/78. •: position of whale caught.

Table 6

Products from Bryde's whales caught (metric tons)

	Total	Per head
Whales caught	114	–
Whale oil	176.000	1.544
Frozen meat	700.938	6.149
Frozen ventral meat	56.464	0.495
Frozen body and ventral blubber	157.174	1.379
Frozen other products	37.546	0.329
Total	1,128.122	9.896

INVESTIGATION PROGRAMME

The Far Seas Fisheries Research Laboratory has formulated a plan to continue its investigations on the same scale in 1978/79.

The proposed permit and supporting document are attached for the review of the Scientific Committee.

REFERENCES

International Whaling Commission. 1977. Report of the Scientific Committee. *Rep. int. Whal. Commn* 27: 36–60.

International Whaling Commission. 1978. Report of the Scientific Committee. *Rep. int. Whal. Commn* 28: 38–92.

Ohsumi, S. 1978. Provisional report on the Bryde's whales caught under special permit in the Southern Hemisphere. *Rep. int. Whal. Commn* 28: 281–7.

Appendix 1

RESEARCH PROGRAMME FOR BRYDE'S WHALES IN THE SOUTHERN HEMISPHERE 1978/79

Far Seas Fisheries Research Laboratory

OBJECTIVES

The Southern Hemisphere Bryde's whale has been classified as an Initial Management Stock at least in the Pacific and Indian Oceans, but the IWC has not yet set quotas for these stocks because of the lack of satisfactory estimates of population sizes. The Scientific Committee has repeated its recommendation that population studies should be carried out on these stocks (IWC, 1977, p. 41), and the collection of biological data, and marking and sightings cruises are also recommended as one of the IDCR programmes for 1977/78 (IWC, 1978, p. 40).

Our Laboratory planned to develop its own programme for population studies of the Southern Hemisphere Bryde's whale to comply with the recommendations of the Scientific Committee for the rational utilisation of whale stocks. Our programme consists of a quick estimation of population size, identification of stock units and the estimation of biological parameters needed for rational management.

Two special permits have been granted to take Bryde's whales for the above purpose from the Government. The first cruise was carried out in 1976/77 season, and a provisional report on the investigation was presented to the Scientific Committee (Ohsumi, 1978). The second cruise was conducted in the 1977/78 season, and the provisional report precedes this section.

This is the research programme for the third cruise for review by the members of the Scientific Committee.

INVESTIGATION ITEMS

This investigation will be carried out in almost the same manner as the past two cruises.

The main items are: (1) whale sighting, (2) whale marking, (3) sampling catch and mark recovery, (4) biological measurements and collection of materials from the whales caught and (5) whale products. Detailed items are shown in Appendix Table 1. Biological measurements and collection will be made on all the whales caught, except body weight measurements and the collection of skull and nasal bones.

SCALE OF INVESTIGATION

(a) Size of the whaling expedition to be used in the investigation

One floating factory, three scouting boats and seven catcher boats.

(b) Proposed research area

(i) South Pacific: 10° S–40° S, 160° E–140° W.
(ii) Indian Ocean: 0°–40° S, 30° E–116° E.

(c) Sighting distance to be covered

(i) South Pacific: 15,000 miles.
(ii) Indian Ocean: 18,000 miles.

(d) Whale marks available

(i) South Pacific: 150 Discovery marks.
(ii) Indian Ocean: 150 Discovery marks.

(e) Number of Bryde's whales to be caught under the special permit

(i) South Pacific: Nil.
(ii) Indian Ocean: No more than 120 whales.

(f) Size and sex ratio of catch

The experimental catch will be conducted without selection for sex and size of whales, as the aim of the research is to estimate the actual population structure of the Bryde's whale.

INVESTIGATION PERIOD

(a) South Pacific

Whale sighting and marking will be conducted by three scouting boats for 30 days in February–March 1979. If the expedition passes through this area after the end of commercial whaling, sighting will also be carried out by seven catcher boats.

(b) Indian Ocean

Three scouting boats will begin sighting and marking on 12 October 1978. Seven catcher boats will begin sighting from 18 October until 27 October when the factory ship *Nissinmaru No. 3* arrives in the research ground of the east Indian Ocean. The experimental catch and biological investigation will begin on 27 October and end by 15 November.

REMARKS ON THE INVESTIGATION

(a) Enough time will be spent making biological measurements and collecting samples from each whale caught.

(b) The whales taken shall not be wasted. Except for the retention for scientific analysis, the whales will be made available for processing. If any profit is made from the cruise it must be added to the reserve fund of the Whales Research Institute.

CO-OPERATIVE ORGANISATIONS

This research project will be carried out with the co-operation of the Nippon Kyodo Hogei Co. Ltd, the Whaling Section of the Fisheries Agency, the Whales Research Institute, Hokkaido University and our Laboratory. The co-operation of other organisations is welcomed.

Our Laboratory will formulate the research programmes, manuals and record sheets, prepare and supply the materials for the investigation and analyse the data and materials collected from the investigation. The Nippon Kyodo Hogei Company has offered a whaling expedition to carry out the investigation. National inspectors from the Whaling Section of the Fisheries Agency will lead the investigation. The Whales Research Institute will investigate taxonomy using the collected bones, and Hokkaido University will take over a portion of the food analysis.

PARTICIPATION IN THE RESEARCH BY FOREIGN SCIENTISTS

Participation of foreign scientists is welcomed and if they wish to participate it must be through inter-governmental contact. At most two scientists can be allowed on board the factory ship because of the limited space of the vessel. We hope members of the Scientific Committee will participate in the investigation. If not, any scientist wishing to participate should have considerable experience in population studies of fisheries resources.

Requests for the collection of biological materials are also welcomed, in so far as they are practicable.

POSSIBLE EFFECT ON CONSERVATION OF THE STOCK

Population studies cannot be satisfactory without obtaining the necessary data and biological materials from the experimental catch.

The Bryde's whale has not yet been exploited in the waters where the experimental catch is planned for the 1978/79 season. According to the results of sighting in the previous two seasons, it is estimated that a similarly sized population is expected to those in the western South Pacific and western Indian Oceans.

If we assume the MSY exploitation rate of the Bryde's whale is 4%, and the MSY population level is 60% of the initial population size, then the planned catch of no more than 120 could be safely taken for a long time from a population of an initial size of 5,000. It can safely be estimated that the population size will be more than 10,000 from the analogy with the Bryde's whale in other areas. Therefore, an experimental catch of no more than 120 Bryde's whales from the eastern Indian Ocean will have no serious effect on the stock or reduce it beyond the MSYL.

Appendix Table 1

Investigation items of Bryde's whales under the special permit in 1978/79

A. Whale sighting
1. Scouting boats
   (1) Date
   (2) Noon position
   (3) Weather and sea conditions at noon
      a. Visibility
      b. Wind direction
      c. Wind force
      d. Water temperature
      e. Water colour
   (4) Scouting distance
   (5) Numbers of schools and individuals of each whale species found
   (6) Cows and calves found
   (7) Direction and distance of school from head of ship
   (8) Remarks
2. Operating catcher boats
   (1) Serial number of school found
   (2) Date and time of the school found
   (3) Position of the school found
   (4) Species of the school
   (5) School structure and composition (estimated body length)
   (6) Record of calves
   (7) Direction and distance of the school from the head of ship
   (8) Swimming direction of the school
   (9) Weather and sea conditions at the finding of the school
   (10) Remarks

B. Catch
1. Time of start of operations
2. Time of end of operations
3. Times engaged in searching, confirming, chasing, handling and towing
4. Serial number of catch
5. Whale species caught
6. Relationship of the whale caught with the school found
7. Time of the death of the whale caught
8. Position of catch of the whale
9. Remarks

C. Whale marking
1. Data and time when school found
2. Position of school found
3. Weather and sea conditions
4. Swimming direction of the school
5. Character of the school
6. Whale species
7. School structure
8. Time of shooting of whale mark
9. Whale mark number
10. Result of shooting of mark
11. Part of body hit by mark
12. Estimated body length
13. Position of the whale at hit
14. Remarks

D. Biological investigation of the whale caught
1. Measurements
   (1) Serial number of the whale caught
   (2) Serial number of the whale processed
   (3) Whale species
   (4) Body length (0.1 m unit)
   (5) Sex
   (6) Stomach contents
      a. Species
      b. Quantity
      c. Size of food
   (7) Foetus
      a. Number
      b. Sex
      c. Body length (1 cm unit)
   (8) Data and time at processing
   (9) Thickness of blubber at a point (0.5 cm unit)
   (10) Weight of each testis (0.1 kg unit)
   (11) Mammary gland
      a. Thickness (1 mm unit)
      b. Colour
      c. Lactation
   (12) Breadth of each cornuate uterus (0.5 cm unit)
   (13) Relative number of open pits and white scars
   (14) External and internal parasites
   (15) Recovery of whale mark
   (16) Body parts weight
   (17) Body proportion
   (18) Remarks
2. Collection of biological materials
   (1) Earplug (both sides)
   (2) Ovaries
   (3) Stomach contents
   (4) Testis tissue
   (5) Mammary gland tissue
   (6) Cornuate uterus tissue
   (7) Vertebrae tissue
   (8) Liver tissue
   (9) Baleen plate
   (10) Foetus
   (11) External and internal parasites
   (12) A skull
   (13) Five nasal bones

E. Products
1. Kinds of products
2. Amounts of each kind of product produced each day

SC/30/Doc 34

Current Status of the Gray Whale

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ABSTRACT

The gray whale, *Eschrichtius robustus,* is confined to the North Pacific Ocean, where there are two geographically isolated stocks: (1) the Korean stock, which winters off South Korea and summers in the Okhotsk Sea, and (2) the California stock, which winters along Baja California and summers in the Bering and Chukchi seas.

The Korean stock was reduced by commercial exploitation to extremely low numbers by the early 1930s. A few individuals of this stock were killed by South Korean whalers until at least 1966. Very few are known to have survived.

The California stock originally numbered about 15,000. Heavy exploitation between 1850 and 1875 reduced it to 4,000 to 5,000. Legal protection from commercial whaling was carried out in 1947, and the stock increased until about 1960. Since then it has remained nearly stable at about 11,000, undergoing an aboriginal catch of about 165 per year in the Arctic. Operation of whale-watching cruise boats is a rapidly expanding business in southern California and Mexico. The cruise boats, along with other vessel traffic, industrial development, and petroleum exploration, may be exerting a detrimental effect on this whale population.

DISTRIBUTION AND SEPARATION OF STOCKS

The former occurrence of the gray whale, *Eschrichtius robustus,* in the North Atlantic is attested to by subfossil and early historical records (Fraser, 1970), but it has been extinct there for several centuries. The species now survives only in the North Pacific, where two geographically isolated stocks have been distinguished: the eastern Pacific or "California" stock and the western Pacific or "Korean" stock (Rice and Wolman, 1971).

The California stock spends the summer mostly in the northern Bering Sea, with a few individuals scattered along the west coast of North America as far south as northern California. This stock migrates down the North American coast to winter along the west coast of Mexico. The main calving grounds are: (1) Laguna Ojo de Liebre and adjacent Laguna Guerrero Negro; (2) Laguna San Ignacio; (3) Bahia Magdalena and confluent waterways, all in Baja California; (4) Yavaros, Sonora; and (5) Bahia Reforma, Sinaloa (Gilmore, 1960). Contrary to many published statements, there is no evidence that San Diego Bay, California, was ever a calving area (Henderson, 1972).

The Korean stock spends the summer in the northern Sea of Okhotsk and migrates down the Asian coast to winter calving grounds off the south coast of Korea. Until about the turn of the century another migration route led down the eastern side of Japan to calving grounds in the Seto Inland Sea (Omura, 1974).

Nishiwaki and Kasuya (1970) and Bowen (1974) hypothesised that three recent records of gray whales in Japan involved vagrants from the California stock, rather than survivors of the Korean stock. Because gray whales mate during their autumn migration, such rare vagrants would make possible interbreeding between the California and Korean stocks. However, this possibility would be greatly reduced if, as seems likely, most vagrants are immature animals as was the 1968 individual.

REPRODUCTION AND MORTALITY

The following data are from samples of gray whales collected mostly from 1964 to 1969 (Rice and Wolman, 1971).

Sexual maturity is attained at a mean age of 8 years (range: 5 to 11 years). The mean annual ovulation rate is 0.52, and the mean pregnancy rate is 0.46 (percentages of animals determined from the total number of mature females).

Annual mortality estimates calculated from the age composition, as determined by ear-plug readings, were 0.095 for females and 0.081 for males. A similar estimate for sexually mature females, based on ovarian corpora counts was 0.082. These estimates are probably higher than the true rate because the population was increasing during the preceding years. The sex ratio is essentially equal.

FORMER AND CURRENT POPULATION SIZES

Korean Stock

The Korean stock probably numbered between 1,000 and 1,500 in the year 1910 (Rice and Wolman, 1971). Although Mizue (1951) and Bowen (1974) concluded that the stock was probably extinct, recent catches in Korea have been reported (see *Exploitation*). Besides these catches, several other gray whales have been recorded in the western Pacific in recent years: One at Otomae (Shiashkotan) in the northern Kuril Islands in 1942 (Mizue, 1951) and two on the southeast coast of Honshu in 1959 and 1968 (Nishiwaki and Kasuya, 1970). In Korean waters, a female with a calf was seen in May 1968 (Brownell and Chun, 1977). In the Sea of Okhotsk, four were seen in June 1967 and one in August 1974 (Berzin, 1974; Berzin and Kuz'min, 1975; Kuz'min and Berzin, 1975).

California Stock

Scammon (1874) estimated that the California gray whale population was probably not over 30,000 from 1853 to 1856, and that by 1874 the number did not exceed 8,000 or 10,000. After a careful analysis of the historical data, however, Henderson (1972) concluded that the population did not exceed 15,000 prior to the initiation of exploitation in 1846.

In 1885/86, Townsend (1887) estimated that only 160 gray whales migrated south past San Simeon, California. Andrews (1916) wrote that "for over 20 years [preceding 1910] the species had been lost to science and naturalists believed it to be extinct". Howell and Huey (1930) said that it was "doubtful whether more than a few dozen individuals survived". However, K. W. Kenyon (pers. comm.) says that he commonly observed gray whales migrating past La Jolla, California, during the 1930s, and calculations by Ohsumi (1976) suggested that the stock attained its lowest size of 4,400 in 1875.

Systematic shore counts of the southward migration were initiated at Point Loma in San Diego, California, in 1952/53 and continued intermittently until 1977/78 (Gilmore, 1960; Rice, 1961). These counts indicated a steadily increasing population until 1959/60 (Table 1), but by the mid-1960s it was apparent that, due to geographical features, the majority of whales passed too far offshore to be seen from land (Rice, 1965) and that increasing boat traffic was causing even greater numbers to migrate far offshore. The high counts during 1975/76 and 1976/77 may be attributed to improved visibility during a prolonged drought period. During 1977/78, a recurring series of storms during the count is surmised to have driven the animals closer to shore than usual, giving rise to unprecedentedly high counts.

Starting in 1967/68, a shore count has been made every winter at Yankee Point or Granite Canyon near Monterey, California, where 95% of the whales pass within 2 kilometres of shore, and boat traffic is at a minimum. These counts (Table 1), which are more consistent than the Point Loma counts, indicate an essentially stable or slightly increasing population. As at Point Loma, the high counts in 1975/76 and 1976/77 may be attributed to improved sighting conditions during a prolonged drought. In 1977/78 the Granite Canyon count was back to "normal", coincidental with the return of normal weather conditions. When the counts are extrapolated to allow for whales missed during periods of poor visibility and for whales passing at night (Rice and Wolman, 1971), they indicate a total population of about 11,000 (±2,000). A detailed statistical analysis of the last 11 years' data is in preparation.

Table 1

Counts of southward-migrating gray whales, 1952/53 to 1977/78.[a]

Season	Number of whales counted: Point Loma[b]	Yankee Point and Granite Canyon[c]
1952/53	982	–
1954/55	1,646	–
1956/57	1,839	–
1959/60	2,344	–
1967/68	1,324	3,120
1968/69	1,154	3,081
1969/70	–	3,064
1970/71	–	3,034
1971/72	–	2,588
1972/73	–	3,304
1973/74	–	3,492
1974/75	–	3,348
1975/76	2,822	3,797
1976/77	3,648	4,058
1977/78	5,232	3,127

[a] Data for 1952/53 to 1956/57 from Gilmore (1960).
[b] Total counts.
[c] "Comparison period" only – 18 Dec. to 4 Feb., except for 25 Dec. and 1 Jan. Count made at Yankee point until 1973/74, and at Granite Canyon thereafter.

Between 1952 and 1973, a number of aerial surveys of the gray whale wintering grounds were conducted by several observers (Hubbs and Hubbs, 1967; Gard, 1974). Hubbs and Hubbs censused lagoons from San Diego southward in Baja California and around Cabo San Lucas. Gard censused Guerrero Negro, Ojo de Liebre, and San Ignacio Lagoons in addition to Magdalena Bay, all on the west coast of Baja California, Mexico. The aerial counts (Table 2) agree with the shore counts in that they indicate that the population was increasing during the 1950s and has remained stable since about 1960.

In the summer of 1968, Zimushko (1970) conducted an aerial survey of gray whales in the coastal waters off the Chukotski Peninsula. On the basis of 124 whales actually sighted, he calculated the total population in the area at about 5,500. In the summer of 1973, Berzin (1974) conducted another aerial survey. On the basis of 290 whales sighted, he calculated the total population at about 7,700.

During 1976 and 1977, Hall (1977) conducted aerial surveys of the northward spring migration passing into the Bering Sea as well as shore counts at Unimak Pass, Alaska, in 1977. On the basis of his studies, he estimated the total population entering the Bering Sea at about 9,000.

During November and December 1977, Rugh and Braham (1979) censused southbound gray whales at Unimak Pass, where they leave the Bering Sea, for a total of 82.5 hours. Extrapolating from these counts, they estimated the population at about 15,000. If we assume that not all gray whales migrate the entire distance to Mexico but that some percentage lay over along the west coast of Canada and the United States, the actual population size is probably between the above estimate and the Rice/Wolman estimate of 11,000 ± 2,000.

Total population estimates depend on the number of animals presumed to migrate at night; further studies are needed on this important part of the migration pattern.

EXPLOITATION

Korean Stock

In waters around Korea, 1,474 whales were taken between 1910 and 1933. Between 1948 and 1966, at least 67 whales were taken in South Korean waters (Brownell and Chun, 1977). Chun examined six gray whales landed at Ulsan, Korea, in 1948. Later, gray whales landed and reported to Chun were the following: 1948, 9; 1949, 4; 1951, 7; 1952, 1; 1953, 7; 1958, 7; 1959, 7; 1960, 8; 1961, 3; 1963, 2; 1964, 3; 1965, 4; 1966, 5. The absence of gray whale catch reports between 1967 and 1975 does not necessarily indicate that no gray whales were taken.

California Stock

The Eskimos living on the shores of the northern Bering Sea and the Chukchi Sea have hunted whales since time immemorial. On the Alaskan side the catch is mostly bowhead whales, *Balaena mysticetus*, and very few gray whales are taken. However, on the Siberian side the catch is almost

Table 2

Aerial Censuses of Gray Whales in Baja California Lagoons, 1952–1973.[a]

			Scammon Lagoon			San Ignacio Lagoon			Guerrero Negro Lagoon	Magdalena Bay Area
Year	Date	Age group	Outside	Inside	Total	Outside	Inside	Total	Outside plus inside	Inside
1952[1]	16–20 Feb.	Adults	246	158	204	152	17	169	35	71
		Calves	1	35	36	2	2	4	1	35
		All	247	193	440	154	19	173	36	106
1953[2]	25–27 Feb.	Adults	86	129	215	21	41	62	77	151
		Calves	5	39	44	–	–	8	10	42
		All	91	168	259	–	–	70	87	193
1954[1]	14–21 Feb.	Adults	189	194	383	69	53	122	142	90
		Calves	14	92	106	12	8	20	22	0
		All	203	286	489	81	61	142	164	90
1955[3]	26 Feb.–4 Mar.	Adults	–	121	–	20	34	54	–	214
		Calves	–	69	–	4	28	32	–	37
		All	–	190	–	24	62	86	–	251
1956[3]	14–17 Feb.	Adults	67	214	281	26	37	63	38	363
		Calves	1	65	66	3	10	13	16	30
		All	68	279	347	29	47	76	54	393
1957[2]	27 Feb.–8 Mar.	Adults	215	56	271	55	26	81	47	74
		Calves	27	14	41	2	14	16	11	23
		All	242	70	312	57	40	97	58	97
1959[1]	20–26 Feb.	Adults	377	432	809	–	–	69	35	21
		Calves	16	180	196	–	–	22	10	5
		All	393	612	1,005	–	–	91	45	26
1960[1]	18–21 Feb.	Adults	124	493	617	–	–	219	17	24
		Calves	2	141	143	–	–	42	9	3
		All	126	634	760	–	–	261	26	27
1961[1]	25–27 Feb.	Adults	140	188	328	–	–	79	7	26
		Calves	22	77	99	–	–	29	5	1
		All	162	265	427	–	–	108	12	27
1962[4]	18–21 Feb.	Adults	104	451	555	–	–	–	31	0
		Calves	2	124	126	–	–	–	2	0
		All	106	575	681	–	–	140	33	0
1964[5]	20–24 Feb.	Adults	252	498	750	–	–	242	0	0
		Calves	0	173	173	–	–	16	0	0
		All	252	671	923	–	–	258	0	0
1970[6]	31 Jan.–1 Feb.	Adults	–	192	–	23	89	112	0	–
		Calves	–	60	–	4	42	46	0	–
		All	–	252	–	27	131	158	0	–
1970[7]	4 Mar.	Adults	39	133	172	31	89	120	0	–
		Calves	7	42	49	5	31	36	0	–
		All	46	175	221	36	120	156	0	–
1973[8]	27–28 Feb.–4 Mar.	Adults	42	271	313	29	40	69	69	25
		Calves	0	204	204	8	17	25	35	8
		All	42	475	517	37	57	94	104	33

[a] Table from Gard (1974).
[1] Censused by C. L. and Laura C. Hubbs and G. C. Ewing.
[2] Censused by R. M. Gilmore and G. C. Ewing.
[3] San Ignacio lagoon censused by R. M. Gilmore and G. C. Ewing; Scammon Lagoon censused by F. B. Phleger, R. Langford and G. C. Ewing on 4 February.
[4] Censused by C. L. and Laura C. Hubbs, G. C. Ewing, L. C. Kuebler, G. E. Lindsay, E. S. Gardner and Eva Ewing.
[5] Censused by C. L. and Laura C. Hubbs, G. C. Ewing, T. J. Walker, R. W. Elsner and Jean Filloux.
[6] Censused by R. and Sylvia S. Gard, M. Rueda, J. F. Castillo and W. Swan (pilot).
[7] Censused by R. and Sylvia S. Gard, J. F. Castillo and F. Morales (pilot).
[8] Censused by R. and Sylvia S. Gard, M. Rueda, C. Sweeney and F. Morales (pilot).

entirely gray whales. Catch statistics are available only for recent years, during which the catch has averaged about 165 gray whales per year (Table 3).

Several Indian tribes on Vancouver Island and in the State of Washington traditionally hunted gray whales, but have not done so since 1928.

From 1846 until about 1900, American whalers exploited gray whales, mostly on their wintering grounds, but also took a few in northern waters during the summer. On the basis of available historical records, Henderson (1972) estimated that the total catch from 1846 to 1874 was about 8,100; this estimate was intentionally on the high side. During the peak of this fishery from 1855 to 1865, the annual catch averaged 474 whales (Table 4). Catches during the three winter seasons from 1883/84 to 1885/86 were 58, 68, and 41, respectively (Townsend, 1887).

Modern style whaling began on the west coast of North America in 1905. A few gray whales were taken in the winter off Baja California and California, mostly between

Table 3

Aboriginal catches of gray whales in Bering and Chukchi Seas, 1965 to 1977 (blank spaces indicate no date available).

Year	Number of whales caught USSR[a]	USA	Total
1965	175	–	–
1966	194	–	–
1967	125	–	–
1968	135	–	–
1969	139	–	–
1970	146	5	151
1971	150	3	153
1972	181	1	183
1973	173	1	179
1974	181	1	182
1975	171	7	178
1976	165	2	167
1977	186	1	187

[a] Data from All-Union Research Institute of Marine Fisheries and Oceanography, Moscow.

1925 and 1929. Factory ships took an average of 52 gray whales per year in the Bering Sea from 1933 to 1946 (Table 5), after which commercial whaling for gray whales was banned by the International Convention for the Regulation of Whaling.

Between 1959 and 1969, 316 gray whales were killed under Special Scientific Permits off California (Table 6).

Table 4

Estimated catches of gray whales by old-style whaling, 1846 to 1874.[a]

Period	Number of whales caught California and Mexico	Bering and Chukchi Seas	Total
1846–1854	716[b]	55	771
1855–1865	4,938	275	5,213
1866–1874	2,007	110	2,117

[a] Data summarised from Henderson (1972).
[b] Midpoint: Henderson estimated 661–771.

In his population assessment, Ohsumi (1976) calculated the sustainable yield of the current population of 11,000 to be 194. He also estimated the maximum sustainable yield (MSY) population size to be 8,500, which is 57% of an estimated initial level of 14,900 and the MSY to be 250. According to M. F. Ivashin (Brownell, 1977), a quota is set each year at approximately 200 whales by the USSR.

POTENTIAL PROBLEMS FOR EASTERN PACIFIC STOCK

The greatest threat to the California gray whale population is increasing industrial development and vessel traffic in the calving lagoons. Considerable harassment is caused by

Table 5

Catches of gray whales from the California stock by modern style whaling, 1905–1947.[a]

Year	Number of whales caught Baja California	California	Washington	Alaska[b]	Bering and Chukchi Seas[c]	Total
1913	–	–	–	1	–	1
1914	19	–	–	–	–	19
1920	–	2	–	–	–	2
1921	–	1	–	–	–	1
1922	–	5	–	–	–	5
1924	–	–	1	–	–	1
1925	100	–	–	–	33	133
1926	41	1	–	–	–	42
1927	29	3	–	–	–	32
1928	9	1	–	2	–	12
1929	2	–	–	–	–	2
1933	–	–	–	2	2	2
1934	–	–	–	–	54	54
1935	–	–	–	–	34	34
1936	–	–	–	–	102	102
1937	–	–	–	–	14	14
1938	–	–	–	–	54	54
1939	–	–	–	–	29	29
1940	–	–	–	–	105	105
1941	–	–	–	–	57	57
1942	–	–	–	–	101	101
1943	–	–	–	–	99	99
1945	–	–	–	–	30	30
1946	–	–	–	–	–	–
1947	–	–	–	–	1	1

[a] Data summarised from Rice and Wolman (1971), except that the figures for 1943, 1946 and 1947 have been changed to agree with those in Kleinenberg and Makarova (1955).
[b] Gulf of Alaska (shore stations).
[c] Pelagic whaling.

Table 6

Catch of gray whales off California under Special Scientific Permits, 1958/59 to 1968/69.

Season	Number of whales caught
1958/59	2
1961/62	4
1963/64	20
1965/66	26
1966/67	125
1967/68	66
1968/69	73

commercial cruise boats which take people into the calving lagoons to see the whales. The first excursion boat entered Laguna Ojo de Liebre in 1970, followed by 8 in 1971, 16 in 1972, 30 in 1973, 22 or 23 per year from 1974 to 1977, and 35 in 1977/78 (Eugene Nitta, pers. comm.).

In Laguna Ojo de Liebre salt barges make daily trips and visits by yachts, fishing boats, and small trailer-transported boats are increasing. Since 1974, tour boats have been prohibited from entering the lagoon but outboard boats are expected to increase due to the new Baja California highway. There are no boat restrictions at any of the other calving lagoons. Most of the large excursion boats now are visiting San Ignacio Lagoon.

Historically, Laguna Guerrero Negro was a gray whale calving area. Numbers of gray whales there increased in the 1950s but decreased to zero in 1964. After salt shipping terminated there in 1967, the whales returned to Guerrero Negro; Gard (1974) counted 104 animals in the lagoon and just outside the mouth in 1973. He also attributed decreases in whale counts in Laguna Ojo de Liebre to barging of salt which began there in 1967, coupled with increasing excursion and pleasure boating. Similarly, a decline in numbers in the Magdalena Bay complex during the 1960s was attributed to increasing boat traffic. Gard concluded that the use of individual lagoons and bays varied immensely with human disturbance.

Oil exploration is proceeding near some of the calving lagoons and may have an adverse effect on the habitat (Steven Swartz, pers. comm.).

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SC/30/Doc 35

The 1977 Catch of Bowhead Whales *(Balaena mysticetus)* by Alaskan Eskimos

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ABSTRACT

Biologists of the National Marine Fisheries Service, a part of the National Oceanic and Atmospheric Administration in the United States Department of Commerce, annually observe the spring and autumn subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos. The objectives of the study are to collect: (1) data on hunting effort, the number of whales harvested, size and sex, the known number killed but not landed, and the number struck but lost; (2) biological samples from harvested whales for a better understanding of age, growth, reproduction, recruitment, cytogenetics, food studies, pathology and mortality; and (3) counts and behavior of whales observed by Eskimos while engaged in whaling activities.

During the spring whaling season of 1977, 26 bowheads were harvested, 3 were killed but lost, and 79 were struck but lost. During the autumn season, 3 whales were landed and none were reported struck but lost by the whalers. Morphometric information and biological specimens were obtained from most captured whales.

INTRODUCTION

Eskimos of the United States of America, residing in coastal villages of Saint Lawrence Island and along the west and north shores of Alaska from Wales to Kaktovik, have traditionally hunted the bowhead whale (*Balaena mysticetus*). The flesh of this animal is prized for food, and the baleen is valued as arts and crafts material. Bowhead whaling has been the economic and social basis of the maritime Eskimo culture, and the subsistence hunt for these whales has been conducted annually since before 1800 BC (Oswalt, 1967).

Bowheads were severely depleted by commercial whaling in arctic waters of the Pacific Ocean in the second half of the 1800s, and by the early 1900s their numbers had been reduced to the extent that whaling was no longer profitable. International concern over the continued survival of the species resulted in complete protection of the bowhead from further commercial whaling since 1931. Aborigines, however, have been allowed to continue taking bowheads for subsistence.

Since commercial whaling ceased in 1916 (Bower and Aller, 1917), the catch of bowhead whales by Eskimos has averaged about 10 whales landed annually through 1969. Beginning in 1970, however, the catch increased significantly and averaged 29 annually from 1970 through 1976 (Marquette[1]). A revised tabulation of the historical catch from 1853 through 1977 is presented in Appendix 1.

Since Eskimos normally do not keep records of their whaling activities, data on annual catches presented in the historical tabulation have been collected by the author from published sources, unpublished notes and manuscripts, personal records compiled by interested individuals, and by personal communication with individuals possessing such information. Although the tabulation is as complete as present knowledge permits, new data are continually being found which necessitates periodic revision of the table.

Because of its isolation in an Arctic environment, the bowhead has until recent years received little biological research effort. The only significant source of biological specimens for scientific study has been the animals taken by Eskimo hunters for subsistence. Strandings resulting from normal mortality are rarely seen, and biological data that may be obtained from this source are few in quantity and of poor quality.

The National Marine Fisheries Service (NMFS), then the Bureau of Commercial Fisheries, first began studies on the bowhead whale in 1961 and 1962 (Rice, 1974). This research was resumed in 1973, when the NMFS, through a contract with the University of Southern California, supported Dr Floyd Durham's studies of the bowhead whale which he began in 1961. Since 1974, the Marine Mammal Division (MMD) of the NMFS has stationed scientists at Point Hope and Barrow, Alaska, to monitor the hunt and gather catch statistics and biological data.

RESEARCH OBJECTIVES AND METHODS

The objectives of current NMFS research are to obtain the information necessary for determining the status of the bowhead whale, the impact of the Eskimo fishery on population size, and the effect that oil exploration and exploitation might have upon this species.

The goals of the harvest monitoring program are to collect data and biological samples, which will provide information on the natural history of the species, and to collect statistics regarding the nature and extent of catch and effort for the fishery. Biologists were stationed at the most important whaling villages (Point Hope and Barrow) during the spring whaling season. Biologists monitored the spring whaling at Point Hope and Barrow from about 20 April to 7 June, and the autumn whaling camps as often as possible and gathered information on the number of bowheads sighted, killed and recovered, and struck but subsequently lost. When a whale was taken, the biologists attempted to obtain measurements, collect specimen material, and take photographs. In addition, they made observations of whaling methods and equipment employed as a first step toward determining if it is possible to reduce the number of whales struck but not recovered.

SPRING WHALING

In 1977, residents of the two St Lawrence Island villages (Gambell and Savoonga), Wales, Kivalina, Point Hope,

[1] Marquette, Willman M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaska Eskimos, with a review of the fishery, 1973–76, and a biological summary of the species. Nat. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, Wash. Proc. Rep. 80p. Presented as Paper SC/39/Doc 30 to the IWC Scientific Committee, June, 1977.

Wainwright, and Barrow engaged in spring whaling. Ice conditions east of Barrow do not permit spring whaling by residents of Nuiqsut or Kaktovik; however, these people participate in the autumn hunt as do the Barrow whalers. NMFS biologists collected information at Point Hope, Barrow, and St Lawrence Island and indirectly learned of whaling activities at other villages from various sources. The locations of Alaska whaling villages are shown in Fig. 1.

Gambell

The whaling season began at Gambell on 1 April and ended 10 May, with 19 crews actively engaged in whaling. Two whales were taken at Gambell, a large male on 22 April and a small male the last week of April (Table 1). No whales were reported killed and lost, but six were known to have been struck and lost by crews from Gambell.

During the third week of May, a small gray whale (*Eschrichtius robustus*) was taken by hunters from Gambell. It was reported that, although the muktuk of the gray is thinner and less desirable than that of the bowhead, the meat from this whale is highly prized for food.

Savoonga

Eight crews from Savoonga participated in whaling from 10 April to 7 May but took no whales. Two whales, however, were reported struck and lost, one because the bomb failed to explode.

Crews from Savoonga leave the village and travel about 45 miles overland to the vicinity of Southwest Cape for the duration of the spring whaling season. These crews reported that spring whaling was poor because of prevailing winds from the south which created a heavy ice-pack in the area of Southwest Cape, resulting in no distinct lead most of the season. Only about 60 bowheads were sighted by Savoonga hunters during the entire spring season.

On St Lawrence Island the bowhead whaling season ends when conditions become favorable for hunting walrus (*Odobenus rosmarus*), and although whaling gear is carried in the boats, few bowheads are taken after the hunting of walrus has begun. The people of Gambell and Savoonga equally divide between the two villages all whales taken.

Wales

Two crews were active during the spring of 1977 at the village of Wales. No whales were taken, and none was struck and lost. Spring whaling for bowheads is conducted here from about 15 April until the end of May, depending upon environmental conditions.

Kivalina

Three crews actively whaled at Kivalina during the spring of 1977. One whale was taken on 9 May (Table 1), and one was killed but lost to shifting ice about the middle of May. Two bowheads were reported struck and lost during the season, which ended the latter part of May.

Point Hope

The whaling season began on 19 April when the first crews went out on the ice, and ended on 28 May when the ice

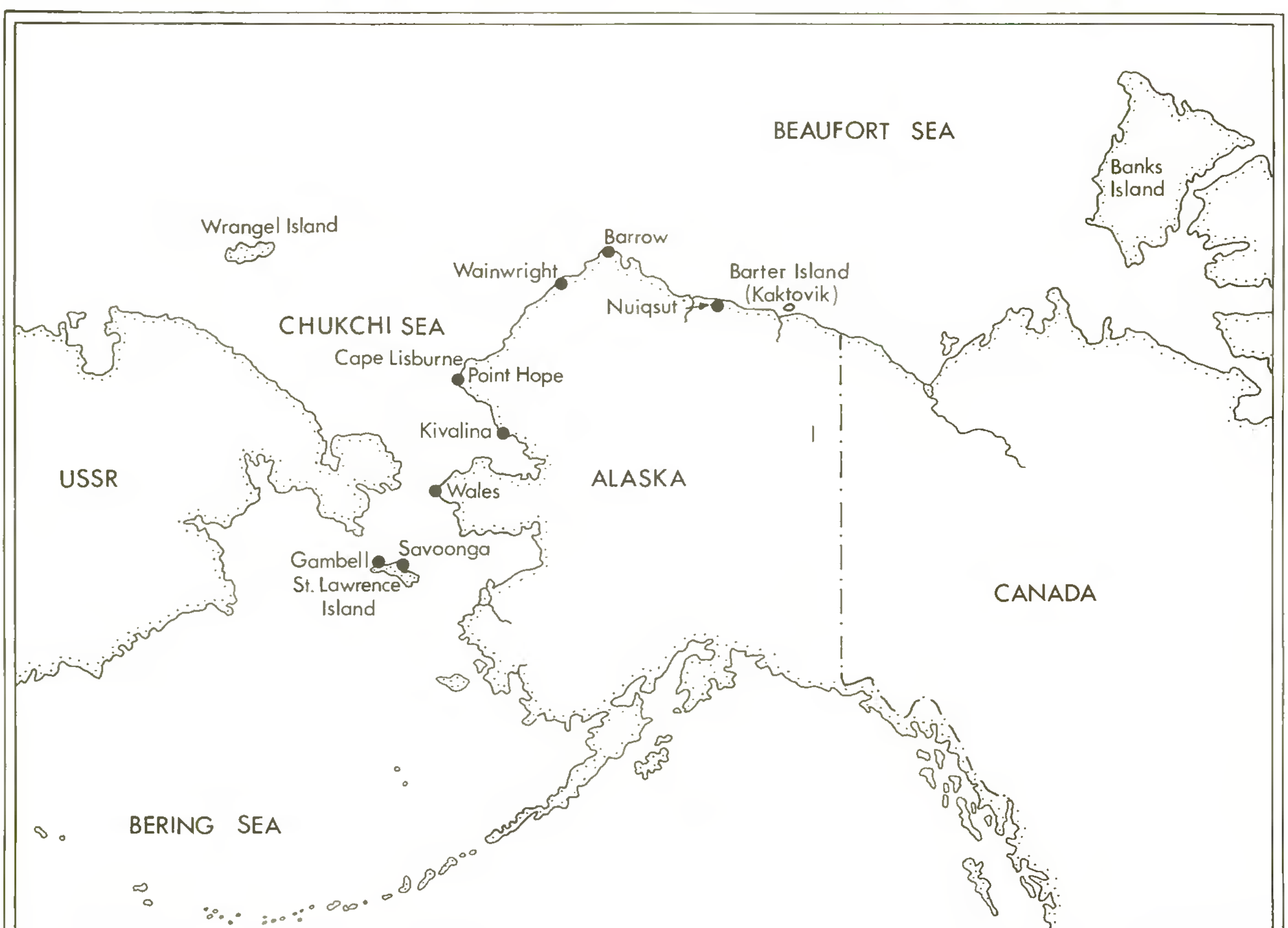

Fig. 1. Map of bowhead whale study area.

Table 1

Biological features of bowhead whales taken during spring whaling season of 1977.

Area and date	Length (centimetres)	Sex	Remarks
St Lawrence Island			
Gambell			
22 April	1,097*	M	–
Last week April	792*	M	–
Kivalina			
9 May	1,036*	–	–
Point Hope			
30 April	887	F	–
24 May	1,475	F	–
Wainwright			
29 May ca.	1,890*	–	–
29 May ca.	853*	–	–
Barrow			
2 May	1,100	M	–
3 May	905	M	–
5 May	900*	M	–
5 May	905	F	–
5 May	1,060	M	–
5 May	950	F	–
7 May	930	M	–
8 May	762*	F	Stinker
10 May	840	M	–
10 May	880	F	–
10 May	1,080	F	–
10 May	1,067*	–	–
11 May	840	F	–
11 May	800	M	–
11 May	1,075	M	–
12 May	800	F	–
12 May	800*	–	–
15 May	1,067*	–	Stinker
28 May	972	F	–

* Length estimated by Eskimos.

became unsafe for travel. NMFS biologists were stationed in the village from 26 April until 28 May to monitor the harvest.

Fifteen whaling crews at Point Hope took two whales in 1977, and biological information was collected by NMFS observers from both whales (Table 1). One young whale 887 cm (29 feet, 1 inch) in length and one adult whale 1,475 cm (48 feet, 4 inches) in length were taken. Although no whales were reported killed and lost at Point Hope, 11 were struck and lost during the spring season.

During the period 18 April to 29 May, personnel were stationed at a whale counting station on the ice. They maintained a 24-hour watch for migrating bowheads, weather and ice conditions permitting, counting 235 whales.

Wainwright

Eight crews were reported to be actively whaling at the village of Wainwright during the spring of 1977. Eskimo whalers estimated the length of two whales captured on 29 May to be 1,890 cm (62 feet) and 853 cm (28 feet) (Table 1). Two bowheads were reported to have been struck and lost during the spring season. Whaling occurred at Wainwright from about the last week of April to the first week of June.

Barrow

The whaling season began on 18 April and ended on 31 May at Barrow when the ice became unsafe for travel. Two observers were stationed at the Naval Arctic Research Laboratory (NARL), Barrow, from 19 April to 31 May.

The number of whaling crews actively engaged in whaling varied almost daily, but approximately 35 crews, two of them from Nuiqsut,[2] were whaling at Barrow some time during the season. Nineteen whales were taken at Barrow and two additional animals were killed and lost, the highest number recorded since NMFS began monitoring the harvest. One of the harvested whales was taken by a crew from Nuiqsut.[2] Data were obtained on each of the landed whales (Table 1). Length of the whales ranged from 762 to 1,100 cm (25 to 36 feet). A small amount of food items was found in one whale, after the stomach had been punctured during butchering, and collected for identification (Table 2). Examination of the total volume of approximately 20 ml resulted in a count of 411 *Calanus glacialis* (Copepod) and 1,894 *Metridia longa* (Copepod), which were most numerous in terms of individuals counted.

Whales recovered several days after death are called stinkers. The muktuk (skin with an equal thickness of blubber), flukes, flippers, and baleen of a stinker can be salvaged but the remainder is discarded. Two of the whales recovered at Barrow were stinkers. A whale usually belongs to the first crew that strikes it, and ownership is established by identifying marks on the harpoon and bomb particles found embedded in the animal. If a crew other than the first one that struck the whale recovers the carcass, it is shared by both crews. Otherwise, if ownership cannot be established, a stinker belongs to the crew that recovered it.

Whaling Methods

The method presently used by Alaskan Eskimos to take whales has evolved from ancestral methods and the adoption of commercial whaling gear and methods introduced by Yankee whalers in the last century. Van Stone (1958) described the era of early commercial bowhead whaling in Alaskan waters. Bockstoce (1977) described the final years of commercial whaling during the period when steam vessels were employed to extend the search for bowhead whales farther and farther into the arctic. The most recent description of the development of current Eskimo whaling methods is that of Durham (1973). Van Stone (1962) describes the traditional method of marking and cutting shares from a whale carcass at Point Hope, which, with some modification, is still in use. A similar though much simplified method of marking and cutting shares from whales is presently used at Barrow.

Whaling Effort

More crews were engaged in spring whaling in 1977 (90) than in 1976 (63) (Table 3). Since the number of crews hunting at the lead varies daily, we maintained a record of their activities throughout the season in an attempt to evaluate hunting effort (Tables 4 and 5). In 1977, Point Hope crews were at the lead 25 days (78% of the time) from 26 April to 27 May. At Barrow, crews were at the lead 35 days (81% of the time) from 18 April to 30 May. Weather conditions at Barrow during this period are presented in Table 6.

[2] Personal communication, Jacob Adams, Barrow, Alaska.

Table 2

Stomach contents of a bowhead whale taken at Barrow, Alaska, during spring whaling season of 1977.[1]

Specimen number	Date	Species	Number of individuals	Comments
77-B-5	5 May	*Thysanoessa raschii* (Euphausiid)	1	1.6 cm long
		Parathemisto abyssorum (Amphipod)	1	0.9 cm long
		Ostracods	3	–
		Limacina helicina (Pteropod)	6	–
		Calanus glacialis (Copepod)	411	–
		Euchaeta glacialis (Copepod)	40	–
		Metridia longa (Copepod)	1,894	–
		Pseudocalanus sp. (Copepod)	2	–
		Fish scale	1	–

[1] Identified by L. Lowry, Alaska Department of Fish and Game, Fairbanks, Alaska.

Other Mammals

In addition to bowhead whales, the following species of mammals were observed or reported in 1977 at Point Hope and Barrow during the spring whaling season.

Belukha	*Delphinapterus leucas*
Bearded seal	*Erignathus barbatus*
Largha seal	*Phoca largha*
Ringed seal	*Phoca hispida*
Polar bear	*Ursus maritimus*
Walrus	*Odobenus rosmarus*

The whalers do not actively pursue belukha during the bowhead whaling season because they frequently sink quickly and require considerable effort to recover, although they are prized for food. A belukha harvest at this time is incidental to the bowhead whale hunt. Rifles are normally used to kill the animals. It is difficult to obtain data on the belukha because these animals are butchered immediately after they are killed, a process that requires but a few minutes to complete after the animal is hauled onto the ice. Belukha harvested by whaling crews at Point Hope and Barrow during the spring season are noted in Table 7.

Table 3

Number of Alaskan Eskimo crews participating in spring whaling in recent years.

Location	1973	1974	1975	1976	1977
Barrow	28	21	30	36	35
Point Hope	11	10	13	14	15
Wainwright	6	2	4	8	8
St Lawrence Is.	–	8	23	–	27
Kivalina	–	5	5	3	3
Wales	–	–	–	2	2
	45	46	75	63	90

Other species killed at Point Hope and Barrow are listed in Table 8. Bearded and ringed seals are taken during periods when bowhead whales are not migrating past the hunters, and polar bears that appear in the vicinity of the hunting camps are pursued and killed.

Table 4

Whaling effort at Point Hope, Alaska, spring 1977.

Date	Number of crews at lead	Remarks
April		
26	0	Lead closed
27	8	Lead discontinuous
28	15	Lead discontinuous
29	15	Lead open
30	15	Lead open
May		
1	14	Lead open
2	14	Lead open, wide
3	12	Lead open
4	12	Lead closed at 1030 hours, open at 1900 hours
5	15	Lead discontinuous
6	12	Lead closed
7	12	Small openings only
8	12	Lead closed except for scattered small openings
9	0	Lead closed
10	6	Lead closed
11	6	Lead closed
12	9	Lead closed except for scattered small openings
13	9	Lead closed, ice movements
14	0	Lead closed
15	0	Lead closed
16	0	Lead closed
17	7	Lead open
18	0	Lead open, windy and sea rough
19	0	Lead open, windy and sea rough
20	13	Lead open, very wide, sea rough
21	10	Lead open, several miles wide, windy and rough sea
22	12	Lead open, several miles wide
23	11	Lead open, several miles wide
24	9	Lead open, several miles wide, ice edge breaking
25	14	Lead open, several miles wide, ice unstable
26	14	Lead open, several miles wide, ice unstable
27	14	Lead open, several miles wide, ice unstable

AUTUMN WHALING

Barrow

During the autumn season, a minimum of four or five crews was known to actively engage in whaling from about 16 September to 18 October. A small female 854 cm (28 feet) in length was taken on 14 October (Table 9). Whaling ceased soon thereafter because of the formation of new ice which prevented travel by boat. Weather conditions at Barrow during this period are presented in Table 10.

Nuiqsut

Four crews were actively engaged in whaling at Nuiqsut, but no whales were taken, and information was not received on animals that may have been struck and lost.

Table 5

Whaling effort at Barrow, Alaska, spring 1977.

Date	Number of crews at lead	Remarks
April		
18	1	Small opening
19	1	Small opening
20	3	Lead open
21	4	Lead open
22	0	Lead closed
23	8	Lead open
24	0	Lead closed
25	0	Lead closed
26	0	Lead closed
27	3	A few small openings
28	13	Lead open
29	15	Lead opening narrow and discontinuous
30	19	Lead open
May		
1	19	Lead open
2	19	Lead open but changing
3	12	Lead open but discontinuous
4	19	Lead open
5	20	Lead open
6	25	Lead open
7	30	Lead open
8	30	Lead open and wide
9	28	Lead open and wide
10	28	Lead open, wide, rough sea
11	20	Lead open and wide
12	18	Lead open and wide
13	20	Lead open and wide
14	20	Lead open and wide
15	20	Lead open and wide
16	2	Lead open, wide, rough sea
17	4	Lead open, wide, fog
18	0	Lead open, wide, rough sea
19	0	Lead open, wide, rough sea
20	0	Lead open, wide, rough sea
21	18	Lead open, wide, diminishing wind
22	14	Lead open
23	14	Lead open
24	13	Lead open
25	11	Lead open
26	6	Lead open with large ice movement
27	6	Lead open
28	7	Lead open
29	0	Lead closed
30	4	Lead open but edge breaking up

Kaktovik

The whaling season began approximately 8 September and ended early in October. Four crews participated in the autumn hunt at Kaktovik, with a fifth crew occasionally joining in the activity. Two whales were landed by the whalers of Kaktovik (Table 9). One whale was a small female that measured 670 cm (22 feet) in length and the second a large male 1,676 cm (55 feet) in length. One captain reported the presence of a large scar on the whale he took which was believed to be an old bomb wound. No information was obtained on whales that may have been struck and lost.

SUMMARY

In 1977, a total of 90 Alaska Eskimo whaling crews hunted bowhead whales in the northern Bering and Chukchi Seas during the spring season, when 26 whales were harvested and an additional 3 were killed but lost. During the autumn hunt in the Beaufort Sea, approximately 13 crews harvested another 3 bowhead whales. Harvest statistics for Alaska whaling villages during 1977 are presented in Table 11.

In 1977, 79 whales were reported stuck and lost and 3 were reported killed and lost for a total of 82 struck and lost. Whales designated as struck and lost are those that have escaped from the hunters after having been wounded. Some whales escape after a single strike by a weapon (including bombs that misfire), while others may be struck two or more times before eluding their pursuers. Although a single animal may experience several continuous attacks by one or more crews before escaping, the event is counted as one whale struck and lost. It should be noted, however, that since these data are obtained from statements made by the whalers, or rarely from the observations of investigators, they represent a minimum known number of animals struck and lost.

At the two villages (Point Hope and Barrow) where NMFS observers were stationed in the spring of 1977, 21 whales were killed and recovered compared to 67 struck and lost and 2 killed and lost. At Barrow, 56 whales were struck and lost for a total of 58 struck but lost. Since 19 were killed and recovered there, 3 animals were struck and lost for each

Table 6

Weather data at Barrow, Alaska, spring 1977.

Date	Temperature (°F) Max.	Min.	Av.	Average wind velocity (m.p.h.)	Wind direction (degrees)
April					
19	9	−9	0	10.6	100
20	15	0	8	12.3	070
21	14	9	12	13.6	190
22	14	3	9	13.3	240
23	21	3	12	12.2	080
24	31	12	22	10.9	060
25	23	11	17	10.7	220
26	13	−2	6	14.8	310
27	6	−5	1	6.7	270
28	6	−6	0	5.5	110
29	9	−11	−1	9.4	060
30	13	−6	4	13.4	070
May					
1	14	−2	6	14.2	060
2	14	2	8	12.5	050
3	17	12	15	7.9	040
4	16	9	13	7.3	190
5	18	1	10	11.0	080
6	21	17	19	14.1	080
7	24	19	22	11.0	090
8	25	21	23	10.1	110
9	26	19	23	14.1	110
10	25	20	23	18.1	100
11	23	19	21	17.0	100
12	25	15	20	9.8	020
13	20	14	17	7.5	080
14	22	17	20	12.3	090
15	23	14	19	12.0	150
16	23	15	19	18.5	070
17	29	23	26	13.0	090
18	26	23	25	18.5	040
19	25	14	20	22.3	030
20	14	10	12	17.5	040
21	13	9	11	12.9	050
22	13	10	12	9.1	090
23	15	10	13	11.4	070
24	20	11	16	10.7	030
25	22	19	21	6.7	090
26	27	21	24	9.8	100
27	29	23	26	6.5	360
28	29	22	26	6.4	250
29	32	19	26	7.3	100

Table 7

Belukha taken by Eskimos at bowhead whaling villages in Alaska during spring, 1977.

Location and date	Killed and recovered					Killed but lost
	Male	Female	Unknown	Length (centimetres)	Fetus	
Point Hope						
April						
21	0	0	1	–	–	0
29	0	1	0	–	1	0
29	0	1	0	–	1	0
29	0	1	0	–	0	0
29	0	1	0	–	1	0
29	0	1	0	–	0	0
29	0	1	0	–	1	0
29	1	0	0	–	0	0
29	0	1	0	–	0	0
29	0	1	0	–	0	0
29	0	1	0	–	1	0
29	0	1	0	–	1	0
29	1	0	0	–	0	0
29	0	1	0	–	0	0
29	0	1	0	–	0	0
29	0	1	0	–	0	0
29	1	0	0	–	0	0
29	1	0	0	–	0	0
29	1	0	0	–	0	0
May						
4	–	–	1	488	–	0
16	0	0	0	–	–	1
17	0	1	0	–	1	0
17	–	–	1	–	0	0
17	–	–	1	–	0	0
17	1	0	0	422	0	0
17	0	1	0	380	0	0
17	1	0	0	407	0	0
17	1	0	0	442	0	0
17	1	0	0	337	0	0
17	1	0	0	319	0	0
17	1	0	0	261	0	0
17	0	1	0	–	1	0
17	1	0	0	–	0	0
17	–	–	1	–	–	0
17	–	–	1	–	–	0
17	–	–	1	–	–	0
17	–	–	1	–	–	0
17	–	–	1	–	–	0
17	–	–	1	–	–	0
20	0	0	0	–	–	1
22	–	–	1	–	–	0
22	–	–	1	–	–	0
22	0	0	0	–	–	1
23	–	–	1	–	0	0
23	0	1	0	340	0	0
23	–	–	1	–	0	0
23	–	–	1	–	–	0
24	1	0	0	396	0	0
24	–	–	1	–	0	0
24	1	0	0	–	0	0
24	–	–	1	–	0	0
27	–	–	1	–	–	0
27	–	–	1	–	–	0
27	–	–	1	–	–	0
27	–	–	1	–	–	0
Totals	14	17	21		8	3
Barrow						
May						
4	1	0	0	460	0	0
4	0	0	0	–	–	1
4	0	0	0	–	–	1
5	–	–	1	–	–	0
5	0	0	0	–	–	1
5	0	0	0	–	–	1
Totals	1	0	1		0	4

Table 8

Mammals other than whales killed at Barrow, Alaska, during spring whaling season of 1977.

Species	Date	Number taken	Remarks
Bearded seal	27 April	–	Killed but lost
Bearded seal	26 May	1	–
Ringed seal	28 April	1	–
	28 April	1	–
	30 April	1	–
Polar bear	9 May	1	–
	10 May	1	–
	14 May	1	–
	15 May	2	–
	26 May	1	–
Walrus	9 May	1	–

one recovered. At Point Hope 11 whales were struck and lost compared to 2 killed and recovered, a ratio of 5.5 whales struck and lost for each one recovered. The Point Hope data are considered reasonably complete, whereas those for Barrow are incomplete, considered an underestimate of the struck and lost ratio, due to the greater geographic dispersion of whalers in that locality.

The fact that a whale is struck and lost does not necessarily mean that it has been fatally injured. Some whales harpooned with the darting gun escape when the propelling charge misfires and fails to shoot the bomb from the gun into the whale, the harpoon line breaks, or the harpoon becomes dislodged. Bombs fired from guns may enter the body of a whale, pass through the soft tissues, and exit from the whale to explode harmlessly in the water. A bomb may also glance off bone structure and exit from the body of the whale to explode in the water. Occasionally, a bomb may strike the whale at such a small angle to the body that it ricochets and does not penetrate the animal. Bombs may enter the body of the whale and then fail to explode or they may pass through the body and into the water. NMFS observers at Barrow noted that bombs failed to explode in about one-half of the 56 whales struck and lost there during the spring hunt.

Evaluation of the problem of whales that have been struck and lost is difficult because carcasses containing pieces of exploded bombs or evidence of wounds caused by bombs are scarce. Whale carcasses are carefully examined for bomb fragments only when necessary to establish ownership (e.g. stinkers) and during such cases the interested parties are quite certain where their bombs

Table 9

Biological features of bowhead whales taken during autumn whaling season of 1977.

Area and date	Length (centimetres)	Sex	Remarks
Barrow			
14 October	854	F	–
Kaktovik			
29 September	1,676*	M*	–
2 October	670*	F	Injury possibly caused earlier by a bomb

* Data provided by Eskimos.

Table 10

Weather data at Barrow, Alaska, autumn 1977.

Date	Temperature (°F) Min.	Max.	Av.	Average wind velocity (m.p.h.)	Wind direction (degrees)
Sept.					
1	39	52	46	14.7	210
2	40	51	47	15.2	220
3	46	50	48	9.6	220
4	34	47	41	15.1	240
5	34	43	39	9.4	090
6	37	42	40	19.4	050
7	34	39	37	15.1	010
8	35	42	39	11.7	240
9	34	39	37	9.8	250
10	32	36	34	16.4	070
11	31	33	32	17.7	070
12	32	38	35	15.5	110
13	33	47	40	18.0	130
14	35	48	42	13.1	250
15	34	41	38	10.6	270
16	31	40	36	11.8	260
17	30	35	33	13.2	080
18	30	33	32	14.7	050
19	30	33	32	11.8	050
20	26	31	29	11.8	010
21	26	33	30	9.1	260
22	26	33	30	14.5	160
23	24	38	31	13.1	140
24	33	43	38	12.5	190
25	35	39	37	14.2	210
26	34	37	36	14.5	250
27	31	35	33	9.1	320
28	27	32	30	15.5	360
29	26	29	28	12.2	290
30	26	33	30	11.7	110
Oct.					
1	33	37	35	18.1	210
2	33	41	37	15.5	220
3	33	38	36	12.2	150
4	31	35	33	10.6	240
5	26	34	30	13.4	220
6	26	33	30	17.7	090
7	27	32	30	14.2	090
8	26	27	27	9.5	120
9	27	31	29	17.8	130
10	29	31	30	28.9	100
11	24	29	27	29.6	080
12	20	25	23	19.0	070
13	13	20	17	11.1	050
14	12	18	15	5.9	040
15	16	20	18	20.1	050
16	14	19	17	13.7	040
17	14	16	15	23.4	050
18	15	19	17	23.7	050
19	15	20	18	13.8	060
20	14	21	18	21.6	070
21	19	23	21	25.3	050
22	15	23	19	25.0	050
23	13	16	15	18.6	050
24	11	16	14	17.3	060
25	11	14	13	18.8	060
26	10	13	12	15.2	030
27	8	11	10	20.3	050
28	10	17	14	22.9	060
29	4	17	11	15.0	220
30	2	5	4	13.2	300
31	−3	2	−1	6.5	340

struck the whale. Also, blubber and other portions of the carcass that may be used for dog feed or abandoned are not examined for remains of bombs or harpoons. No bomb particles from previous strikes are known to have been found in bowhead whales taken by Alaskan Eskimos since NMFS began monitoring the harvest.

Table 11

A summary of bowhead whale harvest statistics by Alaskan Eskimos during 1977

Village	Killed and recovered	Killed and lost	Struck and lost
Spring Hunt			
Gambell	2	0	6
Savoonga	0	0	2
Wales	0	0	0
Kivalina	1	1	2
Point Hope	2	0	11
Wainwright	2	0	2
Barrow	19[1]	2	56
Totals	26	3	79
Autumn Hunt			
Barrow	1	0	0
Nuiqsut	0	0	0
Kaktovik	2	0	0
Totals	3	0	0

[1] Includes 2 stinkers.

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Appendix 1

Bowhead whales taken by Alaskan Eskimos and shore-based stations in the western Arctic (revised August, 1978).

Year	Barrow	Point Hope	Wainwright	Nuiqsut	Icy Cape	Kaktovik	Gambell	Savoonga	Kivalina	Misc.	Total
1852	17	–	–	–	–	–	–	–	–	–	17
1853	7	–	–	–	–	–	–	–	–	–	7
1854–79	–	–	–	–	–	–	–	–	–	–	–
1880	–	5	–	–	–	–	1	–		(Kotzebue Sound) 1	7
1881	18	–	–	–	–	–	–	–	–	–	18
1882	1	–	–	–	–	–	–	–	–	–	1
1883	2	–	–	–	–	–	–	–	–	–	2
1884	10	–	–	–	–	–	–	–	–	–	10
1885	28	12	–	–	–	–	–	–	–	–	40
1886	–	–	–	–	–	–	–	–	–	–	–
1887	11	–	–	–	–	–	–	–	–	–	11
1888	2	–	–	–	–	–	–	–	–	(Wales) 1	3
1889	4	–	–	–	–	–	–	–	–	(Wales) 3	7
1890	1	1	–	–	–	–	–	–	–	(Wales) 0	2
1891	18	–	–	–	–	–	–	–	–	(Wales) 1	19
1892	8	0	–	–	–	–	–	–	–	–	8
1893	–	–	–	–	–	–	–	–	–	–	–
1894	10	3	–	–	–	–	–	–	–	–	13
1895	4	–	–	–	–	–	–	–	–	(Wales) 0	4
1896	6	33	–	–	–	–	–	–	–	–	39
1897	5	–	–	–	–	–	–	–	–	–	5
1898	26	1	–	–	–	–	–	–	–	–	27
1899	–	–	–	–	–	–	–	–	–	–	–
1900	19	–	–	–	–	–	–	–	–	–	19
1901	–	1	–	–	–	–	–	–	–	–	1
1902	–	2	–	–	–	–	–	–	–	–	2
1903	4	4	–	–	–	–	–	–	–	–	8
1904	2	1	–	–	–	–	–	–	–	–	3
1905	5	2	–	–	–	–	–	–	–	–	7
1906	6	–	–	–	–	–	–	–	–	–	6
1907	9	0	–	–	–	–	–	–	–	–	9
1908	23	13	–	–	10–12	–	–	–	–	–	46–48
1909	11	13	–	–	1	–	–	–	–	–	25
1910	2	–	–	–	–	–	–	–	–	–	2
1911	1	3	–	–	–	–	–	–	–	–	4
1912	2	1	–	–	–	–	–	–	–	–	3
1913	4	1	–	–	–	–	–	–	–	–	5
1914	1	2	–	–	1	–	–	–	–	–	4
1915	–	3	–	–	–	–	–	–	–	–	3
1916	5	7	1	–	–	–	–	–	–	1	14
1917	7	3	–	–	3	–	–	–	–	2	15
1918	2	7	–	–	–	–	–	–	–	–	9
1919	2	2	–	–	–	–	–	–	–	–	4
1920	11	3	–	–	–	–	–	–	–	–	14
1921	–	2	–	–	–	–	–	–	–	–	2
1922	1	13	3	–	–	–	–	–	–	–	17
1923	–	1	–	–	–	–	–	–	–	2	3
1924	1	16	0	–	3	–	–	–	–	9	29
1925	19	10	2	–	1	–	–	–	–	–	32
1926	4	13	1	–	–	–	–	–	–	–	18
1927	2	3	2	–	–	–	–	–	–	–	7
1928	11	–	–	–	–	–	–	–	–	–	11
1929	15	–	–	–	–	–	1	–	–	–	16
1930	7	–	–	–	–	–	–	–	–	–	7
1931	11	1	6	–	–	–	–	–	–	–	18
1932	7	–	–	–	–	–	–	–	–	–	7
1933	5	–	–	–	–	–	–	–	–	–	5
1934	4	–	–	–	–	–	–	–	–	–	4
1935	6	–	–	–	–	–	–	–	–	–	6
1936	4	4	1	–	–	–	1	–	–	–	10
1937	9	–	–	–	–	–	1	–	–	5	15
1938	4	5	2	–	–	–	–	–	–	–	11
1939	6	–	–	–	1	–	–	–		(Point Lay) 1	8
1940	0	5	–	–	1	–	5	–		(Point Lay) 1	12
1941	8	14	1	–	–	–	–	–	–	–	23
1942	10	–	1	–	–	–	–	–	–	–	11

Appendix 1 (continued)

Year	Barrow	Point Hope	Wainwright	Nuiqsut	Icy Cape	Kaktovik	Gambell	Savoonga	Kivalina	Misc.	Total
1943	6	–	–	–	–	–	–	–	–	–	6
1944	0	–	2	–	–	–	–	–	–	–	2
1945	3	3	6	–	–	–	–	–	–	–	12
1946	9	2	1	–	–	–	–	–	–	–	12
1947	4	6	1	–	–	–	–	–	–	–	11
1948	5	0	–	–	–	–	–	–	–	–	5
1949	0	4	2	–	–	–	–	–	–	–	6
1950	4	2	2	–	–	–	–	–	–	(Cape Lisburne) 1	9
1951	9	4	–	–	–	–	–	–	1	–	14
1952	0	2	–	–	–	–	1	–	–	–	3
1953	17	4	–	–	–	–	2	–	–	–	23
1954	1	3	–	–	–	–	0	–	–	–	4
1955	19	1	1	–	–	–	2	–	–	–	23
1956	2	2	2	–	–	–	1	–	–	–	7
1957	0	3	0	–	–	–	0	–	–	–	3
1958	0	2	0	–	–	–	0	–	–	–	2
1959	0	1	0	–	–	–	–	–	–	–	1
1960	15	4	0	–	–	–	–	–	–	–	19
1961	6	2	1	–	–	–	1	–	–	–	10
1962	5	6	1	–	–	–	0	–	–	–	12
1963	5	3	2	–	–	–	0	–	–	–	10
1964	11	1	1	–	–	2	0	–	1	–	16
1965	4	2	0	–	–	–	1	–	–	–	7
1966	7	5	1	–	–	–	2	–	–	–	15
1967	3	1	0	–	–	–	–	–	–	–	4
1968	10	3	2	–	–	–	1	–	–	(Nome) 1	17
1969	11	3	3	–	–	–	1	–	–	(Wales) 1	19
1970	16	8	0	–	–	–	–	–	1	–	25
1971	13	6	2	–	–	–	1	–	1	(Wales) 1	24
1972	19	14	2	–	–	–	2	–	1	–	38
1973	17	7	3	1	–	3	2	4	–	–	37
1974	9	6	1	–	–	2	2	–	0	–	20
1975	10	4	0	–	–	–	1	–	0	–	15
1976	23	12	3	–	–	2	1	7	0	(Wales) 0	48
1977	20	2	2	0	–	2	2	0	1	(Wales) 0	29

SC/30/Doc 36

Preliminary Report of the 1978 Spring Bowhead Whale Research Program Results

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INTRODUCTION

The following is a preliminary review of results obtained during the spring 1978 bowhead whale research program conducted by personnel of the Marine Mammal Division, NWAFC, NMFS, NOAA. Because research is still being conducted as of this writing, the results discussed below include only data collected through 30 May 1978. A comprehensive analysis of results of research conducted in the spring will not be undertaken until after the spring research season ends on or about 10 June 1978. At that time additional complementary research projects (e.g. vessel survey) will not have been completed; thus an analysis of all research conducted in 1978, including spring, summer, and fall projects, will not be conducted until December 1978. Since an analysis of research leading to an estimation of the size of the western Arctic population of bowhead whales cannot be made until all of the FY 1978 project results are in, the information contained in this report should be considered preliminary.

The objectives of the 1978 bowhead whale research plan were to:

(1) estimate the abundance of that part of the western Arctic bowhead whale population which migrates past the spring Eskimo whaling camps;
(2) determine the temporal and spatial distribution of bowheads before, during and after the spring–summer migration period; and
(3) collect biological samples from the whales that were harvested so an assessment of age and reproductive status of the whales taken could be made.

To assess the relationship of bowhead whale movements to the census effort, an integrated research program was conducted which included:

(1) three ice-based census camps designed to count whales passing by in the nearshore lead near Barrow, Alaska;
(2) aerial surveys conducted at the site of the camps to help validate sightings made by the ice camp observers;
(3) land camp observations of the early and late migration patterns of bowheads in conjunction with aerial and vessel surveys; and
(4) an exploration of the usefulness of active sonar and passive recordings as tools for determining the distribution and abundance of whales near the ice-based counting camps.

During 1976 and 1977 personnel from the Marine Mammal Division conducted population studies dealing with the distribution and abundance of bowhead whales in the northern Bering Sea and Arctic Ocean under the Alaska Outer Continental Shelf Environmental Assessment Program (OCSEAP) (Braham and Krogman, 1977). The OCSEAP project was the forerunner of the expanded 1978 bowhead research effort. Because of this expanded research we are now able to make a more precise abundance estimate of the western Arctic population than has previously been published. We have also developed reliable procedures to evaluate the biases associated with the census effort.

In summary, this report addresses the following major topics:

(1) a population index estimate of the number of whales migrating past the Alaska Eskimo whaling camps; and
(2) a comparison of this year's results with those obtained in 1976 and 1977.

The report also summarizes information about bowhead whale distribution; evaluates those factors related to the movement and behavior of whales passing the counting camps and associated census biases; discusses the 1978 spring hunt; and itemizes the biological samples collected to date and the planned analyses.

Use of trade names does not necessarily imply endorsement of these items by the National Marine Fisheries Service.

METHODS, RESULTS AND DISCUSSION

Aerial surveys

The objectives of the aerial survey project were to:

(1) delineate the temporal and spatial distribution of bowhead whales during the spring–summer migration period; and
(2) help validate the census counts at the Pt Barrow ice camp.

Aerial surveys were not intended to produce a population estimate.

Between 19 April and 23 May 1978, 174 hours of aerial survey were flown in search of bowhead whales in the waters from St Lawrence Island northeastward to Pt Barrow, Alaska, and eastward to Banks Island, Northwest Territory, Canada (Fig. 1). Systematic aerial surveys were used to delineate gross migratory routes. Replicate surveys examined details of distribution and movements of whales across the Bering Strait, across nearshore leads, and up to 75 miles offshore from those leads at Pt Lay and Pt Barrow; and tested the efficiency of the ice camp observers at counting as whales passed the counting station. By 30 May an estimated 450 bowhead whales were seen, many no doubt duplicates from preceding days.

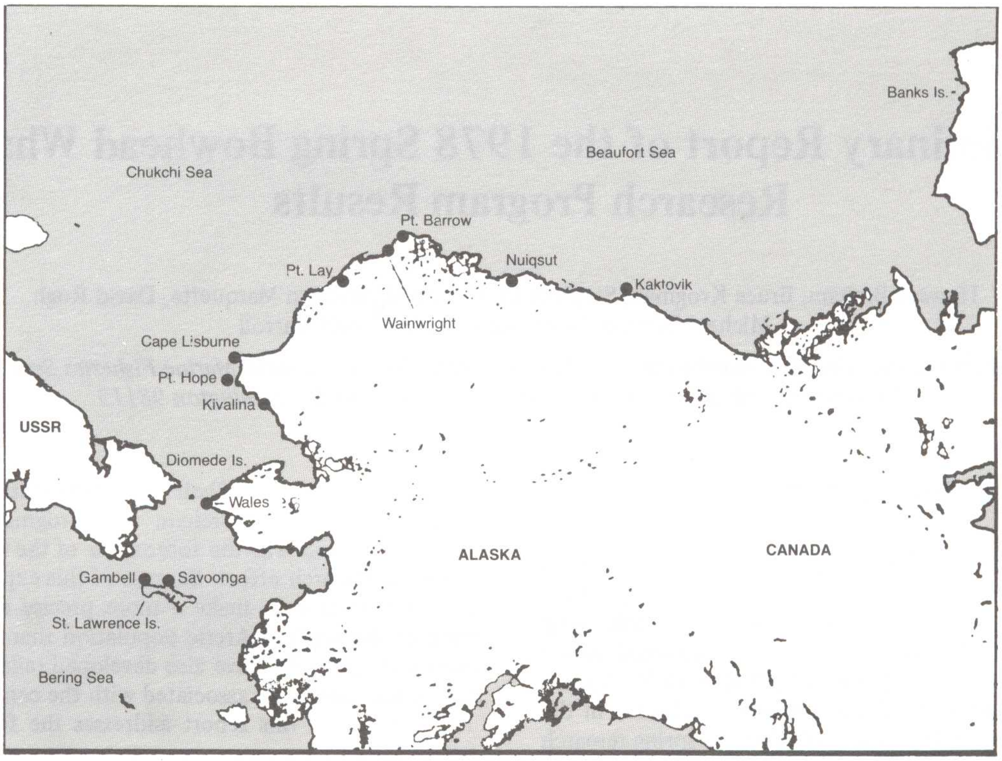

Fig. 1. Bowhead whale study area.

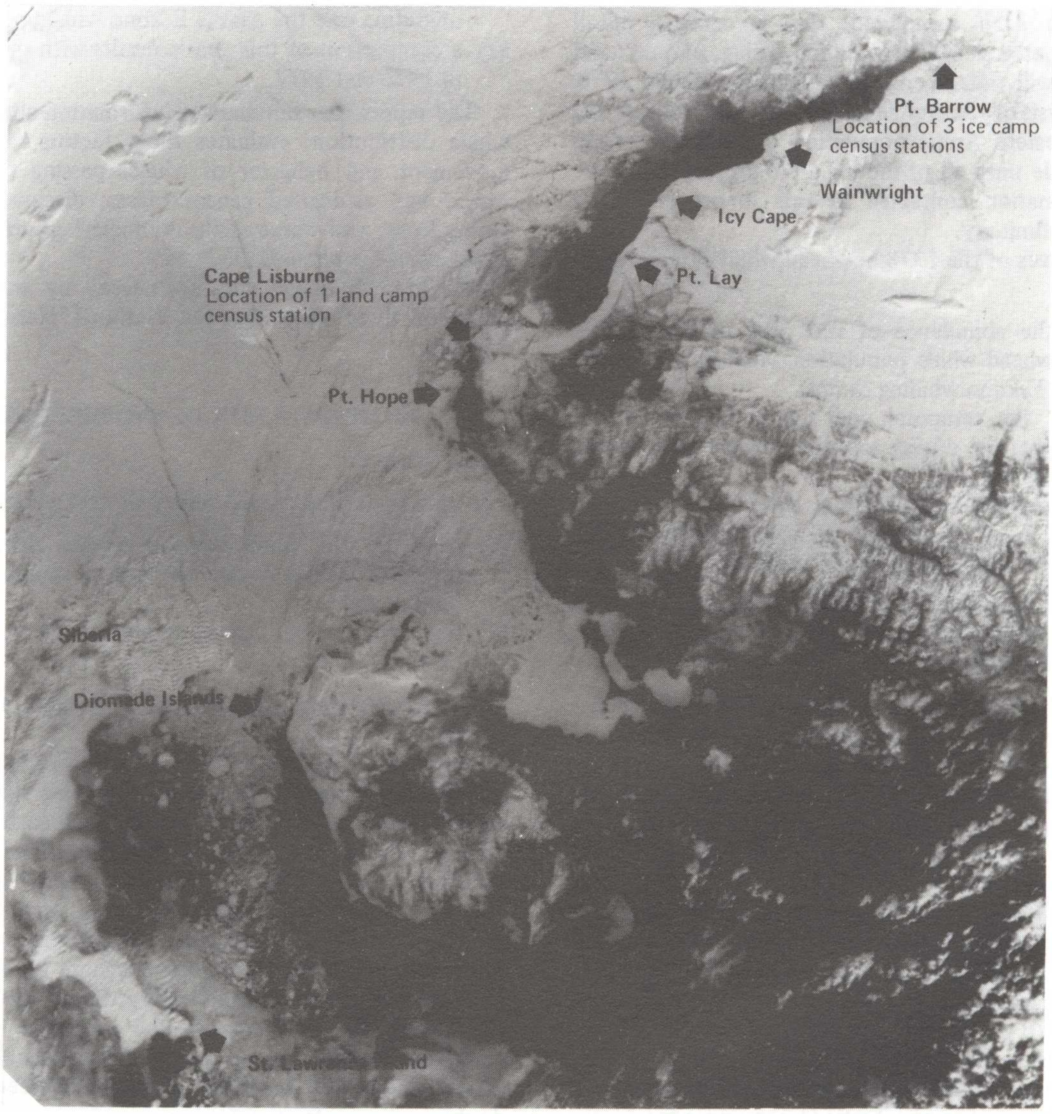

Fig. 2. Ice conditions in the Bering, Chukchi, and Beaufort Seas, 12 May 1978.

Distribution and migration timing

During the 1978 spring migration, the majority of bowheads passing the northwest tip of St Lawrence Island apparently remained close to the Soviet coast migrating through the Bering Strait west of Big Diomede Island (Fig. 1). Once north of the Bering Strait, they followed a narrow migratory corridor, generally corresponding to the northerly (10°–20° magnetic) oriented pack ice fracture zone, passing within a few hundred meters to as far as 45 km seaward of Pt Hope and Cape Lisburne. North of Cape Lisburne the nearshore lead widened to as much as 56 km before narrowing dramatically just south of Pt Barrow (Fig. 2). This condition persisted throughout the survey period.

From Pt Lay northward the whales remained within the nearshore lead, showing preference for the ice edges (i.e. the shorefast ice, refrozen lead and the pack ice edges), and holes in the refrozen lead in areas of calmer water. Far fewer animals were seen in the open water of the leads, and none was seen outside the nearshore lead system despite the fact that 45.4% of our survey effort near Pt Barrow was offshore (Table 1). The narrowing of the lead near Pt Barrow and the apparent absence of whales in offshore leads appears to have brought essentially all migrating bowhead whales within viewing range of the Pt Barrow ice camp census teams.

After the whales passed Pt Barrow, they continued to use the nearest shore lead system at least to 141° W longitude, reaching the northwest coast of Banks Island, Canada, by early May. Two whales were observed off NW Banks Island on 8 May by pilots from the Naval Arctic Research Laboratory. No whales were seen along the southwestern shore of Banks Island on 13 May 1978. Poor weather prevented more detailed surveys of the northwest tip of Banks Island where satellite imagery showed open water. Surveys of the Beaufort Sea this year support the hypothesis proposed by Braham and Krogman (1977) that the spring migration to the western Canadian arctic occurs well offshore, the nearshore lead being approximately 100 km north of the coastline.

On 22 May six bowheads were observed heading northwest north of the Bering Strait toward the north side of the Chukotskiy Peninsula, USSR. Animals migrating later in the spring may avoid the nearshore lead in favor of more open water passages west of the Bering Strait into Soviet waters of the Chukchi Sea. The Soviet government did not grant our request to conduct aerial surveys closer than 12 miles

Table 1

Comparison of aerial survey counts for bowhead whales in the nearshore lead and in areas seaward of the pack ice edge in the eastern Chukchi Sea, May 1978

		Nearshore leads			Offshore leads		
Date	Area	No. miles	A[1]	D[2]	No. miles	A	D
4 May	Barrow 156°–157° 30′	106.2	14	0.13	209.5	0	0
5 May							
A	Barrow 156°–157° 30′	112.0	17	0.15	103.5	0	0
B	Pt Lay 163°–163° 30′	20.0	1	0.05	75.0	0	0
C	Other areas 155°–163° 00′	268.5	18	0.07			
6 May							
A	Other areas 156° 30′–164° 10′	364.0	50	0.14			
B	"Ice Camp" 156° 31′–156° 26′				33.0	0	0
7 May							
A	Barrow 156° 45′–159°	90.5	2	0.02			
B	S.W. Barrow 159°–160°	23.0	0	0	163.0	0	0
8 May							
A	Barrow 156°–158°	66.5	7	0.11	214.0	0	0
B	Other areas 155°–156°	51.0	11	0.22			
10 May							
A	"Ice Camp" 156° 20′–156° 52′				67.0	0	0
B	"Ice Camp" 156° 22′–156° 59′				100.0	0	0
12 May							
A	Barrow–Deadhorse 156° 40′–148°	215.5	27	0.13	143.8	0	0
B	Deadhorse–Inuvik 148°–140° 35′	100.0	14	0.14	64.0	0	0
16 May	"Ice Camp" 156° 11′–156° 42′				58.0	0	0
Totals		1,477.2	161	0.11	1,230.0	0	0

[1] A = number of animals.
[2] D = density; animals/linear mile.

offshore. Additional survey assessment of bowhead movements after the spring whaling period is planned along the Siberian coast and also during a summer vessel cruise.

Validation of the ice camp census study

Bowhead whales passing the ice camp counting stations off Pt Barrow, Alaska, were independently tallied from the aircraft as it flew an oval "race track" pattern over the lead immediately adjacent to the camps. During the 19 simultaneous survey periods (ranging from 16 minutes to 2 hours 39 minutes in duration) whales were scored by both ice camp and aerial teams. The aircraft counted 93 whales; the corrected ice camp counts accounted for 83.5 whales (among mean pooled value for the two camps) (Table 2).

The difference in the number of whales counted by the two ice camp teams and by the aircraft team ranged from –9 to +8.5 whales for a mean difference (D) of –0.5. A paired t-test indicated no significant difference in the number of bowhead whales counted from the air or ice. This indicated that the ice camp observers were observing essentially all whales present or that both survey methods were biased in the same direction.

The aerial survey test for ice camp observer efficiency resulted in a positive correlation for paired counts collected during the simultaneous ice camp and aerial surveys of the nearshore lead ($P<0.05$; where $r_{sample} = 0.459$ and $r_{critical} = 0.456$ for a two tailed test at 17 d.f.). This indicated that the samples were drawn from the same population.

Because of the rigorousness of the aerial "race track" method, it appears safe to conclude that whales rarely passed both ice camps without being observed. Only two groups of two animals each were seen solely by the aircraft team and missed by the ice camp observers during the simultaneous sampling periods. Those four whales missed by the ice camp observers were behind unusually large ice floes in the lead immediately across from the ice camps. This condition was rare during the aerial survey period 3 to 20 May. These missed whales constituted only 4% of the total number of whales counted by the aircraft team during the 19 ice camp-aerial survey flights (Table 2). Four anomalous sessions, numbers 16–19 in Table 2, introduce the possibility that during some periods, particularly during periods of high whale density, the ice camp observers may have overcounted (estimated to be 10–20%). These values representing possible over or undercounting have not been systematically evaluated yet. These problems are addressed in the section discussing the ice camp census study.

Ice camp census

The objectives of the ice camp bowhead whale census were to:

(1) determine a population index for 1978;
(2) develop a method whereby a level of uncertainty (confidence interval) can be ascribed to the index;
(3) reduce sample bias;
(4) provide a basis for comparing the 1978 index with indices developed in 1976 and 1977;
(5) determine the effective sample space adjacent to the ice camp which is being surveyed by observers; and
(6) collect behavioral data (e.g. dive times) which may be useful toward defining the statistical parameters used in ice camp, aerial and shipboard studies.

Table 2

Comparison of aerial and combined ice camp counts of bowheads in the nearshore lead north of Pt Barrow, Alaska, May 1978

No.	Date	Approx. start time	Approx. end time	Total time	Total counts: Ice Camp[1]	Aerial survey	Difference
1	3 May 1978	1622	1644	22 min	4	6	–2
2	4 May 1978	1007	1225	2 hr 18 min	0	0	0
3	5 May 1978	1919	2100	1 hr 41 min	6	8	–2
4	6 May 1978	1001	1114	1 hr 13 min	6.5	5	+1.5
5	6 May 1978	1129	1145	16 min	2	1	+1
6	6 May 1978	1416	1546	1 hr 30 min	9.5	4	+5.5
7	6 May 1978	1549	1613	24 min	2	3	–1
8	8 May 1978	1010	1104	54 min	1.5	2	–0.5
9	8 May 1978	1202	1228	26 min	1.5	2	–0.5
10	8 May 1978	1443	1543	1 hr 0 min	5.5	4	+1.5
11	8 May 1978	1657	1752	55 min	1.5	6	–4.5
12	8 May 1978	1958	2047	49 min	4	5	–1
13	9 May 1978	0935	1214	2 hr 39 min	4	3	+1
14	9 May 1978	1424	1550	1 hr 26 min	6	2	+4
15	9 May 1978	1556	1730	1 hr 34 min	0	2	–2
16	10 May 1978	0945	1047	1 hr 2 min	2	11[2]	–9
17	10 May 1978	1152	1240	48 min	2	9	–7
18	10 May 1978	1445	1634	1 hr 49 min	18.5	10[3]	+8.5
19	10 May 1978	1720	1809	49 min	7	10[4]	–7
				23 hr 35 min	83.5	93	D = – 0.5

[1] Corrected ice camp total based on mean count recorded by South Camp plus mean number of missed whales by South Camp as recorded by North Camp.
[2] 4 whales seen by aircraft on offshore side of ice floe near pack ice edge; missed by both ice camps.
[3] Aircraft plotted 2 whales moving through area which were recorded as "new" whales from 4–6 times each; a third whale logged as new by North Camp was judged by aircraft to be a duplicate.
[4] 2 whales moving together logged inaccurately as new whales on second surfacing.

Summary of field events

Bowhead whales were counted as they migrated northeasterly through the nearshore lead system near Pt Barrow, Alaska. The field survey started 15 April and is expected to end during the first week of June. Because of the constant daylight during the late spring and summer in the Arctic, a 24-hour observation schedule was maintained. Two camps with 8 persons each were deployed on the shorefast ice next to the nearshore lead approximately 4.8 km north of Pt Barrow. A schedule was maintained in which 2 observers at each camp watched together (for a total of 4 observers) for shifts of 3 hours in length.

The two camps, called South Camp and North Camp, were located 833 m apart. Whales moved along the nearshore lead from South Camp toward North Camp. South Camp maintained the primary count of whales while the mission of North Camp was to estimate the number of whales missed by South Camp observers.

To measure the uncertainty of an observer's judgments at South Camp regarding single and multiple sightings of the same whale, each observed whale was categorized as (1) a newly sighted whale, when an observer was sure the whale had not been seen before; (2) a duplicate whale, when an observer was sure that the whale had been seen before; and (3) a conditional duplicate whale, when an observer was unsure whether or not the whale had been seen before.

To determine the number of whales missed by South Camp, South Camp radio-broadcasted immediately all sighting information to the North Camp observers. By monitoring radio messages from South Camp, North Camp observers were alerted to whales by the counting station. Communication was one way, in that North Camp observers never radioed back information which could alert South Camp to whales that South Camp had not yet seen. For each sighting made by North Camp observers, a decision was made as to whether or not the observed whale was definitely seen by South Camp or was definitely not seen by South Camp. If the North Camp observers were unsure as to whether or not the whale was observed by South Camp, a question mark was recorded.

The Alaska Eskimo Whaling Commission (AEWC) sponsored a whale counting camp manned by residents of the Barrow community. Two NMFS biologists assisted camp members from the Barrow community with data collection procedures. Methodology employed at the AEWC camp was comparable to our 1976 and 1977 observations in that most watches (≅ 65%) were kept by a single person extending from 4 to 8 hours in length. The AEWC Camp was positioned approximately 5 km southwest of South Camp.

Eskimo whalers independently participated by recording hours watched and number of whales seen. (Only three of their whaling captains' logbooks (from Barrow) were available at the time of this writing.)

A summary of the actual counts for all camps and observers is given at the bottom of this page. Although the primary mission of North Camp was to estimate the number of whales missed at South Camp, a total count was also obtained and recorded for comparative purposes.

Population index for 1978

Assuming the best estimate of whales passing one location during a period not watched is a count made during that period at the nearest location, the data from more than one camp were synthesized (Fig. 3) to achieve a total observational effort of 967 hours and 24 minutes out of a total of 1,104 hours (equates to 87.6% of total time available). The index based upon these combined data will hereafter be referred to as the "Combined South Camp Index".

The contribution of whale counts by the AEWC Camp to the Combined South Camp Index equals one as the number of whales tallied by that camp was one during times when South Camp was not watching. The contribution of Eskimo whalers to the Index equaled 368 (expected during 72 hours of watch) based on 26, 213, and 105 whales observed during 24, 24, and 19 hours 30 minutes of watch made respectively on 29 and 30 April and 1 May when the South Camp observers could not watch. Evaluation of counts among different Eskimo whalers, combined with results of aerial surveys made on 29 April and 1 May confirm that a peak number of whales moved by Pt Barrow during this period.

The 1978 index is a mean index and as presented in this document is the summation of the estimated number of whales that passed by South Camp per day. The mean index (I_x) is calculated as the average of the low index (I_L) and the high index (I_H). The low index is calculated as the summation of the products of the rate of whales per hour of watch during each day multiplied by 24 hours; with rates based only on new sightings (conditional duplicates are treated as duplicates thus contributing zero whales to the low index). The high index is calculated as the summation of the products of rates per hour times 24 hours with rates based on new sightings plus conditional duplicates (conditional duplicates are treated as new whales, thus making a full contribution to the index). The mean Combined South Camp Index as presented below is considered the best estimate using available data because it is likely that some conditional duplicates will be new whales and some will be duplicates:

$$I_x = \frac{I_L + I_H}{2} = \frac{1,797 + 2,017}{2} = 1,907$$

and the measure of uncertainty (μ_I) is equal to:

$$\mu_I = \pm \frac{I_H - I_L}{2} = \frac{2,017 - 1,797}{2} = \pm 110$$

Summary of counts for all camps and observers.

Camp name	Period of watch	Total hours watched	New sightings	Conditional duplicates	Total sightings
South Camp	15 April–30 May	867:47	1,389	212	1,601
North Camp	21 April–24 May	505:37	1,157	327	1,484
AEWC Camp	24 April–24 May	589:32	885	104	994
Eskimo whalers	29 April– 2 May	67:30	344	–	344

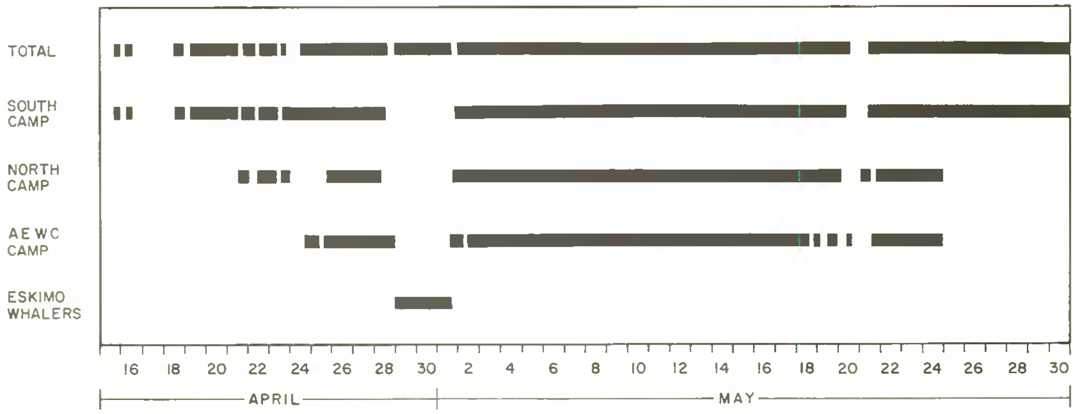

Fig. 3. Watch effort summary for bowhead whale counts near Pt Barrow, Alaska, 15 April–30 May 1978. Horizontal lines indicate periods of watch. The best estimate of the number of whales passing South Camp during periods when South Camp was not counting is a count made during the interval by observers at the nearest camp. For example: Eskimo whalers watched 29 April–1 May, when no other camps watched, and their counts have thus been included in the synthesized total. The 1978 Combined South Camp Index is based on this combined effort, with 91.4% effort attributable to South Camp, 0.1% to North Camp, 2.4% to the AEWC Camp, and 6.1% to the Eskimo whalers (See p. 295 for explanation.)

Therefore, the 1978 mean Combined South Camp Index is equal to 1,907 ± 110.

Addressing conditional duplicate whales, and the potential for over-counting, an evaluation was made of the percentage of conditional whales within each total of the AEWC, South and North Camps. AEWC tallied 11% conditionals, South Camp 13.2% conditionals and North Camp 22% conditionals. Since North Camp observers were faced with the more rigorous problem of evaluating not only their own single versus probable multiple sightings (i.e. of the same whale) but also whales missed or not missed by South Camp observers, the higher percent of conditionals at North Camp probably reflected a closer measure of observer ability to discriminate new from duplicate whales.

To adjust the mean Combined South Camp Index to include 22% conditional duplicates (which results in a more conservative estimate) one proceeds as follows:

$$\text{conditionals} = I_H \times 0.22 = 2{,}017 \times 0.22 = 444$$

and

$$I_L = I_H - \text{conditionals} = 2{,}017 - 444 = 1{,}573$$

Thus, a corrected mean index equals:

$$I_{\bar{x}} = \frac{I_L + I_H}{2} = \frac{1{,}573 + 2{,}017}{2} = 1{,}795$$

where:

$$u = \frac{I_H - I_L}{2} = \frac{2{,}017 - 1{,}573}{2} = \pm 222$$

resulting in:

$$I_{\bar{x}} = 1{,}795 \pm 222$$

This adjustment equates to a downward correction of 12.5% to the most conservative index (I_L); a 5.9% downward adjustment to the mean index ($I_{\bar{x}}$); and a 0% downward adjustment to the least conservative index (I_H).

This new estimate of 1,795 ± 222 does not take into account the number of whales missed. Estimates using North Camp data for the percentage of whales which passed undetected by South Camp were based on 110 two-hour sample blocks. One method of determining the highest percentage of total whales missed by South Camp (29.6%) is to accept that North Camp observers were correct in every instance when they felt sure a whale had been missed by the South Camp. The lowest calculable estimate (11.8%) of the percentage of whales missed is to allow whales missed to equal the number missed by South Camp as recorded by North Camp minus the number of new whales seen by South Camp. The calculated number missed is treated as zero for every block that the number missed becomes a negative value. From these calculations the mean estimate becomes 20.7% missed whales.

A significant but low correlation was established between the number of whales counted by South Camp and the number of whales recorded as missed by North Camp ($P < 0.001$, $r_{sample} = 0.329$, $r_{critical} = 0.187$) based on a two-tailed test with 108 d.f. Based upon the procedure described above, and the resultant low correlation, a correction should be applied once to the calculated index, rather than to individual time periods of watch by counting stations used for the Combined South Camp Index. The summarized adjustments, therefore, are as follows:

	Correction factor	Combined count	Index
Lowest index (I_L)	11.8%	1,573 ÷ (1–0.118)	1,783
Mean index (I_x)	20.7%	1,795 ÷ (1–0.207)	2,264
High index (I_H)	29.6%	2,017 ÷ (1–0.296)	2,865

Applying percent adjustments for number of whales missed results in a best estimate of 2,264 whales with a total measure of uncertainty of 1,082 ($I_H - I_L$) of which 481, or 44% of the uncertainty, lies between the mean and the lowest estimate, whereas 601 or 56% lies between the mean and the highest estimate.

In summary, based upon this preliminary analysis, the best estimate of the number of bowheads which passed by Pt Barrow from 15 April through 30 May was 2,264 with the above-stated range of uncertainty.

Comparison of indices, 1976–1978

The 1978 index (Fig. 4) was higher than indices achieved in 1976 (762 revised from 796 originally quoted in Braham and Krogman (1977), and 715 in 1977). The increase in counts is attributed to several factors. First, increase in survey effort is responsible for much of the change. Fig. 5

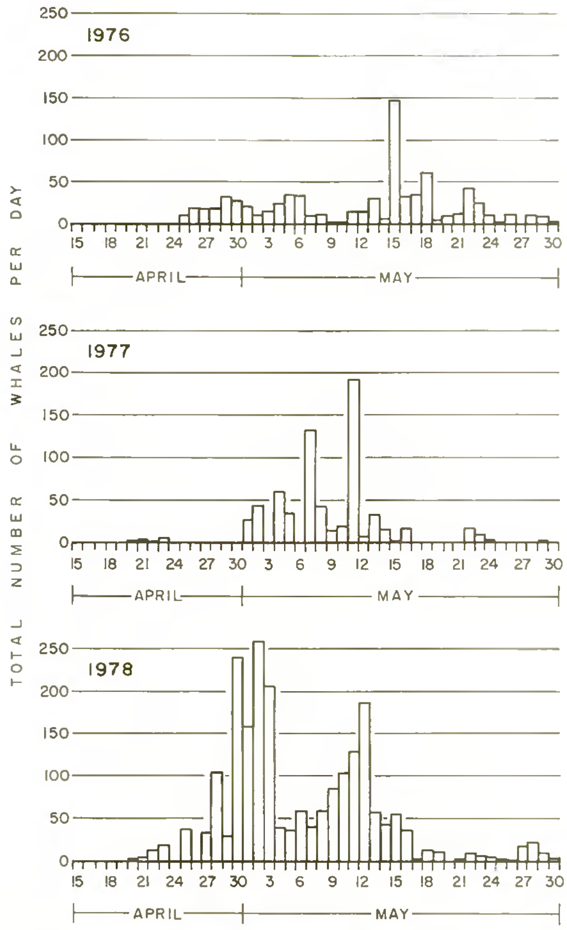

Fig. 4. Comparison among years (1976–1978) of estimated total number of bowhead whales migrating northwardly past Pt Barrow, Alaska, from 15 April–30 May. For purposes of comparison, totals are based on hourly rates per day times (x) 24 hours.

partially illustrates the increase in effort by comparing the number of hours watched/day during the same time frame among years.

The graphs clearly illustrate the variation in watch effort among years. For all years the strategy was to maintain an unbroken 24-hour watch schedule. The 1976 and 1977 watch-effort histograms illustrate how often this strategy was diluted by fog, closed leads and unstable ice conditions.

During 1976, observers were not able to begin counting until 25 April and then the lead remained essentially closed until 30 April. The lead was again closed, or nearly so, one or more days preceding 1, 6, 13, and 22 May. Similar events occurred in 1977 when the lead remained closed 24–29 April and again from 2–4 May. During 1978, the lead partially closed once from 28 April through 1 May in the vicinity of South Camp, but Eskimo whalers were able to make counts where the lead was open further south. It should be noted that in late May the lead was closed for a few days, but not until after most whales had moved through.

In addition to the outstanding environmental conditions, another factor contributing to the increase in the index was a change in location of the ice camps. During 1976 and 1977 the primary location for counting was 10–20 km to the southwest of Pt Barrow, where our observers stationed themselves near Eskimo whalers. In that vicinity, the lead is generally 11–32 km in width, whereas immediately north of Pt Barrow, where the 1978 camps were located, the lead width was generally 1–11 km wide. This year the lead was

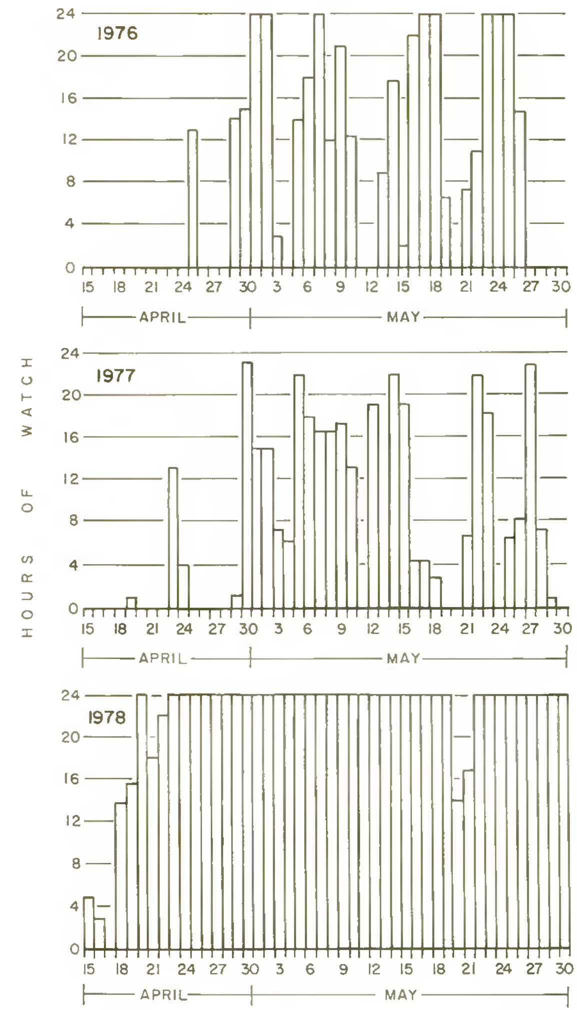

Fig. 5. Comparison among years (1976–78) of observer effort (total hours of watch/hour) expended from 15 April–30 May. The schedules for 1976 and 1977 called for rotating single observers every four hours, whereas the 1978 schedule called for two teams of two observers each (four total) to rotate every three hours. Percent of total survey hours watched were: 1976 – 37.0%; 1977 – 35.8%; 1978 – 86.7%.

open wider than 500 meters approximately 94% of the time.

Another important factor contributing to a higher count this year was the increase in observer effort. The 1978 observer schedule called for 2 people on watch rotated each 3 hours, whereas in years past, with much reduced funding levels, the observer schedule called for 1 person on watch rotated every 4 hours.

Observers at South Camp conducted all watches from an unusually high perch (as high ice ridges were called). Height of eye at the South Camp was approximately 11.8 meters above sea level yielding a view to the horizon of 10 km. More typical of years past, observers were located on young ice with eye height varying between 2 and 4 meters yielding a view to the horizon of 4 to 6 km.

In conclusion, factors which contributed to the increased count in 1978 were: (1) better survey location and conditions; (2) increase in observer effort; and (3) adjustment for negative bias due to missed whales.

Calf counts

From 25 April through 30 May, 18 bowhead whales were identified as calves by the South Camp. These sightings were distributed throughout the survey period somewhat uniformly. The 18 young of the year bowhead calves represent approximately 1.3% of the total number of bowheads seen by the South Camp observers to 30 May. Extrapolated to the mean Combined South Camp Index of 2,264, so far at least 29 bowhead whales may have been added to the population. This value does not consider calf mortality and also should be viewed with extreme caution because of the bias associated with the difficulty of seeing calves swimming by beyond more than a few hundred yards. Also, cows with calves may migrate late in the season (Marquette, 1977) after our ice camp counting stations close.

Land Based Counts

The research objectives of the Cape Lisburne land-based whale counting study were to:

(1) delineate the onset and termination of the bowhead whale spring migration along the nearshore lead system; and
(2) attempt to census the population migrating by Cape Lisburne.

Four researchers arrived at Cape Lisburne on 1 April. During the first week a camp was established by digging snow caves near the western-most bluffs of the Cape. The snow caves provided adequate shelter until early May, when an early thaw made it imperative to use tents. Systematic watch efforts began 2 April but were intermittent until the camp was completely established on 10 April. Observations were made from four sites at different altitudes, depending upon the height of the cloud ceiling. Behavior of whales was especially easy to observe from the 280 m high bluffs which overlook nearly continuously open waters. A watch is still in effect as of 30 May, and is expected to continue into mid-June.

Between 2 April and 24 May, 541 hours of systematic watch were conducted of which 339 were in good to excellent visibility (Fig. 6). Poor weather was generally the limiting factor. Temperatures as low as −26°C were recorded and winds frequently rose above 60 knots in exposed areas. Low clouds and high winds prevented work 32% of the time and fog occluded parts of the open leads 54% of the time. Initially six hours were not watched each night due to darkness, but by 10 May a 24-hour watch was attempted.

For 16 days after the initial watch effort began no bowhead whales were observed. A tentative bowhead sighting was made on 14 April but we feel that it may be in error due to observer inexperience. On 18 April a significant number of bowhead whales was observed, leaving us with the impression that 18 April was the beginning of the migration past Cape Lisburne. This "wave" of animals lasted for five days (Fig. 7). Because of a corresponding pulse of whales, the season's first occurring at the Pt Barrow ice camps three days later on 21 April (Fig. 4), it was apparent that our census camps were in position well in advance of the spring bowhead whale migration along the northwest coast of Alaska.

Excluding 37 tentative or potential duplicate sightings, 242 bowhead whales were seen (Table 3). Using only counts from good to excellent visibility conditions and calculating the number of whales passing during unobserved periods, an estimated 608 bowheads passed within our viewing range at Cape Lisburne to 29 May. The daily totals of bowhead counts through the season are graphed in Fig. 7. Due to problems with visibility during periods when counts should have been high, based on records from the Barrow ice camp, this estimate is undoubtedly low. Counts have yet to be corrected for changes in sighting ability with visibility, and for factors of partial obstruction of the lead relative to the whale corridor, for site differences, and differences between observers.

Bowhead whales generally passed Cape Lisburne on a

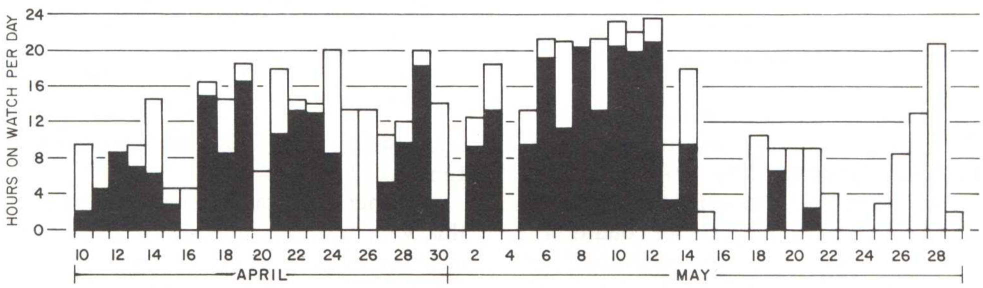

Fig. 6. Bowhead whale watch effort at Cape Lisburne, Alaska, 1978. Upper box indicates number of hours spent on watch per day; shaded area shows number of hours spent in good to excellent visibility.

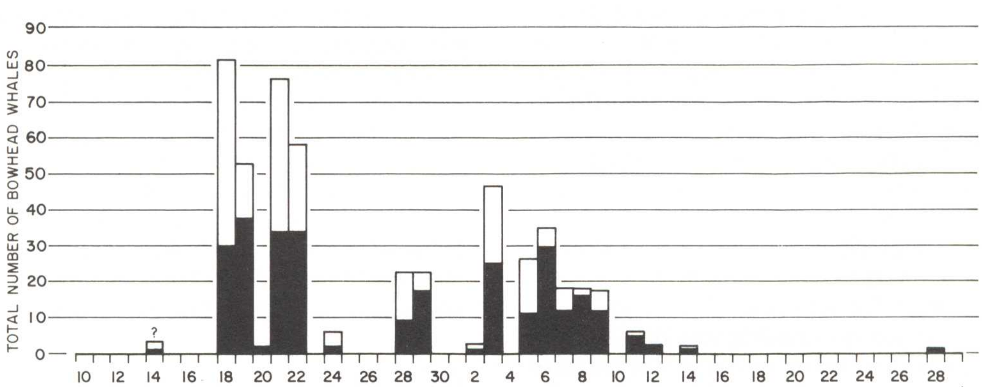

Fig. 7. Bowhead whale sightings from Cape Lisburne, Alaska, 1978. Shaded area indicates actual counts; upper box is the estimated number of whales passing that day based on only good to excellent visibility, using actual and conditional duplicate sightings.

northeasterly course. Under some lead conditions, whales passed near the fast ice, but most were seen on the offshore side of the lead close to the pack ice. The further west the far side of the lead occurred, the further west whales were seen. There were 170 bearings made on whales sighted (using a T1A theodolite). The average sighting was 4.5 km from the observers; the maximum distance was 14.8 km, which approaches the outer limit of reliable visibility under

Table 3

Summary of bowhead whale sightings at Cape Lisburne, Alaska, 1978

Date	Observation time	Good–excellent visibility time	Bowhead counts	Bowhead rate[1]	Estimated total[2]
April					
2	0:10	0	0	?	0
3	0	0	–	–	–
4	0	0	–	–	–
5	1:30	1:30	0	0.0	0
6	0	0	–	–	–
7	3:00	0	0	–	–
8	0	0	–	–	–
9	0	0	–	–	–
10	9:30	2:00	0	0.0	0
11	4:30	4:30	0	0.0	0
12	8:30	8:30	0	0.0	0
13	9:25	7:04	0	0.0	0
14	14:41	6:45	1?	0.15	3.6
15	4:27	2:58	0	0.0	0
16	14:38	0	0	0.0	0
17	16:20	14:50	0	0.0	0
18	14:45	8:20	28–29	3.48	83.5
19	18:25	16:45	31–37	2.21	53.0
20	6:44	0	2	?	64.4
21	17:50	10:45	33–34	3.16	75.8
22	14:32	13:16	32–34	2.41	57.8
23	14:00	13:00	0	0.0	0
24	20:00	8:15	2	0.24	5.8
25	13:15	0	0	?	2.9
26	13:40	0	0	?	2.9
27	10:35	5:30	0	0.0	0
28	12:00	9:35	9	0.94	22.6
29	20:20	18:15	13–17	0.93	22.3
30	14:05	3:25	0	0.0	0
May					
1	6:05	0	0	?	1.2
2	12:30	9:42	1	0.10	2.4
3	18:35	13:00	19–25	1.92	46.1
4	0	0	–	–	36.2
5	13:45	10:00	8–11	1.10	26.4
6	21:45	20:00	27–29	1.45	34.8
7	21:02	11:30	9–12	0.78	18.7
8	20:30	20:30	13–16	0.78	18.7
9	21:15	13:25	7–12	0.76	18.0
10	23:20	20:30	0	0	0.0
11	22:10	20:10	5	0.25	6.0
12	23:30	21:00	2	0.10	2.4
13	9:25	3:45	0	0.0	0
14	18:00	9:30	1	0.11	2.6
15	2:00	0	0	?	–
16	0	–	–	–	–
17	0	0	–	–	–
18	10:45	0	0	?	–
19	8:50	6:15	0	0.0	0
20	8:20	0	0	?	–
21	8:20	2:30	0	0.0	0
22	4:05	0	0	?	–
23	0	0	–	–	–
24	0	0	–	–	–
25	3:00	–	0	–	–
26	8:19	–	0	–	–
27	13:00	–	0	–	–
28	20:41	–	1	–	–
29	2:00	–	0	–	–

[1] Rate of sightings is based on counts of whales seen during good to excellent visibility conditions divided by the respective hours. All conditional duplicates and tentative sightings are included.

[2] Estimates include interpolations for days without good visibility.

excellent conditions. A frequency distribution of bearings suggests two major migration corridors, one at 2–3 km (1–2 km beyond the fast ice) and the second at 7–10 km from the observers.

Sightings made at 14 km occurred on one day. It is not known how often whales passed at this distance on other days, nor is it known how many whales travelled past Cape Lisburne more than 15 km to the west. Poor weather conditions prevailed during times when we had planned to survey beyond 15 km with an airplane.

Rates of movements based on 46 pairs of sightings were calculated using a theodolite and a hand programmed calculator: a total of 14.3 hours of observation covering 60.2 km of whale routes. The maximum time spent observing any one whale was 1 hour 58 minutes.

Bowhead whales passing Cape Lisburne travelled at a speed of 2.6 knots. The speed of whales moving between Cape Lisburne and Pt Barrow was estimated to be 1.0–3.2 knots, depending on whether one compares the 18 April peak at Cape Lisburne to the 21 April or the 28 April peaks at Pt Barrow. Because the lead was persistently open, it is felt that the 18 April/21 April data are most comparable, and that bowheads travel at a rate of 2.6–3.2 knots. Data collected during aerial surveys indicate that bowheads were travelling at about 3.0 knots.

Surface and dive times were measured on 15 bowheads, and totalled 105 minutes for 180 surfacings during 5 hr 30 min of observations. The mean at-surface-time for 101 recorded blows was 8.0 sec. During 36 breaches the mean was 5.0 sec. Mean dive time made within a blow sequence was 18.4 sec (n = 144); the median was 11 sec. Dives between blow sequences ranged from 1 min 39 sec, to over 28 min with no apparent regularity.

Sixty-five, or 23% of all bowheads sighted from Cape Lisburne, were seen breaching. As many as 39 breaches were counted in one unbroken series. On 26 occasions fluke-slapping was noted, with a maximum of 33 high slaps occurring in a single series. Synchronous breaching and fluke-slapping, with as many as four whales participating, were observed on several occasions, suggesting that these behaviors have a communicatory function. Milling and loitering, believed to be occasions for courtship and copulation, were recorded five times. Whales were seen resting at the surface five times.

Most whales were seen along common corridors, the corridors varying according to ice conditions. There seemed to be a strong tendency for the whales to follow each other even to the point of selecting common breathing sites both among scattered holes and along the far shore of the open lead.

Harvest Data and Biological Samples

The objectives of the harvest monitoring and biological sampling project were to:

(1) collect biological samples for reproductive, age and growth, and food studies; and
(2) determine catch and hunting effort expended by the Eskimos during the harvest of bowhead whales in the spring.

For the harvest monitoring activity, biologists were stationed at five whaling villages during the whaling season (Fig. 1). In each village the NMFS observers worked in close cooperation with the local AEWC representative and individual whaling captains to provide a team approach to monitoring the harvest and collecting biological samples. In addition, the biologists spent considerable time obtaining information on bowhead whale natural history and historic Eskimo whaling activity from local whaling captains, crew members, and knowledgeable elders in the villages.

The biologists visited each whaling camp as often as was possible and gathered information on the number of bowheads sighted, killed and recovered, and struck but subsequently lost. When a whale was taken, the biologists obtained morphological measurements, collected specimen materials for sex and age determination, tissue samples for chemical and biochemical analyses (e.g. for chromosomal counts, and enzyme separation of individual whales), and took photographs for later verification of individual whales.

During the 1978 spring season, two biologists were stationed at each of the following locations: Gambell and Savoonga (combined), 10 April to 15 May; Point Hope, 20 April to 29 May; Wainwright, 22 April to 23 May; and Barrow, 17 April to 30 May. Whaling activities at Kivalina were monitored by the Point Hope crew, and at Wales by the NMFS enforcement team stationed on St Lawrence Island.

Whaling activities for 1978

Residents from the seven coastal villages of Gambell and Savoonga on St Lawrence Island, and Wales, Kivalina, Point Hope, Wainwright, and Barrow were actively engaged in the 1978 spring hunt (Fig. 1). Ice conditions east of Barrow do not permit spring whaling by residents of Nuiqsut or Kaktovik, but Eskimos at these villages participate in the fall hunt in September and October, as do the Barrow whalers. The 1978 spring whaling activities are summarized in Table 4.

Gambell. Whaling began at Gambell on 14 April and ended 21 April after the quota of one bowhead was filled. Twenty-one crews were actively engaged in whaling. One whale was taken and four others were reported struck and lost.

Savoonga. Eight crews at Savoonga began whaling at 0700 hours on 16 April, and by 0845 hours had filled their quota of one whale landed. No other whales were reported struck or lost.

Wales. Three crews were actively engaged in whaling at the village of Wales, but no whale has been taken to date. Information is not available at this time on whales that may have been struck and lost.

Kivalina. Three crews were actively engaged in whaling but no whales had been taken or struck at Kivalina by 16 May. As a result of unfavorable ice conditions few whales were seen migrating within reach of the Kivalina hunters and their quota of one whale was transferred to the village of Point Hope on 16 May.

Point Hope. Fifteen crews were actively engaged in whaling at the village of Point Hope. The whaling season began 17 April and ended 4 May when the second whale was taken to complete their quota. On 16 May villagers from Kivalina transferred their quota of one whale to Point Hope in the hope that a better opportunity existed there for taking a whale during the remainder of the spring season. Point Hope Eskimos often share their whales with Kivalina villagers.

Wainwright. Although there were eight crews at Wainwright, only five were actively engaged in whaling at any one time during the season. The whaling season began 27 April and ended 19 May when the second whale had

Table 4

Bowhead whaling activities by Alaskan Eskimos, Spring 1978

Village	No. of active crews	Whaling season		NMFS/AEWC quota		Whales landed			Whales landed	Struck and lost
						Sex and length				
		Began	Ended	Landed	Struck	Female (cm)	Male (cm)	Date		
Gambell	21	14 April	21 April	1	2	–	1,383	21 April	1	4
Savoonga	8	16 April	16 April	1	2	–	1,090	16 April	1	0
Wales[1]	3	–	–	1	2	0	0	–	0	0
Kivalina[2]	3	26 April	16 May	1	2	0	0	–	0	0
Point Hope	15	17 April	–[3]	2	2	930	–	2 May	2	0
							970	4 May		
Wainwright	5	27 April	19 May	2	2	1,630[4]	–	6 May	2	0
						–	1,516	19 May		
Barrow	27[6]	17 April	3 May	3	4	851	–	1 May	4	1
						–	840	2 May		
						–	838[5]	2 May		
						–	975[5]	3 May		
Totals	82			11	16				10	5

[1] Unused quota reverts to Nuiqsut.
[2] Whaling quota transferred to Point Hope on 16 May.
[3] Whaling still active as of 30 May.
[4] An embryo 37 cm in length found in whale.
[5] Designated as an *ingutuk* by the Eskimos.
[6] Registered with the AEWC.

been taken, filling the quota. A female, pregnant with a 37 cm (14.5 inches) fetus, was taken on 6 May.

Barrow. The whaling season began on 17 April and ended on 5 May at Barrow. A total of 27 whaling captains had registered for whaling this spring. Barrow generally has had as many as 36 crews out in a single spring season. Although the village of Barrow had been allotted three whales, or four whales struck, four whales were landed of which 2 were designated as *ingutuks* by the whalers.

As of 30 May 10 bowhead whales were harvested by 82 whaling crews in five villages. This means that an autumn hunt for the remaining two whales will be conducted by the villages of Nuiqsut and Kaktovik.

Whales struck and lost

Although it was not possible for NMFS enforcement agents to monitor activities of the whaling crews while hunting was in progress (radio communication between crews was invariably in the Eskimo language), the Eskimo Reporting Officers or local AEWC Representatives were most helpful in reconstructing events once the hunters returned. Consequently, as in past seasons, data on struck and lost whales were obtained primarily from statements made by the whalers. In some cases, these were corroborated by entries in AEWC/NMFS Whaling Captain's Logbooks.

Five whales were reported as struck and lost during the spring hunt (Table 4). This number is low compared with those struck and lost during the spring hunts of previous years (Marquette, 1977):

Year	No. lost	No. crews
1973	10	45
1974	27	46
1975	26	75
1976	35	63
1977	79	90

Although much better information concerning the exact nature of strikes in unretrieved whales would be desirable, we have good confidence in the tally of strikes as recorded. The probable reasons for the low struck and lost record this year were:

(1) an average whaling period of about 15 days for 1978 as opposed to 35–40 days during 1974–77;
(2) increased concern by whalers and close adherence to the AEWC regulations; and
(3) weapon improvements (see Appendix).

The fate of unretrieved whales is unknown. That a whale has been struck and lost does not necessarily imply that it has been fatally injured. Of particular import may be the fact that some bombs fired into whales fail to explode. Table 5 indicates that of 26 bombs used to successfully land five whales, ten, or 38%, failed. The likelihood of survival by a struck and lost whale would be improved if a bomb failed to explode within it. However, it must be noted that evidence of previous strikes, e.g. old imbedded bombs or harpoons, has not been found since NMFS began monitoring the harvest.

Table 5

Bomb failures recorded for five whales landed during the spring 1978 bowhead whale hunt; data are not available for the remaining five whales landed

Whale identification[1]	Number of bombs used	Number which failed
78B1	2	1
78B3	4	2
78WW1	6	0
78WW2	5	3[2]
78G1	9	4
Totals	26	10

[1] Specimen numbering code: 78 (year); letter (village); number (order taken that year).
[2] Presumed failures.

Table 6 summarizes the circumstances under which three whales were struck and lost. This information was obtained from the AEWC/NMFS Whaling Captain's Logbooks. Unfortunately, similar data were not available for the fourth whale lost at Gambell, nor for the whale lost at Barrow. After evaluating the comments in the table, one might conjecture that the third whale could have survived after being struck.

Table 6

Circumstances under which three bowhead whales were struck and lost at Gambell, St Lawrence Island, during the Spring 1978 hunt

Date	Time	Comments
19 April	1245	One bomb was used and exploded in whale; harpoon was pulled out and whale swam under ice
21 April	1420	All bombs failed but the number used was not known; whale swam under ice
21 April	2200	Whale was successfully struck, but both shell and bomb in darting gun failed, and all gear was lost as whale swam under ice

Table 7 provides limited evidence that struck and lost whales are still alive shortly after an encounter. Unfortunately, these whales were struck at an unknown time and place, so it is impossible to estimate how long the whales survived.

Table 7

Sightings of struck and lost bowhead whales by NMFS research personnel during the Spring 1978 hunt

Date	Location	Observer	Comment
3 May	Off Pt Barrow	AEWC ice camp observer	Whale towing float; swimming slowly
5 May	46 km S. of Wainwright	Aerial survey observer (1 sighting)	Whale trailing long line
12 May	42 km NE of Barrow	Aerial survey crew (2 sightings)	Whale trailing yellow line without float

The above data are admittedly limited and conjectural. The nature of the wounds typically inflicted by harpoons and bombs is a persuasive reason to consider all struck whales as mortalities until such time as more information may allow modification of this view.

Biological samples

All biological samples collected from whales taken this year are summarized in Table 8. Biological samples from 11 whales have been sent to six cooperating scientists for purposes of establishing normal histology; pathology; chromosome and genetics studies; comparative cetacean blood protein chemistry; and enzyme studies on stock discreteness (Table 9).

A chromosome count on one whale (No. 78B4) that had been designated as an *ingutuk* was 2n = 42. Bowhead whales characteristically have a 2n = 42 count (Gordon Jarrell, Univ. Alaska, pers. commn). Other baleen whales studied, excluding right whales, which have not been tested, have a chromosome count of 2n = 44.

Additional tissue analyses will be conducted to assess stock discreteness, and to determine whether character homogeneity is high in this population. Baleen, eyes and ear plugs will be analyzed at a later data for use in aging individual whales.

Acoustics and Sonar Feasibility Study

Passive sonar (acoustics)

In order to assess the feasibility of using passive sonar as a censusing technique, underwater recordings were made during the peak of the bowhead migration past the Pt Barrow ice camp counting stations. The objectives of this study were to:

(1) determine whether bowheads vocalize during migration, and if so, the regularity of vocalization; and
(2) familiarize ourselves with the special technical and logistical problems inherent in doing underwater acoustic work in the Arctic.

Between 9–19 May 1978, twenty-seven 15-minute tape recordings were made at North Camp, where visual counting was in progress. Recordings were made on a Uher model 4400 tape recorder. The omni-directional KSP Industries hydrophone was suspended at a depth of 10 meters through a hole drilled in the ice approximately 50 meters back from the edge of the lead. As whales passed through the lead, ice camp observers reported to the acoustic recording crew the estimated range, direction, species (bowhead, beluga, or both) and the number of animals under observation at the time.

A preliminary study of the tapes indicates that vocalizations assumed to be bowhead were recorded over 60% of the time bowheads were observed passing within 2,000 meters of the hydrophone. When whales observed passing within 1,000 meters of the hydrophone are considered, the percentage of bowhead vocalizations heard increased to approximately 80%.

The tentative identification of the sounds was based on the fact that bowhead whales were present, and on the close resemblance of the sounds recorded at Pt Barrow to sounds of right whales (*Balaena glacialis*). The bowhead sounds were of low amplitude and tended to be obscured by the louder, more-or-less continuous vocalizations of ice seals (especially the bearded seal, *Erignathus barbatus*).

Since we cannot at this time differentiate between individuals on the basis of differing "voices", we were unable to tell whether more than one whale was heard during any of the numerous instances when pairs or groups of whales were seen passing. Nevertheless, bowheads passing Pt Barrow at the peak of the 1978 spring migration did vocalize frequently.

Determination of the proportion and range of variability of vocalizing versus non-vocalizing whales would require, in addition to a larger sample size, an array of hydrophones placed in the lead and a more complex receiving and signal processing system. The technology for such a system is already well developed for military use. Adapting it for whale censusing under Arctic environmental conditions may prove to be cost-prohibitive; however, the array technique will be investigated and tested in summer 1978 for use as a monitoring system in 1979.

Active sonar

To assess the feasibility of active sonar as a bowhead censusing technique, a Wesmar model SS230 scanning sonar device was tested at Pt Barrow during the 1978 spring migration. Agencies participating in the experiment were

Table 8

Biological features of bowhead whales taken during Spring 1978, and specimen samples collected

Date	16 April	21 April	1 May	2 May	2 May	2 May	3 May	4 May	6 May	19 May
Length, cm	1,090	1,383	851	840	838[2]	930	975[2]	970	1,630	1,516
Sex	M	M	F	M	M	F	M	M	F	M
Specimen no. and samples	78S1[1]	78G1	78B1	78B2	78B3	78H1	78B4	78H2	78WW1	78WW2
Baleen	4	6	4		3	1	6	1	4	5
Eyes	2	2	1	1	1	1	2	1	1	2
Ear: plugs		2					1		1	
glove finger		2	1				1		1	
ossicles		2	2				1		1	1
bullae		2								
Ovaries						2			2	
Ectoparasites	1								1	1
Hair									1	1
Stomach contents	1									
Blood			1		1		1			1
Urine				1						
Cartilage					1					
Mandible				1	1		1			1
Rib			1[3]		1[3]					
Vertebrae					1		1			1
Histological tissue:										
Skin			1[3]	1	1[3]	1	1	1	1	1
Blubber		1	1[3]		1[3]					
Liver	1		1	1	1	1	1	1		1
Lung	1		1	1		1	1	1		1
Kidney	1			1	1	1	1	1	1	1
Heart	1			1	1	1	1	1		
Testes	1			1			1			1
Stomach							1			
Spleen							1	1		
Vagina									1	
Penis	1									1
Intestine, small						1		1		1
Intestine, large							1			1
Mammary									1	
Umbilicus									1	
Diaphragm					1	1				1
Bladder				1						
Muscle			1[3]		1[3]		1[3]			1
Tongue										1
E.M. tissue:[4]										
Liver			1				1			1
Heart							1			
Lung							1			
Muscle										1
PCB tissue:[5]										
Liver			1	1	1	1	1	1		1
Blubber	1		1	1	1	1	1	1	1	1
Kidney						1		1		
Mesentary					1					
Karyotype tissue:										
Skin							1			
Lung							1			

[1] Specimen numbering code: 78 (year); Letter (village); Number (order taken that year).
[2] Whales designated as *ingutuk* by the Eskimos.
[3] Collected and donated to NMFS by Mayor E. Hopson.
[4] Electron microscopy.
[5] Polychlorinated biphenyl analyses.

Table 9

Biological samples from 11 bowhead whales taken in 1977 and 1978 sent to six cooperating scientists

	Samples sent[1]					
Bowhead whale number	Blood	Eyes	Liver, lung, skin, misc.	Intestines	Urine and urogen. system	Follicular fluid
77B7			√			
77B9			√			
77B19			√			
78B1	√	√				
78B2			√		√	
78B3[2]	√		√			
78B4[2]	√	√	√			
78H1						
78H2						
78WW1						√
78WW2	√			√		

[1] One tissue sample of each specimen collected in 1978 sent to University of Pennsylvania School of Veterinary Medicine.
[2] Reported to be an *ingutuk* by AEWC.

the Naval Arctic Research Laboratory, Alaska Department of Fish & Game, and the National Marine Fisheries Service.

The 60 kHz instrument was installed intermittently at North Camp, with the soundome suspended at a depth of 5 meters through a hole drilled in the ice, approximately 50 meters from the edge of the lead. Due to a variety of problems, actual operation time by the NARL Bioacoustics Group totaled less than 5 hours during the 3 weeks NMFS representatives were on hand to assist them. Several targets appeared on the cathode ray tube display while whales were passing within range of the instrument (1500 meters), and some were interpreted by the operators to be whales. But all attempts to track targets, even for a few seconds (which would have provided a measure of verification), proved unsuccessful.

The Wesmar system was selected for compactness (which allows it to be quickly removed from the ice when necessary), a low power requirement, and relatively low cost. It did not receive an adequate trial in the 1978 season and will be tested further in 1979, but initial results were not encouraging.

Acoustic tag

A whale tracking feasibility test was attempted this year with the objective of helping the Alaskan Eskimos reduce their struck and lost rates when harvesting bowheads. At the beginning of the season two Eskimo whaling crews at Barrow were equipped with four 30 kHz transmitter tags to be attached to their harpoon float lines. Portable receivers and directional hydrophones for use in umiaks were also provided and crews were instructed in the use of the equipment. The test was intended to determine whether the crews could track a struck, tagged animal and thereby effect the capture of a whale that might otherwise escape.

Since the Barrow quota was three whales and nearly 30 crews were on the ice, we did not expect that any of the tags would actually be attached to whales. However, two were, but in the urgency of going after the whales neither crew switched on the transmitters. Fortunately, both whales were captured.

Although results were not conclusive, participating crews were enthusiastic over the potential usefulness of the equipment and expressed hope that the tests would be repeated next year.

SUMMARY AND CONCLUSIONS

1. No bowhead whales are believed to have migrated past our census camps before the camps became operational. The beginning of the migration past Cape Lisburne was 18 April. The subsequent first arrival of bowheads at Pt Barrow was on 21 April, 3 days later. the distance and time needed to travel fits our estimates of an individual whale's travelling speed of approximately 3.0 knots.
2. Our best estimate of the number of bowhead whales in that segment of the population passing Pt Barrow, Alaska, between 15 April and 30 May using data from the Pt Barrow ice camp census study is 2,264. This estimate is corrected for total observation time (87.6% of the total time during the season), duplicate sightings, and validation of whales believed to have been missed. The absolute lower end of the estimate is 1,783 animals, and the upper end 2,865.
3. No bowhead whales were seen in offshore leads in the Chukchi Sea between Pt Barrow and Point Hope, even though a similar aerial survey effort took place nearshore (54.6%) and offshore (45.4%). The migration of the western Arctic population of bowhead whales occurred in the nearshore leads along the northwest coast of Alaska to Pt Barrow. It appeared that the entire population migrating during the spring 1978 was available for counting by the ice camp census teams.
4. Correlated observations between the aerial survey and ice camp census teams indicated that both methods were sampling animals from the same population (i.e. sample universe). Preliminary results suggest that the two counting methods verified individual whale sight-

ings. This means that if a bowhead was present it was highly probable that the ice camp census teams counted it.

5. The 1978 population index is based on the combined effort of the NMFS whale counting camps, the AEWC camp and Eskimo whalers. The percent effort to the index attributable to each group was: South Camp, 91.4%; North Camp, 0.1% (adjustments reflected in the South percent effort); AEWC Camp, 2.4%; and Eskimo whalers, 6.1%.
6. The census index for 1978 was higher than for 1976 and 1977 because of the following, and perhaps other, reasons:

   a. The observation effort in number of days was more than twice as great in 1978 as in either 1976 or 1977.
   b. The person/hours of watch in 1978 was four times as great, or five times as great if the AEWC Camp is considered, as for 1976 or 1977.
   c. The nearshore lead was open essentially the entire season.
   d. Wind and fog were less of a problem than in past years.
   e. The lead was characteristically open 3–6 km (2–4 miles) most of the season, allowing for continued observation across the lead.
   f. The 1978 census camps were located farther north than the 1976–77 camps, and at a place where the lead is narrower, thus increasing the chances of viewing the entire lead.
   g. Shorter watch hours, greater rotation of observers, and an additional year of experience probably accounted for less bias associated with observer effectiveness.
   h. Less whaling activity in 1978 near Barrow along the edge of the nearshore lead may have resulted in fewer whales moving further away from the fast ice.
   i. The observation point and camp, north of Pt Barrow on grounded sea ice, was a much more stable platform than ever before, reducing the need to move away from the lead when ice conditions were not safe.
   j. The viewing platform (perches on top of second year grounded ice) this year was higher than in 1976–77 allowing us to look farther across the lead.

7. Our hypothesis proposed in 1976 that beyond Pt Barrow bowhead whales migrate offshore through the Beaufort Sea to northwest of Banks Island, Canada, in the spring was corroborated. That segment of the population which migrates in the nearshore lead along the northwest coast of Alaska does not appear to head west into the Chukchi Sea, but rather north and east into the Beaufort Sea.
8. The location of bowhead whales in the winter and early spring remains unknown. Presumably they occur in the southwest Bering Sea near the ice front from the Pribilof Islands to the coast of the USSR.
9. Bowhead whale "vocalizations" (i.e. sounds) were successfully recorded. This preliminary study has shown that some whales can be detected while moving by the ice camps, and that acoustics may be a possible tool in future counting plans. Active sonar did not prove useful this year owing to the limited capability and availability of the system used.
10. Ten bowhead whales have been landed as of 30 May 1978. Additionally, five whales were reported to have been struck but lost. Without corroborating evidence it was assumed that all five whales perished. The number of struck and lost was significantly lower this year than in past years, probably owing to the short whaling period, increased hunter efficiency, and less mechanical failure of the weaponry.
11. The chromosome number of one bowhead whale taken this year (No. 78B4, a reported *ingutuk*) was 2n = 42. This fits the known chromosome count for bowhead whales, but is different than the 2n = 44 for other baleen whales (i.e. other than the right whale, which has not been studied).
12. Eighteen (18) young of the year calves were seen by the South Camp observers between 25 April–24 May. This count is 1.3% of the total count at South Camp (1,389) for the period 15 April–30 May. Through simple extrapolation for the mean Combined South Camp Index (2,264), it is estimated that at least 29 calves may have been added to the population this year. Several factors suggest that this is an underestimate.

ACKNOWLEDGEMENTS

We wish to express our gratitude to members of the Alaska Eskimo Whaling Commission for their cooperative support during the development of our research plan and their subsequent participation in this year's spring research. Mr Jacob Adams (AEWC President), Mr Arnold Brower, Sr (Barrow Boat Captains' Association President), and Dale Stotts (Environmental Coordinator), played particularly pivotal roles in insuring that the research plans were appropriately staged and coordinated during the initial stages of field activities. Staff support personnel at the Naval Arctic Research Laboratory were helpful in providing the often complicated logistic support needed for a successful operation. The U.S. Air Force Station at Lisburne served as a base camp for intermittent retreats and for camp staging of our Cape Lisburne observation post. Aircraft charters were arranged through Office of Aircraft Services, Anchorage, the Naval Arctic Research Laboratory, Barrow, and Cape Smyth Air Service, Barrow. Finally, we wish to thank the men, women, and children of the Eskimo villages that housed us this spring (Barrow, Wainwright, Point Hope, Gambell, and Savoonga) for their kindness and interest in our work. It is not easy to accept outsiders into your villages, especially during difficult times such as those of this past year, yet on the whole we were accepted graciously.

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Appendix

REPORT TO THE IWC REGARDING EFFORTS OF THE UNITED STATES TO IMPROVE THE EFFICIENCY OF METHODS UTILIZED IN THE ABORIGINAL HARVEST OF BOWHEAD WHALES

During the latter portion of the 19th Century, commercial whalers operating in the Bering and Chukchi Seas introduced explosive killing devices to Eskimos who hunted bowhead whales for subsistence purposes. The manufacture and use of these devices has remained essentially unchanged during the 20th Century. The devices used consist of a hand-thrown "darting gun" which implants a harpoon in the whale, the impact of which triggers a charge that propels an explosive "bomb" but does not implant a harpoon. Use of the darting gun requires that the hunters approach the whale at close range. The shoulder gun may be fired from any distance within the range of the gun. The explosion of the bomb inside the whale is intended to be the killing method.

Both the darting gun and shoulder gun are manufactured by a single company in Doylestown, Pennsylvania by a small family enterprise which has been passed from father to son during this century. Prior to 1977 there had been no direct contact between the hunters who utilize the devices and the manufacturer. After the manufacturer ships the devices to the North Slope of Alaska, the hunters load the weapons according to instructions included with the devices and based upon their own experience or preference and also make select modifications to both guns and bombs to suit their preferences and methods of hunting. Following the 1977 harvest when information collected through interview with Eskimo hunters indicated that as many as 77 strikes may have occurred which did not result in the landing of a whale, and in response to the concern of the IWC, the National Marine Fisheries Service (NMFS) arranged for meetings between the manufacturer and representatives of the Alaska Eskimo Whaling Commission (AEWC).

In a meeting held 14 October 1977, in Washington, D.C., Eskimo hunters and the manufacturer compared notes and information on the use and manufacture of the devices, resulting in several suggested changes. Subsequent to that meeting, the U.S. Government contracted with the manufacturer to modify a darting gun and shoulder gun incorporating the changes that had been discussed. When the modifications were completed, the manufacturer travelled to the North Slope of Alaska and visited several whaling villages to demonstrate the modifications and consult with the hunters regarding the hand loading of both the propellant charges and explosive charges which had reportedly caused several "misfires" and resulted in whales being struck and lost in the past. As a result of this cooperative effort, further modifications to the devices are being made by the manufacturer and it is expected that a less wasteful manner of taking will result.

In conjunction with this effort, regulations were promulgated by the AEWC which required that whales may be struck with a harpoon or darting gun with line and float attached or simultaneously with a harpoon and shoulder or darting gun. The purpose of the Eskimo whaling regulations is to avoid "long range" attempts with the shoulder gun which were reportedly the cause of many whales being struck and lost in the past.

Some of the changes to the guns and bombs which already have been effected are:

1. the barrel of the guns has been manufactured of bronze instead of steel, reducing the problem of rust interfering with proper discharge and travel of the bombs;
2. the weight of both guns has been reduced to facilitate ease of handling;
3. hot rolled steel has been used in the harpoon shaft to improve flexibility and reduce the likelihood of the harpoon dislodging itself from the whale;
4. the bottom surface of the toggle head of the harpoon has been widened to provide for better retention once it has been implanted in the whale;
5. the point on the bombs has been made shorter and blunter to provide for more certain penetration, reducing the possibility of misplacement or "glancing" effect;
6. the barrels have been shortened to allow a visual check as to whether the bomb is properly seated before firing, a reason cited for under-firing and misfires;
7. loading procedures have been thoroughly reviewed with the hunters to assure proper and safe firing of the explosive charges; and
8. the NMFS has begun investigations to determine if a more suitable explosive powder can be utilized. The standard black powder is highly susceptible to moisture, causing misfires. Also, black powder is much less explosive than some of the newer powders. The safety of the hunters is a paramount consideration in this investigation.

SC/30/Doc 41

Comments on Magnitude of Early Catch of East Pacific Gray Whale *(Eschrichtius robustus)*

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ABSTRACT

Currently accepted estimates of the magnitude of the early, sailing vessel, commercial catch and kill of gray whales, and the early, shore-based, aboriginal catch and kill, are subject to much interpretation. Existing estimates of total kill for the period of peak catch, and of population size at the beginning of the period of historical whaling have not adequately taken into account known substantial removals by aboriginals from at least the 1700s to the early 1920s. The "virgin" population size was probably larger than currently estimated, and the "initial" population level, at the beginning of commercial exploitation in 1846, may have been below the "virgin" level.

INTRODUCTION

The gray whale *Eschrichtius robustus* (Fig. 1) is the only living species of the family Eschrichtiidae, and now survives in only two North Pacific populations. Two populations probably occurred in the North Atlantic up to historic times, but they are now extinct (Mitchell, 1974). Their extinction may have been affected by commercial whaling (Mitchell and Mead, 1977).

The western North Pacific population, the Asian or "Korean" stock, has had its center of abundance off the Asian coast, migrating from winter calving grounds off Korea (Andrews, 1914) and in the Seto Inland Sea, off Japan (Omura, 1974), to summer feeding grounds in the Okhotsk Sea (Krasheninnikov, 1754).

The eastern North Pacific population, the "California" stock, migrates from winter calving grounds in lagoons along the coast of Baja California (Scammon, 1874) and mainland Mexico (Gilmore and Ewing, 1954) to summer feeding grounds in the Bering Sea and adjacent waters of the Arctic Ocean (Gilmore, 1960; Maher, 1960) and the northwest coast (Pike, 1962).

Although the migration is mainly along shore, on the Continental Shelf, a substantial portion of the route may run off shore from about the latitude of the Aleutian Island chain across the Gulf of Alaska to British Columbia, on the fall or southern migration. Recent counts (Hall *et al.*, 1977) show that up to 9,000 whales, apparently most of the eastern population, pass along the coast from Cape St Elias to Unimak Pass. Accordingly, some of the migration route takes this species more than 200 miles off shore, placing it outside the jurisdiction of coastal states at that time and place.

Some population assessments have been made, and monitoring of current population abundance by direct counts has been of long standing interest (Gilmore, 1960; Hubbs and Hubbs, 1967). In addition to early, commercial whaling carried out by a fleet of sailing vessels by shore whalers, and subsequent mechanised pelagic whaling the eastern population has been subjected to a long history of aboriginal whaling by residents of the Siberian peninsula. St Lawrence Island, Aleutian Islands and the Pacific Northwest coast. In carrying out assessments of the population, both the commercial removals and the aboriginal catch must be considered (Ohsumi, 1976).

In this paper, on the eastern stock, I comment on the magnitude of the estimated early commercial catch and its struck-but-lost rates in the pelagic sailing vessel fishery, the magnitude of the early aboriginal catch and its struck-but-lost rate along the shores bordering the migration route of of the eastern stock, and whether the carrying capacity of the gray whale's environment has changed.

ASSESSMENTS OF EAST PACIFIC POPULATION

Estimates of current size, based mainly on sighting surveys from shore, were well summarised by Rice and Wolman (1971). They concluded that recovery to a level of about 11,000 occurred by 1969–1970.

The first estimate of the initial size of the East Pacific population was that of Scammon (1874, p. 23n), who estimated the gray whale population as "probably not over 30,000" between 1853–1856, declining to 8,000–10,000 by 1874. Henderson (1972) examined commercial production statistics, and estimated landed catch from these by means of oil conversions. He also adjusted this for a struck-but-lost (and moribund) rate of 0.10 for the component taken in the lagoons and near shore on the coast, and 0.20 for the component taken off shore. He evaluated the magnitude of the estimated removals relative to the contemporary estimates of abundance, and concluded that the initial population of eastern grays, "when pursuit began in 1846, was closer to fifteen or twenty thousand than to thirty or forty thousand" (1972, p. 185). Rice (1975) reviewed population assessments, and accepted the pre-1846 stock level as no more than 15,000 animals. Ohsumi (1976) carried out calculations to assess the initial stock size of the eastern population. Using commercial catch data generated by Henderson (1972), Townsend (1886), and Rice and Wolman (1971), and aboriginal catch data from VNIRO and Rice (1975), Ohsumi used a population model where catch statistics and the population size and its relative level in a given year are known or assumed. He examined four series of calculations:

"Case 1. Forward calculation based on assumptions that population size was 14,900 and had remained [at] its virginal level in 1846, and that aboriginal hunting has been negligible before 1965.

Case 2. Backward calculation based on assumptions that population size was 11,000 and it was 74% of the virginal population level in 1965, and that aboriginal hunting was negligible before 1965.

[1] Supported by Center for Environmental Education, Washington, D.C.; submitted to IWC Scientific Committee, June 1978, Cambridge, England, reviewed and revised subsequently.

Case 3. Forward calculation based on assumptions that the population level had already [been] reduced by the American whaling started in 1846, and aborigines have taken 1.5% of population size in each year. In this case, population size in 1846 was estimated to be 11,600, and it had been stable before that year.

Case 4. Backward calculation based on assumptions that the population size was 11,000 and 74% of the virginal level in 1965, and that the rate of exploitation by aboriginal hunting has been 1.5% in each year"
(Ohsumi, 1976, p. 356).

Ohsumi concluded that Cases 1 and 2 were not tenable: that Cases 3 and 4 were realistic: and that the original, virginal population size was "somewhat larger than 15,000" but was reduced by aboriginal hunting to 11,600 by 1846 at the beginning of commercial whaling. The low was 4,400 in 1875, with subsequent recovery to 11,000 and "stability" in the early 1960s. He also concluded that the present sustainable yield is 194, i.e. 1.76%, from the stock of 11,000.

Accepting the argument that the carrying capacity of the environment for this stock has changed, Ohsumi also stated that the "potential virginal population size from the present carrying capacity of this stock is estimated to be 14,900", and that MSY would be 250 at 57% of this level, i.e. 2.94%. He considered the present population to be 30% higher than the level for maximum sustainable yield. Ohsumi's (1976) assessment clearly depends heavily on the documented catch history, both commercial and aboriginal. The present level of removals by the USSR on behalf of Siberian aborigines (average = 162 per annum, 1965–1976) is 83.5% of the sustainable yield of 194 from the present population calculated by Ohsumi. In making the argument that an MSY of 250 at 57% of the present, "potential virginal" maximum stock size of 14,900 could be removed, but also assuming that the original virginal population was "somewhat larger than 15,000", and that the population "grew to become stable from early 1960s", Ohsumi has also based his argument on the view that the carrying capacity of the environment of the eastern stock has diminished.

ASSUMPTIONS

I herein examine the following assumptions for the east Pacific population, taken from explicit statements or implicit in the assessments of Ohsumi (1976):

1. The level of early commercial catch and kill (total removals) was as estimated by Henderson (1972).
2. The level of early aboriginal catch and kill (total removals) was as estimated by Ohsumi (1976).
3. The carrying capacity of the winter calving and breeding grounds, the migration route, and/or the summer feeding grounds, has changed: and the change is in the direction of reducing the number of gray whales that could exist in the absence of exploitation.

Examination of Assumptions

1. The level of early commercial catch and kill (total removals) was as estimated by Henderson (1972):

Henderson's (1970; 1972) historical examination of the history of exploitation is exhaustive for the eastern Pacific gray whale during its southward migration. He constructed an approximation of the catch history by applying an oil conversion of 35 bbls per whale to the production statistics from the *Whalemen's Shipping List and Merchants' Transcript* (New Bedford) and archival records, applied loss rates to the resulting estimation of catch, and reconstructed the catch history. His use of an adult whale oil yield of 35 bbls appears reasonable, based upon contemporary accounts and known yield. The oil yield might have changed through time but this change was not considered because of the crudity of the data. The loss rates used by Henderson (1972, p. 260) were 0.20 of landed catch for "shore whalers" (Scammon, 1874, p. 251) and 0.10 for "lagoon and along-shore whalers in vessels". Henderson believed that the struck-but-lost rate would be less in lagoon whaling, because the carcasses would more often be retrieved, or the whales would not be able to swim so far.

I suspect that the loss rates used by Henderson are too low, for the following reasons. The gray whale was called the "Devilfish" with similar names in Siberian, Russian and Japanese, precisely because it was unpredictable, likely to turn on a boat once struck, and difficult to kill. Some contemporary accounts mention higher struck-but-lost rates (e.g. 0.20, Scammon, 1874, p. 251). However, in the absence of better data, Henderson's figures are acceptable as the minimum rates.

In conclusion Henderson's oil conversion unit, struck-but-lost rates, and resulting estimated catch, appear to be reasonable approximations of the fishery based on the published data. I consider that assumption 1 is reasonable.

2. The level of early aboriginal catch and kill (total removals) was that as estimated by Ohsumi (1976):

Ohsumi (1976, p. 355) cites data for aboriginal catches from the eastern North Pacific population, from VNIRO records and Rice (1975). Ohsumi stated:

"Recent catch of gray whales by aboriginal hunting is

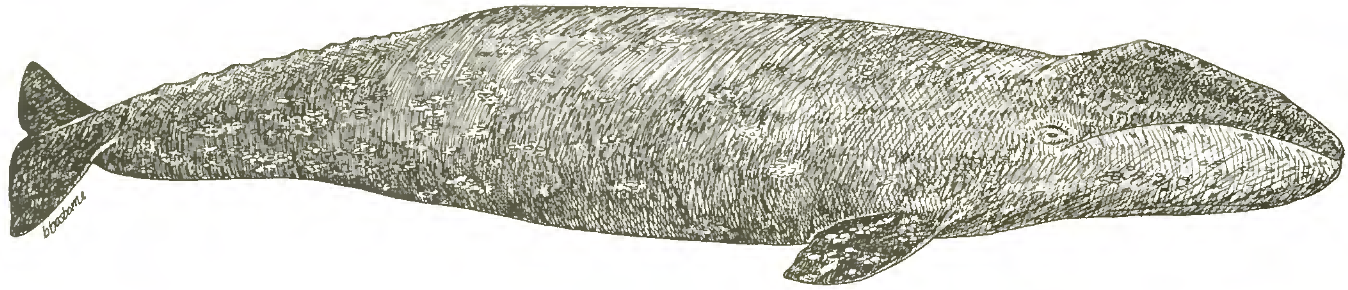

Fig. 1. California gray whale *Eschrichtius robustus*. Drawing by B. Osborne, from Mitchell (1973).

165 annually in average (Rice, 1975). This is 1.5% of the present population size. . . . I assume in this study that the aboriginal rate of exploitation has been constant to be 1.5% throughout the years"
(Ohsumi, 1976, p. 355–6).

By this calculation, even at a maximum population size of "somewhat larger than 15,000", Ohsumi would estimate catch by aboriginals at approximately 225 per year (even though extrapolating past aboriginal catches from current takes by a modern catcher boat may not be valid).

I have reservations on this point. I believe that the published evidence, below, is sufficient to indicate that the aboriginal catch and struck-but-lost rates, for the late 18th and the 19th centuries, were high and that the removals by aboriginals before, and during, the peak commercial catch could be several times as large as Ohsumi estimated. This suggests that the initial population size was larger than indicated by Ohsumi's model.

The following peoples may have carried out local, subsistence or other fisheries for cetaceans in the area of the migration route of the eastern Pacific gray whale (cf. Scammon, 1869, p. 38). These are from west to east, and north to south:

Chukchi	Haida
Koryak	Kwakiutl
Kamchadal	Nootka-Makah
Inuit	Clallam
Aleut	Quileute
Koniag	Quinault
Chugach	Tillamook (Coast Salish)
Tlingit	Chinook
Tsimshian	Oregon Indians
	California Indians

I surveyed most of the literature that Heizer (1968, p. 346) indexed for the North Pacific Coast, and a few other references, but make no claim for completeness of this survey. It is apparent that there is a substantial literature on this subject that needs to be brought to the attention of cetologists.

Chukchi – Steller (1774, p. 101) described Chukchee or Tschuktschi whalers, who "catch whales in great quantity, from the mouth of the Anadyr River down to the farthest cape [Cape Navarin?], approach nearest the European method of capture". Bogoras (1904–9, pt 1, p. 124) and Aldrich (1889, p. 56–7) also describe Chukchi whaling. This catch was mainly gray whales; the present catch has averaged about 165 per annum, 1965–1976 (Wolman and Rice, 1979; Rice and Wolman, 1971). Ohsumi (1976) assumed that early catch levels were of the same magnitude.

Koryak – The Koryak were whalers, and hunted with technology similar to that of the Chukchi, and caught gray whales. They also took whales with nets (Tooke, 1801).

Kamchadal – The native inhabitants of Kamchatka were not a major whaling group. Krasheninnikov (1754, p. 141) describes sickness resulting from eating a drift whale, that might be symptomatic of aconite poisoning (Heizer, 1938a, p. 441). The southern Kamchadals might have practised a poison fishery (Heizer, 1938a).

Inuit – The Inuit of the Bering Sea–Chukchi Sea–Beaufort Sea region have long hunted gray whales (Scammon, 1869, p. 37) using the harpoon-line-drogue technique. Alaskan eskimos used the flesh of the gray whale for dog food, and traded the oil with interior tribes (Scammon, 1869, p. 48). There are no data on early catches (cf. Storro-Patterson, 1977, p. 47). More recent Alaskan catches (Maher, 1960; 1954–59) are in the order of 1.5 per annum. The natives of St Lawrence Island and on the Chukotskiy Peninsula hunt gray whales.

Aleut – The Aleuts pursued large whales of many species (Pinart, 1875, p. 5), mainly by use of hand-thrown spears tipped with the poison aconitum (Heizer, 1938a). Heizer's map (1938a, fig. 56, see Fig. 2) of the distribution of the aboriginals practising aconite poison whaling (see Grieve, 1962, p. 92–3; Bogoras, 1909; Jochelson, 1908; Pinart, 1875, p. 9; Heizer, 1938b; Bissett, 1976; Bancroft, 1886, p. 583) matches precisely the shorewards summer distributions of the east and west North Pacific stocks of the right whale (*Eubalaena glacialis*) and straddles the distribution of the gray whale (Fig. 1). The right whale probably was taken, although other species were clearly involved. It is important to know what percentage of the kills, and the struck-but-lost component in this fishery, were right whales, gray whales and minke whales, and whether bowheads were taken. The loss rate of whales struck was very high, approaching 0.90 to 0.95 according to some sources (e.g. loss of 19 out of 20, Elliott, 1886, p. 153). Heizer (1938a) has summarised some of these statements and records: Von Kittlitz (1858, p. 266–9), Fox Islands, Aleutians, 9 lost out of 10 struck; Veniaminov (1840, pt 2, p. 231), Aleutians, 30–60 struck per annum, 33 secured on average, sometimes only 10.

It appears that this loss may be 50% and probably higher, with an assumed high mortality in the escapement of poisoned animals. There is some question regarding the potency of aconitum (Bisset, 1976). Whether or not the drug itself or another poison or bacterial agent was introduced into the whale as a result of the elaborate practices of the Aleuts, contemporary accounts indicate that the method worked.

The juxtaposition in time of known high kills and moribund escapements in the aconite poison fishery, and the known high kills in the American gray whale fishery (Henderson, 1972) is significant. The pelagic fleet selected calves or yearlings because the epimeletic behaviour elicited enabled them to kill the cow efficiently. The aboriginals may have selected the same age category since young whales may have been easier to approach and process. Substantial high removals of young would have had great delayed effect on population abundance. I suggest that the aboriginal fishery (e.g. Heizer, 1943), especially the aconite poison component (e.g. Heizer, 1938a), may have played an unsuspectedly large role in this depletion and had a substantial impact on population levels.

Koniag – The Koniagmiut were whalers, and used the same poison-tipped lance technology as the Aleuts (Holmberg, 1855). Struck-but-lost rates were high. For one year, 1831, Von Wrangell (1839, p. 54–5) states that only 43 were recovered of 118 whales struck. There is no reason to believe that this is not typical. Mainly small whales were selected (Lisiansky, 1814). (The changing technology, resulting by 1833 in the use of European harpoons and vessels and the services of a skilled English harpooner (Von Wrangell, 1839, p. 55), may represent yet another undocumented chapter in the early exploitation of the gray whale.)

Chugach – The Chugach, on Chenega Island, Prince William Sound, S.E. Alaska, took big whales, little finners, beluga, blackfish and porpoises (Birket-Smith, 1953, p. 33). Whaling was important to them, and they took cetaceans all year long. They may have used aconite poisoning (Birket-Smith, 1953, p. 33–4).

Tlingit – The Tlingit were not a whaling people, instead they had an aversion to whale blubber or meat (MacLeod, 1925; 1929). (Only the Yakutat, the most northerly Tlingit tribe, whaled and ate whale products, MacLeod, 1929, p. 147–8.) Heizer (1938a) has suggested that this aversion stems from the high loss rate in the Koniag poison fishery centered on Kodiak Island. Dead whales might float to shore on the Northwest Coast, anywhere north of the Queen Charlotte Islands, in Tlingit country. Thus their fear of eating whale products might stem from a long history of eating poisoned whales. This cultural pattern might reflect a long history of substantial numbers of drift whales coming ashore – an idea in agreement with the loss rate of up to 0.95 in the aconite poison fishery.

Tsimshian – There is no evidence of whaling, or whale-eating, among Tsimshian Indians (MacLeod, 1925, p. 148). "For superstitious reasons the whale has never been hunted in this last named locality [Tsimshian], and the eating of whale's blubber has been prohibited to them by tradition and custom" (Niblack, 1890, p. 292).

Haida – The Haida were not major whalers, and in fact venerated the killer whale in ceremonies and symbols. The Haida did, however, prize stranded whales (MacLeod, 1929, p. 112); they scavenged stranded whales, ate the flesh and blubber, and stored the oil (Curtis, 1916, p. 131).

Kwakiutl – The Kwakiutl were not whalers. There is some evidence that the Hayales, an extinct tribe of Quatsino Sound, took whales (MacLeod, 1925, p. 148). There is a legend of a killer whale having been killed (Boas, 1896, p. 579); but whale meat and blubber were obtained in trade and from stranded whales (Curtis, 1915, p. 331).

Nootka-Makah – These peoples, and the Clallam, Quinault and Quileute Indians, were the chief whalers of the northwest coast (Kroeber, 1939; Heizer, 1938a; 1968; Whattam and Martin, 1976; Drucker, 1951, p. 49). The Makah gave up whaling earlier than the Quileute, before 1836 (MacLeod, 1929, p. 113). But in early days the hunt and the capture was a major part of the culture of these whalers (e.g. Roberts and Swadesh, 1955, p. 316; Sproat, 1868, p. 226–9; and Heizer, 1938a; 1968). The Nitinat took mainly gray and humpback whales (Sapir, 1924), and the gray whale was a main catch for most of the neighbouring Indian tribes.

The gray whale was the preferred quarry and the most common whale taken by Nootka whalers (Curtis, 1916, p. 18; Anon., n.d.), mainly in the Spring, during the peak of whaling (Drucker, 1951, p. 48; Swanson, 1956, p. 53). The Nootka preferred "those small [whales] with hunches on their backs, as being the most easy to kill" (Meares, 1791, p. 240), a preference deriving from the seasonality of occurrence and the role of the gray whale in the whaling complex derived from Eskimo whalers (Swanson, 1956, p. 55). The Nootka also hunted humpbacks and some killers, but not the sperm or blue whales (Drucker, 1951, p. 48–9). Also, and much less commonly, apparently the black right whale was also taken (Drucker, 1951, p. 48–9; Koppert, 1930, p. 60 for the Clayoquot, a Nootka tribe).

According to a Nootka legend, "many" whales were ten in one year for one whaler (Curtis, 1916, p. 105).

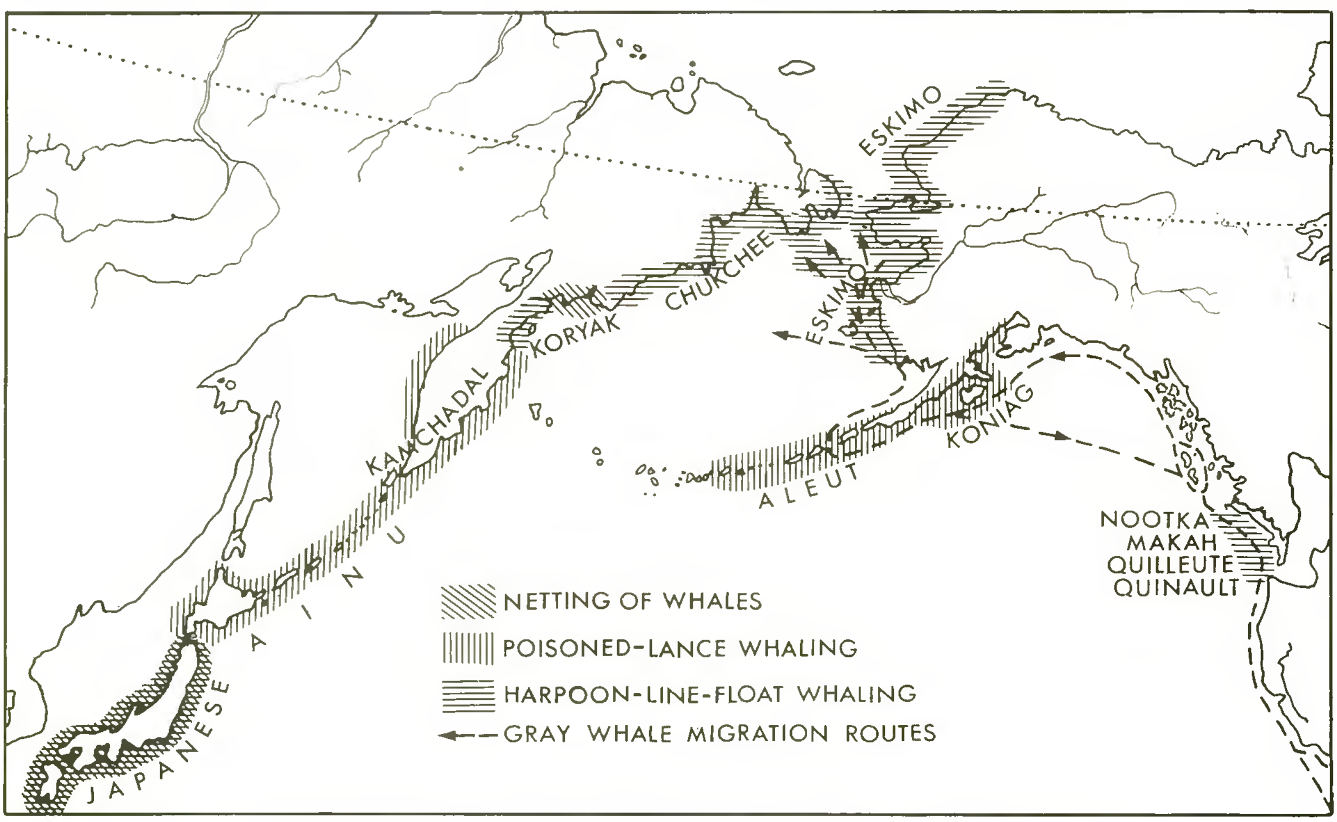

Fig. 2. Chart of the migration route of the Eastern stock of the gray whale *Eschrichtius robustus*. Details of migration from Gilmore (1960; 1978a, b), Pike (1962), Braham (1977), Hall *et al.* (1977) and others. Distribution of aboriginal peoples and hunting technology from Heizer (1938a, Fig. 56). Chart by G. Ferrand.

Only the great whalers of "ancient traditional times" took 10 whales in one season (Drucker, 1951, p. 49). Indians took "some of those enormous whales" during winter at Clayoquot (Meares, 1791, p. 203); and through 1916, the Clayoquot "recently" killed whales "in the primitive manner" (Curtis, 1916, p. 40).

Nootka whalers pursued whales "almost every day" during the Spring season, but in the season of 1802 or 1803, there was little success (Jewitt, 1849, p. 43, 108). For the two full and one partial whaling seasons of 1803–1805, Jewitt (1931, *in* Drucker, 1951, p. 50) records: Chief of Nootka village spent 53 days hunting, with 8 whales struck and lost, and one whale killed (i.e. struck-but-lost rate = 89%); and Moachat chiefs killed 4 whales, effort and lost whales not recorded. (Another Jewitt account, 1849, p. 108–9, 115, indicates that in Spring 1804, 4 whales were taken, including one struck, lost and beached, but several were harpooned and lost).

Whaling was abandoned for several generations, then in the late 19th or early 20th Century, one generation had only three whalers who took 19 whales (one whaler took 13 whales in 12 years with 2 crews: Drucker, 1951, p. 50). Of eight 20th Century Nootkan whalers two had successful careers, killing four whales but losing several more after striking (Drucker, 1951, p. 49–50). By about 1916, whaling was rarely followed by any Nootka tribe (Curtis, 1916, p. 40). About 1935–1936, Drucker spoke with an Ahousat (Nootka tribe) chief said to be the last on the coast to have killed a whale (Drucker, 1951, p. 28). The general decline of Nootka whaling coincided with the reduction of the gray whale population (Swanson, 1956, p. 52).

The gray whale was the preferred target and the species most frequently taken by the Makah (Swan, 1870, p. 19; Pinart, 1875, p. 9–10; Collins, 1892, p. 245; Waterman, 1920, p. 42). The Classet of Cape Flattery, a Makah tribe, took about 20 whales per season (Wilkes, 1845, Vol. 4, p. 487). In 1856, the Makah sold $8,000 worth of whale oil (Pettitt, 1950, p. 43).

The Makah were formerly "more successful in killing whales than they have been of late years" and it was then unknown "whether whales were more numerous" in earlier times, or the Indians were becoming indifferent to whaling (Swan, 1870, p. 22). By about 1870, they had temporarily abandoned whaling (Swan, 1870) for sealing, which they actively pursued between 1860–1890 (Waterman, 1920, p. 48). By about 1916 they revived whaling (Curtis, 1916, p. 40) and were still active about 1920 (Waterman, 1920, p. 48). One former whaler killed four whales in one year – a mark of prestige (Colson, 1953, p. 208).

Clallam – The Clallam Indians were whalers and took large whales (Gunther, 1927, p. 204) but only casually. They would only go to sea when a whale was sighted, and were not active hunters like the Makah or Nootka. They took porpoises and blackfish also, from canoes (Gunther, 1927, p. 204).

Quileute – Reagan (1925) describes Quileute whaling. The gray whale was apparently the main catch. The Quileute found it more economical to buy whale products from Americans than to hunt whales, so "gave up" whaling from 1836 on (MacLeod, 1929, p. 113). Gray whale bones have been found in archaeological sites near Lapush (Reagan, 1917). Aboriginal whaling was carried out until 1928 in coastal Washington (Anon., 1949).

Although the Quileute chiefly hunted the gray whale (Reagan, 1925, p. 25), they also took "summer whales" in August and "winter whales" in June–July (Curtis, 1913, p. 145). By 1874, it was increasingly difficult to capture whales from canoes as whales had decreased due to commercial whaling (Pettitt, 1950, p. 43). In the summer of 1888, nine finbacks were taken by the Quileute reservation, at that time comprised of 252 Indians (Collins, 1892, p. 243).

Sometimes several whales were killed in one day while some whalers took no whales during the entire season (Curtis, 1913, p. 146–7). One good whaler took approximately 40 whales over about 50 years, and helped to kill "many others" – up to three whales per season (Curtis, 1913, p. 147). But this whaling was obsolete by the early 20th Century, by which time there was only one surviving whaler (Curtis, 1913, p. 145). The Quileute took their last whale in 1904, but subsequently stranded whales were utilized, the last one found in 1928–1930 (Pettitt, 1950, p. 43).

Quinault – The Quinault followed whaling, using the same harpoon-line-float method as their neighbours (Olson, 1936, p. 44–8). They learned whaling from the Makah via the Quileute, and were the only whaling tribe of the Salish; by 1912, with a population of 759, there were only a few whalers left among them (Curtis, 1913, p. 4, 55). (In 1850, there were only two Quinault whalers; Olson, 1936, p. 44.) They also used stranded whales, each winter 1–2 washing up on the beach (Olson, 1936, p. 46).

Tillamook (Coast Salish) – I have no references at hand for Tillamook whaling. They apparently were not whalers. (The Quinault were the only whaling tribe of the Salishan stock; Curtis, 1913, p. 4).

Chinook – Apparently, the Chinook used to whale off the mouth of the Columbia River (MacLeod, 1929, p. 112), but now "do not attack the whale", and highly prized beached whales (Bancroft, 1875, vol. 1, p. 233).

Oregon Indians – "Whales [are] spoken of in accounts of tribes living all along the coast of Oregon and Washington and whale products of various sorts are utilized" (Waterman, 1920, p. 47). But the gray whale was not hunted by Oregon Indians since the whaling "complex" did not reach farther south than coastal Washington (Swanson, 1956, p. 55).

California Indians – The northern California tribes knew, and may have fished, large whales (Kroeber and Barrett, 1960). The Yuroks knew the gray whale as the "*hewska kämuks*" or bastard whale (Kroeber and Barrett, 1960, p. 123). The gray whale was not hunted by California Indians such as the Chumash, since the whaling "complex" did not reach this far south (Swanson, 1956, p. 55).

In conclusion, "the number of these animals which are destroyed by the natives for food, must be very considerable" (Meares, 1791, p. 240). Gray whales were killed by natives of the Chukchi–Bering–Beaufort Seas, in the aconite poison fishery of the Aleuts and Koniags, and by at least four major tribes along the northwest coast. I conclude from these data that annual removals (including struck-but-lost whales) from the east Pacific stock of the gray whale were substantially more than heretofore recognised.

Assumption 2 (from Ohsumi, 1976) then may not be well-founded, as there is likelihood that the aboriginal removals (including the struck-but-lost component) were greater than the 174 to 223 estimated by Ohsumi. Also, the pre-1846 population was likely not at "virginal" levels, but may have been substantially reduced by aboriginal whaling long before the advent of commercial whaling.

3. The carrying capacity of (a) the winter calving and breeding grounds, and/or (b) the migration route and (c) the summer feeding grounds has changed; and (d) the change is in the direction of diminishing the absolute number of gray whales that could exist in the absence of exploitation:

This assumption, implicit in the argument of Ohsumi (1976), is difficult to address directly since few quantitative data are available. However, some workers have commented on possible changes in:

(a) *The winter calving and breeding grounds.* There may have been disruption of breeding activities associated with developments for commercial salt production in Baja California (Lindsay, 1967; Gard, 1974). The discovery of breeding grounds on the mainland Mexico coast, at Yavaros and Bahia Reforma (Gilmore and Ewing, 1954; Gilmore *et al.*, 1967; Gilmore, 1960) may or may not represent a post-1900 expansion of breeding areas. Gilmore (1960) listed San Diego Bay, California as a calving area no longer occupied; a different view is that there is no firm evidence for this (Henderson, 1972).

(b) *The migration route.* Aspects of the exact migration route have been mooted for many years (e.g. Pike, 1962; Rice and Wolman, 1971). There are few documented changes in the environment along the migration route that can be clearly shown to influence gray whale behaviour. Among those factors mentioned or obvious are: increased marine pollution, increased ship activity, submarine geophysical exploration including seismic mapping, and the like. Recent information (Gilmore, 1978) indicates that parts of the migration path off southern California shores used by gray whales presently may represent a change because earlier surveys, before 1969, did not find this offshore migration (Gilmore, 1978). This suggests that human activities might have deflected the migration path in this area. Wolman and Rice (1979) suggest, on the basis of systematic shore-based counts of the southward migration, "that increasing boat traffic was causing even greater numbers to migrate far off-shore". In 1977/78 the count from Pt Loma was higher than the count farther north at Yankee Point and Granite Canyon for the first time (Wolman and Rice, 1979). These data, too, indicate a deflection in migration route.

(c) *The summer feeding grounds.* There is little direct evidence for changes in the quality of the local habitat on the summer feeding grounds, mainly the Bering Sea and adjacent waters. However, there may be indications of the direction of possible changes.

Many workers assume that local, relative population abundance on the feeding grounds is the result of competitive interrelationship between individual whales for food and space (see for examples: Lockyer, 1972; Gambell, 1973; Mitchell, 1974; Omura *in* Mitchell, 1974; Laws, 1977).

If competition between whale species occurs for prey species, then changes, especially recovery rates from heavy exploitation, over the last century in population levels of right, bowhead and gray whales indicate that the gray whale has been the more successful species.

The gray whale in the Bering Sea area eats mainly infaunal benthic species of invertebrates (Pike, 1962; Rice and Wolman, 1971, p. 25). Possible competitors such as the North Pacific right whale, *Eubalaena glacialis pacificus,* and the bowhead, *Balaena mysticetus,* are both now reduced to 10% or less of initial population levels (Breiwick, Mitchell and Chapman, 1978; Mitchell, 1977).

If competition between whale species acts through competition for "whale space" or in some other indirect manner (e.g. as is postulated for the southern sei whale and fin whale) then the gray whale in the Bering Sea area is the successful species. The history of exploitation of all other species of large whales in this region (e.g. balaenopterids) is one of increased exploitation and diminishing population size for the last few decades – the opposite of the trend for the gray whale.

(d) *Direction of change in environmental carrying capacity.* The above essay on Assumption 3 (from Ohsumi, 1976) indicates that if major changes have occurred, they would have been in predictable directions. Reductions in the number and quality of winter calving and breeding grounds would serve to restrict maximum growth of the population. The fact that the gray whale has a few additional calving grounds on the mainland Mexico coast (Gilmore *et al.*, 1967) indicates that this may not be a severely limiting factor; nevertheless, the increase in tourist-vessel traffic in the calving lagoons may be having an adverse effect on the population (Rice, 1975).

Possible changes in the migration route are not well documented, and it is difficult to envisage how these might severely restrict the maximum growth of the population. By the very nature of the migration, the gray whale is adapted to move from areas more amenable to calving and breeding presumably through less hospitable waters, to areas best suited for the feeding requirements of the species. Therefore changes in the route of migration are surely less significant than at the respective termini.

Changes in the summer feeding grounds would nearly all be to the favour of the gray whale, in lessening competition with other species for food, and in lessening the number of other whales that might compete for "whale space". The direction of change here would be to allow maximum growth of the population.

DISCUSSION AND CONCLUSIONS

The level of early commercial catch and kill (total removals) was estimated realistically, but conservatively, by Henderson (1972). I suspect that further research on the details of struck-but-lost rates in lagoon whaling, kelp whaling, and various types of coast whaling (e.g. "along the breakers", and "sailing them down"; Scammon, 1874) may show a higher rate obtained in the fisheries.

The level of the early aboriginal catch and kill (total removals) was, in my view, larger than that currently estimated. My cursory literature review, using sources mainly from Heizer (1968), indicates that the aboriginal take of whales, most of them probably gray whales (e.g. Scammon, 1874, p. 29–31) was likely very high but it is difficult to make an estimate of the total removals at the present time. I think that the removals may have been so substantial that the population of gray whales was below the true virgin level at the onset of commercial whaling, possibly far below this level and even near "MSY" level. If so, then Ohsumi's assumptions of increase of yield at 57% level, and changes in the carrying capacity of the feeding grounds, are not well founded. With these indications that removals could have been substantially greater than those used in previous calculations of initial population size and current yield, it is clear that more work must be carried out to document the catch history of the eastern Pacific population of the gray whale before any major management decisions based on population levels are made.

Possible changes in the calving and breeding grounds, the migration route, and/or the feeding grounds are moot. Limited evidence indicates that changes have occurred in the migration route as a direct result of harassment by man, but there are no quantitative data available on changes in the carrying capacity of the calving, breeding and feeding grounds. Postulated changes related to competition for prey and/or for "whale space" indicate that such change would be in the direction of increasing, not decreasing, the maximum population of gray whales that could be currently carried by the environment.

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SC/30/Doc 46

California Gray Whale (*Eschrichtius robustus*) Fall Migration Through Unimak Pass, Alaska, 1977: A Preliminary Report

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ABSTRACT

California gray whales were censused from 20 November to 9 December 1977 as they passed Cape Sarichef, Unimak Island, Alaska, on their fall migration out of the Bering Sea. During 82.5 hours of systematic observations, 2,055 southbound whales were sighted. Assuming no diurnal variation in rates of movement, 11,179 ± 878 whales passed during the study period. Adding an estimated 3,920 ± 1,463 whales for sightings missed before and after the survey, based on the distribution of rates of sightings, approximately 15,099 ± 2,341 gray whales left the Bering Sea through Unimak Pass. The east shore of this pass is undoubtedly the principal migratory corridor (71% of the sighted whales passed within 815 m of the shore). Peak counts occurred on 22 and 23 November when a maximum rate of 52.8 per hour was reached. Correlating this peak with the peak in counts at Point Loma, California, on 11 January 1978, allowed us to calculate a mean travel speed of 4.3 km/hr along the coastal contour.

INTRODUCTION

The timing and location of the California gray whale's (*Eschrichtius robustus*) fall migration out of the Bering Sea have been speculated on since Scammon (1874) described their general route. Pike (1962) assumed the whales left the Bering Sea in November and December based on a letter from G. T. Bush of the US Coast Guard at Cape Sarichef. Bush counted some 200 gray whales passing Cape Sarichef between 5 and 15 December 1962. We conducted vessel and helicopter surveys in the eastern Aleutian Islands and along the western Alaska Peninsula coast on 21–25 October 1976 (Braham, Everitt, Krogman, Rugh and Withrow, 1977) but found no gray whales. From these records we estimated that the peak of the whale migration should occur in late November or early December.

Scammon (1874) assumed that the gray whale 'follows the general trend of an irregular coast . . .' (p. 32). This tendency to follow the coastline during the spring was demonstrated by Pike (1962) as far north as Dixon Entrance, British Columbia. Evidence also comes from fall sightings of gray whales at Yakutat Bay and on the southwest side of Kodiak Island by personnel of the National Marine Fisheries Service and the Alaska Department of Fish and Game (MacIntosh and Calkins, pers. comm.) and in the spring by Wilke and Fiscus (1961). The fall migration probably is as coastal as the spring migration (Braham, 1979). Whales passing into or out of the Bering Sea would then be most likely to use the easternmost passes, as described by Ichihara (1958), Pike (1962), Rice and Wolman (1971), and later by Gilmore (1978), although use of passes to the west has been hypothesised (Gilmore, 1968). The lack of of sightings to the west of Unimak Pass and the many sightings along the north coast of the Alaska Peninsula (Braham *et al.* 1977) encouraged us to survey Unimak Pass, as that seemed the most probable route for gray whales exiting the Bering Sea.

METHODS

A single observer (Rugh) maintained systematic watches for gray whales during daylight hours at Cape Sarichef from 20 November to 9 December 1977. The observation point, used consistently throughout this study, was 34 m above sea level on the bluff directly west of the US Coast Guard Station. The viewing area covered an arc of 150°, which meant a surface area of 12 km^2 when 3 km is considered the outer limit of visibility. During the 17 days of observation, the average time on watch was 4.9 hours per day (range 1.3 to 7.0 hr/day). There were never more than 7.5 hours of daylight during any one day of the study period. Each passing whale was recorded when it crossed an imaginary line extending 70° W of N from the observation point. Notes were made on timing, pod size, direction of movement, size of individuals, distance from shore (in degrees below the horizon measured with an inclinometer), and significant behaviors. Photographs, notes, and sketches were made to identify characteristic markings of individuals. Every half hour environmental conditions were recorded.

STUDY AREA

Cape Sarichef on Unimak Island, Alaska, was selected because it is a promontory from which gray whales could be easily watched during their southbound migration through Unimak Pass (Fig. 1). The US Coast Guard/Loran Station at Cape Sarichef provided a convenient support facility. The cape is the westernmost point of Unimak Island (54° 36′ N, 164° 56′ W) – the western end of the land mass separating the eastern Bering Sea from the North Pacific Ocean. False Pass is the only pass to the east, but breakers and depths of less than 4 m at the north entrance apparently discourage whales from using it as a route.

During the study period from 20 November to 9 December, temperatures ranged from –5°C to +6°C (mean 0°C) and winds rose to velocities over 90 km/hr (mean 33 km/hr). The wind was from the north and northeast, 92% of recorded time. During observation periods, overcast and partly cloudy conditions were noted 70% of the time; precipitation occurred in the form of rain, sleet, or snow 7% of the time.

RESULTS AND DISCUSSION

Census

A total of 2,163 gray whales were counted going south and 108 going north during 82.5 hours of systematic observations from Cape Sarichef. Subtracting northbound from

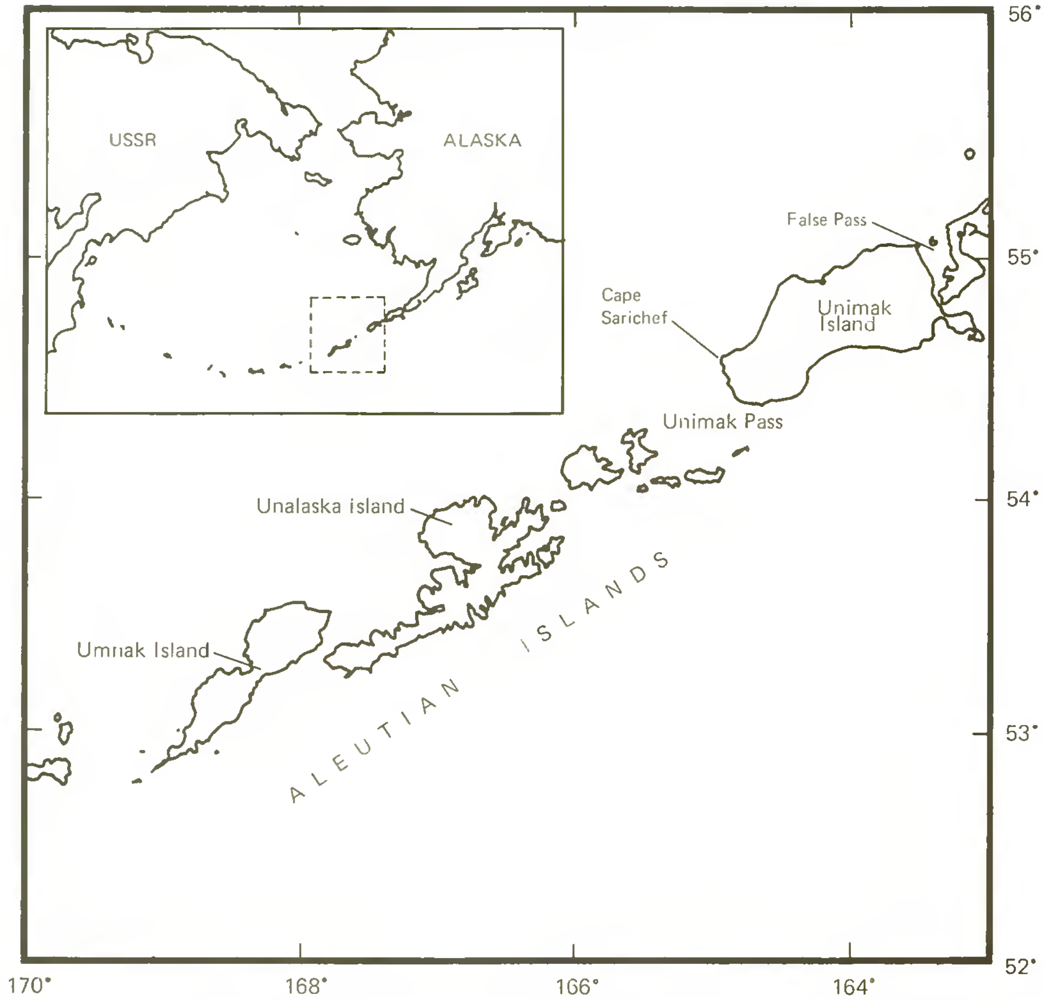

Fig. 1. Study area at Unimak Pass. The observation point was located at Cape Sarichef on Unimak Island, Alaska.

southbound sightings (it was assumed all of these whales eventually went south) gave a net total of 2,055 migrating whales (Table 1). The mean number of whales-per-hour was calculated for each day and multiplied by 24 hours (we assumed no diurnal variations in our estimate that 11,179 whales passed).

A 95% confidence interval was determined *a posteriori* by using southbound counts from each 15 min interval with each day treated as a separate domain (j). The sum of the daily variances ($\Sigma \operatorname{var}(\hat{y}_j)$) equals the variance for the estimated total number of whales ($\hat{y}$) passing during the study period. Therefore, the confidence interval was estimated as $\hat{y} \pm t_a \sqrt{\operatorname{var}(\hat{y})}$ where $t_a = 2.093$ from a t-distribution table for $a = 20$ (number of days) and $\operatorname{var}(\hat{y}) = \Sigma \operatorname{var}(\hat{y}_j)$. Utilising Cochran's (1963) techniques for estimating the standard error of totals over sub-populations (domains), each $\operatorname{var}(\hat{y}_j)$ was calculated as $(N_j^2)(\operatorname{var}(\bar{y}_j))$ for $N_j = 96$ (number of intervals per domain), where $\operatorname{var}(\bar{y}_j)$ was based on $s_j^2/n_j\,(1 - n_j/N_j)$, s_j is the standard deviation for each day, and n_j is the number of sampled periods per day. Values for unsampled domains were estimated by using $(\Sigma y_1 + \Sigma y_3/n_1 + n_3)$ where j = 1 and 3 are days neighboring the unsampled domain (j = 2). The variance for unsampled domains was estimated by treating neighboring days as representative of the missing day, letting $n_2 = n_1 + n_3$. Therefore 11,179 ± 878 gray whales passed Cape Sarichef between 20 November and 9 December.

Table 1

Summary of gray whale counts from Cape Sarichef, Alaska, 20 November to 9 December, 1977

Date		Whale count	Hours of watch	Whales per hour	Whales per 24-hour
November	20	27	1.25	21.6	518.4
	21	93	4.25	21.9	525.2
	22	249	5.00	49.8	1,195.2
	23	277	5.33	52.8	1,266.3
	24	196	5.00	39.2	940.8
	25	238	7.00	34.0	816.0
	26	189	5.50	34.4	824.7
	27	110	4.00	27.5	660.0
	28	44	2.00	22.0	528.0
	29	–	No watch	–	est. 425.6
	30	89	5.50	16.2	388.4
December	1	81	5.00	16.2	388.8
	2	87	5.25	16.6	397.7
	3	–	No watch	–	est. 375.5
	4	89	6.00	14.8	356.0
	5	71	4.00	17.7	426.0
	6	94	7.00	13.4	322.3
	7	73	6.00	12.2	292.0
	8	–	No watch	–	est. 276.6
	9	48	4.50	10.7	256.0
Total		2,055	82.5		11,179

Coast Guard personnel at Cape Sarichef first sighted whales in late October (treated here as one whale for 31 October); by 12–13 November 'lots' of whales were seen (treated here as five whales per hour). Using these accounts and our data for 20–23 November, we applied theoretical distributions which enabled us to estimate the number of whales passing prior to our survey. An exponential curve fitted these points well ($r^2 = 0.96$) based on $\hat{y} = 0.05e^{0.3x}$ with an estimated 1,709 whales for 31 October to 20 November. A power curve fitted even better ($r^2 = 0.98$), based on $\hat{y} = 0.04x^{2.17}$ although with a dramatically higher estimate of 3,895 whales. The mean of these two estimates, 2,802, approached the estimate from the best curvilinear fit drawn graphically (Fig. 2) to approximate the count distribution (2,621). Therefore we may estimate 2,802 ± 1,093 whales passed before our survey began. (In all cases referring to population estimates, $\hat{y}$ is the estimated number of whales passing on day x).

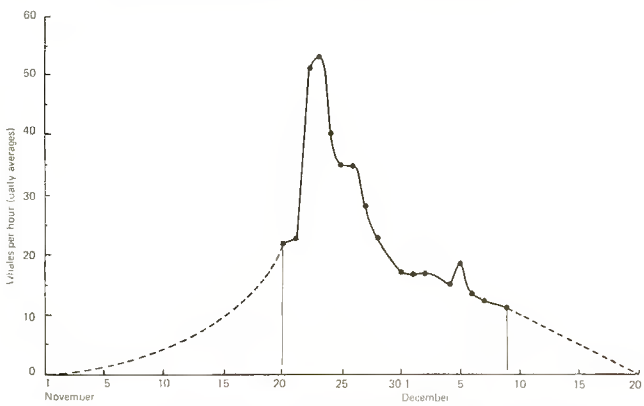

Fig. 2. Distribution of counts of gray whales migrating south past Cape Sarichef, Alaska, November and December, 1977. Areas to the left of 20 November and to the right of 9 December are extrapolated.

Similarly, applying a linear regression ($\hat{y} = 17.42 - 0.85x$; $r^2 = 1.00$) to data for 2–9 December (excluding the anamolous 5 December count) allowed us to estimate that 1,487 whales passed after the survey was terminated (including the 5 December value merely adds three whales to this estimate). A second order polynomial equation ($\hat{y} = 16.58 - 0.03x - 0.06x^2$) also approximated the distribution of counts after 9 December ($r^2 = 0.90$). By this method we calculated that 748 whales had passed. Using both of these estimates, we approximated that 1,118 ± 370 whales went through Unimak Pass after the end of our survey.

Adding the estimated 2,802 ± 1,093 whales passing prior to our survey, and the 1,118 ± 370 passing after our survey to the 11,179 ± 878 estimated during the survey resulted in a total of 15,099 ± 2,341 gray whales migrating out of the Bering Sea.

Rice (1975) estimated that 11,000 (±2,000) gray whales pass the counting stations in California (based on an assumed constant day and night travel rate). Presumably all whales swim south of the Alaska Peninsula in the fall, but it seems unlikely that the entire population continues to the southern extension of their migratory route. Hatler and Darling (1974) observed gray whales off Vancouver Island, British Columbia, most of the winter. Other sporadic sightings made between California and British Columbia suggest that some animals do not complete their southern migration. There is also evidence that a portion of the population does not go as far north as the Bering Sea (Pike, 1962; Hatler and Darling, 1974), but the size of this portion and how much it might affect a total population estimate of 15,000 is unknown.

Evidence from sightings in California shows that the gray whale population has stabilised since 1960 following its rise from exploitation levels in the late 1800s (Rice, 1975). Henderson (1972) estimated that the population prior to the period of commercial harvesting was not more than 15,000, an estimate also used by Rice (1975), although considerably less than Gilmore's (1955) estimate of 25,000. This 15,000 figure matches our estimate of the present gray whale population of 15,099 animals, although we have not included an estimate of the number of whales that stay south of the Bering Sea in the summer.

Sightability of Whales

Seven categories of visibility were devised, from excellent to unacceptable, combining all factors bearing on the observer's ability to sight a surfacing whale within the 12 km^2 viewing area. If counts were strictly dependent on visibility, time spent during good to excellent conditions should have resulted in higher counts than during poor conditions. Kendall's Test for Independence (Hollander and Wolfe, 1973), applied to counts categorised by visibility through the season, showed no significant correlation ($P = 0.14$). Therefore all visibility categories could be treated equally. When the observer was convinced whales could pass unseen, the visibility was considered unacceptable and the systematic watch suspended.

Whale counts were compared on a per minute basis as a function of time from the beginning of each watch period ($n = 49$ for the first 30 minutes, dropping to 26 at 120 minutes). The per minute averages were tested for a decrease in counts that might have been related to observer fatigue through the two-hour watch period. A low slope coefficient ($r^2 = 1.56 \times 10^{-6}$) indicated no correlation between time of watch and whale counts; therefore no correction factor was necessary.

Whales were visible to the observer for an average of 19.5 ± 1.9 sec, established by multiplying the mean number of blows observed per whale, 3.9 ± 0.3 ($n = 247$), and the mean time at the surface, 5.0 ± 0.1 sec ($n = 292$). Surface times were measured between the blow and the submergence of the caudal ridge or fluke. These timings ranged from 1.4 to 9.2 sec. On calm days when spray from a blow would hover, a whale's presence would be recognised for even longer periods. Southbound whales that did not deviate from their course were seen up to eleven times each. A whale could be followed for potentially longer periods, but during this census emphasis was placed on counts. Whales were identified by single blows only 3.2% of the time, suggesting small likelihood of 'zero blows', that is, whales passing without being recorded.

Distance from Shore

Distance offshore was recorded for each whale by measuring its angle below the horizon with a handheld inclinometer. These angles were converted to meters offshore and corrected for the distance to the outermost rocks along the shore. All whale sightings occurred within twelve distance sectors, including the most distant (1.7 to 3.0 km).

Of all the southbound whales sighted, only 29% were more than 815 m offshore (sectors 1 and 2) compared to 64% off Granite Canyon and 89% off Point Loma, California (Rice, pers. comm.). The whales apparently follow the shore of Unimak Island much more closely than the shores of California, perhaps related to the way the Alaska Peninsula obstructs the general orientation of their route.

The distribution of sightings offshore of Cape Sarichef was more a function of whale distribution than of visibility decreasing with distance. No difference between counts made in excellent versus poor conditions was evident when plotted against distance offshore ($P < 0.001$; Kendall's Test for Independence). Also, when the surf was high, one would have expected whales to be less visible farther offshore. The data show, however, that when the surf was less than 2 m high, 22% of the sightings were more than 815 m offshore compared to 72% when the surf was high (Fig. 3). High surf conditions shifted whale distribution seaward, presumably because of the increase in noise or the dangers of the nearshore surf. During calm weather whales passed very close to the rocky shore, some as close as 13 m.

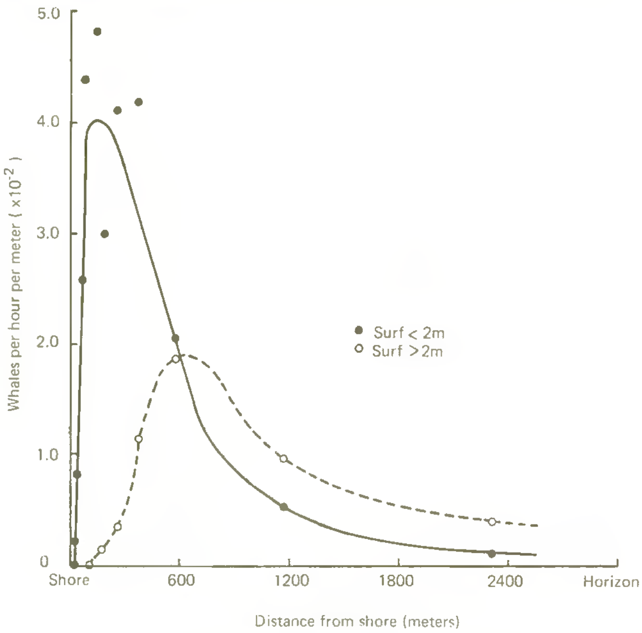

Fig. 3. Density distribution of gray whales offshore of Cape Sarichef, Alaska, 20 November to 9 December 1977. Sightings occurring during surf conditions greater than 2 m are indicated by the dashed line.

Seventy-three per cent (73%) of the whales within 50 m of shore were yearlings or small whales, whereas beyond 100 m 77% of the whales were medium to large. Leatherwood (1974) also observed no yearlings in offshore areas off southern California.

Relative Whale Sizes

Whenever conditions allowed, whale sizes were estimated and recorded. A total of 553 animals were categorised, of which 13% were large, 57% medium, 25% small (presumably 2–3 year olds), and 5% were yearlings. Large whales decreased in occurrence as the season progressed while yearlings became more common; most yearlings (93%) passed during the first week of December. Medium and small whales showed no distinct temporal trend during the study.

Using a least squares procedure, a polynomial equation ($\hat{y} = 4.31 - 2.93\,x + 0.44x^2 - 0.01x^3$) was applied to the data to approximate the percentage distribution of yearling sightings ($\hat{y}$) versus time (x). From this relation, the number of yearlings passing each day during the study period was estimated (using only $\hat{y} > 0$ for 26 November to 9 December). The sum of these estimates, 337 yearlings, is 3.0% of the population passing during the survey (11,179).

Pod Sizes

There was no apparent change in pod size through time ($r^2 = 0.17$), the mean size being 1.95 ± 0.07 whales and maximum 9 (for 1,253 pods). Only those groups traveling close enough together to allow frequent contact were considered pods. Although many whales traveled in loose association, they appeared haphazardly arranged relative to the discrete pods which swam and surfaced together.

Course Deviations

Not all whales were strictly southbound. Course deviations were noted on 171 occasions involving 324 whales, which is 12% of the whales passing Cape Sarichef. These deviations increased through time indicating a greater percentage of casual travelers later in our survey. Initially only 2.2% of the sightings were recorded as other than southbound; by the end of the study period, this occurred with 29.2% of the sightings. Most (61%) of the deviations were northbound whales (it was assumed all whales turned south eventually). It was likely, then, that whales intent on getting to the winter breeding lagoons, such as pregnant females, would have been at the front of the migration, making few diversions while enroute. Later whales may have been more involved in social interactions and were less likely to reach California that year.

Diurnal Variations

Whale counts were categorised by time of day to test for diurnal variations. Time was adjusted relative to the position of the sun (daylight hours became increasingly fewer as the study progressed). Data for each 15 min interval were divided by the total estimate for the respective day in order to remove seasonal variations in numbers of whales passing the observation point. Mean values show no apparent pattern (Table 2). No regression can be found in counts from dawn to noon ($r^2 = 0.05$) nor from noon to dusk ($r^2 = 0.15$). Cumulative twilight data (adding dawn and and dusk figures) also show no trend in counts relative to light level ($r^2 = 0.09$).

If whales slowed down with increased darkness, their surface timings might have increased; that is, with slowed movement, we may expect whales to spend more time at the surface with each blow. Using cumulative dawn and dusk data to increase the sample size, surface timings were compared as a function of light. No statistically significant regression was apparent ($r^2 = 0.50$).

If whales slowed their rate of travel at night, there might have been an increase in the number of deviations from a strictly southbound course. That is, with decreased light levels, we might expect a greater incidence of whales swimming north, traveling irregularly, or engaging in social interactions. Using pooled dawn and dusk data in the same manner as for surface timings, we found no significant trends in direction of travel ($r^2 = 0.53$) with decreases in light.

Although Gilmore (1960) and Adams (1968) used arbitrary correction factors to estimate nocturnal rates (50% and 70% respectively), and Hubbs and Hubbs (1967) as well as Ramsey (1968) believed there was some evidence of diurnal variations in rates of movement, we found no evidence to reject the hypothesis that night-time travel

Table 2. Mean counts of whales ($\bar{x}_1$) distributed through the day as observed from Cape Sarichef, Alaska, 20 November to 9 December 1977. Counts are corrected ($\bar{x}_2$) to remove seasonal variation by dividing each value by the estimated total for the respective day. Values for (n) indicate number of data points. The standard deviation (S.D.) is based on the corrected values for each day

	$\bar{x}_1$	$\bar{x}_2$	n	S.D.
	5.0	0.46	1	–
	4.7	1.98	3	0.94
−4 hr				
	4.5	0.99	6	0.92
	5.7	1.24	9	0.49
	4.5	1.16	11	0.53
Sunrise				
	5.5	1.00	12	0.90
−3 hr				
	5.8	1.30	16	1.14
	5.3	1.26	10	0.52
	5.8	1.00	12	0.85
	4.4	1.24	18	1.22
−2 hr				
	7.4	1.22	13	1.22
	12.8	1.20	7	0.22
	8.3	1.09	7	0.36
	10.2	1.08	6	0.61
−1 hr				
	7.0	1.23	7	0.74
	9.7	0.72	6	0.70
	7.9	0.35	10	0.66
	5.9	1.27	11	1.03
Noon				
	7.1	0.86	10	0.59
	7.4	1.61	12	1.17
	7.0	1.21	12	0.87
	7.0	1.58	11	0.98
+1 hr				
	7.1	1.37	12	0.94
	6.2	0.91	12	0.85
	9.2	1.80	18	2.85
	7.2	1.23	9	0.77
+2 hr				
	6.2	1.59	12	1.39
	5.2	0.99	13	0.79
	7.1	1.30	13	0.89
	5.6	0.80	12	0.58
+3 hr				
	5.9	1.00	13	0.64
Sunset				
	7.5	0.78	5	0.48
	8.4	0.80	3	0.70
	7.0	0.49	2	0.69
+4 hr				
	5.0	1.55	1	–

rates equal daytime rates. Cummings *et al.* (1968), Rice and Wolman (1971), IWC (1976 and 1977), and Leatherwood (pers. comm.) have also found no apparent differences between day and night rates of travel.

Rate of Travel

Distinct peaks in whale counts were observed at Cape Sarichef on 23 November 1977 and at Point Loma on 11 January 1978 (D. Rice, pers. comm.) with rates of 53 and 48 whales per hour respectively. The shortest possible route between these points across the Pacific Ocean is 4,413 km (2,383 nm). A route following the coastal contour is 5,056 km (2,730 nm). The pelagic route, only 643 km shorter, is not especially advantageous if gray whales rely on coastal features for guidance while migrating (Gilmore, 1960; Pike, 1962). Coastal sightings, referred to earlier, allow us to assume the coastal contour is the preferred migratory route.

In order to cover the 5,056 km between Cape Sarichef and Point Loma in 49 days, whales must have averaged 4.3 km/hr. But if traveling rates dropped at night to 50% of daytime rates (Gilmore, 1960), an average of 5.9 km/hr must have been maintained during daylight hours (47% of this portion of their migration occurred during the day calculated from average sunrise and sunset timings for Cape Sarichef and Point Loma plus two hours of twilight per day). If no travel occurred at night, the whales would have averaged 9.1 km/hr.

Wyrick (1954) and Cummings *et al.* (1968) calculated gray whale travel rates at 8.5 and 10.2 km/hr respectively for observation periods of less than three hours per whale. Rice and Wolman (1971) estimated speeds of 7 to 9 km/hr. Leatherwood (1974) calculated a mean rate of 2.8 km/hr based on two to three days of observation, but this was for northbound whales which travel slower than southbound whales. Pike (1962) estimated speeds of 3.7–7.4 km/hr from sightings made between British Columbia and San Diego, California. Our estimated rate of 4.3 km/hr for a 49 day period matches Pike's calculation well. It is apparent that the greater the distance used to calculate the rate of migrating whales, the slower the average speed will be – which may be related to deviations in the migration either when whales use detours or when they spend time involved in non-migratory activity. It seems evident there is adequate time for whales to use a course following the coastal contour rather than a direct, pelagic route. From these calculations, it is not evident, however, as to whether or not there is a reduced rate at night.

CONCLUSION

On the basis of 82.5 hours of observations and 2,163 gray whale sightings made from Cape Sarichef at the west end of Unimak Island, Alaska, it is estimated that 11,179 ± 878 whales migrated south out of the Bering Sea between 20 November and 9 December 1977. Combined with extrapolations for whales passing prior to the survey (2,802 ± 1,093) and after the survey (1,118 ± 370), these data resulted in a total population estimate of 15,099 ± 2,341 gray whales exclusive of those that did not migrate into the Bering Sea in the spring. No correction factors for visibility, observer fatigue, or diurnal variations in net rates of movement appear to be necessary. This population estimate equals the estimate made by Henderson (1972) for the original stock size.

We have delineated the time frame of the migratory exit from the Bering Sea as being from early November to late December; an estimated 74% of the whales passed between 20 November and 9 December.

The principal migratory corridor was through Unimak Pass with 71% of the whales sighted within 815 m of the west shore of Unimak Island.

It was approximated that 3.0% of the whales were yearlings. Small whales tended to follow the coast more closely than larger whales.

The mean pod size was 1.95 ± 0.07 whales with no apparent seasonal trend.

Course deviations (12% of the recorded sightings turned from a south-bound migratory course) increased throughout the study period indicating that the whales most likely to reach the breeding lagoons in Baja California were already at the front of the migration in Unimak Pass.

Gray whales appear to select a coastal route on their migration from the Bering Sea to Baja California. Between

Cape Sarichef and the counting station at Pt Loma, California, this would mean 5,056 km, which was covered in 49 days at an average rate of 4.3 km/hr.

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Bryde's Whales in the Equatorial Eastern Pacific

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ABSTRACT

During February to April 1975, Bryde's whales, *Balaenoptera edeni,* were widely distributed in the equatorial eastern Pacific between 10° N lat. and 06° S lat., from 90° W long. to 110° W long. Neither sei whales, *B. borealis,* nor fin whales, *B. physalus,* were identified in this area. Adult Bryde's whales occurred singly (or rarely in pairs) in loose aggregations of as many as seven. In surfacing and diving behavior they resemble fin whales more than sei whales. The total population in the area is estimated at about 10,000, or 7 whales per 1,000 mi². There were 9 calves per 100 adults. Calving appears to take place during the northern winter.

INTRODUCTION

Bryde's whales, *Balaenoptera edeni,* were long confused with sei whales, *B. borealis.* Following Omura's (1966) elucidation of the diagnostic features of *B. edeni,* this species was found to inhabit tropical and warm temperate coastal waters around the world. Only during the past few years, however, have Bryde's whales been discovered to range widely on the high seas. In the eastern South Atlantic, a migratory offshore population (which breeds during the southern winter) and a resident coastal population (which breeds year-round) are distinguishable (Best, 1977). Offshore populations of Bryde's whales have also been found in the western and eastern Indian Ocean (Ohsumi, 1978), the Southwest Pacific (Ohsumi, 1978), and the North Pacific (Ohsumi, 1977; Privalikhin and Berzin, 1978).

During the 1975 Soviet–American Cooperative Cetacean Research Cruise on the catcher boat *Vnushitel'nyi* (Berzin, Volkov and Moroz, 1976), I had the opportunity to observe Bryde's whales in the far offshore waters of the eastern equatorial Pacific. The other cetologists on this cruise were A. A. Berzin of TINRO, Vladivostok, and W. E. Evans, then with the Naval Undersea Center, San Diego (for first half of cruise only). I. F. Moroz (hydrographer), A. F. Volkov (planktologist), and two technicians, all from TINRO, comprised the remainder of the scientific staff.

Most of the whales here referred to as Bryde's whales were erroneously reported as sei whales and fin whales by Berzin (1978), although he admitted that "some of [the sei whales] were probably Bryde's whales". I am certain that most of them were Bryde's whales, and believe that all of them were. W. E. Evans concurred in my identification of them. During many research and whaling cruises in the eastern North Pacific over the past 20 years, I have become thoroughly familiar with all five species of *Balaenoptera* in life. I saw no whales during the cruise of the *Vnushitel'nyi* that I identified as, or even suspected of being, either sei or fin whales. There are no other published records of either of these two species in this area. The only other rorquals I identified during the cruise were blue whales, *B. musculus* and minke whales, *B. acutorostrata.*

Volkov and Moroz (1977) reported on oceanographic conditions in relation to cetacean distribution, and I (Rice, 1977a) reported on sperm whale populations in the cruise area.

AREA AND METHODS

The *Vnushitel'nyi* has a gross tonnage of 844, an overall length of 65 m (213 ft), and a 4,000 horsepower diesel-electric power plant. The cruising speed is 10 knots and the top speed 18 knots.

We departed from San Pedro, California, on 18 February 1975 and sailed a series of pre-established transects between the equator and 10° S latitude (Fig. 1). From 20 to 24 March we stopped at Balboa, Canal Zone. We then sailed a series of transects between the equator and 17° N latitude. The cruise terminated at Balboa on 26 April.

A regular watch for mammals was maintained from sunrise to sunset. This included one man in the crow's nest, 18 meters above the surface, and two observers on the bridge, 11 meters above the surface. I spent about 10 hours a day on watch, and Berzin and Evans were also on watch much of the day. In addition, there were usually several off-duty crew members watching on the bridge.

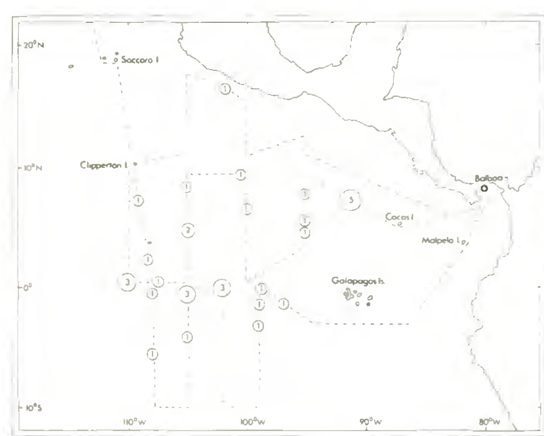

Fig. 1. Distribution of Bryde's whales in the equatorial eastern Pacific. The broken line is the cruise track of the *Vnushitel'nyi;* the encircled numbers indicate the positions and numbers of aggregations of Bryde's whales sighted (see Table 1 for details).

Whenever possible, the radial distance from the observer to the whale when first sighted was calculated from the time taken at known speed to close with the animal.

IDENTIFICATION

The pair of lateral ridges on the rostrum is the only feature by which Bryde's whales may be certainly identified in the field. This feature is impossible to see at any distance, and difficult to see even when the whale is close. The observer must have his binocular focused on the whale's head the instant it breaks the surface, before the whale begins to roll forward. I observed the ridges on at least one whale in each group that we encountered, except for the three groups seen on 31 March and 18 April (Table 1). The latter whales I judged to be Bryde's whales on the basis of their size, dorsal fin, and behavior. I saw no whales that definitely lacked ridges on the rostrum.

The estimated lengths of all of the whales observed (except for calves) were between 10 and 15 m – mostly 11 to 13 m.

The dorsal fin of the Bryde's whale is intermediate in relative size and shape between that of the sei whale and that of the fin whale. On the sei whale the dorsal fin is large and erect with a convex leading edge; on the fin whale the dorsal fin is smaller and more backswept with the leading edge slightly sinuate (concave basally, convex distally), and it is positioned farther back on the body.

In color Bryde's whales are indistinguishable from sei whales. On none of the whales did I see a white lower lip on the right side, characteristic of the fin whale. The more extensively white underparts of the fin whale can rarely be seen in the field, so ventral coloration is not a useful field mark for Bryde's whales.

Scars on the skin were not numerous on most of the whales observed. Only two (seen on 11 April) were noted as being heavily scarred, and on them the scarring was not continuous, as it is on most eastern North Pacific sei whales (Rice, 1977).

DISTRIBUTION

Bryde's whales have been previously reported in the coastal waters of the eastern north Pacific from southern California (Morejohn and Rice, 1973), Mexico (Rice, 1974, 1977), Colombia (Anon., 1925), Ecuador (Ingebrigtsen, 1929) and northern Chile (Aguayo, 1974). Clark (1962) reported "sei" whales in mid-ocean between Guayaquil, Ecuador, and the Galapagos Islands, and in the immediate vicinity of the latter archipelago; however he cautioned that "it is thus possible that the sei whales in this equatorial region are really Bryde's whales, but it is impossible to differentiate between the two species when at sea",

We found Bryde's whales widely distributed over the open ocean west of 90° W longitude, between 10° N latitude and 06° S latitude (Fig. 1).

Eastern North Pacific sei whales range during the winter from about 36° N to 18° N lat. (Rice, 1977b). These observations suggest that the winter grounds of Bryde's whales and sei whales are mutually exclusive, contrary to the opinion of Berzin (1978).

BEHAVIOR

Group Size

Almost all the whales that I observed (except for cows with calves) were singles. On only three occasions (28 March, 5 April, and 11 April) did I see two adults travelling close together and surfacing and diving in unison, and I never saw a pod of more than two. In contrast, sei and especially fin whales often travel in pods of three to six or more.

In spite of this lack of sociability, when we encountered one whale we usually found others within an area of several square kilometers. These aggregations averaged 2.6 whales, and contained as many as seven whales. Their frequency distribution was as follows:

Size of aggregation	No. of aggregations	No. of whales
1	9	9
2	12	24
3	5	15
4	2	8
5	2	10
6	2	12
7	1	7

Surfacing and Diving

When surfacing, Bryde's whales usually rise obliquely so that the head is first to break the surface. The dorsal fin does not clear the water until after the whale has inhaled and is rolling forward to dive. In this habit Bryde's whales resemble fin whales. On one occasion during the *Vnushitel'nyi* cruise, and on several other occasions along the coast of Mexico, I have seen whales positively identified as Bryde's whales that broke the surface horizontally like a sei whale, so that the dorsal fin and head emerged almost simultaneously.

The diving and blowing rhythms of Bryde's whales are highly variable. I timed dives that lasted from 1 to 11 minutes, interspersed with series of one to seven blows at 12 to 18 second intervals. The average dive lasts about 5 minutes, followed by about five blows at 15 second intervals – a pattern much more like that of fin whales than sei whales.

Breaching

I saw Bryde's whales breaching on two occasions – on 4 and 5 April. On each occasion a single whale breached twice in succession. They rose clear of the surface in a long smooth arc, and fell into the water on their backs with a tremendous splash, as minke whales often do. In the course of hundreds of encounters, I have never seen a sei whale breach, and have seen a fin whale do so only once.

Escape Reactions

When chased by a vessel, Bryde's whales characteristically swim close to the surface and attempt to elude the vessel by frequently changing course, rather than by increasing their speed as fin and sei whales tend to do. This habit makes Bryde's whales difficult to approach closely enough to mark, except when the sun is high and the water is clear, when an observer in the crow's-nest can easily follow their movements underwater.

Feeding

I saw no overt feeding behavior.

POPULATION SIZE

Bryde's whales were encountered more frequently than any other species of cetacean (33 times) during the cruise. A total of 85 individuals was counted (Table 1).

The total population in each 10° square of latitude and longitude was calculated with the formula

$$P = N \times A/(D \times W)$$

where

P = population
N = number of whales observed
A = area of square
D = distance cruised
W = width of transect

The total water area of the ten 10° squares surveyed between 20° N and 10° S latitude was 2,917,000 square miles or 10,003,000 square kilometers (Table 2). The total distance cruised in this area was 12,630 miles (23,388 km). This does not include excursions from the established course in pursuit of marine mammals. Throughout the cruise there were almost exactly 12 hours between sunrise and sunset, so the distance cruised during daylight was half the distance of the total cruise track, or 6,315 miles (11,694 km) (Table 3). The amount of time that visibility was significantly impaired by weather was negligible. Where the ship's track coincided with the boundary between two 10° squares, I have allotted half the distance to each of the squares (except for the leg along the 110th meridian from 0° 30′ N to 10° 00′ N, the western boundary of the study area, which was entirely allotted to the square immediately to the east).

The distance from the vessel at which eleven Bryde's whales were first sighted ranged from 0.1 to 5.0 miles, with a mean of 1.55 miles. The effective transect width is therefore taken to be 3.10 miles.

The sum of the individual population estimates for each 10° square (Table 4) is 9,913. If we combine the data for

Table 1

Bryde's whales sighted during the cruise of the *Vnushitel'nyi*

Date	Position		Number
25 February 1975	07° 14′ N	108° 40′ W	5
26 February 1975	02° 22′ N	108° 22′ W	6
27 February 1975	00° 33′ S	108° 17′ W	1
1 March 1975	05° 40′ S	108° 10′ W	3
5 March 1975	04° 07′ S	105° 11′ W	4
6 March 1975	00° 54′ S	105° 03′ W	2
6 March 1975	00° 34′ S	105° 00′ W	6
6 March 1975	00° 30′ S	105° 00′ W	2
7 March 1975	00° 03′ S	102° 15′ W	3
7 March 1975	00° 00′	102° 02′ W	4 (incl. 2 calves)
7 March 1975	00° 08′ S	102° 00′ W	7 (incl. 2 calves)
13 March 1975	03° 25′ S	99° 00′ W	3
14 March 1975	01° 23′ S	99° 01′ W	2
14 March 1975	00° 09′ S	98° 55′ W	1
15 March 1975	01° 22′ S	96° 40′ W	5 (incl. 1 calf)
28 March 1975	07° 28′ N	90° 15′ W	2
28 March 1975	07° 29′ N	90° 18′ W	1
28 March 1975	07° 36′ N	90° 29′ W	2
28 March 1975	07° 48′ N	90° 46′ W	2
28 March 1975	07° 57′ N	91° 07′ W	1
30 March 1975	07° 23′ N	95° 07′ W	2
31 March 1975	05° 31′ N	95° 02′ W	1
31 March 1975	04° 36′ N	95° 01′ W	2
4 April 1975	07° 31′ N	99° 54′ W	2
5 April 1975	09° 30′ N	100° 25′ W	3
7 April 1975	08° 23′ N	105° 08′ W	3 (incl. 1 calf)
8 April 1975	04° 45′ N	105° 07′ W	2 (incl. 1 calf)
8 April 1975	04° 40′ N	105° 06′ W	1
10 April 1975	00° 30′ N	107° 30′ W	1
11 April 1975	00° 35′ N	110° 00′ W	1
11 April 1975	00° 35′ N	110° 00′ W	2
11 April 1975	00° 58′ N	110° 01′ W	2
18 April 1975	16° 26′ N	101° 36′ W	1

Table 2

Water area of each 10° square surveyed in the eastern Pacific (in thousands of square nautical miles).

	West longitude				
Latitude	120–110°	110–100°	100–90°	90–80°	80–70°
20–10° N	326	293	163	–	–
10–0° N	–	357	357	321	54
0–10° S	–	357	350	339	–

Table 3

Distance cruised during daylight in each 10° square (in nautical miles).

Latitude	West longitude				
	120–110°	110–100°	100–90°	90–80°	80–70°
20–10° N	255	652	352	–	–
10–0° N	–	1,335	740	805	180
0–10° S	–	1,095	680	220	–

Table 4

Calculated population of Bryde's whales in each 10° square.

Latitude	West longitude				
	120–110°	110–100°	100–90°	90–80°	80–70°
20–10° N	0	145	0	–	–
10–0° N	–	2,243	2,334	0	0
0–10° S	–	3,365	1,826	0	–

the four 10° squares within 10° of the equator, from 90° to 110° W longitude, where nearly all of the sightings were made, the population estimate is 10,001. The calculated population density in this area is 7.0 whales per thousand square miles (or 142 square miles per whale).

CALVES

The number of calves identified was seven, or 9% of the number of older animals. Calves stay close beside their mothers and produce inconspicuous blows, so they are easily overlooked unless the mother is approached closely. Cows with calves were never accompanied by another whale.

Most of the calves were about 6 meters long. The smallest was judged to be 5 meters, the largest 6.5 to 7.0 meters. The uniformity in size of the calves indicates that calving is seasonal during the Northern Hemisphere winter. This seasonality suggests that these Bryde's whales are migratory and spend the summer in the North Pacific.

EPIZOITES

A single whalesucker (*Remora australis*) was clinging to the flank of the female with a calf seen on 8 April. No other epizoites were observed.

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SC/30/Doc 50

A Note on the Method of Estimated Net Rate of Increase from Age-Compositions[1]

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ABSTRACT

In this paper the method is given for correcting estimates of the net rate of increase of a population that was growing for many years at a constant instantaneous rate and then subject to exploitation for a short period. The method is applied to the minke whale stock in Area IV of the Southern Hemisphere.

The instantaneous coefficient of net annual increase in the unexploited stock, i, is obtainable from the age composition at the beginning of exploitation, provided that it has been operating for all or most of the years since the birth of the oldest year-classes there represented. The appropriate formula is:

Apparent natural mortality $M' = M + i$

Ohsumi (1977) found $M' = 0.125$ for Southern Hemisphere minke whales from the data for 1971/2–1972/3.

If the excess of recruitment over mortality were to continue after exploitation, a new age-composition would be established after all year-classes have passed through a period of exploitation (i.e. after a lapse of time equal to the life-span minus age at recruitment), which would give an estimate of Z′ from its right-hand limb. In this situation

$$Z' = Z - i = F + M - i$$

Ohsumi (1979) has estimated (Z′) from the seasonal age-compositions 1971/2–1976/77. His Table 12 gives an average value in all Areas, for males and females, of 0.149. In this period only a few of the recruited year-classes have been exploited since their recruitment, so these are under-estimates of the eventual Z′ that would be established. Equally, however, the value

$$i = (Z') - M$$

is an *over*-estimate of i, because some of the recruited year-classes have, in the period for which data have been compiled, been exploited since their recruitment. In this transitional situation the younger recruited year-classes will show a log-slope, in the age-composition, of Z′, but the older ones will show a slope of M′. The estimates of (Z′) made without distinguishing between these older and younger groups will be intermediate in value. The correct estimation of i is therefore

$$i = (Z') - M - kF$$

where F is the average whaling mortality rate operating over the period and k is a factor (less than unity) which reflects the relative number of recruited year-classes which have been subject to exploitation from the date of their recruitment, weighted to take into account that they will be more numerous in the catches than the older year-classes. Thus the estimate

$$i = 0.149 - 0.095 = 0.054$$

used by Ohsumi is somewhat too high.

Ohsumi's estimates of (Z′) in Area IV, from which values of F have been obtained by age-composition analysis, are

♂	♀	♂ + ♀
0.135	0.138	0.137

The range of estimates of i can be obtained by subtracting M and Z = F + M from these; the results are

	♂	♀	♂ + ♀
i (upper)	0.040	0.043	0.042
i (lower)			
*Effort**			
CSW_1	–0.112	–0.263	–0.187
CSW_2	–0.077	–0.226	–0.152
CSW_3	0.021	–0.067	–0.023

* See the Report of the Special Meeting on Southern Hemisphere Minke Whales (this volume).

Inspection of the age compositions makes it clear, however, that the slope of the right hand limb is still a reflection mainly of the increase rate pertaining to the period prior to exploitation; that is, there is no sign of an inflexion in them. Thus the i (upper) values given are most likely good approximations to the present net rate of natural increase. If data for all Areas are pooled we obtain somewhat higher i values of

$$i_{♂} = 0.049$$

$$i_{♀} = 0.059$$

$$i_{♂+♀} = 0.054$$

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[1] This paper was prepared and made available as an unnumbered Document during the Special Scientific Meeting on Minke Whales, Seattle, May 1978.

SC/30/Doc 51

Proposal for a Modified Management Policy

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ABSTRACT

A critique of Allen (1979) is given with alternative suggestions for a procedure of classifying whale stocks and determining appropriate quotas. The proposal is based on the concept of sustainable gross production by a population and the dependence of this quantity on population density and structure. The illustrative example given is for the generalised logistic model of population growth, used hitherto by the IWC for the assessment of baleen whale stocks. Includes two mathematical appendices.

A. COMMENT ON: 'TOWARDS AN IMPROVED WHALE MANAGEMENT PROCEDURE' by K. R. Allen (1979)

This attempt to find solutions to some of the problems arising from application of the New Management Procedure (NMP) is to be welcomed. It is understandable that, given the present circumstances, a spreading of the workload of the Scientific Committee over time would seem desirable. However, the present difficulties arise essentially from the fact that the research and evaluation efforts made by countries are not commensurate with the demands made by the Commission; if more than a handful of scientists, mostly working part-time only, were involved in whale assessments, there would be little difficulty in getting through the full range of business in an annual meeting, since there would have been far more intensive preparatory work. A second weakness at present is the state of the data base and accessibility to it. The Committee works inefficiently because detailed data on effort, age distribution and so on are not made available fully and promptly by countries involved nor is there yet a well organised data base in the Secretariat of the Commission.

Dr Allen's proposal to spread assessments and reviews over a five-year cycle seems to me to accept the inevitability of insufficient scientific effort and poor data submission and availability, and diverts attention from the primary need to improve these.

The proposal also continues an independent single-species-stock approach which is increasingly seen as a weakness of the NMP. It is true that in focusing on observed stock changes, a degree of empiricism is accepted which would take into automatic account any observed consequences of some interspecific relations among the whale species. However, remnants of possibly fallacious assumptions remain in the paper – for example 'Stocks which have been previously unexploited must decrease if any exploitation is to be allowed' (p. 144). This is not necessarily true if the previously unexploited stock had been increasing as a result of changes in its available food supply.

Another difficulty in revising assessments in rotation lies not in the biological interactions but in the use of common effort data in multispecies whaling. Practically all estimates of (a) 'initial' stock size and (b) relation of present level to some earlier level, depend on the relation of catches, through a time series, to catches per unit effort (CPUE). Changes in our appreciation of CPUE as an index of abundance – for example, effects of technological improvements, or of changes in effective searching time and efficiency – affect *all* assessments. If we find that there is a substantial bias in all previous estimates should we really wait up to five years before we correct this bias for some quota determinations? We have experienced other changes in research results which affect many assessments – for example the periodicity of ear-plug laminations.

Some of the above objections might not matter much in practice if we really felt we could observe the direction of stock change over a short period of years and hence estimate the replacement yield. However, I have great doubts regarding the reliability of present CPUE indices, except as gross indicators (and, usually biased indicators) of extreme depletion. This, combined with time-lags even in the single species system, makes unexpected population 'crashes' seem quite likely if the new procedure were to be applied. It is true that large and sudden decreases in quotas create disturbances in whaling industries, but I suggest that human institutions can respond more quickly, more flexibly and over a wider range than can whale populations.

If the maximum sustainable yield level (MSYL) is not to be taken as the optimum level (p. 143) then the entire new procedure still rests on a definition of that level, and an estimation of it (p. 143). The quotas that emerge from it depend substantially on the chosen level and the absolute value of the estimate. Although the MSYL has been rather arbitrarily chosen, there was some logic in choosing a yield model giving a curve skewed to the right and not merely the selection of one because it is more 'conservative' than the symmetrical logistic (e.g., Ohsumi's fin-whale model; consideration of the biological features of mammalian population dynamics). Also the '60% model' is not in all respects more conservative than the 50% model; it provides for earlier protection, but at the same time can overestimate the yielding capacity at high stock levels.

The indices or categories of 'reliability' proposed are entirely subjective. If the quota is to be a variable portion of replacement or sustainable yield it would be better to determine that fraction by criteria of data availability rather than presumed reliability of estimates; this would at least give a direct incentive for improvement. Thus one could envisage a points system based on length of time series, fineness of effort data, number of age determinations reported, and so on.

B. ALTERNATIVE PROPOSAL

The following proposal is still open to some of the criticisms made in section A above regarding Allen's proposals (1979) such as derivation basically from a single species case. However, it does, I think simplify classification; have some of the advantages of the 'step procedures' that have been suggested, without their disadvantages; provide a means of quota decision when little information is available; provide automatic, and variable, safety factors; and not depend critically on the assumed or estimated levels of MSY. Criticism of the NMP within the IWC has focused on the fact that changes in scientific assessments can lead to sharp changes in quotas, and also on whether the '90% rule' is an adequate safety measure. Externally it has been observed that devotion to the attainment of MSY is not economically justified in the long run, and it attaches no value to the enhanced stability that would be expected in stocks held somewhat above MSY levels. In addition I have observed (Holt, 1977) that for some stocks it would also be reasonable to ensure maximum sustained product yields by holding stocks above MSY levels by number.

The response within the IWC has been to examine various suggested 'step procedures' and different safety factors. As to the criticisms of MSY, it is perhaps unrealistic to suppose that there could be at this time, and considering the state of most of the whale stocks, any international agreement to seek an economic optimum state; such an approach would also have to take account of Colin Clarke's bio-economic models incorporating discount rates that might be higher than the maximum net increase rates of whales (Clarke, 1973). In addition of course, we have to develop a procedure that can be applied where interspecific interactions via predation on a common food basis and/or environmental trends make necessary the application of multispecies models and consideration of continuously changing states.

My purpose here is to suggest, for the single species model, that it is possible to use as the basis for a procedure a biologically determined characteristic of yield models, but one other than the MSY. This characteristic is the *biological production* of the stock, defined as the sustainable yield plus the total natural deaths, which is equal to the number (or weight) of annual recruits in a steady state.

For illustration I take the modified logistic giving an MSYL/initial level of 60%, which has been applied both to baleen whales and to female sperm whales. This model, giving the familiar right-hand skewed curve of sustained yield against stock size, is not discordant with such data as exist for whales and also for some other large mammals, and it has been said that its adoption by the IWC instead of the symmetrical logistic is a conservative procedure. This is true with respect to the level at which a stock becomes protected, but the reverse can be true with respect to quota levels for Sustained and Initial Management Stocks. This is most evident when the recruitment – stock size function is an interpolation between an estimate of r in the unexploited or lightly exploited stock, r_1, and the estimate from biological considerations of the highest value that r might reach, in the extremely depleted stock, r_0. In this case then, for the same values of r_0, r_1, M and initial stock size, the 60% model predicts much higher sustainable yields, and hence higher quotas under the NMP for all stock sizes higher than about 55% of initial level.

The actual quotas calculated on both models are critically dependent on the assumed or estimated value of r_0. I have observed (Holt, 1977) that values used by the IWC Scientific Committee to establish sei whale quotas are such that as the initial stock is reduced not only does r increase but also the recruitment $R = rP$ increases before decreasing. I suggested that in the absence of information to support such a value it would be safe to adopt an upper limit of r_0 such that R would never be expected to exceed the recruitment in the unexploited stock, R_1.

Suppose, however, we act on the hypothesis that R can increase up to a point. This means that the curve of gross production, $R = P(F + M)$ against P has a maximum $R_{max} = MSP$. This occurs at a stock level somewhere between P_{MSY} and P_1.

Fig. 1 shows the curves of sustainable yield, Y, and of R for a minke whale stock, if it was in a steady state, with

$$r_1 = M = 0.095$$

and

$$r_0 = 0.155$$

These values would correspond with the situation in which the stock was originally (that is before pelagic whaling reduced its competitors) in a steady state with r_1 equal to the present – and unchanged – M_1 and that the present high r, determined from catch curves for example, is nearly as high as is biologically possible, given the new level of food supply, and that r would now decline toward the original value r_0 as the stock grows toward a new asymptote, unimpeded by whaling.

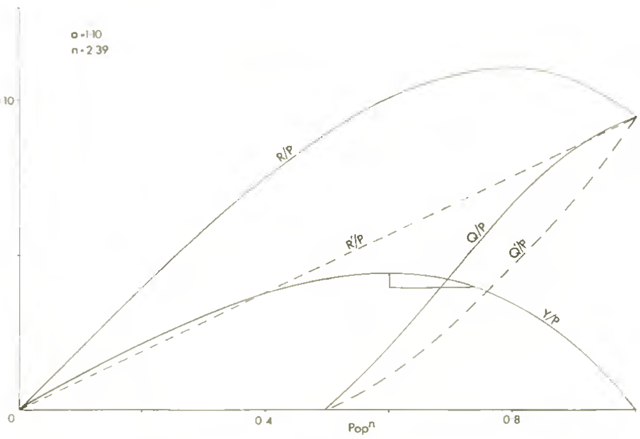

Fig. 1. The curve of sustainable yield, biological production and quota as a fraction of population, P.

The maximum sustained production occurs in this case at 79% of the (eventual) unexploited level. Whaling to hold the stock at MSP level would give a value:

$$\frac{Y_{opt}}{Y_{max}} = 0.82$$

compared with a value of 0.90 achieved by the NMP. This ratio varies greatly, however, with parameter values, and for low enough reproduction coefficients reaches zero – i.e., MSP is at the unexploited level.

The above difficulty is eliminated by a policy seeking to take some proportion of the sustained production. The proportion would need to decrease with decreasing stock size.

There are several possible rules to govern this decrease. A desirable rule might make an automatic compromise between two different objectives; maintenance of high yields, and maintenance of the health of the whale population within an ecosystem and of its functional role in that system. The former objective dictates MSY as an appropriate criterion if we are limited to biologically determined criteria, modulated essentially by safety considerations such as the avoidance of overshoot, the deleterious effects of errors in estimation of MSY and/or of MSYL, and the minimisation of large changes in quotas resulting from trivial changes in assessments. The latter objective could be met by MSP; surely a population kept at that level would be 'healthy', fulfil its role and be reasonably stable. A rule that ensures that quotas are set to stabilise a stock somewhere between these two levels could be to set a quota as a fraction of the biological production ranging linearly from unity at MSP level down to zero at MSY level. However, we are not sure of either of these levels. It is convenient to take the highest possible level for MSP, which is unity (the unexploited population), and the lowest possible level for MSY. It is recognised that whale population curves are, if anything skewed to the right, so that the lowest MSYL is 0.5 of the initial.

Appendix 1 shows the results of applying such a rule in a range of situations and demonstrates its advantages. One result is the merging of the Sustained Management and Initial Management categories. Another is of course that a stock enters the protected category when it is at or below 50% of its initial level, as compared with 45% and 54% by the NMP for the 50% and 60% MSY assumptions respectively. However, the grading of quotas is spread over a much wider range of stock sizes, which guards against large abrupt quota changes in either direction (except there being a radical reassessment of the state of the stock). The rule gives quotas for what are at present defined as Initial Management Stocks which diminish gradually as the stock is reduced, and leads to stabilisation at levels fairly close to those attained under the NMP, but with an effective variable safety factor which derives directly from the application of the simple rule, and varies, for a broad range of parameter values and assumptions, from about 9% to about 25%.

It may be worth noting that the stabilised stock and yield levels which are likely to be obtained by application of the quota rule suggested here are not far from the likely levels for maximum net economic yield with zero discount rate (Holt, 1978). It would be interesting to examine how they relate also to population stability expressed as a function of p.

Appendix 2 develops the mathematical argument of Appendix 1 for the more general case in which the natural mortality, M, as well as the recruitment rate, r, is density dependent.

Appendix 1

For the general class of logistic population growth – yield models we can write:

$$r_p = (r_0 - r_1)(1 - p^n) + r_1 \qquad (1)$$

where

r = rate of recruitment

p = population size relative to maximum natural size ('initial')

Subscript 1 = value in 'initial' stock
0 = value when stock is vanishingly small, i.e., the highest possible value of r_0

If the regulation of the population is through the density dependence of recruitment only then

r_1 = M constant

There is a maximum in the number of recruits, for $p<1$, if

$$r_1 < -\left(\frac{dr}{pdp}\right).$$

For the '60% logistic model' this requires that

$$\frac{r_0}{r_1} > \frac{3}{2}$$

and for the 50% logistic model

$$\frac{r_0}{r_1} > \frac{2}{1}\quad .$$

For the yield curve with MSY at $p = 0.60$, $n = 2.39$, while for the symmetrical logistic $n = 1$. The biological production of the stock, when balanced, is the combined annual number of deaths by whaling and natural causes, and is equal to $R = r_pP$ where

P = initial population number

so

$$R_p = Pp[r_0 - (r_0 - r_1)p^n]$$
$$= PpM[1 + a(1 - p^n)] \qquad (2)$$

where

$a = (r_0 - r_1)/r_1$ and is positive.

R has a maximum value, R_{max}, at

$$p_{opt} = \left[\frac{a + 1}{a(n + 1)}\right]^{1/n} \qquad (3)$$

So that

$$R_{max} = P.M.\frac{(a + 1)^{n+1/n}}{(n + 1)} \cdot \frac{n}{a^{1/n}} \qquad (4)$$

From equation 3 note that

$$p_{opt} \geqslant 1 \quad \text{when} \quad a \leqslant \frac{1}{n}$$

That is, the maximum production is, in such cases, given by the unexploited population, although it could be increased further if the natural mortality were reduced or if the carrying capacity of the environment for the population increased.

For the same population model

$$p_{msy} = \left(\frac{1}{n + 1}\right)^{1/n} \qquad (5)$$

so that

$$p_{opt} = p_{msy} \cdot \left(\frac{a + 1}{a}\right)^{1/n} \qquad (6)$$

Thus

$$p_{msy} \leqslant p_{opt} \leqslant 1$$

Note that the sustainable yield

$$Y = R - MPp \tag{7}$$

so that

$$Y_{max} = PM\left(\frac{an}{n+1}\right)\left(\frac{1}{n+1}\right)^{1/n} \tag{8}$$

and

$$\frac{Y_{max}}{R_{msy}} = \frac{an}{an + (n+1)} \tag{9}$$

The fishing mortality rate is given by:

$$F = \frac{Y}{Pp} \tag{10}$$

and in general

$$\frac{Y}{R} = \frac{F}{F+M} = E$$

for a given value of p.

Although assessments for whales are usually considered in terms of population levels, it may be useful also to follow the practice more common in fisheries management and examine relationships of yield and biological production with the fishing mortality. For this purpose we establish, from equations 2 and 10, that

$$F = aM(1 - p^n)$$

from which the level of fishing mortality which, if maintained, leads to population extinction is

$$F_{ext} = aM$$

and from equations 3 and 5

$$F_{msy} = aM \cdot \frac{n}{n+1}$$

and

$$F_{opt} = aM\left(\frac{n-1}{n+1}\right)$$

Thus the relation of F_{msy} with F_{opt}, and of both of these with the extinction mortality, are independent of a and M, and given by

$$\frac{F_{opt}}{F_{msy}} = \frac{(n-1)}{n} = 0.58 \text{ for } n = 2.39$$

$$\frac{F_{msy}}{F_{ext}} = \frac{n}{(n+1)} = 0.7 \text{ for } n = 2.39$$

and

$$\frac{F_{opt}}{F_{ext}} = \left(\frac{n-1}{n+1}\right) = 0.4 \text{ for } n = 2.39$$

This brings out a point which is commonly not appreciated – that the more the curve of sustainable yield against population size is skewed to the right, as it appears to be for whales (and, indeed, for large mammals generally), then the closer the fishing mortality to give MSY is to that which would, if sustained, exterminate the population.

Recent analyses of data for the minke whale of the Southern Hemisphere provide an illustration of the relationships conveyed by the above equations.

$$M = r_1 = 0.095$$

Assume $n = 2.39$.

The recruitment rate has, with an improvement in environmental carrying capacity, increased to about 0.15, so that $r_1 \geq 0.15$ and therefore $a \geq 0.58$. Now, $1/n = 0.42$ (corresponding, in this case, with $r_0 = 0.135$) so that these stocks would have had maximum production at sizes somewhat less than their unexploited levels under the original environmental conditions, with $p_{opt} \leq 0.91$. From biological considerations, r_0 could be as high as 0.20. This value would give $a = 1.10$, $p_{opt} = 0.79$. Similarly, if $r_0 = 0.25$, $a = 1.63$, $p_{opt} = 0.73$. The yield and production curves for these parameters with $r_0 = 0.20$ are given in Fig. 1.

It may be useful to determine what increase in the carrying capacity for minke whales in the southern ocean is represented by the increase from $r_1 = 0.095$ to $r_2 = 0.15$. If we define the carrying capacity (i.e., the asymptotic level of growth curves of unexploited populations) as J, and designate:

J_1 = original carrying capacity

J_2 = new carrying capacity

and

$$j = \frac{J_2}{J_1}$$

then it is readily shown that if r_0 = constant then

$$j = \frac{r_0 - M}{r_0 - r_2}^{1/n}$$

If $r_0 = 0.20$, $M = 0.095$, $n = 2.39$ then $j = 1.36$ and if $r_0 = 0.25, j = 1.61$.

It is interesting to note that if $r_0 = 0.20$, the minke stock just after the increase in carrying capacity and before exploitation began was at a level slightly less than required for maximum production:

$$\frac{1}{1.36} = 0.73$$

Similarly, if $r_0 = 0.25$, the stock was at that time very close to the new MSY level:

$$\frac{1}{1.61} = 0.62$$

Returning now to the proposed modified management policy, based on R_{max}, we take the minke whale parameters, with $r_0 = 0.20$, for the purposes of demonstrating its application to a single stock, steady state situation. This is illustrated in Fig. 1 which shows the curve of sustainable yield, of biological production and of quota, all as a fraction of population, P. The quota is calculated as

$$Q = 2R(p - 0.5)$$

It will be seen that if the assessment was correct the stock would stabilise at $p = 0.70$, with

$$Y = 0.95Y_{max}$$

Under the present procedure stabilisation would be achieved at $Y = 0.90Y_{max}$, with $p = 0.74$, $Q = 0.042p$. A stock would be protected when $p \leq 0.54$, but under the proposed new procedure only when $p \leqslant 0.50$. However, under this proposed scheme quotas would change more gradually over the whole range of exploited stock sizes.

Still with the 60% MSYL model, but with the higher a, we find

for a = 1.63, Q = 0.060 stabilising at 91% of MSY, p = 0.73

for a = 2.00, Q = 0.071 stabilising at 89% of MSY, p = 0.75

In this last case the quota would actually increase somewhat as the stock was reduced from p = 1 to p = 0.95, but thereafter would decrease as in the other examples.

If we now assume a 50% MSYL model which, if 90% of MSY is taken stabilises at p = 0.64, we find that:

for a = 1.1, proposed procedure Q = 0.025P stabilising at 90% MSY, p = 0.63

for a = 1.63, proposed procedure Q = 0.034P stabilising at 87% MSY, p = 0.67

for a = 2.63, proposed procedure Q = 0.051P stabilising at 82% MSY, p = 0.71

Although the results do not much differ from the present procedure, it will be seen that higher safety limits are automatically achieved when quotas are high because a is assumed or found to be relatively large, and especially when a 50% MSYL is adopted rather than a 60% MSYL.

An advantage of the new proposal is seen if we begin with an unexploited or very lightly exploited stock about which we know little; we must suppose that we have estimates of M and of the initial stock size. Then the initial quota is MP, but as the stock is reduced we do not know whether the biological production will first increase or decrease or remain little changed. Now all production curves lie above the diagonal line:

$R^1 = pM$ (shown dashed on Fig. 1)

If we have no other information we can establish a conservative quota by applying the proposed rule to this line, so

$Q = PMp(2p - 1)$

If the new stock followed a 60% MSYL model, this would stabilise at p = 0.76, 80% of MSY, Q = 0.037P. Similarly, for the 50% MSYL model, stabilisation is at p = 0.68, 85% of MSY, Q = 0.023P. If one were prepared to assume that 60% MSYL or indeed, any other model, applied then a minor upward adjustment of Q could be made, corresponding not with the straight diagonal but with an R curve that has a slope at $p \rightarrow 0$ the same as that of the Y curve, so that the former would not intersect with the latter.

Suppose that, subsequently, a measure of increase in r was obtained as stock is reduced giving an estimate of the slope of the right hand side of the curve of r against p, as $p \rightarrow$ unity. If we are prepared to assume that whale yield curves are, if anything, skewed to the right then this slope gives an estimate of the upper bound of r_0, by linear extrapolation back to p = 0, corresponding with a 50% MSYL curve. A revised, lower, estimate of r_0 could be obtained if, from biological considerations, this were considered to be unrealistically high, or if one were prepared to assume that the MSYL was not less than some given value greater than p = 0.5.

It is easily shown that for any given slope of the r-curve at $p \rightarrow$ unity the following relation holds between a and r for any pair of models indicated by subscripts u and v:

$a_u n_u = a_v n_v = \ldots$

Thus, referring to Table 1, the 50% MSYL model corresponding with the 60% MSYL model for $a_{50} = 1.10$, with the same slope of r at $p \rightarrow$ unity, has $a_{60} = 2.39 \times 1.10 = 2.63$, shown in the right hand columns of R/P and Y/P.

Table 1

Exemplary calculations of sustainable production and yield
(M = 0.095 and maxima are underlined)

		R/P						Y/P					
	a	1.10	1.63	2.00	1.10	1.63	2.63	1.10	1.63	2.00	1.10	1.63	2.63
p	n	2.39	2.39	2.39	1.00	1.00	1.00	2.39	2.39	2.39	1.00	1.00	1.00
1.00		0.095	0.095	0.095	0.095	0.095	0.095	0	0	0	0	0	0
0.95					0.095						0.005		
0.90		0.106	0.117	0.124	0.095	0.099	0.108	0.021	0.031	0.038	0.009	0.014	0.023
0.81						0.101						0.024	
0.80		0.111	0.127	0.139	0.093	0.101	0.116	0.035	0.051	0.063	0.017	0.025	0.040
0.79		0.111						0.036					
0.73			0.129						0.060				
0.71				0.143						0.075			
0.70		0.109	0.129	0.143	0.088	0.099	0.119	0.042	0.062	0.076	0.022	0.033	0.052
0.69							0.119						0.053
0.60		0.101	0.123	0.137	0.082	0.094	0.117	0.044	0.066	0.080	0.025	0.037	0.060
0.50		0.090	0.110	0.124	0.074	0.086	0.110	0.042	0.063	0.077	0.027	0.039	0.062
0.40		0.075	0.093	0.106	0.063	0.075	0.098	0.037	0.055	0.068	0.025	0.037	0.060
0.30		0.058	0.072	0.082	0.050	0.061	0.081	0.030	0.044	0.054	0.022	0.033	0.052
0.20		0.040	0.049	0.056	0.036	0.044	0.059	0.021	0.030	0.037	0.017	0.025	0.040
0.10		0.020	0.025	0.028	0.019	0.023	0.032	0.011	0.015	0.019	0.009	0.014	0.023

Once the stock has been reduced to 80% of its 'initial' level the 60% model is noticeably more 'conservative' (5+% difference) for the same set of parameters.

The situation is otherwise if, instead of having estimates of the 'initial slope' of the r-curve, we were to adopt an estimate of r_0 from other considerations, such as inter-specific comparison. Then in each case the 60% MSYL curve is always much less conservative, giving e.g., 20+% higher quota at 80% of initial stock or less. The same argument applies of course to the application of the present management procedure.

In Table 2 are given the values of F corresponding with the entries in Table 1; the right hand columns show these as % of the highest sustainable value, F_{ext}. Fig. 2 illustrates one of the pairs of curves of production and yield against fishing mortality, for a = 1.10, n = 2.39.

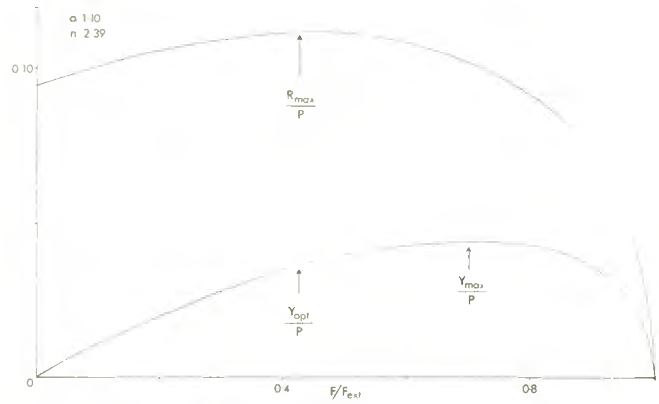

Fig. 2. One of the pairs of production and yield against fishing mortality.

Table 2

		F						F/F_{ext} %	
	a	1.10	1.63	2.00	1.10	1.63	2.63		
p	n	2.39	2.39	2.39	1.00	1.00	1.00	2.39	1.10
1.00		0	0	0	0	0	0	0	0
0.95					0.010				
0.90		0.023	0.028	0.042	0.011	0.016	0.025	0.22	0.10
0.81						0.029			
0.80		0.044	0.064	0.078	0.022	0.031	0.050	0.41	0.20
0.79		0.046							
0.73			0.082						
0.71				0.106					
0.70		0.060	0.089	0.109	0.033	0.047	0.075	0.57	0.30
0.69							0.078		
0.60		0.073	0.110	0.133	0.044	0.062	0.100	0.70	0.40
0.50		0.084	0.126	0.154	0.055	0.078	0.125	0.81	0.50
0.40		0.093	0.138	0.170	0.066	0.093	0.150	0.89	0.60
0.30		0.100	0.147	0.180	0.077	0.109	0.175	0.95	0.70
0.20		0.105	0.150	0.185	0.088	0.124	0.200	0.97	0.80
0.10		0.110	0.150	0.190	0.099	0.140	0.225	0.99	0.90
0		0.110	0.155	0.190	0.110	0.155	0.250	1.000	1.000

Note: Values for Y_{max} underlined.
Values for Y_{opt} double underlined.

Appendix 2

In the text of this paper I refer to the generalised logistic model in which the natural mortality, M, is constant. Here I consider this model with both r and M density dependent.

In this general case we write

$$M = M_1 + (M_0 - M_1)(1 - p^m)$$

Writing

$$b = \frac{M_0 - M_1}{M}$$

and remembering that

$$M_1 = r_1$$

we have

$$r = r_1(a + 1 - ap^n)$$

and

$$M = r_1(b + 1 - bp^m)$$

The expression for gross production, R, is the same as the case for M constant, but the expression for yield, Y, is now different, thus

$$Y = pP(r - M)$$
$$= pPr_1(a - b - ap^n + bp^m)$$
$$= r_1pP[(a - b)(1 - p^n) - b(p^n - p^m)].$$

First consider the special case when n = m, that is when the exponent of density dependence is the same for births (or recruitment) and for natural deaths. Then the expression becomes essentially of the same form as that for M = constant:

$$Y = r_1pP(a - b)(1 - p^n).$$

Since

$$p_{max} = \left(\frac{1}{n+1}\right)^{1/n}$$

$$Y_{max} = r_1 P(a - b)\left(\frac{1}{n+1}\right)^{1/n} \cdot \frac{n}{n+1}$$

In the more general case, where $n \neq m$, there is no exact analytical solution. However, it can be said that the yield curve lies between, and has a maximum at a population level between, that for a single exponent of value n and that for an exponent of value m, and does not depart far – especially near the maximum – from the curve with an exponent $(n + m/2)$.

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SC/30/Doc 54

On the Status of the Gray Whale Stocks in the Coastal Waters of the Chuckotka Peninsula

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ABSTRACT

The results of investigations of gray whales taken for native needs on Chuckotka, have been presented. The analysis of data for a series of years has shown that an annual catch of gray whales within the quota of 200 set by the Soviet authorities has had no negative impact on the abundance of the California–Chuckotskaya population.

The gray whale is the main commercial species of the Chuckotka state fisheries farms. In the past the gray whale was subjected to severe exploitation to near extinction by the pelagic whaling fleets, and regulations prohibiting the catch of this species were introduced in 1946. From 1972 a national quota of 200 whales was established to satisfy the needs of the native people.

Systematic studies of the gray whales from the Chuckotka regions began in 1965. During this period extensive material on the biology, abundance and distribution of this species was collected (Zimushko, 1967, 1969, 1969a, 1970, 1970a, 1970b, 1971).

Gray whales are only found in the North Pacific and are divided into two populations; the California–Chuckotskaya population (in summer this population is found in the Bering Sea and in the Chukchi sea, moving into the California waters in winter) and the Okhotsk–Korean population which is extremely depleted.

Data from aerial surveys carried out by Soviet specialists in 1968, 1973 and 1975 showed the main concentrations of gray whales in the Chukchi sea to be off the Heart-Stone Cape (67° N, 171° W), and off the Inchoun Cape (67° N, 170° W), as well as in the regions around 67° 50′ N, 165° 50′ W. The centres of concentrations in the Bering Strait were approximately 66° N, 170° W; 65° 30′ N, 171° W; 65° N, 170° W; 64° 30′ N, 172° W; 63° 30′ N, 173° W. There are also concentrations at 65° 25′ N, 178° W and 64° 40′ N, 175° W in Anadyr Bay. The gray whales off the Koryak coast near the Capes of Hatyrka and Mayno-Pilgino are concentrated at 61° 50′ N, 174° 10′ E and 61° 30′ N, 177° 15′ E.

Recent information on the abundance of gray whales varies somewhat. According to Soviet data the abundance of gray whales in the California–Chuckotskaya population was about 7,700 in 1975. This figure is somewhat lower than that of Rice and Wolman (1971) who estimated the population to be between 8,000 and 12,000.

From 1969, the subsistence whaling of gray whales from large vessels was stopped and they are now taken by the whaling ship *Zvezdny*. At present this ship is used by the six state fishing farms situated along the 450 miles of coast.

The following numbers of whales were taken from 1969 to 1977 (Ivashin and Mineev, 1978):

1969	1970	1971	1972	1973	1974	1975	1976	1977
139	146	150	181	173	181	171	163	186

The average lengths of whales taken since 1965 are:

1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1977
11.8	12.3	12.3	12.9	12.3	12.9	12.2	12.8	12.6	12.7	12.55 m

The largest female taken during this time was 14.4 m, and the largest male 14.1 m.

Length at maturity was found to be 12.0 m in females and 11.5 m (3–6 years) in males. 42 immature females were taken in 1965, 25 in 1966 and 28 in 1967. In 1977 44% of the females taken were pregnant. Mating occurs from December–March, while the parturition peak was observed to be in January. Gestation in gray whales lasts nearly a year. Parturition begins as soon as the females arrive for their winter stay in the Californian lagoons (December–February). About 57% of the mature females reproduce each year, resulting in an annual increase in population of about 16.5%–18%. The average size of embryos by months (in cm):

	Males		Females
21 February–10 March	96		–
July	126		137
August	166		173
8 August–24 September	205	Sept.	246
October	341		340
14 December–20 January	462		–

The average size at birth is about 490 cm.

The available data show that more females than males have been taken over all the seasons of fishery:

	1965	1966	1967	1968	1969	1970	1971	1972
% females	58	49	62	76	72	78	50	85
% males	42	51	38	33	28	22	50	15

This is probably because the average size of gray whale females is more than that of the males, and thus the whalers trying to catch the largest animals resulted in disproportionately high catches of females compared with the sex ratio of the animals in nature.

In 1977 we observed and registered animals at the settlement of Lorino where the most whales had been planned to be delivered (60 out of 240) and from July to October, 52 whales were transported. 19 whales were examined from

7 September to 22 October, and most of them were females (16 or 84.2%).

The average size of the animals investigated was 12.55 m which was comparable to those of previous years. The smallest female was 9.8 m and the largest – 14.0 m (average length: 12.57 m). The smallest male was 11.3 m, and the largest 12.0 m (average length: 11.76 m).

Most of the females investigated were immature (6 or 37.5%) with no corpora lutea or signs of any previous pregnancy. One of these immature females was 12.6 m in length, somewhat longer than the average length at maturity (12 m). However, in contrast to this, an 11.8 m female taken was pregnant for the first time and therefore body length cannot be regarded as an accurate indication of maturity and evidence of ovulation is needed.

A Chuckotka custom of slitting the abdominal cavity just after killing (to cool the body) results in embryo loss even before transportation to land. For this reason the ovaries were not always detected thus making it difficult to examine the physiological condition of the females. Although no embryos were found during our work pregnancy was ascertained by the presence of a corpus luteum in the ovaries or (if they were absent) by the state and structure of the uterus mucous membrane. The greater portion (7 or 70%) of mature females were pregnant.

The high percentage of pregnant females in the catches suggests a high reproductive capacity of gray whales. The present restriction on gray whale catches allowing only aboriginal catches (limited to 200 by Soviet authorities) will surely allow the stocks of this species to completely recover very soon. The recent reports by Zimushko showed a significant quantitative increase in the number of the whales seen in the fishing areas and this has been confirmed by the captain of w/v *Zvezdny* who has been taking gray whales since 1969.

An analysis of the available data shows that the annual take of 200 gray whales has not reduced their abundance despite the high proportion of females in the catches. However, as well as a quantitative quota for gray whales a quota by sex ensuring that equal numbers of males and females are taken should be introduced. As a rule the gray whales live in pairs and so a selective fishery might not be very difficult. Such a strategy would be least harmful to the stocks and would result in the most rapid recovery to their optimal abundance.

The high percentage of immature females taken is not a reflection of the actual proportion in the population but is due to the fact that the whaling took place in the coastal waters near to the settlements where the whales had to be delivered, and in general the younger animals inhabit these regions during feeding.

The data show that the California–Chuckotskaya population is steadily increasing and will soon reach its original level.

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SC/30/Doc 55

Preliminary Report on the Bryde's Whale Catch Taken by Special Permit in the Southern Hemisphere During the 1977/78 Whaling Season

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INTRODUCTION

The International Whaling Commission (IWC) only allows exploitation of a whale species when its stock condition has been adequately assessed. Bryde's whale stocks are almost unexploited by the fishery in the Southern Hemisphere although it is known that Bryde's (but registered as sei whales in the tables of the Bureau of Whaling Statistics) whales were taken (Ohsumi, 1977) by a combined catcher-factory ship operating under the Somali flag in the area lying south of South Africa. The Japanese whalers successfully took Bryde's whales under a scientific permit south of Madagascar Island during the 1976/77 season (Ohsumi, 1977). The necessary biological and other information would allow a more complete understanding of different problems relating to this whale species. In addition, the marking and sightings of Bryde's whales within their area of distribution would aid the acquisition of the necessary information on their number, amongst other things. At the same time, the great significance of Bryde's whale population structure studies is clear, and emphasises the importance of registering every whale taken in the future.

In accordance with a permit issued by the USSR Ministry of Fisheries in November 1977, the Soviet Antarctic whale catcher *Sovietskaya Rossiya* took five Bryde's whales for scientific purposes. The examination and the collection of materials were made with several objectives in mind, especially the examination of several factors as a means to possible stock identification (e.g. morphometric data, internal and external parasites).

AREAS OF OPERATION

All five Bryde's whales were taken on 19 November 1977, when the fleet was south of Madagascar Island (28° 47′ S, 44° 29′ E).

WEATHER CONDITIONS

It should be noted that on the whole weather conditions were unfavourable for investigations on the day of the whaling (Atmospheric pressure: 760 mm; water temperature: 23°C; air temperature: –24°C; winds: easterly and north-easterly, strength up to 7 on the Beaufort wind scale; visibility: 0.5 miles and less, dark sky, rain showers often observed; sea conditions: up to 7 on the Beaufort scale.) Up to 20 Bryde's whales were observed from the fleet vessels throughout a day.

WHALES TAKEN

16 Bryde's whales were encountered during the day by four whale catchers. Two whales were taken from a group of five animals and one each from groups of six, three and two animals. Three animals were males (body length: 9.1 m, 10.3 m and 12.3 m) and two females (11.2 m and 13.2 m).

Body Colouration

The dorsal surface and sides of the whale are grey with a sharp transition to the white underside, but with a white-pink tint in the area between the umbilicus and the anus. Thoracic and caudal flippers are of the same colour as the back and sides.

External Parasites

Four *Penella balaenoptera* were registered on the external side of the thoracic flippers closer to the proximal ends on both females. The length of the visible part of the *Penella* varied from 3–4 cm. *Penellae* were collected and registered and further analysis will be made in the laboratory. The determination of their species is of great interest, if one takes into account the opinion of Ivashin and Golubovsky (1977) that *Penellae* of the Bryde's whales inhabiting this area are different from those of the Antarctic Area.

Buccal Cavity

An examination of the buccal cavity showed that the palate surface was white with a slightly bluish tinge. On the whole, the shape and colouration were typical for this whale species.

Baleen plates

The baleen plates were black. About 20–30 minor plates, 5–7 cm in height were found in the fore part of the baleen row, which were straw coloured like the baleen fringe. The results of the baleen plate counts are given in Table 1 (according to Williamson, 1973).

Table 1

The number of baleen plates

Sex Length	Male 9.1 m	Male 10.3 m	Male 12.3 m	Female 11.2 m	Female 13.2 m
Conventional row					
Right	253	249	254	247	260
Left	257	244	259	255	260

The number of the baleen plates varied insignificantly depending on the individual studied.

Ear plugs

Ear plugs were taken from all five whales, but appeared to be amorphous in three animals. Determination of the number of layers will be made in the laboratory. An attempt was made to determine age from the baleen plates, but no positive results were obtained: 34 age ridges were counted while examining the baleen plate of an 11.2 m immature female, whereas no trace of a corpus luteum was found in the ovaries.

Physiological Condition

It was established from the examination of the testis section that the 9.1 m male was immature and that the 12.3 m male was mature. The testes of the 10.3 m male were provisionally considered mature but further analysis is necessary.

Table 2

Physiological condition

Sex Length	Male 9.1 m	Male 10.3 m	Male 12.3 m	Female 11.2 m	Female 13.2 m
Physiological condition	Immature	Mature	Mature	Immature	Lactating

Weight and size characteristics of the whale testes and ovaries are given in Table 3.

Feeding

Anchovy were exclusively found upon examination of the stomachs (the species was not determined) and also on the plates of the baleen row, apparently as the result of a whale belch during their feeding. The rate of the stomach filling was a mean one (the weight of its whole content – 50–60 kg).

Internal Parasites

No endoparasites were discovered while examining and dissecting the digestive tract, the urino-genital system, the liver and the lungs.

Body Measurements

Body measurements were systematically taken for each whale as shown in Table 4. It should be noted that some

Table 3

Weight and size of the testes and ovaries

				Size (cm)					
		Weight (g)		Right			Left		
Sex	Length	Right	Left	Length	Width	Height	Length	Width	Height
Male	9.1 m	1,000	964	28.7	9.6	6.0	30.0	9.6	5.0
Male	10.3 m	1,310	1,240	36.3	11.0	6.8	36.0	11.2	6.4
Male	12.3 m	1,980	1,960	44.0	9.7	7.4	44.5	9.9	7.2
Female	11.0 m	218	242	16.3	7.2	4.4	15.9	6.8	4.8
Female	13.2 m[1]	340	334	19.9	11.0	5.3	19.4	5.2	5.6

[1] 7 traces of corpora lutea were counted on the whale ovaries.

Table 4

The results of the measurements of the Bryde's whales

	Male		Male		Male		Female		Female	
Measurements	cm	%	cm	%	cm	%	cm	%	cm	%
1. Body length	910	100	2,030	100	1,230	100	1,120	100	1,320	100
2. Snout to centre of blowhole	150	16.5	172	16.7	215	15.5	191	17.1	240	18.2
3. Snout to angle of mouth	155	17.0	174	16.9	223	18.1	210	18.8	257	19.5
4. Projection upper/lower jaw	24	2.6	30	2.9	28	2.3	36	3.2	25	1.9
5. Tip of lower jaw to angle of mouth	176	19.3	212	20.6	254	20.7	246	22.0	289	21.9
6. Snout to centre of eye	160	17.6	200	19.4	237	19.3	220	19.6	271	20.5
7. Centre of eye to centre of ear	56	6.2	58	5.6	72	5.9	65	5.8	80	6.1
8. Length of flipper along external edge	115	12.6	139	13.5	163	13.3	156	13.9	176	13.3
9. Length of flipper along a curve	170	18.9	203	19.7	254	20.6	269	24.0	224	17.0
10. Maximum width of flipper	24	2.6	22	2.1	32	2.6	28	2.5	37	2.8
11. Length of dorsal fin	26	2.9	35	3.4	41	3.3	–	–	43	3.3
12. Dorsal fin from fin tip to base	14	1.5	15	1.5	22	1.8	–	–	25	1.9
13. Fluke notch to anterior insertion	230	25.3	250	24.3	235	27.2	300	26.8	338	25.6
14. Fluke length left	110	12.1	138	13.4	147	12.0	127	11.3	155	11.7
right	112	12.3	135	13.1	149	12.1	132	11.8	158	12.0
15. Fluke depth left	53	5.8	63	6.1	70	5.7	65	5.8	74	5.6
right	54	5.9	63	6.1	72	5.9	62	5.5	76	5.8
16. Fluke width	212	23.3	270	26.2	284	23.1	249	22.2	298	22.6
17. Height of peduncle near end of dorsal fin	100	11.0	114	11.1	131	10.7	128	11.4	128	9.7
18. Fluke notch to anus	243	26.7	281	27.3	306	24.9	295	26.3	317	24.0
19. Fluke notch to umbilicus	401	44.1	455	44.2	533	43.3	492	43.9	547	41.4
20. Fluke notch to ventral grooves	401	44.1	455	44.2	533	43.3	492	43.9	547	41.4
21. Anus to genital slit	53	5.8	64	6.2	73	5.9	12	1.1	18	1.4
22. Thickness of blubber in the midlateral area	2.5	0.3	2.8	0.3	3.6	0.3	3.3	0.3	3.5	0.3

correlation exists between measurements 2, 3, 5 and 6 and body length, the rostrum increasing as the body length increases, but no such relationship is revealed by the other measurements which is evidence of individual variability.

Table 5

The results of the weighing of the 11.2 m female

NN	Body parts	Weight kg	Weight %
1	Integumentary fat	750	7.05
2	Peritoneum	1,200	11.28
3	Tongue	200	1.88
4	Dorsal meat	2,800	26.32
5	Ventral meat	2,050	19.27
6	Vertebral column with ribs	1,600	15.04
7	Cranium (no flesh)	150	7.05
8	Lower jaws	400	3.76
9	Liver	124.8	1.17
10	Kidney	36.7	0.34
11	Heart	40.5	0.38
12	Spleen	1.0	0.01
13	Baleen (no flesh)	111.0	1.04
14	Stomach and intestines	105	0.99
15	Lungs, throat and trachea	400	3.75
16	Flukes	71	0.66
	Total	10,040	100.00

Weighing

It was not possible to weigh all the animals caught due to the unfavourable weather conditions and heavy seas. Data for an 11.2 m female Bryde's whale are shown in Table 5.

SIGHTINGS

In November, 54 Bryde's whales were sighted during the passage of seven whale catchers within the chosen whaling area, 90° E–44° E, which suggests that the Bryde's whales are distributed over a large area in the Indian Ocean and that stocks of commercial importance can be found there. A more precise evaluation of this would result from an investigation of the area by special scouting vessels during the spring–summer period.

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SC/30/Doc 56

Distribution of Whales in the North Pacific on Expeditional Data of 1965/66, 1969/70 and 1975

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INTRODUCTION

Investigation into the distribution of commercial whale species in and beyond present fisheries regions and other information on populations are very important for both science and industry. To attempt to solve such problems the collection of sightings data by research vessels, whalers themselves and during specialised scientific cruises (1965/66 – *Vnushytelny*; 1968 – *Druzhny*; 1969/70 – *Verny*; 1975 – *Vnushytelny*) was organised.

The main working area of the above expeditions covered the near equatorial zone in the eastern Pacific. The cruises of 1965/66 and 1969/70 were conducted in winter and those of 1968 and 1975 in spring–summer. On the journey from the Sangar Strait to the investigation area the vessels steamed around the clock, although observations were only made in daylight, but on arrival the ships steamed only during the day. The areas to the east of 140° W to the American coast and from Los Angeles to Ecuador were the most intensively studied.

RESULTS

Comparative analysis of the results obtained *en route* and in the areas of intensive research revealed seasonal irregularity in the distribution of commercial whale species.

Practically no whales were found to the east and south-east of Hawaii up to 135° W. No whales were detected on the Pacific route by scientific research vessels. The area between Sangar Strait and Hawaii is more or less uniformly inhabited by whales. In March, whale concentrations of 8–10 and even 50–60 individuals were registered near Japan and at distances of 200–500 miles to the east of the Kuril Islands and Japanese coast. In August–September sperm whales are occasionally found (individuals or small groups of 5–7 animals). To the south-east between 168° E and 178° E no whales were observed in any season. To the south-east of this zone, from 178° E to about 155° W, sperm whales occurred as a rule in August–September in mixed concentrations of about 100 individuals or more. In spring, sperm whales in this area are scattered and do not form large concentrations. Baleen whales are rare throughout the year in the area between the Sangar Strait and the Hawaiian Islands where a total of only four fin whales, three minke whales (March) and three sei whales were observed by the expeditions.

The region of more consistent sightings effort was also characterised by irregular distribution of whales. Sperm whales were prevalent in the North Pacific, the largest concentrations being seen to the north and west of the Galapagos Islands between 10° N and the equator almost to 170° W, most often in spring. In March–April groups from 10–20 to 100 individuals were seen. In the summer and autumn the number of sperm whales in this region was somewhat lower although large numbers were seen near the Galapagos Islands. Large groups of small females and juveniles were observed to the east, west and south of these islands.

Baleen whales are scattered quite uniformly in this region but no large concentrations were seen. In June 1975 more than one hundred blue whales were observed to the west of the southern tip of the California peninsula by the whaler *Vnushytelny* during five days of observation. In March 1975 between 8° N and 10° N two groups of blue whales (20 individuals in total) were found to the north of the Galapagos Islands. On the basis of size, colouration, some behavioural features and other characters these whales were identified as pigmy blue whales. Whales of this species were also found in this area in June, but in small numbers. During the seasons of the investigation, single humpback whales, minke whales, sei whales and fin whales were observed. In the Galapagos Islands area the most numerous baleen species were fin whales (14 individuals) and sei whales (10 individuals). Unfortunately, all the expeditions whose data have been analysed worked in winter in the southern part of the near equatorial east Pacific and therefore no definite conclusions can be drawn on the distribution of whales to the north of the equator during this period.

In addition to the sightings data, the hydrological surveys conducted during the expeditions revealed some regularities in whale distribution with respect to the environment. In particular a positive relationship between the occurrences of the intensity depth of the temperature jump layer and the distribution of baleen whales has been determined, and adherence of sperm whales to areas of upwelling has also been noted.

CONCLUSIONS

From 1965–75 therefore, the North Pacific waters to the west of America were investigated by the survey whalers. This has shown that only the sperm whales form dense commercial stocks; that the number of blue whales is being restored; that in spring and summer single and scattered individuals of the baleen whale species are found. New data on the distribution of pigmy blue whales have been collected and some regularities in baleen and sperm whale distribution have been revealed. At the same time it is important to note that the research to the north of the equator was only conducted in spring and summer. In order to obtain a complete picture of the present all-year-round whale distribution in this area additional expeditions are needed to incorporate autumn and winter as well.

SC/30/Doc 57

Revealing of Differences in the Antarctic Baleen Whale Stocks on the Basis of the Analysis of the 'Jacobson's Organ' Position

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Odessa Branch of Azcher NIRO

ABSTRACT

Measurements determining the position of the Jacobson's Organ were taken and data for sei and fin whales analysed as a possible means of differentiating between stocks. Interspecific differences between the two species were found and sexual dimorphism was revealed for both species. The latter means that future comparisons between stocks should be made separately by sex. The study suggests that one stock of sei whales is present off the Prince Edward, Crozet and Kerguelen Islands in the Indian Ocean and that whales found off the Chilean coast and Graham Land also form a single stock. Sei whales from the Eastern Atlantic differ greatly from those from the Indian Ocean and the Pacific Ocean (off Peter the Great Island). Differences between sei whales of the Indian and Pacific Oceans are less pronounced. Fin whales found off the Prince Edward, Crozet and Kerguelen Islands are also apparently a single stock and differences are found between fin whales from this group, the Atlantic Ocean and the Pacific Ocean. It is suggested that the position of the Jacobson's Organ may be useful as a population character for other species of baleen whales.

INTRODUCTION

The body shape of baleen whales is so specific that it is difficult to find morphological differences within any one species which would allow intraspecific differentiation. Some fifty years ago, whales were considered as cosmopolitan (especially the fast swimming baleen whales), but results obtained from the treatment of some morphometric material did allow some differences to be determined in the mean sizes and proportions of some body parts from whales inhabiting the Northern and the Southern Hemispheres (Tomilin, 1953, 1957; Sleptsov, 1955). In addition, marking data showed that the whales of the two Hemispheres do not mix but appear to be isolated from each other (Tomilin, 1946, 1957). These two facts served as the basis of the supposition that the whales of each Hemisphere are independent subspecies (Tomilin, 1953, 1957) or even species (Zemsky and Budylenko, 1975).

The analysis of the whales distribution led to the idea of the existence of "local whale stocks" with their own migration paths and breeding areas (Klumov, 1955). However, no morphological differences were found in the whales of these stocks which would allow identification of these local stocks within the populations. Considerable effort over a long time span to find some morphological differences between the whale stocks gave no results. Some scientists were of the opinion that no differences could be found since there were no obstacles in the ocean which could isolate the whale stocks and therefore that the whales represent a single homogeneous stock (Zenkovich, 1965).

However, there are no grounds to make any exceptions with regard to whales from our knowledge of theoretical population biology and it is quite obvious that populations exist within whale species. The most important consideration in any rational whale management strategy having a well grounded biological base is the capability to differentiate between the different populations. Urgent searching for differences in sperm whale stocks of the Northern Hemisphere has already given positive results (Berzin, 1975). It is necessary to continue searching for differences in the baleen whales as well.

MATERIALS AND METHODS

As every population possesses its own genetic and hence phenotypic fund, it is necessary to find those characters which can help to reveal population differences. The two clearly identified hollows having the configuration of the letter "C" (called the Jacobson's Organ) lying at the end of the rostrum were studied and efforts were made to analyse its position. The shape of the Jacobson's Organ is characteristic of different whale species. Thus the hollows are located with the convex parts against each other in fin whales, and vice versa in sei whales (Fig. 1). Individual variability in the shape of the hollows is clearly shown within a species. Thus for example the apertures of the inner canals can be open either in the forefront of the hollow, in its central part, in its side or even on the bottom of the hollow. These apertures are named "centres" of the Jacobson's Organ throughout this paper. It was decided to analyse the location of the Jacobson's Organ on the rostrum, measuring the distance from its centre to the end of the rostrum (l_1) and the beginning of the baleen row (l_2), as well as the distance from the end of the rostrum to the baleen row (L), which is the sum of the first two measurements.

It is difficult to determine strictly fixed measurements of the morphometry of whales, and the standard series of measurements is so large that it is difficult to measure them for many whales and to collect a large enough sample size under whaling conditions when the whole body is "dissected" on the deck of a factory ship in a matter of minutes. However, the strictly determined measurement of the Jacobson's Organ can easily be carried out by one person using a small ruler for practically all whales taken. Such data were collected by the author with the help of scientific workers V. A. Neizhko, A. F. Flyorov and V. I. Shevchenko who were present as a research group on the *Sovietskaya Ukraina* from 1971 until 1975 and their efforts are greatly appreciated.

The above measurements were made for more than 600 whales of different species, but the only measurements analysed were exclusively for sei and fin whales caught in

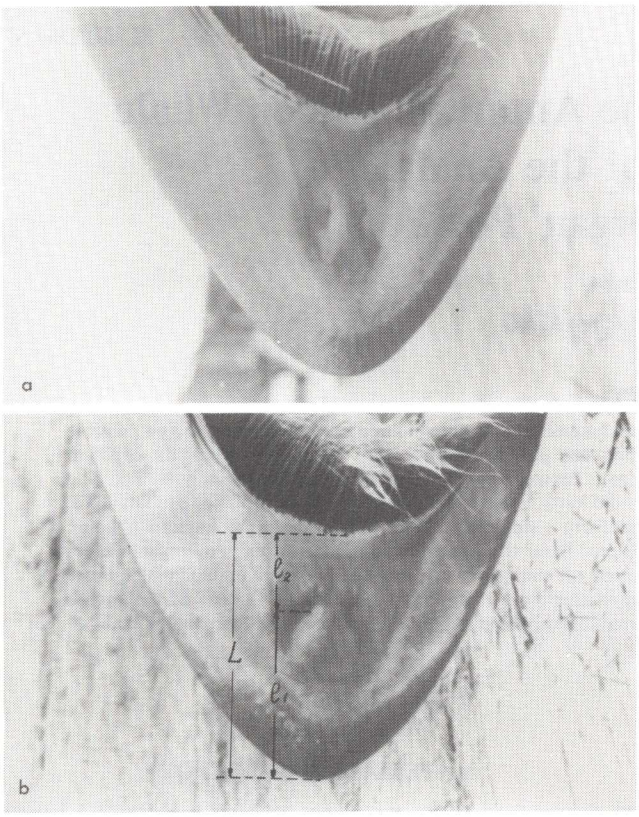

Fig. 1. The shape of the Jacobson's Organ in (a) sei whales and (b) fin whales and the measurements l_1, l_2 and L.

dense, clearly isolated stocks. Comparisons were made between sei whale stocks found in the Gough Island area (December), the areas of the Prince Edward, Crozet and Kerguelen Islands (January–February), off the Chilean coast (January) and off the coast of Graham Land (February). A total of 317 sei whales were measured from these stocks.

Comparisons were also made for fin whales from the stock of the Prince Edward, Crozet and Kerguelen Islands area (January–February) and those from the area around Peter the Great Island. The total number of fin whales measured from these stocks was 194 (Fig. 2).

RESULTS

The analysis of measurements showed that in sei whales the average distance of l_1, was 9.5 cm and of l_2 was 5.0 cm, and in fin whales 12.0 cm and 5.5 cm respectively. The relationship l_1/l_2 (which determines the relative position of the Jacobson's Organ on the whale's rostrum) is 1.9 in sei whales and 2.2 in fin whales. Thus the Jacobson's Organ is located relatively nearer to the beginning of the baleen row in fin whales than in sei whales.

It is known (Sleptsov, 1955; Tomilin, 1953) that sexual dimorphism exists in baleen whales and, in particular, in minke whales is expressed in the greater length of the females. Ivanova (1961) noted in his study of the body proportions of whales using the method of Mackintosh and Wheeler (1929), that the lengths of the head and of the tail are somewhat greater in sei whale females than males although the differences were not stable.

Our measurements clearly revealed sex differences in both sei and fin whales. The distance from the end of the mouth to the Jacobson's Organ and from the Jacobson's Organ to the beginning of the baleen row appeared to be somewhat greater in females than males of equal body length (Fig. 3). This discovery of sex differences means that any further analysis must be carried out separately for males and females.

Sei whales

The graphical analysis of the three measurements showed that in January–February no great differences were revealed for males and females in the sei whale stocks of the Indian Ocean near the Prince Edward, Kerguelen and Crozet Islands. Apparently, sei whales of the same "stock" are found off these Islands during these months. For this reason they have been grouped together as the "Indian Ocean" sei whales.

No differences were found when comparing sei whales taken off the Chilean coast and off the north-western coast of Graham Land although there is not enough morphological data to confirm this. Graham Land lies in the Drake Strait, and one can suppose that the sei whales of the Falkland stock are found there on their feeding migrations.

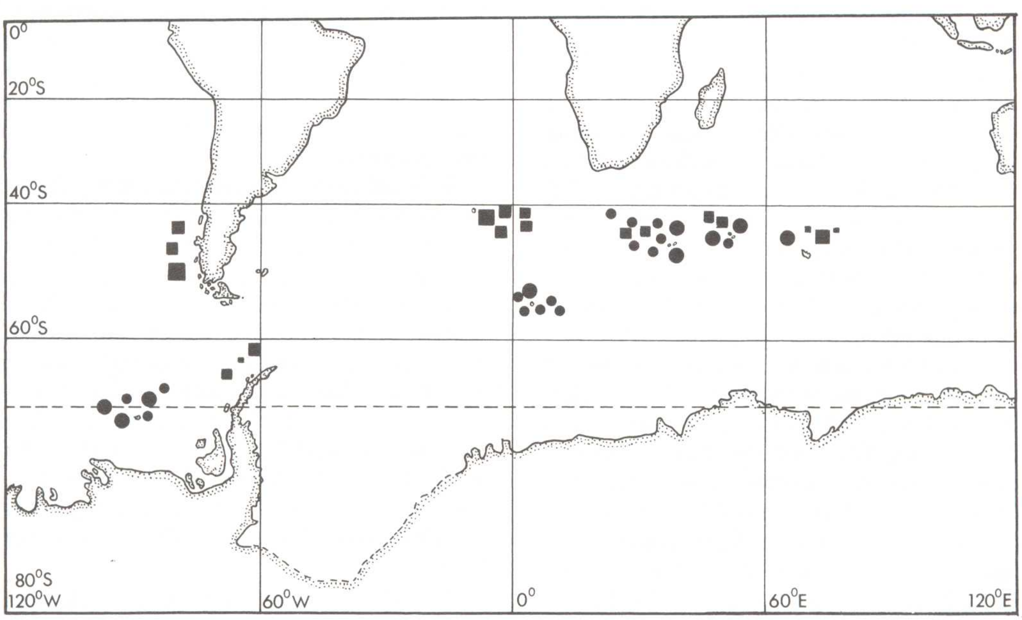

Fig. 2. The areas of the sei whale (■) and fin whale (●) stocks investigated.

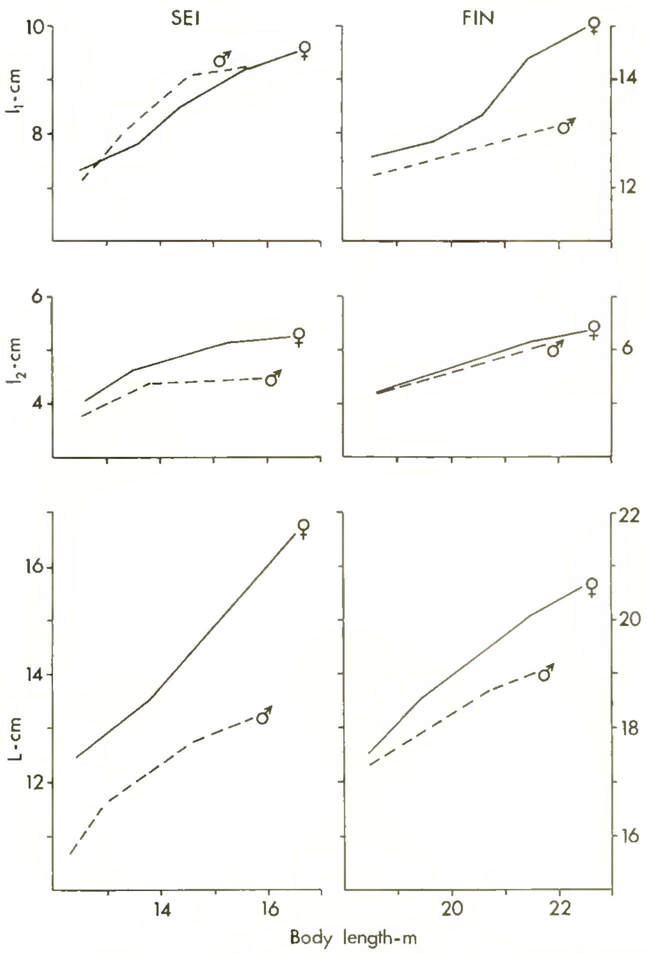

Fig. 3. Sexual dimorphism in sei whales (the Gough Island area) and in fin whales (the Peter the Great Island area) as shown by l_1, l_2 and L measurements.

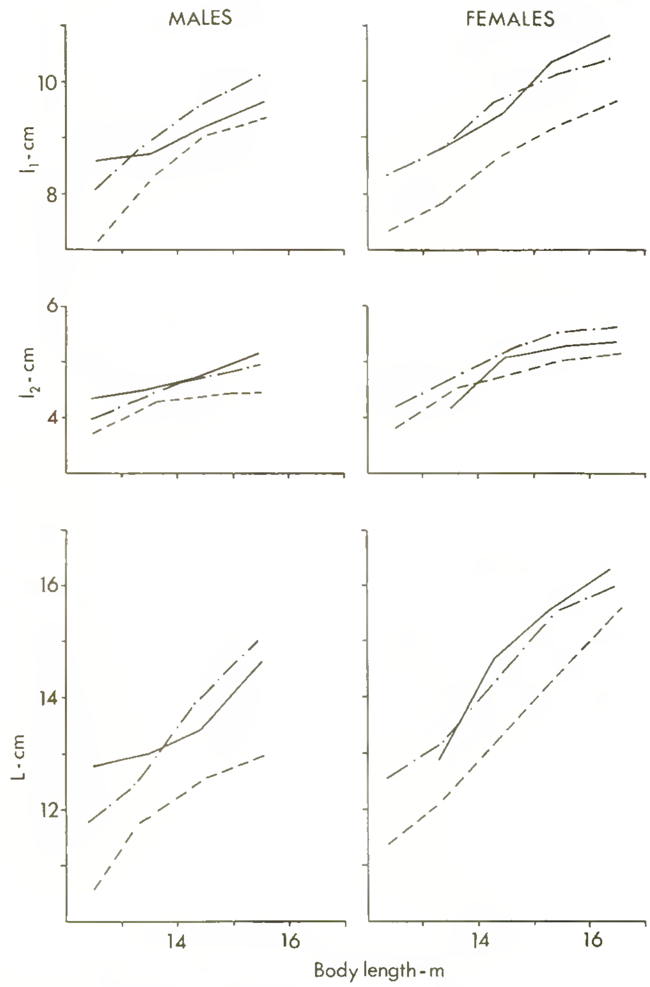

Fig. 4. l_1, l_2 and L measurements in sei whales.
Chilean coast and the Graham Land area ————
Prince Edward, Crozet and Kerguelen Islands area —.—.—
Gough Island area – – – –

Whales from this area were not measured due to the cessation of whaling operations in the area during latter seasons. However, investigations of the white scars found on the body of whales (Shevchenko, 1977) confirm the above view, as does the fact that the endoparasite of the genus *Lecithodesmus* found previously in sei whales of the Falkland stock was not found in the liver of sei whales from off Graham Land and Chile. The underskin fat of the Graham Land sei whales is a light lemon colour, especially in the area of the caudal peduncle, differing from sei whales taken in the other areas.

A comparison of the three measurements for sei whales from the Indian Ocean, the Atlantic Ocean (the area of Gough Island) and the Pacific Ocean (Chilean stock) is shown in Fig. 4.

Each of the three measurements taken for sei whales (males and females) from the stock found in the Gough area clearly differ from both those for the sei whales from the Indian Ocean which are geographically near to them and from those from the Chilean stock which are far from them. Differences revealed in the neighbouring stocks of Indian and Atlantic sei whales were also confirmed by investigations of white scars (Shevchenko, 1977).

It is interesting to note that the differences revealed between the geographically isolated sei whale stocks of the Pacific and the Indian Oceans are less severe using this criterion but this clearly cannot be taken as suggesting their closer genetic propinquity. It is more likely that the differences between these populations will be revealed by other characters in the future.

Fin whales

As in the case of sei whales the comparison of the three measurements for fin whales found off the Prince Edward, Crozet and Kerguelen Islands in January and February did not reveal any differences. Apparently fin whales from the same populations are found in this area of the Indian Ocean during these months. Clear differences were shown when comparing fin whales of the Indian Ocean and the Atlantic Ocean (Bouvet Island). The divergence is even more pronounced when comparing fin whales of the Indian Ocean and especially of the Atlantic Ocean (Bouvet Island) with fin whales from the stock off Peter the Great Island (Fig. 5).

Therefore this analysis has shown differences in the character investigated for both sei and fin whales of different stocks are probably related to different populations.

The analysis of measurements determining the position of the Jacobson's Organ was also carried out for minke whales, but the volume of material collected for this species was not sufficient to obtain any significant results.

Undoubtedly further morphological differences will be revealed in the course of future studies, which will improve our ability to determine the number and borders of whale populations, and their migration routes and enable us to regulate whaling and determine catch limits more precisely.

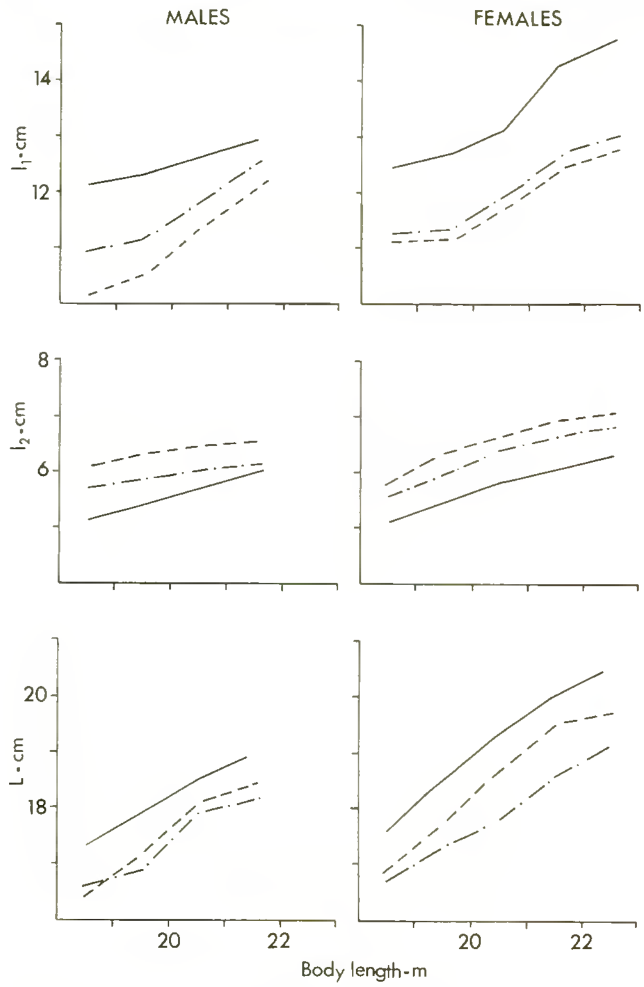

Fig. 5. l_1, l_2 and L measurements in fin whales.
Peter the Great Island area ———
Prince Edward, Crozet and Kerguelen Islands area —·—·—
Bouvet Island area – – – –

CONCLUSIONS

1. The analysis of a large sample size of strictly fixed measurements may show significant differences in the body proportions of whales. Measurements determining the position of the Jacobson's Organ on the whale rostrum may be used for this analysis in baleen whales.
2. The analysis of the Jacobson's Organ data showed that this organ is found relatively closer to the beginning of the baleen row in fin whales than in sei whales.
3. Sexual dimorphism as characterised by the size of measurements l_1, l_2 and L was found in both sei and fin whales, where the lengths appeared to be greater in females than in males of similar body length. This led to the conclusion that the comparison of the whales from different stocks should be made separately by sex.
4. The comparison of sei whales of the Indian Ocean in the areas off the Prince Edward, Crozet and Kerguelen Islands revealed no differences. Apparently these migration paths are exclusive to the populations of the Western Indian Ocean area. Sei whales found off the Chilean coast and off Graham Land were also of one type found exclusively in this region. One can suppose that these animals may be related to the same Chilean–Peruvian population which in January feeds at 40° S and in February is found off the coast of Graham Land. Sei whales of the Eastern Atlantic stock differ greatly from both those of the Island Group in the Indian Ocean and from those found off Peter the Great Island. The differences between sei whales of the Indian and Pacific oceans are less pronounced.
5. Fin whales feeding in January and February off the Prince Edward, Crozet and Kerguelen Islands did not show any differences with respect to the position of the Jacobson's Organ on the rostrum and apparently are part of the same Western Indian Ocean population. They clearly differ from the whales of the Atlantic Ocean (Bouvet Island) and the animals of the Pacific Ocean (Peter the Great Island) which also differ from each other.
6. The measurements which determine the location of the Jacobson's Organ as a population character may also be used for other species of baleen whales.

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Minke Whales

Photograph by courtesy of Peter Best.

Report of the Special Meeting on Southern Hemisphere Minke Whales Seattle, May 1978

1. INTRODUCTION

The meeting was held at the kind invitation of the US NOAA National Marine Fisheries Services at their Northwest and Alaska Fisheries Center, Seattle, 17–23 May 1978. Grateful thanks are offered for all the facilities and secretarial services which were greatly appreciated by the participants.

The Scientific Committee agreed at its meeting held in June 1977 that the recommendations for catch limits for Southern Hemisphere minke whales were only an interim measure pending the holding of a special meeting in spring 1978 to examine all existing data for minke whales. A satisfactory assessment would require the submission of specified detailed analyses, which were included in the agenda of the meeting.

Those attending the meeting were:

K.R. Allen	Australia
S.J. De Moura	Brazil
T. Doi Y. Fukuda S. Ohsumi	Japan
R.G. Borodin M.V. Ivashin	U.S.S.R.
C. Lockyer	U.K.
J.M. Breiwick D.W. Rice M.F. Tillman A.A. Wolman	U.S.A.
S.J. Holt	FAO/UNEP
J.R. Beddington	IUCN
P.B. Best Y. Shimadzu	Invited participants
L.V. Sagen	University of Washington (Interpreter)
R. Gambell	Secretary to the IWC
P. Spong	Greenpeace Foundation (observer)

2–3. APPOINTMENT OF CHAIRMAN AND RAPPORTEURS

Tillman was appointed chairman of the meeting and Gambell and Rice the rapporteurs.

4. ADOPTION OF AGENDA

The Agenda adopted is shown in Appendix 1.

5. REVIEW OF DOCUMENTS AND STATISTICAL MATERIAL

The documents submitted are listed in Appendix 2. In addition there were available very extensive compilations of Japanese data encompassing catch, effort, sightings, age, reproduction and feeding information.

The subcommittee was especially appreciative of the great deal of work undertaken by the Japanese scientists in preparing all the catch, effort and biological data requested by the Scientific Committee last June, as necessary prerequisites for the present meeting. The absence of any comparable Soviet material, particularly on catching effort and age-length data was especially regrettable, considering that the meeting had been delayed by six weeks on the understanding that all the requested data would be forthcoming.

6. EFFORT MODIFIERS

Ohsumi (paper S.14) provided an extensive analysis of the breakdown of catcher's hour's work (CHW) of a catcher boat in a day, into the times engaged in searching, chasing, handling, and towing. He concluded that catcher's searching hour's work (CSW) for Japanese vessels would be the most appropriate basis for measuring effort since catcher day's whaling (CDW) or CHW may include much waste time which changes with population abundance. Thus these latter statistics may not provide catch per unit efforts which reflected population density. He further concluded that CSW should be corrected for wind force, visibility, and period within season. The latter correction was to account for differential abundance and behaviour of the sexes.

Based upon the lack of correlation between tonnage and uncorrected CHW, it was concluded that vessel size had no effect upon the efficiency of operation. Moreover, the use of Asdic by Japanese catcher boats was constant throughout the history of exploitation.

In the Japanese operation, other whale species are only rarely taken during minke whaling and the CSW for minke whales can thus be regarded as almost pure. Since the Soviet operation takes a mix of species, use of these effort data (CDW) to reflect abundance of minke whales would be difficult.

It was noted that Japanese gunners have always selected for larger whales. However, the Soviet operation changed its strategy in the 1974/75 season to take only larger whales. Despite the apparent goal of both operations to take larger whales, comparison of the size distributions of catches by the two countries indicated that Russian catchers consistently took significantly larger whales from 1974/75 on.

In considering 'seeking behaviour', the subcommittee noted that this phenomenon was primarily associated with younger animals. Given the above selection for larger animals and distribution of younger animals in lower latitudes outside the whaling grounds, it was felt that effort measures would not be biased by this behaviour. However, it was thought that such behaviour would be more likely to affect sightings data, e.g. by biasing the estimate of the effective width of the trackline.

Consideration of the weather modified CSW indicated that the weather correction, as applied by Ohsumi (paper S.14), assumed a multiplicative relationship of the effect of wind and visibility on searching efficiency. Although the evidence presented could not support or refute this assumption, it was believed that the true relationship might be additive rather than multiplicative. It was recommended that a multiple regression analysis be undertaken to determine the appropriate weather correction.

After further consideration of the within-season correction as applied by Ohsumi (paper S.14), from Area IV to other Areas, most of the subcommittee believed that it introduced significant biases which were unsupported by the data for other Areas, noting in particular the extreme mid-season peak for females in Area IV only. Examination of the evidence for a seasonal correction (including analysis also of Area III data) indicated that an alternative possibility to a correction for each ten-day period of the season was to pool data for the season, excluding the first and second ten-day periods (first 20 days of November) only.

Other members of the subcommittee disagreed, believing that the seasonality factor given in paper S.14 correctly accounted qualitatively for the observed mid-season peaking in abundance of females.

All members agreed, however, that a seasonal correction was desirable, if done properly, since females were always more available than males during a season. It was recommended that further data pertaining to the effect of seasonality be gathered and analysed.

7. STOCK IDENTITY

Best (paper S.1) recognized two colour phases in southern minke whales at Durban. The majority had asymmetrically coloured baleen and either plain or two-tone flippers. About 3% of minke whales had nearly all-white baleen and flippers with a striking white patch and shoulder blaze. These latter animals appeared to mature at a smaller size than the others.

Doroshenko (paper S.6) gave preliminary information based on certain morphological characters (body proportions, organ shapes, colour, baleen, fluke and ventral groove counts, etc.) which tend to indicate at least four units: Brazilian, Indian, New Zealand and Chile-Peruvian. Further data are required to refine and define these groups.

Wada and Numachi (paper S.15) found no conclusive evidence from ventral groove length, flipper and baleen colour to identify stocks, but their biochemical studies point to two distinct stocks divided by longitude 130°E.

Thus there is some confirmation of a distinction between stocks in Areas IV and V. In order to investigate distinctions between these and other Areas, it is recommended:

(1) that the morphological data now accumulating in various laboratories should be analyzed, i.e. by canonical analysis;
(2) that material to fill the gaps in the Japanese coverage should be collected for biochemical study;
(3) that marking on breeding grounds during winter (e.g. off Brazil) should be encouraged.

Holt examined the distribution of catches within the Antarctic by 1° square from raw data presented by Ohsumi. Regions of concentration of catches were detected from the eastern half of Area II to the western half of Area IV and from the eastern half of Area IV into Area V. These two regions were separated by about 30° of longitude. It was considered that such a distribution of catches might have arisen through operational convenience in taking Area quotas. However such a distribution appeared in both Soviet and Japanese catches consistently and both before and after the imposition of Area quotas. It was pointed out that this analysis did not take the distribution of effort into account, and it was recommended that an examination of the geographical distribution of CPUE should be undertaken on a 5° square basis.

Sightings data (paper S.17) do not indicate any discontinuity of distributions as suggested by the catches.

In the absence of other evidence, it was agreed for the time being to continue to use the standard six Areas for the management units of the Southern Hemisphere minke whale.

8. INTERSPECIFIC COMPETITION

Best (paper S.4) showed that feeding of minke whales is very limited off Durban, and although the food composition by species and size is the same as that of fin and sei whales in the same area, there cannot be very great competition here. He also makes the comment (paper S.3) that minke whales differ from other baleen whales in that they do not wean their calves on the Antarctic feeding grounds, so that *Euphausia superba* presumably does not play an important part in the diet of weaned calves.

Ohsumi (paper S.13) found that *E. superba* is the main food of the exploited minke whales in the Antarctic, so that there is likely to be competition for the food between this species and blue, fin, humpback and sei whales.

Evidence for interspecific competition for food is inferred from the observed decline of the mean age at transition phase (paper S.10) here equated with age at sexual maturity from analogy with fin and sei whales. This decline in age at maturity reflects a faster growth rate and thus presumably more food made available by exploitation of other species.

Appendix 3 is a compilation of information on euphausiid consumption by the baleen whales (excluding right whales) in the Antarctic. This can be taken as an indication of the possible degree of overlap and competition between the species. Minke whales were taking a small proportion (0.8%–2.5%) of the total euphausiid consumption by the initial baleen whale stocks, but a much larger proportion (17%–33%) in the current situation, depending on stock size assumptions.

The Antarctic seal stocks are estimated to eat up to five times (64×10^6 tons – Laws, 1977, *Phil. Trans. R. Soc. Lond. B.*: 91) the euphausiids now taken by minke whales. If the euphausiid stocks are still as productive now as in the earlier part of this century, the reduction of the blue and fin whale stocks will have made more food available to the other species feeding on them, including the minke whales. These benefiting species may then be expected to show increased growth rates and/or enhanced reproductive rates.

Another indication of the interaction of minke whales and other species is derived from the high values of the slope of the right hand limb of the age distributions of catches obtained during initial exploitation of the southern stocks. These values substantially exceed the estimated value of M and so suggest that they are actually reflecting enhanced recruitment rates.

The species composition, distributions and size classes of the euphausiids taken by baleen whales in the Antarctic need to be studied further to determine the extent of the competition more precisely.

9. BIOLOGICAL PARAMETERS

Age at sexual maturity

Estimates were available by several methods from Masaki (paper S.10). The direct evidence for males is limited by the scarcity of immature animals in the catches and complicated by different maturation rates of the different parts of the testes. Since the age at maturity in males is not critical to the assessments at this time, the subject was not pursued further. However, earplug transition counts indicate a current average age of 6.2 years, assuming that the transition layer is formed at sexual maturity. This has still to be confirmed in minke whales.

The mean age at which 50% of the females are mature (6.2 years), the modal age at first ovulation (7 years) and the earplug transition count (6.4 layers) all point to a current average age of 6–7 years.

The only way to estimate the age at sexual maturity in earlier years is from the earplug transition counts. These indicate an age range in the year classes up to 1944 of 13 years to 15 years in the different Areas for both sexes. The overall average is 14 years for males and females.

The apparent rate of decline in the age at sexual maturity is therefore very much greater than in southern fin and sei whales.

Age at recruitment

Ohsumi (paper S.14) presented an analysis using the size distributions of total pelagic catches, an ideal age-length key built from current estimates of the biological parameters, and the computer program TAGK (Allen, 1977, *Rep. int. Whal. Commn* 27: 254–6) to find the age distribution of the catches. These in turn were used in the program CPOP (Allen, 1977, *Rep. int. Whal. Commn* 27: 257) to develop estimates of the mean age at recruitment.

The biological parameters used were those determined from separate von Bertalanffy equations for each Area and sex, which were fitted through the known lengths at birth, sexual and physical maturity. The parameters used are shown in Table 1.

Table 1

Von Bertalanffy parameter values used for the ideal age-length key

Area	Female			Male		
	k	t_o	l_∞	k	t_o	l_∞
I	0.286	−1.55	28.6	0.233	−3.15	27.0
II	0.278	−2.56	29.1	0.242	−3.64	27.5
III	0.283	−1.82	29.2	0.233	−3.45	27.7
IV	0.266	−2.38	29.3	0.248	−3.11	27.7
V	0.264	−2.59	29.4	0.246	−3.34	27.7
VI	0.256	−1.85	28.7	0.253	−2.08	27.7

The overall mean values for the mean age at recruitment derived from the most reliable Area estimates for each sex are 5.9 years for females and 7.1 for males. It was agreed that integer values of 6 and 7 years could be used for females and males respectively.

Pregnancy rate

Masaki (paper S.10) demonstrated monthly variations in the observed pregnancy rate, with lower values in November and February than December due to differential migrations of the reproductive classes. The apparent pregnancy rate is estimated as 89%, but if all animals with corpora lutea are included, the value is 95%. The true pregnancy rate is not likely to equal the ovulation rate as claimed, since this implies that all ovulations are fertilized. Soviet data (paper S.16C) agree with the Japanese records.

Off Brazil only 3 pregnant animals have been recorded in 8,446 whales landed (Moura *et al.*, paper S.11). Best (paper S.3) found only one pregnant female in his sample of 109 mature female minke whales from Durban, but 69 ovulating animals. Ovulation is common in lactating females, and from 3 calf lengths he deduced that the oestrous cycle occurs about 4 months post-partum. If the gestation period is 10 months, then the calving interval exceeds 12 months and is probably closer to 14 months. The apparent pregnancy rate therefore could reach 86%. Such a cycle would eventually bring the females out of phase with the breeding season, even though it is thereby extended, and the 'true' pregnancy rate, calculated from the incidence of non-lactating females off Durban, is 78%.

Females with calves, as well as immature whales, are found outside the Antarctic whaling grounds in summer (Gambell *et al.*, 1975, *Rep. int. Whal. Commn* 25: 240–52). These mature females may represent the out-of-phase animals.

The foetal growth line plotted by Masaki (paper S.10) from the modes of the monthly compositions indicates a gestation period of about 10 months if the length at birth is taken as 2.8 m as proposed by Ivashin and Mikhalev (1978, *Rep. int. Whal. Commn* 28: 204). If the mean date of birth is the end of May, and since no lactating females or females accompanied by calves appear in the Antarctic at the start of the whaling period (November), lactation must be completed at least in some animals by this time, so that this phase of the reproductive cycle probably lasts not more than 6 months.

On the basis that the minimum calving interval is 14 months and conceptions are possible at any time, the maximum pregnancy rate could be 12/14 = 86%. On theoretical grounds the assumption of an eight, six or five month conception season will produce pregnancy rates of 85%, 80% and 75% respectively.

The relationship between the demographic parameters of the minke whale was developed on the assumption that natural mortality operates at a 10% higher level for the first h years of life ($h \leqslant t_m$) and the dynamics of sexually mature females are given by the equation:

$$X_{t+1} = X_t e^{-M} + X_{t-t_m} e^{-(t_m+h/10)M} f(t-t_m)$$

X_t = number of sexually mature females at time t
M = natural mortality rate
t_m = age of sexual maturity
f(t) = pregnancy rate /2.

At equilibrium in the unexploited state

$$X_{t+1} = X_t = X_{t-t_m}$$

giving

$$t_m = 1/M\ [\ln[f(t)/(1-e^{-M})] - \frac{hM}{10}]$$

If h = 1, as assumed below, the expected values of t_m are given in Table 2 for various values of natural mortality and pregnancy.

Table 2

Age at sexual maturity calculated to balance various combinations of natural mortality rate (M) and pregnancy rate

M	Pregnancy rate 75%	80%	86%
0.09	16.2	17.0	17.8
0.095	14.8	15.5	16.3
0.10	13.6	14.3	15.0

The comparison between the present observed values for these parameters and the theoretical relationships suggests that if M = 0.095 and, as the evidence suggests, the initial age of sexual maturity was 13–15 years, the original pregnancy rate was between 63% and 76%. Thus if the current pregnancy rate is 78%, no change is implied, but if the current rate is 86%, it is likely that there has been an increase in pregnancy rate since the initial period. This is a small relative change compared to that observed in southern blue, fin and sei whales. There is no evidence of change in the pregnancy rate during the six years of recent exploitation.

Natural mortality rate

Ohsumi (paper S.12) presented an extensive review of cetacean comparative biology for relevant parameter values to develop an estimate of 0.095 for the natural mortality coefficient in southern minke whales. This is based primarily on data for males, but the same value is adopted for both sexes. The apparent changes in recruitment rates since the 1940s prevent detection of any contemporary changes in natural mortality from the age composition of the catches.

There are no estimates of natural mortality in the pre-recruited phase of the population. A study of the relative incidence of strandings of juveniles and adults might provide some evidence on this point.

The natural mortality rate assumed for the first year of life in the previous section (10% higher than for the later years) was derived from an analogy with terrestrial mammals.

Recruitment rate

Ohsumi (Table 12, paper S.14) provided estimates of the slopes of the right hand limb (Z^1) of the age distributions of fully recruited animals in each season, 1971/72–1976/77. Given the hypothesis that stocks were increasing prior to exploitation, it was assumed that these values estimated the gross recruitment rate, r. The mean values obtained over Areas were 0.154 and 0.144 for females and males respectively, with an overall mean of 0.149.

Upon consideration of the above values, it was concluded that they would be biased slightly upwards by the inclusion of age distributions from later years in which fishing mortality would be included for the recently recruited year classes. Consequently, the age curve analysis would tend to overestimate r. A plot of cumulative catches versus Z^1 in various Areas showed a reasonable correlation between the two. The most likely explanation of this phenomenon was considered to be possible variation in recruitment rates between Areas.

Ohsumi (Table 13, paper S.14) also provided estimates of the total proportion of newly recruited animals in the catch (r_{II}) which were obtained from CPOP (Allen, 1977, *Rep. int. Whal. Commn* 27: 257). These values were also taken to be estimates of the gross recruitment rate. The average values obtained over Areas were 0.164 and 0.140 for females and males respectively, with an overall average of 0.152. Due to the small sample size, it was believed that these values would tend to underestimate r.

Despite their inherent biases, it was felt that the two sets of values tended to corroborate each other giving a gross recruitment rate just prior to the onset of exploitation of 0.15.

10. POPULATION MODELS

It seems reasonable to assume that prior to the exploitation of the other baleen whales in the Southern Ocean the minke whale population was at some equilibrium density. This assumption is the basis of the relationship between the demographic parameters derived in Table 2. Data on the age of sexual maturity over time presented by Masaki (paper S.10) and subsequently discussed above indicated a decrease from 13–15 years in the initial stock to 6–7 years in the current stock. This change implies that if other demographic parameters remained constant, the population prior to exploitation in 1971/72 was increasing. It was noted that likely rates of increase might be estimated by simulation techniques.

Following exploitation of the stock, the possibility exists for using catch per unit effort as a measure of population abundance. After extensive discussion of the most appropriate measure of effort, the meeting decided to use catch per catcher's searching hour's work, C/CSW. The values of this measure over time in Area IV were then examined. A linear regression of the natural logarithm of C/CSW against time was performed for both sexes separately and combined. In each case the slope of the regression was found to be negative but not significantly different from zero ($p = 0.05$), which made interpretation of the observed trends quite difficult.

Nevertheless, the subcommittee agreed to proceed with the calculation of population abundance using the estimates of the slopes obtained from these linear regressions and the values of the 90% confidence limits about these estimates. Since data from scouting boat sightings did not indicate any appreciable change in density in Area IV, it was also agreed to proceed with this calculation assuming that the slope was zero.

There were two points involved in the above decision which need some explanation. The first is the decision to use only data from Area IV. The reasoning behind this was that although CPUE data for Area III were available, these were extremely variable and unlikely to indicate anything about population abundance. This was reflected in the Z values calculated for this Area.

The second point concerns the decision to exclude the data point for the 1977/78 season. This was done firstly to facilitate comparison with the Z estimation procedure and secondly because processing time per whale for the only fleet *(Nissin Maru)* operating in 1977/78 had doubled between 1976/77 and 1977/78. It was felt that such variability implied that CSW for this year might not reflect accurately the true effort.

For comparative purposes, similar analyses might be undertaken for Area III and for Areas III and IV combined and in all cases with the 1977/78 data point included.

11. SIZE LIMITS

Lockyer (paper S.9) reviewed data on growth and maturity in southern minke whales. The mean size at sexual maturity for both sexes combined is 25 ft at which stage about 70% of growth in body weight has been completed. Allen (*Rep. int. Whal. Commn* 26: 159–60) showed yield isopleths for fin whales related to age at recruitment and fishing effort. These showed that except when the population is close to the MSY level the imposition of minimum size limits varying over a wide range would produce little change in yield.

An adequate level of recruitment could be ensured by the imposition of a minimum size limit and/or catch limit.

If a size limit for minke whales is set much above the mean size of sexual maturity, there is a very small range of lengths remaining before the maximum size of the species is reached. A high size limit might also increase the proportion of females in the catch to levels which are considered undesirable for the stability of the populations.

However, it should be noted that a size limit of 25 ft would have the effect of stabilizing present catching practice, thus preventing increased exploitation of smaller minke whales. Also, it would appear that a size limit of this order would not lead to any significant change in the ratio of females to males in the catches.

It should be possible to maintain an adequate level of recruitment through the adoption of a suitable catch limit. Given the above circumstances there are no compelling reasons to advocate the need of any particular length for a minimum size limit.

12. POPULATION ESTIMATION PROCEDURE

Estimates of Z have been obtained by the following formula which eliminates effects due to recruitment:

$$Z = \ln \frac{A_1}{A_2} \cdot \frac{B_1}{B_2}$$

where A_1 and A_2 are the proportion of the catch which is of age t or more in year 1, and of age t+1 or more in year 2 respectively; and B_1 and B_2 are the overall CPUEs for the same catches in years 1 and 2 respectively.

The age data have been based on the age distribution of the Japanese catch obtained from the size distribution of the Japanese catch and using separate age-length keys for each sex, Area and year including all animals aged in the Japanese catches. The CPUE data used were also those derived from the Japanese operations. The three effort series used were CSW omitting the first two ten-day periods of November (CSW_1); CSW_1 adjusted by Ohsumi's (paper S.14) weather correction factors (CSW_2); and CSW adjusted by Ohsumi's (paper S.14) method for weather and within season cycles (CSW_3) (Table 3). Z was estimated by the computer programme ZMK which obtains a series of estimates for each sex, Area and year by using a series of different values for t from 12 to 21. All these year classes seemed to be fully recruited and no consistent trends in Z were observed as t was increased.

Since no data were available in Area III for 1972/73, an estimate of 2Z was obtained for the period 1971/72 to 1973/74 and halved to give an annual value. Only one of

Table 3

Japanese pelagic catches per unit effort by Area, season, and sex

		C/CSW_1			C/CSW_2			C/CSW_3 *	
Area	Season	Male	Female	Combined	Male	Female	Combined	Male	Female
I	1975/6	0.533	0.377	0.910	0.445	0.314	0.759	1.002	0.749
	1976/7	0.382	0.818	1.200	0.292	0.626	0.918	0.663	1.304
II	1973/4	0.176	0.974	1.150	0.172	0.949	1.121	0.337	1.528
	1974/5	0.171	1.681	1.852	0.150	1.475	1.625	0.281	2.111
	1975/6	0.158	0.251	0.409	0.162	0.251	0.413	0.356	0.528
III	1971/2	0.637	0.686	1.323	0.528	0.572	1.100	1.078	1.003
	1973/4	0.280	1.027	1.307	0.202	0.742	0.944	0.366	0.789
	1974/5	0.407	0.591	0.998	0.321	0.467	0.788	0.567	0.499
	1975/6	1.501	2.231	3.732	0.940	1.362	2.302	2.251	3.271
	1976/7	1.032	2.179	3.211	0.930	1.965	2.895	2.090	3.956
	1977/8	2.457	3.792	6.249	1.316	2.030	3.346	3.249	4.635
IV	1971/2	0.615	1.144	1.759	0.473	0.880	1.353	0.867	1.038
	1972/3	0.941	0.821	1.762	0.827	0.722	1.549	1.530	0.873
	1973/4	0.470	0.956	1.426	0.368	0.718	1.086	0.781	1.189
	1974/5	0.324	0.308	0.632	0.240	0.228	0.468	0.586	0.684
	1975/6	0.707	0.846	1.553	0.646	0.773	1.419	1.310	1.610
	1976/7	0.471	0.478	0.949	0.431	0.437	0.868	1.293	1.155
	1977/8	0.467	1.287	1.754	0.574	1.582	2.156	1.103	2.339
V	1974/5	0.433	0.707	1.140	0.524	0.856	1.380	1.197	2.237
	1975/6	0.267	0.164	0.431	0.456	0.280	0.736	1.107	0.836
	1976/7	0.732	0.704	1.436	0.668	0.642	1.310	2.613	3.579
	1977/8	0.280	0.287	0.567	0.256	0.263	0.519	0.476	0.402
VI	1973/4	0.213	0.064	0.277	0.125	0.038	0.163	0.343	0.099
	1975/6	0.155	0.113	0.268	0.159	0.115	0.274	0.283	0.156
	1976/7	0.437	0.839	1.276	0.536	1.029	1.565	1.373	2.450
	1977/8	0.377	0.200	0.577	0.227	0.121	0.348	0.527	0.326

*Values from Ohsumi's Table 8 (paper S.14).

Table 4

Estimated values of Z obtained using different CPUE data

Effort	Sex	Area	1971/72	1972/73[1]	1973/74	1974/75	1975/76	Mean	Mean by Sex	Mean by Area	Variability
CSW_1	M	III	0.608	(0.608)	0.159	−1.502	0.168	−0.142	0.074		
(Not	M	IV	0.138	0.568	0.432	0.077	0.019	0.247		III −0.237	Comb.SD 0.854
corrected	F	III	−1.068	(−1.068)	1.155	−1.529	0.118	−0.331	0.076		SE 0.201
for weather)	F	IV	1.033	−0.276	1.171	−0.951	1.027	0.401		IV 0.324	IV SD 0.324
											SE 0.102
			0.178	−0.042	0.729	−0.976	0.333	0.075[2]			
CSW_2	M	III	0.657	(0.657)	0.183	−1.271	−0.194	−0.156	0.048		
(Weather	M	IV	0.005	0.684	0.488	−0.133	0.018	0.212		III −0.162	Comb.SD 0.761
corrected)	F	III	−0.035	(−0.035)	0.904	−1.271	−0.274	−0.169	0.128		SE 0.179
	F	IV	0.899	−0.118	1.186	−1.162	1.027	0.366		IV 0.289	IV SD 0.709
											SE 0.224
			0.382	0.297	0.690	−0.959	0.144	0.088[2]			
CSW_3	M	III	0.716	(0.716)	0.209	−1.575	−0.132	−0.195	−0.024		
(Corrected	M	IV	−0.004	0.546	0.347	0.053	−0.374	0.114		III −0.231	Comb.SD 0.817
for weather	F	III	0.215	(0.215)	0.900	−2.080	−0.098	−0.266	−0.004		SE 0.193
and season)	F	IV	0.875	−0.433	0.591	−0.797	0.788	0.205		IV 0.159	IV SD 0.564
											SE 0.133
			0.450	0.261	0.512	−1.100	0.046	−0.014[2]			
CSW_1	M+F	IV	0.586	0.146	0.801	−0.437	0.523	0.324[2]			

1 Values in parentheses assumed from previous year and used only when calculating mean for 1972/73. Excluded when calculating all other means.

2 Mean value calculated from combined data for each effort measure.

this pair was, however, used in calculating average Z in the Area over the period of exploitation.

Table 4 shows the values of Z for the various measures of Japanese effort with means by year, Area and sex. The differences introduced by various ways of adjusting effort are relatively minor. The differences between years are larger, particularly in that 1974/75 gives consistently large negative values, except for males in Area IV. Values for Area III are usually lower than for Area IV and often negative, while those for males tend to be lower than those for females. These differences are consistent with the facts that more females have been caught than males and that Area IV has been more intensely exploited than Area III (Table 5).

The right hand column of Table 4 shows the S.D. and S.E. of mean Z for the results as a whole, and for Area IV. Even for Area IV the S.E. tends to be about equal to the mean. Since a constant value of M is to be subtracted from the estimated Z to obtain F, which will thus have the same

Table 5

Estimated total efforts equivalent to Japanese CSW (EJCSW)

Season \ Area	I	II	III	IV	V	VI	All
1971/72		[959]	268 + [155]	1520			4402
1972/73		[888]	485 + [55]	2581			9238
1973/74	(1212)[1]	155 + [1045][2]	1299 + [132]	5245		47	9158
1974/75	(1805)	435 + [561]	1363 + [115]	3669	644	0	8619
1975/76	1149	2896 + [1931]	571 + [29]	564	1464	592	9200
1976/77	786	(2113) + [2488]	896 + [0]	1917	1022	117	9341
1977/78	(447)	(884) + [2488?]	288 + [0]	549	1560	913	4641 + [2488?]
Average 1971/72–1976/77[3]	1238	1400 + [1312]	814 + [81]	2583	1043	250	8326
1971/72–1977/78	1080	1297 + [1480?]	739 + [69]	2292	1431	780	8155?

1 ( ) Where no Japanese effort was exerted; estimated from Japanese and USSR comparisons where possible in preceding or following years.

2 [ ] Land station effort equivalents.

3 Or since whaling started, if later than 1971/72.

errors as Z, the relative errors for F will be many times its estimated values.

The variability of Z arises in part from variation in the amount of effort which causes the fishing mortality. It is therefore of interest to calculate the coefficient of efficiency

$$q = \frac{F}{f} = \frac{Z - M}{f}$$

where f = fishing effort

The estimates of total effort in Table 5 were used for this purpose. These estimates are of total equivalent Japanese CSW (EJCSW) obtained by multiplying the CSW values by the ratio total catch/Japanese catch in each Area in each season (and following year in the Areas where land stations operated). The value of M was taken as 0.095. The resulting estimates of q are given in Table 6 for Area IV. Great variability is still apparent.

However, Ohsumi (paper S.14) estimated the exploitable population size in Area IV to be 52,800, considering the population has been steady through the years 1971/72–1977/78.

As discussed in the Population Models section, values of F could also be derived from the estimates of the slope of the linear regression of the natural logarithm of C/CSW against time or their 90% confidence limits or an assumed slope of zero. This method requires an adjustment for any natural rate of increase of the population. Beddington and Ohsumi agreed to calculate these results and to present them to the Annual Meeting in June.

The next step in obtaining stock estimates for other Areas would be by making the calculation:

$$\text{Average stock in Area Y} = \text{Stock in Area IV} \cdot \frac{\text{Density in Y}}{\text{Density in IV}} \cdot \frac{\text{Effective Area of Y}}{\text{Effective Area of IV}}$$

Table 6

Estimated q values for Area IV

Seasons	1971/72–1972/73	1972/73–1973/74	1973/74–1974/75	1974/75–1975/76	1975/76–1976/77
Average total effort (EJCSW)	2051	3913	4457	2117	1241
q males × 10^{-3}	0.067	0.145	0.098	0.038	0.015
q females × 10^{-3}	0.504	−0.071	0.265	−0.466	0.196
q both sexes × 10^{-3}	0.286	0.108	0.182	−0.214	0.106

Mean q = 0.079 × 10^{-3}

Both the changes in age structure of samples from year to year and those in CPUE can contribute to the variability of the estimates of Z; it seems that the latter contributes more than the former.

The Z value, all years and both sexes combined for Area III, was negative (−0.237) for all effort measures and so could not be used to estimate F and hence stock numbers. The values for Areas III and IV combined were positive for the CSW_1 and CSW_2 effort measures, but in both cases less than M = 0.095; these pooled values therefore could not be used either. Estimates of F and, hence, population could therefore be calculated only for Area IV, for which the data were evidently as a whole internally more coherent.

Stock estimates for Area IV could then be calculated from the equation

$$\bar{P} = \bar{C}/F$$

where $\bar{C}$ is the average catch during the period of exploitation (1,226 for males, 1,523 for females) and F, the instantaneous rate of fishing mortality.

Table 7

Population estimates from Z values

	Area IV ♂	Area IV ♀	Combined
CSW^1	8,066	4,977	12,004
CSW^2	10,479	5,620	14,170
CSW^3	64,526	13,845	42,292

The above estimates are for the average exploitable stock, in the years 1971/72–1976/77. They do not involve any assumption as to whether this stock was changing in size.

Estimates of the relative density could in principle be derived from the corresponding CPUE data or from sightings. The relative CPUE results are given in Table 8. Sightings data presented by Ohsumi for south of 60°S (paper S.14) were considered unsuitable because raw data given in paper S.17 indicated that Area IV was atypical in having a large proportion of the population north of 60°S.

Table 8

Relative densities (sexes combined) based upon Japanese pelagic C/CSW

Area	I	II	III	IV	V	VI
Relative density	0.75	0.64	1.34	1.00	0.58	0.35

13. CLASSIFICATION AND CATCH LIMITS

Evidence given above indicates that the minke whale population was increasing prior to the beginning of exploitation. Ohsumi (paper S.14) had estimated the size of the original minke whale population at the start of the century making assumptions regarding changes in the net recruitment rate over time. However, the meeting considered that it was not possible to make such a calculation at this time. Although it might be possible to simulate relative changes in the minke whale population size using the observed rate of change in the age at sexual maturity, it is not possible to determine reliably what the 'initial' population was, or what the present changing capacity of the minke whale environment (and hence its MSY level and MSY) might be. Under the present management procedure of the IWC, the Scientific

Committee would therefore not be able to recommend an appropriate classification of the stocks even if the calculations were available. This is basically a consequence of the multispecies interdependence of the Antarctic baleen whale and other stocks, and requires a decision by the Commission on an appropriate management strategy.

In the meantime and as a holding measure the Commission might wish to set catch limits at the level of the present replacement yield, i.e. that catch which will maintain the population at the same level for one year. Appropriate replacement yields could be calculated given the range of current population estimates.

However this matter has been deferred through lack of time to the June meeting of the Scientific Committee.

14. OTHER BUSINESS

The subcommittee briefly discussed the question of the representation of IUCN at the meeting. Beddington had been invited to participate in the meeting in his personal capacity by the Chairman, and was subsequently nominated as the IUCN observer. FAO and UNEP representatives have the status of advisers to the Scientific Committee, and the Rules of Procedure made it possible to give the IUCN observer similar status. It was agreed that this should be done for the present meeting and that it may be appropriate to ask IUCN if they would wish their observer to have this status permanently. Beddington agreed to pass this information on to IUCN headquarters, and the Scientific Committee is asked to consider the matter at its June meeting.

Appendix 1

AGENDA

1. Opening remarks
2. Election of Chairman
3. Appointment of rapporteurs
4. Adoption of Agenda
5. Review of documents and statistical material
6. Effort modifiers – changes in whaling equipment, techniques, and strategy; consideration of 'seeking' behaviour; changes in distribution of effort; consideration of disproportionate catches of females; consideration of effort which is directed to other species in addition to minke whales.
7. Stock identity – variation in baleen and flipper coloration, morphometrics, and biochemical characteristics; analysis of density distribution and feeding grounds.
8. Interspecific competition
9. Biological parameters – age at sexual maturity, age at recruitment, pregnancy rate, natural mortality rate, and changes over time.
10. Population models – examine assumption of recruitment proportional to female numbers.
11. Size limits
12. Estimates of stock sizes and MSY – separate assessment for each sex.
    - 12.1 Initial stock sizes
    - 12.2 Present stock sizes
    - 12.3 MSY stock sizes and MSY
13. Classification and catch limits
14. Other business

Appendix 2

DOCUMENTS SUBMITTED TO THE MEETING

S.1 BEST, P.B. External characters of minke whales landed at Durban.

S.2 BEST, P.B. The seasonal abundance, migration and group composition of minke whales off Durban.

S.3 BEST, P.B. Observations on the reproductive condition of female minke whales off Durban.

S.4 BEST, P.B. A note on the feeding of minke whales off Durban.

S.5 BROWN, S.G. The marking of minke whales in the Southern Hemisphere.

S.6 DOROSHENKO, N.V. Population structure of the minke whale in the Southern Hemisphere.

S.7 HOLT, S.J. Calculations of the mean age at recruitment from catch curves (S.H. Minke).

S.8 KIRKWOOD, G.P. and ALLEN, K.R. Program to estimate baleen whale population sizes (Baleen).

S.9 LOCKYER, C. Review (in minke whales) of the weight/length relationship and the Antarctic catch biomass, and a discussion of the implications of imposing a body length limitation on the catch.

S.10 MASAKI, Y. Yearly change of the biological parameters for the Antarctic minke whale.

S.11 MOURA, S.J.C., ROCHA, J.M. and MELLO, R.L.S. Summary of 'Some aspects of minke whale stock exploited off Brazil'.

S.12 OHSUMI, S. Interspecies relationships among some biological parameters in cetaceans and estimation of natural mortality coefficient of the Southern Hemisphere minke whale.

S.13 OHSUMI, S. Feeding habits of the minke whale in the Antarctic.

S.14 OHSUMI, S. Population assessment of the Antarctic minke whale.

S.15 WADA, S. and NUMACHI, K. External and biochemical characters as an approach to stock identification for the Antarctic minke whale.

S.16 U.S.S.R.
- A. Length distributions
- B. Catch by squares
- C. Pregnancy data
- D. Corpora lutea frequencies
- E. Stomach fullness data

S.17 Japan
Minke whale sightings density charts.

Appendix 3

Euphausiid consumption of baleen whales (excluding right whales) in the Antarctic (preliminary data)

1. Original (1920s)

	I	II	III	IV	V	VI
Species	Stock size ($\times 10^{-3}$)	Mean weight (metric tons)[u]	Total Antarctic biomass (metric tons $\times 10^{-3}$)	Daily intake of euphausiids (metric tons $\times 10^{-3}$)[w]	Residence times (days)[x]	Euphausiid consumption (metric tons $\times 10^{-3}$)
Fin (expl.)	400[e]	50	20,000	800[1]	120	96,000
Fin (unexpl.)	100	10	1,000	50[3]	120	6,000
Blue (expl.)	200[f]	88	17,600	704[1]	120	84,480
Blue (unexpl.)	50	20	1,000	50[3]	120	6,000
Sei (mat.)	150[g]	18.5	2,775	28[2]	100	2,800
Sei (imm.)			no consideration (lower latitude)			
Humpback (expl.)	100[h]	27	2,700	135[3]	120	16,200
Humpback (unexpl.)	25	12.5	312.5	18.75[4]	120	2,250
Minke (total) A	52[i]	7	364	14.6[1]	120	1,752
Minke (total) B	170[j]	7	1,190	47.6[1]	120	5,712
Pygmy Blue (total)	10[k]	56[v]	560	22.4[1]	120	2,688
					Total including A	218,170
					Total including B	222,130

[1] 4% of mean body weight
[2] 1% of mean body weight (75% of diet non-euphausiid)
[3] 5% of mean body weight
[4] 6% of mean body weight

2. Present

	I	II	III	IV	V	VI
Species	Stock size ($\times 10^{-3}$)	Mean weight (metric tons)[u]	Total Antarctic biomass (metric tons $\times 10^{-3}$)	Daily intake of euphausiids (metric tons $\times 10^{-3}$)[w]	Residence times (days)[x]	Euphausiid consumption (metric tons $\times 10^{-3}$)
Fin (expl.)	84[l]	48	4,032	161[1]	120	19,320
Fin (unexpl.)	42[l]	10	420	21[3]	120	2,520
Large Blue (total)	4.5[m]	62	279	11[1]	120	1,320
Pygmy Blue (total)	7.4[n]	56	414	16.6[1]	120	1,992
Sei (mat.)	56[p]	17.5	980	9.8[2]	(a) 120	1,176
					(b) 100	980
Humpback (total)	3.5[r]	22	77	3.85[3]	120	462
Minke (total) A	162[s]	7	1,134	45.36[1]	120	5,443
Minke (total) B	400[t]	7	2,800	112[1]	120	13,440
					Total A + a	32,233
					A + b	32,037
					B + a	40,230
					B + b	40,034

e. Ohsumi, S. and Masaki, Y. 1974. *Rep. int. Whal. Commn* 24: 111.
f. Gulland, J.A. 1972. *New Scientist* 54: 199.
g. Ohsumi, S. and Masaki, Y. 1974. *Rep. int. Whal. Commn* 24: 112.
h. Mackintosh, N.A. 1973. *Discovery Rep.* 36: 95.
i. Ohsumi, S. Paper S.14 this meeting.
j. IWC 1978. *Rep. int. Whal. Commn* 28: 55.
k. Ichihara, T. and Doi, T. 1964. *Norsk Hvalfangsttid.* 53: 145.
l. IWC 1976. *Rep. int. Whal. Commn* 26: 44 updated by IWC 1977. *Rep. int. Whal. Commn* 27: 38.
m. Masaki, Y. and Yamamura, K. 1978. *Rep. int. Whal. Commn* 28: 258 (Sum of zones A + B, Table 20).
n. Masaki, Y. and Yamamura, K. 1978. *Rep. int. Whal. Commn* 28: 258 (Sum of zones D + E, Table 20).
p. IWC 1978. *Rep. int. Whal. Commn* 28: 82.
r. Masaki, Y. and Yamamura, K. 1978. *Rep. int. Whal. Commn* 28: 258.
s. IWC 1978. *Rep. int. Whal. Commn* 28: 55.
t. Ohsumi, S. Paper S.14 this meeting.
u. Based on Laws, R.M. 1977. *Phil. Trans. R. Soc. Lond.* B: 91.
v. Ichihara, T. 1966. pp.79 *In:* Norris, K. (ed.) *Whales, Dolphins and Porpoises.* University of California Press, L.A.
w. Based on Sergeant, D.E. 1969. *Fisk. Dir. Skr. Ser. HavUnders.* 15: 246–58.
x. Based on Lockyer, C. 1976. Paper ACMRR/MM/SC/41, FAO Scientific Consultation on Marine Mammals, Bergen.

EXPLANATORY NOTES TO TABLES

I. The exploited stock sizes have been derived from various reference sources as indicated. The unexploited initial stock sizes for fin, blue, and humpback whales (where given) have been derived as 25% of the initial exploitable stock sizes after a consideration of the age at recruitment and natural mortality. For the current fin whale stocks, an estimate of 50% of the current exploitable stock size has been taken.

II. The mean body weights given for the exploited stocks have largely been based on the figures given in Laws (1977). However, the mean weights of the unexploited components of these stocks have been derived from mean lengths using weight/length conversions in Lockyer (1976). Mean body weights per total current stock sizes of blue and humpback whales have been derived as the resultant of

$$\frac{(2\overline{W}_e + \overline{W}_u)}{3}$$

where $\overline{W}_e$ and $\overline{W}_u$ are the mean weights of the exploited and unexploited components respectively. The mean body weight for the pygmy whale has been derived from a consideration of the body weights given in Ichihara (1966).

III. Total Antarctic biomass is the product of stock size and mean body weight.

IV. Daily food intake has been considered as intake of all euphausiids, not specifically *Euphausia superba* because of the difficulties in apportioning the food type intake in the complex diets reported for several species such as sei whales, and also fin and minke whales. Other euphausiids would include species such as *E. vallentini*, *E. spinifera* and *E. crystallorophias.* The actual feeding rates *per diem* as denoted in the footnotes are derived chiefly from Sergeant (1969). However, in the case of sei whales, the 1% value was derived from an analysis of data given in Kawamura, A. (1974) *Sci. Rep. Whales Res. Inst., Tokyo* 26: 25–144, where approximately 75% of the diet is calculated as non-euphausiid. (An overall food intake for sei whales was assumed as 4%.) Furthermore, originally higher feeding rates were assumed for immature animals of all species.

V. Residence times were based on the conclusions given in Lockyer (1976). However, residence times for minke whales were based on peak arrival times in the Antarctic in late November as deduced from changes in abundance observed off Durban, South Africa (Best, paper S.2), data on Antarctic densities given by Ohsumi (paper S.14), and changes in abundances of minke off Brazil as reported by Williamson, G.R. (1975) *Sci. Rep. Whales Res. Inst., Tokyo* 27: 37–59. The peak departure time from the Antarctic has been estimated to be late March.

VI. Total euphausiid consumption is the product of *per diem* consumption and residence times, and represents the annual euphausiid removals by whales in the Antarctic.

Miscellaneous notes

Where more than one estimate is given, as for example minke whale stock sizes, and residence times for sei whales in the current table, this is because of uncertainties. The alternative estimates are intended to give an indication of the possible upper and lower limits of euphausiid consumption by the stock.

The Marking of Minke Whales in the Southern Hemisphere

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Few minke whales have so far been marked in the Southern Hemisphere. At the close of the 1976/77 Antarctic whaling season, 68 minke whales were estimated to have been effectively marked to the south of 40° south latitude in the six Southern Hemisphere whaling Areas (Table 1). These were marked during Antarctic cruises carried out in the pre-war years by the Discovery Committee ships and cooperating German vessels, and in the post-war years by vessels taking part in the international whale-marking scheme. A larger number of minke whales has been marked in the separate USSR marking scheme.

Table 1

Numbers of minke whales estimated to have been effectively marked in the Southern Hemisphere whaling Areas, south of 40°S, during Antarctic whale marking cruises (pre-war – Discovery Committee; post-war – international marking scheme)

	Whaling Areas south of 40°S						
Season	I	II	III	IV	V	VI	All Areas
1934/35	–	2	–	–	–	–	2
1938/39	–	–	1	–	–	–	1
Total	–	2	1	–	–	–	3
1955/56	–	–	–	1	–	–	1
1967/68	–	–	–	5	–	2	7
1975/76	1	3	16	–	3	–	23
1976/77	–	–	25	2	1	6	34
Total	1	3	41	8	4	8	65

While the number of whales marked is very small, it should be remembered that prior to the 1971/72 season, catches of minke whales in the Antarctic were also small. In the twelve whaling seasons 1959/60 to 1970/71 inclusive, only 1,294 whales were taken, the largest catch in one season being 605 whales in 1967/68. Until minke whales were taken in large numbers, there was little purpose in marking them and only in the last two seasons (1975/76 and 1976/77) has the systematic marking of this species been attempted.

In addition to the Antarctic marking, four minke whales have been marked in Area III in the Indian Ocean north of 40°S. These were marked during cruises from Durban in 1971 and 1975, and during the International Indian Ocean marking cruise in 1973–74.

Only one mark return has so far been reported from these minke whales marked in the international scheme. The .410 mark was recovered the day after firing in Area III and the return is not significant. Details are:

Mark No. 32344, Fired 17 February 1977 in position 67°02′S, 61°06′E; recovered 18 February 1977 (from refrigerator vessel) in position 66°48′S, 59°41′E approximately. Mark recovered from back meat; sex and length of whale unknown. It was recorded as a possible hit on an animal estimated to be 28 feet long.

The standard Discovery 12-bore mark is unsuitable for the marking of minke whales because of its size and the possibility of seriously injuring these animals with it. The earlier marking was done with this mark but in all that carried out in the last two seasons, and earlier in the Indian Ocean, the .410 mark has been used.

There is clearly a need for much greater numbers of minke whales to be marked before any very useful series of mark returns can be expected.

S6

Populations of Minke Whales in the Southern Hemisphere

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The population reductions of the main commercial species of baleen whales in the Southern Hemisphere during the last few years have led to the development of the pelagic harvesting of minke whales. In the waters of the Antarctic the minke whale has a circumpolar distribution (Arsenyev, 1961; Ohsumi, Masaki and Kawamura, 1970; Budylenko and Pervushin, 1972; Doroshenko, 1972). The distribution suggests seven local populations in the Southern Hemisphere, each wintering in a specific area with separate migration routes to the summer feeding grounds (Doroshenko, 1972). Each population has been provisionally named according to its winter habitat. Thus, in the South Atlantic there are the Brazilian, African and the lesser part of the Madagascan populations; in the South Pacific sector of the Antarctic there are the New Zealand, Pacific and Chilean-Peruvian populations; and in the Indian Ocean, the Indian population and the greater part of the Madagascan population are to be found.

At the present time, Southern Hemisphere minke whale catch limits are set for six statistical Areas which may not correspond to discrete biological stocks. For rational harvesting it is necessary to identify such stocks and establish stock boundaries and population sizes and on this basis determine scientifically based recommendations for catch limits and open seasons for each population.

Population genetics is becoming important in the study of whales. As we know, local populations differ from one another in their phenotype and gene frequencies. That is to say, each population has a whole series of morpho-physiological features characteristic of it alone but within the general genetic pool of the species. A good basis for conducting population studies can be found in the reviews of Yablokhov (1966), Timofeyev-Resovsky, Yablokhov and Glotov (1973), and Mair (1974) among others.

Recently the first works on the population morphology of North Pacific sperm whales *(Physeter macrocephalus)* have appeared (Berzin, Lagerev and Isakov, 1975; Veinger, Lagerev and Melnikov, 1975). Little information of this sort is to be found in the literature of North Pacific baleen whales. Certain data on individual morphological characters for local fin whale and sei whale populations in Antarctic waters have been presented by Mikhalev, Shevchenko and Neizhko (1975) and for southern minke whales by Satake and Omura (1974). Many works have been devoted to the morphology of whales of various geographical regions.

Our analysis of morphological data on minke whales has indicated four individual populations in the Southern Hemisphere: Brazilian, Indian, New Zealand and Chilean-Peruvian (Doroshenko, 1975).

Comparison of the body proportions of whales from these populations reveals a noticeable difference in head size (Fig. 1). The shortest headed whales are those of the Chilean-Peruvian and Brazilian populations; whales of the Indian population have relatively long heads; and the whales with the longest heads are those of the New Zealand population. These whales also have the largest gape and a relatively long rostrum. According to the data at our disposal (2 skulls from the New Zealand and 4 skulls from the Indian populations), the average length of rostrum in the New Zealand stock was 67.0% of the skull length while for the Indian population it was 64.3% of the skull length.

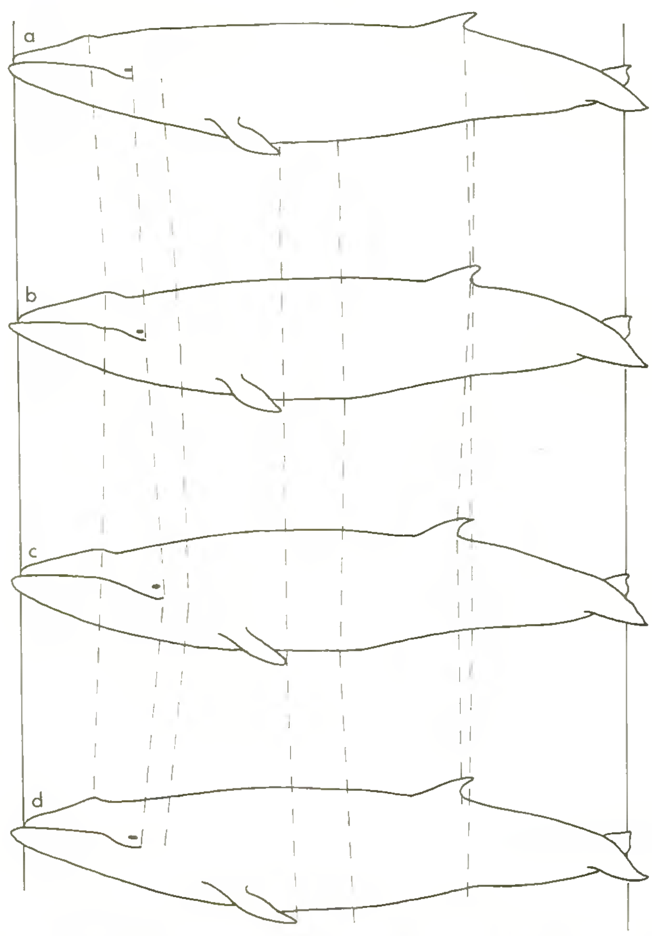

Fig. 1. Body proportions of the minke whales in the Southern Hemisphere (a) Brazilian population (b) Indian population (c) New Zealand population (d) Chilean-Peruvian population.

Comparison of the proportions of the rear portion of the body showed small differences, for instance the somewhat more posterior position of the dorsal fin in whales of the Indian population and the more forward position of the dorsal fin in whales of the New Zealand population.

No significant differences in the position of the anus were observed between populations. A clear difference in position of the umbilicus was observed, with it being located nearer the centre of the body in the Brazilian and New Zealand populations than in the other populations. The Chilean-Peruvian stock possessed longer flippers.

Morphological comparison of populations involves considerable practical difficulties. Under harvesting conditions, collecting substantial data on the usual series of whale measurements in one harvested group is virtually impossible due to the speed with which flensing is carried out. Moreover, most of the measurements are not of strictly determined points and this may lead to inaccuracies, since measurements are made by various investigators. This means that more precisely defined and easily measured characters are needed, which would permit the gathering of a large amount of data in the course of one season. These requirements are met to a certain extent, by the method of population study suggested below, which is based on a series of morphological features, simplified where possible into elementary discrete characters:

1. Shape of the fluke notch:
   Type 1 – narrow fluke notch,
   Type 2 – oval fluke notch,
   Type 3 – one fluke crosses over the other.
2. Colour of flipper on dorsal side:
   Type 1 – solid colour,
   Type 2 – transverse stripe (light grey or dark grey) at base of flipper.
3. Colour of the palate:
   Type 1 – solid colour,
   Type 2 – pigmented spot at base of palate.

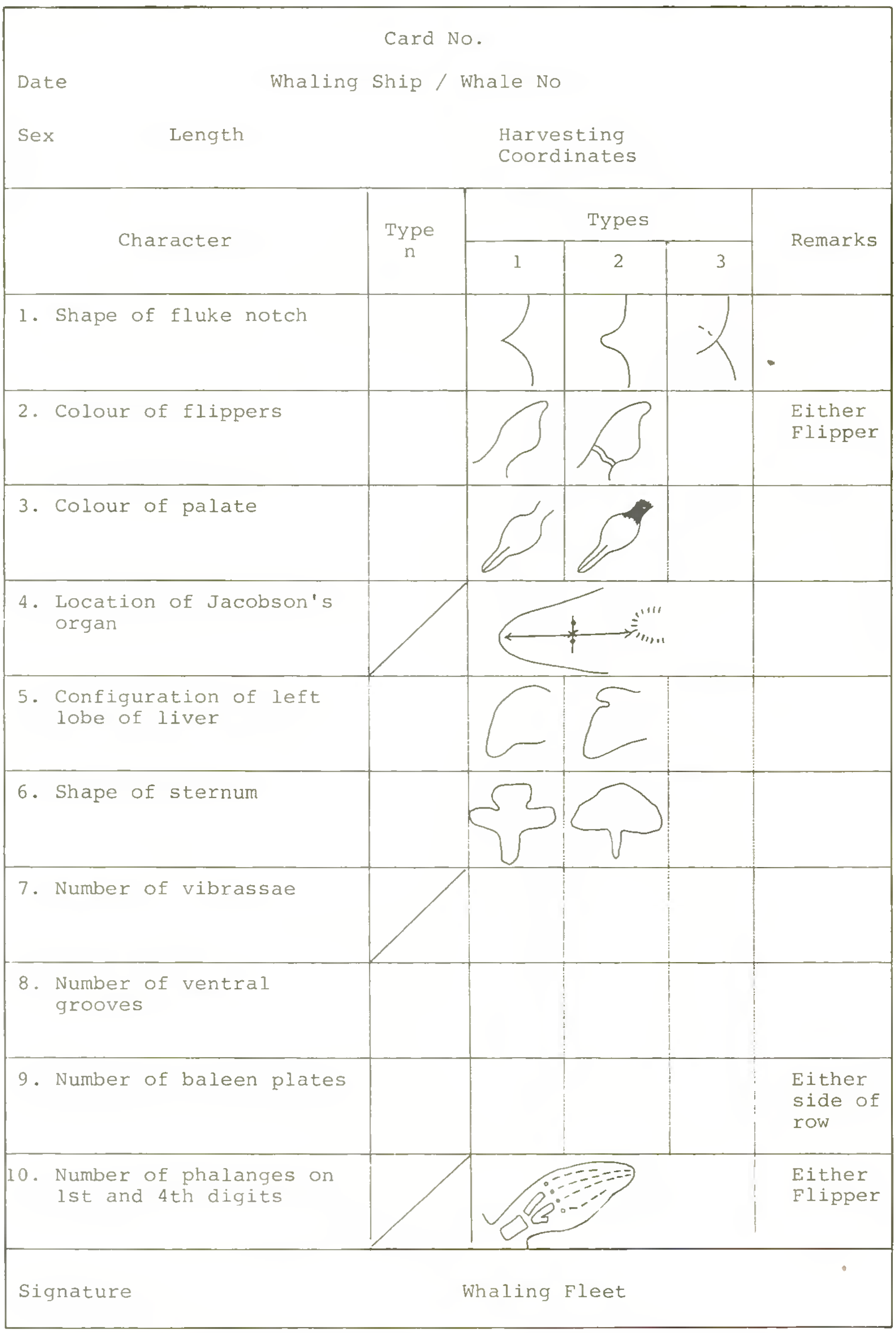

Fig. 2. Card for detailing morphological features as used in this study.

4. Location of Jacobson's organ:
   1) distance from tip of snout to centre of Jacobson's organ,
   2) distance from centre of Jacobson's organ to the baleen plates.
5. Configuration of the left liver segment:
   Type 1 – lateral edge of the left liver lobe is even,
   Type 2 – lateral edge has a deep notch.
6. Sternum shape:
   Type 1 – cruciform,
   Type 2 – mushroom shaped.
7. Number of vibrissae:
   1) on the maxillae,
   2) on the mandible.
8. Number of ventral grooves on a line with the base of the flippers.
9. Number of baleen plates on one side of the baleen series.
10. Number of phalanges on the first and fourth digits of the flippers.

A special card was made up for convenience in collecting data under harvesting conditions (Fig. 2).

Data were collected in the Antarctic waters of the Indian Ocean (Indian population) and in the southwest Pacific (New Zealand population). In the 1975/76 season 800 minke whales were examined for the above-mentioned characters on the ships of the whaling fleet *Sovietskaya Rossiya,* although not all of the characters chosen were easily measured. Some of them, such as determining the configuration of the left lobe of the liver, the shape of the sternum and the number of phalanges on the digits of the flippers were very time consuming.

Analysis of the data collected shows a clear geographical variation of characters of the two populations compared (Table 1).

The shape of the notch in the tail flukes of minke whales is found to vary mainly in the first and third types. In the Indian population, 28.7% of the sample exhibited Type 1 and 17.7% Type 3 whereas in the New Zealand population these values were 33.6% and 11.0% respectively. No significant difference was observed for Type 2 (53.6% in the Indian population and 55.4% in the New Zealand population.

Marked differences between the populations were noted in the colour of the flippers, in the number of baleen plates and in the number of phalanges on the first and fourth digits of the flippers (characters 2, 9 and 10).

Minke whales of the Indian population had a transverse stripe at the base of the flippers in 55.5% of the sample as opposed to 75.2% of the New Zealand sample. Data available from other regions, the southwest Atlantic (Brazilian stock) and the southeast Pacific (Chilean-Peruvian stock) also showed a marked difference between populations. A sample of the Brazilian population showed a transverse stripe on the flippers to be present in only 26.1% of the cases, while in the Chilean-Peruvian population 48.8% exhibited this character.

Character 9, the number of baleen plates on one side of the row deserves special attention. The New Zealand sample possessed many more baleen plates (274) than the Indian

Table 1

Frequency of occurrence of morphological characters in various minke whale populations

No.	Character	Type n	Populations Brazilian	Indian	New Zealand	Chilean-Peruvian
1.	Shape of fluke notch	n	–	519	202	–
		1		28.7	33.6	
		2		53.6	55.4	
		3		17.7	11.0	
2.	Colour of flippers	n	230	562	204	185
		1	73.9	44.5	24.8	51.2
		2	26.1	55.5	75.2	48.8
3.	Colour of palate	n	–	269	153	–
		1		27.6	23.6	
				72.4	76.4	
4.	Location of Jacobson's organ	n	–	38	77	–
		1		25.0	24.4	
		2		50.4	49.4	
5.	Configuration of left lobe of liver	n	–	22	–	–
		1		75.0		
		2		25.0		
6.	Shape of sternum	n	–	13	–	–
		1		53.8		
		2		46.2		
7.	Number of vibrissae	n	–	246	145	–
		1		10.2	9.7	
				22.1	22.0	
8.	Number of ventral grooves	n	–	183	104	–
				46	46	
9.	Number of baleen plates	n	–	42	30	
				242	274	
10.	Number of phalangeal digits	n	–	16	10	–
		1st		5	4	
		4th		5	4	

sample (242). This character plus the body measurements (from the end of the snout to the corner of the gape) and the skull index (length of rostrum) showed that there were real differences between the populations examined.

Comparison of the number of phalanges on the digits of the flippers (character 10) showed distinctive differences in the number of phalanges on the first and fourth digits. The Indian population sample usually had five phalanges on the first and fourth digits, while the New Zealand sample had four phalanges on these digits. No differences were observed in the number of phalanges on the second and third digits (usually seven to eight). It should be mentioned that data collected on this character are not very numerous (only 26 whales were examined), and further research is necessary.

Other characters examined showed little variation, apart from the colour of the palate (character 3). The minke whale palate is usually a pale pink colour, but some whales were observed to have a grey-blue patch or spotted area from the base of the palate for one-fifth of its length. More of the New Zealand stock had an all-pink palate (76.4% as against 73.4%).

No differences were observed in the location of the Jacobson's organ in the two populations, but it is possible that with a larger sample this character might be a reliable criterion for distinguishing whale populations.

The populations did not differ significantly in the number of vibrissae on the head (character 7): the maxillae had on average 10 vibrissae (2 on each side of the naris and 3 on each side of the maxillae) and the mandible, 22 vibrissae (3 to 4 on the side branches of the mandible and 14 to 16 on the symphysis). No differences in the number of ventral grooves in the two populations were found (character 8).

In the process of searching for morphological characters to distinguish between stocks of minke whales, we examined individual internal organs and elements of skeletons of the catch, although only for the Indian population were a large amount of data collected.

Our attention was attracted to the configuration of the left lobe of the liver and the shape of the sternum (characters 5 and 6). The left lobe of the liver has two types of configurations, one with a smooth lateral edge and the other with a notch in it. Of the 22 animals examined, 75.0% had a smooth edge to the left lobe.

The sternum also has two types, cruciform and mushroom shaped. Among the 13 animals examined, a slight prevalence of the cruciform type was observed (53.8%). With a sufficient amount of data, these characters (especially the sternum shape) may become good markers for population studies of whales.

Thus, analysis of the data presented has shown a marked difference in the frequency with which some morphological characters are met in minke whales of these two different regions of the Southern Hemisphere. Especially well marked is the difference in frequency of occurrence of shapes of fluke notches, colour of flippers, number of baleen plates and number of phalanges on the first and fourth digits of the pectoral flipper.

These data testify to the existence of different populations of minke whales, namely, the Indian and the New Zealand stocks, occupying specific Antarctic areas in summer. The Indian population is thought to inhabit the area between 55°E and 110°E and the New Zealand one between 135°E and 165°W. Their northern border line is limited by latitudes 58°S to 60°S and the southern one coincides with the ice edge.

There is little doubt that significant differences can be revealed while investigating other populations of minke whales as differences in the coloration of the pectoral flippers in the whales of the Brazilian and Chilean populations suggest. Preliminary data allows us to conclude that the whales of the Chilean-Peruvian populations have their feeding and growing area between 70°W and 115°W south of latitude 60°S. In summer, the Brazilian population inhabits the area lying between 30°W and 70°W and latitude 55°S to the north and the ice edge to the south.

The migratory life-style of cetaceans means that the above limits are approximate and may vary somewhat according to the seasons.

The method suggested should be regarded as a first stage in the use of morphological features in population studies of whales. To develop this approach, it is necessary to study whales wherever they are harvested, to find new marker characters and to verify the characters suggested by the collection of a substantial amount of data.

Perfection of research methods and further accumulation of data will enable us to discover the boundaries of various populations and rationally approach the problem of optimal harvesting of their numbers.

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S7

Calculations of the Mean Age at Recruitment from Catch Curves (Southern Hemisphere Minke Whales)

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ABSTRACT

The method used by Ohsumi and Masaki to compute mean age at recruitment gives a biased estimate if the catch curve does not represent a stable age distribution. In the case of the minke stocks of the Southern Hemisphere, which appear to have been steadily and rather rapidly increasing for many years prior to the beginning of the exploitation in the early 1970s, the bias is significant, and appropriate adjustment must be made, involving use of a better estimate of natural mortality than that obtained from the shape of the right-hand limbs of these catch curves. A correction formula is derived.

If the catch curve represents the stable age composition of a stationary population the formula used by Ohsumi and Masaki (1975) is correct, i.e.

$$R_x = \emptyset_x/\emptyset_{x-1}e^{-z}$$

and

$$x_r = \Sigma x.R_x/\Sigma x$$

where Z = M if the population is unexploited.* If, however, the unexploited population is growing or declining this gives a biased estimate. In this case the correct calculation is to use the true or assumed natural mortality rate (M) rather than the apparent rate M^1. Thus the correction factor (k) to be applied is

$$k = e^{-(M-M^1)}$$

In the case of the minke whale, where $M^1 = 0.124$ (average, both sexes), and if assumed M = 0.09 the correction is k = 1.035 so that the mean age of recruitment is 6.62 rather than 6.40.

For the sexes considered separately the values are

males: 6.09 instead of 5.9
females: 7.15 instead of 6.9

if it is assumed that M in both sexes is 0.09. If, however, the true natural mortality is different between the sexes, and approximately in the ratio 0.129 : 0.122 then the corrected estimates become:

males: 6.12
females: 7.16

These differences, while worth taking into account in future work, are not in themselves sufficient to account for the discrepancies in the two ways used to compute replacement yields.

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Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Atlantic minke whale at initial population level. *J. Fish. Res. Bd. Can* 32(7): 995–1001.

*R_x = recruitment in number at age x
$\emptyset_x$ = number of animals in age-class x
z = total mortality coefficient
x_r = age at recruitment

Program to Estimate Baleen Whale Population Sizes (BALEEN)

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INTRODUCTION

This programme implements a modified and extended version of the sei whale dynamics model (Allen and Kirkwood, 1978; Kirkwood and Allen, 1978). The mechanisms causing density-dependent changes to parameters have been altered, and the model has been modified to allow the age at recruitment to be less than the age at first parturition. The programme and model can be used where quantified changes in ages at recruitment and first parturition are believed to have occurred. They are therefore appropriate for use in estimating sei and minke whale populations where such changes are suspected as a result of the lowered populations of blue and fin whales with which they compete for food. Subsections of the model and programme could be used for any baleen whale species.

The core of the programme is the revised dynamics model, which calculates the sizes of various population components of an initially stable and unexploited population. If desired, the programme then estimates initial population sizes using a general maximum likelihood technique (Kirkwood, 1978), which compares actual and expected catches.

ALTERNATIVE MODELS

The programme provides for two pairs of alternatives in the structure of the model.

The first pair relates to the nature of the available biological data. In all cases, times series for age at recruitment and at first parturition are required, but only one alternative requires a times series of pregnancy rates. The other operates on an overall recruitment rate without separating birth and mortality components.

The second pair of alternatives relates to the driver of the density-dependent functions. This may be either the mature female population of the target species alone, or the equivalent population of all competing species combined.

Combination of these alternatives provides four model options which may be selected. These are:

Option 1. Time series of only ages at first parturition and recruitment are available, density-dependence in the model operates on the target population only.

Option 2. Time series of pregnancy rates are also available, density-dependence operates on the target population only.

Option 3. Times series of ages at first parturition and recruitment are available, density-dependence operates on the total competing population.

Option 1 is a special case of Option 3.

Option 4. As for Option 3, but pregnancy rates are also available.

Option 2 is a special case of Option 4.

DENSITY-DEPENDENCE ASSUMPTIONS

Each of the model options involves different assumptions on density-dependence, and correspondingly different functions have to be used.

In *Option 1* full pregnancy data are unavailable, and the recruitment rate to the age at first parturition is assumed to be dependent on the density of the target species. Any observed changes in ages at first parturition and recruitment are assumed to be externally caused.

At the original unexploited equilibrium, the recruitment rate to the age at first parturition, t_{px}, is taken as equal to the natural mortality rate, M. The recruitment rate to age t_{px} at notional zero population level, r_o, is calculated from a supplied maximum pregnancy rate and the zero level juvenile mortality rate; the latter being calculated as described under Option 2. Then while the age at first parturition remains at t_{px}, the recruitment rate to age t_{px} resulting from a female mature population level P is assumed to be

$$r = (r_o - M)\left[1 - \left(\frac{P}{P_x}\right)^{n+1}\right] + M \qquad (1)$$

for a density-dependence exponent n, and where P_x is the unexploited mature female population level. Similarly, keeping the age at recruitment greater than t_{px} for simplicity, the recruitment rate to $t > t_{px}$ is

$$r = \frac{(r_o - M)\left[1 - \left(\frac{P}{P_x}\right)^{n+1}\right] + M}{(1 - M)^{t_{px} - t}} \qquad (2)$$

Suppose the population is at its original unexploited equilibrium with age at first parturition t_{px}. Now let the age at first parturition decrease due to external forces to $t_p < t_{px}$. Clearly the population will increase and in particular the numbers of females of age t_{px} or more will increase, and ultimately stabilize at some higher level. Denote the number of animals of age t_{px} or more originally by P_{xo}, and the new higher stable level after the change from t_{px} to t_p by P_{x1}. Then the following equality should hold:

$$\frac{M}{(1 - M)^{t_{px} - t_p}} = (r_o - M)\left[1 - \left(\frac{P_{xo}}{P_{x1}}\right)^{n+1}\right] + M \qquad (3)$$

The RHS represents the recruitment rate to age t_p just before the change in age at first parturition, while the LHS represents the recruitment rate to age t_p just after the change. This implies that

$$P_{x1} = P_{xo}\left\{1 + \frac{M}{r_o - M}\left[1 - (1-M)^{t_p - t_{px}}\right]^{-\frac{1}{n+1}}\right\} \qquad (4)$$

Following this through, we have the unexploited stable number of females of age t_{px} or more in year i given by

$$P_{xi} = P_{xo} \left\{ 1 + \frac{M}{r_o - M} \left[1 - (1-M)^{t_{pi} - t_{px}}\right]^{-\frac{1}{n+1}} \right\} \quad (5)$$

in an obvious notation, while the recruitment rate to age $t(<t_r)$ in year i is given by

$$r_{ti} = \frac{(r_o - M)\left[1 - \left(\frac{P_i}{P_{xi}}\right)^{n+1}\right] + M}{(1-M)^{t_{pi}-t}} \quad (6)$$

where P_i is the current number of females of age t_{px} or more and t_r is the age at first exploitation.

In *Option 2* time series of pregnancy data are available, and it is therefore possible to split recruitment into pregnancy (births), juvenile and natural mortality segments. Now the only assumed density-dependence occurs in the juvenile mortality rate, which is assumed to be given by

$$M_i' = (M_x' - M_o')\left(\frac{P_i}{P_x}\right)^{n+1} + M_o' \quad (7)$$

where M_x' is the unexploited juvenile mortality rate calculated to balance the population, while M_o' is the zero level juvenile mortality rate, calculated as

$$M_o' = M + K(M_x' - M) \quad (8)$$

with K having an arbitrary value between 0 and 1. The value of P_{xi} is calculated exactly as in Option 1. Again the major assumption is that changes in ages at first parturition and recruitment are externally caused.

In *Option 3* the density-dependent factors are regulated by the total whale population density, and it is again assumed that the changes in t_p and t_r are the result of internal causes. Because full pregnancy data are unavailable, a formulation similar to that of Option 1 is employed.

Equations (1) and (2) can still be used in a modified form. However, instead of using the device of (3) and (4), we can argue directly to obtain an expression for P_{xi}. The driver of density-dependence is now taken to be the sum of the mature female population of the primary species plus half the population of the competing species, reduced by a 'competition factor' A. We thus have for the operating component of the density-dependent function

$$\frac{P_i + AB_i/2}{P_{xi} + AB_x/2} \text{ instead of } \frac{P_i}{P_{xi}}$$

where B_i is the current population size of the competing species and B_x is their unexploited population size.

Then, since we assume that the competing component of the absolute maximum population which can be supported is given by $P_{xo} + AB_x/2$, a drop in the population of other whales enables an expansion in the maximum number of the target species. Thus

$$P_{xi} = P_{xo} + A(B_x - B_i)/2 \quad (9)$$

and

$$r_{ti} = (r_o - M)\left[1 - \left(\frac{P_i + AB_i/2}{P_{xi} + AB_x/2}\right)^{n+1}\right] + M \quad (10)$$

In *Option 4* full pregnancy data are available and, as in Option 2, recruitment now consists of births, and juvenile and adult mortality components. The calculations are carried out exactly as in Option 2, except that density-dependence is calculated as in Option 3.

OPTIONS IN APPLICATION

The programme as a whole is designed to provide estimates of initial populations and of catchability coefficients. Occasions arise however when it is useful to obtain a time series of population sizes on the assumption that the same model applies with given sets of vital parameters and annual catches and with a supplied initial population size. An option which uses only the model component of the programme and bypasses the estimating routine is available for this purpose.

Another option allows estimates to be obtained either for a single data set, or for a number of sets using an estimated common q per unit area.

OUTPUT OPTIONS

Four sets of output tables are available, and may be selected by requesting the appropriate option.

(i) Table of input data containing ages at first parturition and recruitment, pregnancy rates, and blue and fin whale population sizes.
(ii) Table of catch and effort data.
(iii) Tables of time series of population components for each parameter combination and calculation option selected.
(iv) A summary table containing, for each parameter combination and calculation option selected: the table number, the calculation option, the parameters used, and the current values of important population component sizes.

TECHNICAL FEATURES

The programme is written in CDC 7600 FORTRAN.

A general restriction is that the time series of ages at first parturition and recruitment must be monotonically non-increasing.

AVAILABILITY

Copies of the programme and operating instructions may be obtained from the authors.

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Review (in Minke Whales) of the Weight/Length Relationship and the Antarctic Catch Biomass, and a Discussion of the Implications of Imposing a Body Length Limitation on the Catch

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ABSTRACT

The body weight/length correlation in minke whales is reviewed and a formula predicting total body weight inclusive of body fluids is derived from body length. The proportional weights of muscle, blubber, bones and viscera in the body are presented, the muscle weight constituting 62.4% of total body weight and more than in other balaenopterid whales.

The data on catches of Antarctic minke whales are reviewed. Generally since 1971/72 season, females have dominated the catch in the ratio 3:2 males, unlike seasons preceding this time when males were dominant. The average body lengths of the catches are 28.1 ft in females and 26.9 ft in males. The change in sex ratio in the catches is regarded as an indication of sexual segregation because the change has been associated with a shift in areas of operation. The CPUE is found to be affected by climatic variability. Since 1971, over 70% of the catches have been taken from 60°–70°S, and the juvenile component of the catches has been small, between 2% and 19% of the total.

Using the weight/length conversion formula, the catch statistics are presented as biomass at body length distributions.

On the consideration of the composition of the catches by sex and maturity, and the length and weight distributions of the catches, and the area of operation, it is suggested that there is currently no pressing requirement for a minimum size limit, but that if one were to be set, 25 ft would be an appropriate size limit.

WEIGHT/LENGTH RELATIONSHIP

There are sufficient weighings of minke whales for a weight/length correlation to be formulated. Ohsumi, Masaki and Kawamura (1970) produced a weight/length formula

$$W = 0.0466\ L^{2.31} \qquad \ldots (1)$$

where W is body weight in tonnes and L is body length in metres, based on the weights of six whales weighed by parts, and ranging in size from 7 to 9 metres. They observed that the body weight/length relationship in minke whales from the Southern Hemisphere was similar to that of minke whales from the Northern Hemisphere.

Lockyer (1976) produced a weight/length formula for the minke whale, based on 22 weighings by parts. The whales concerned were taken mainly from the Antarctic but included four whales from other geographical origins. The formula was

$$W = 0.0076\ L^{3.23} \qquad \ldots (2)$$

for whales ranging in size from 3 to 11 metres.

By allowing a token correction for blood and fluid losses of 6% total body weight (Lockyer, 1976), this formula (2) can be adjusted to

$$W = 0.0081\ L^{3.23} \qquad \ldots (3)$$

For all practical purposes of converting body length statistics (normally presented in feet rather than metres), to a body weight form, the formula can be used as follows:

$$W = 0.0001745\ L^{3.23} \qquad \ldots (4)$$

where L is body length in feet.

In Fig. 1, the weight/length relationship of the minke whale is shown, using the equivalent formulae (3) and (4).

Ohsumi, Masaki and Kawamura (1970) noted the proportional weights of the body tissues in minke whales (Table 1).

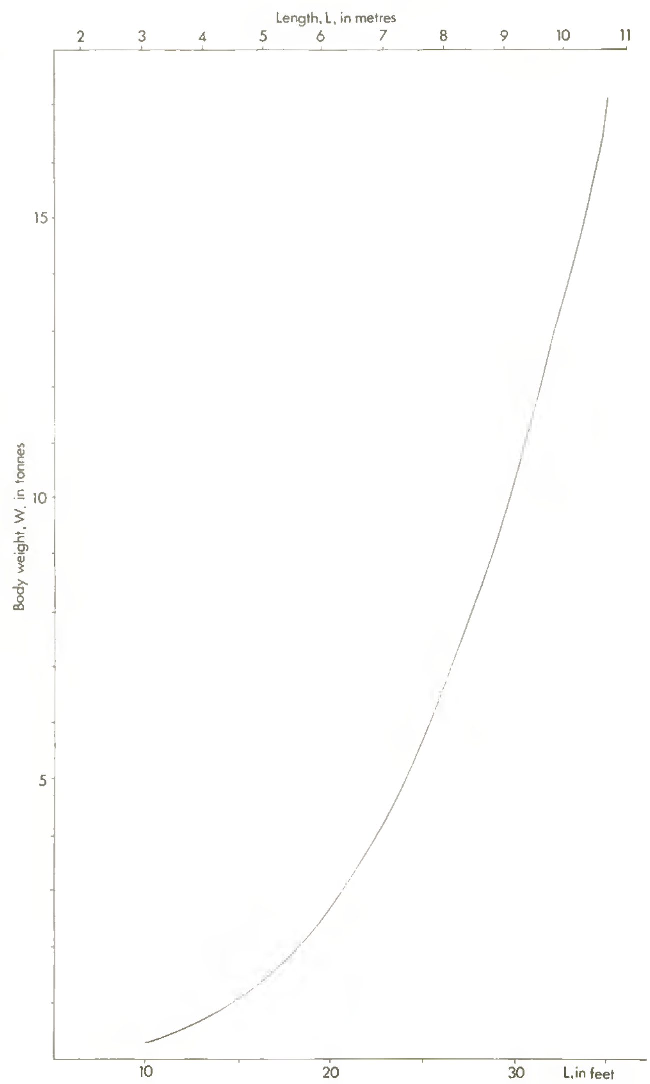

Fig. 1. Body weight/length curve derived from weight/length formulae, for the southern minke whale.

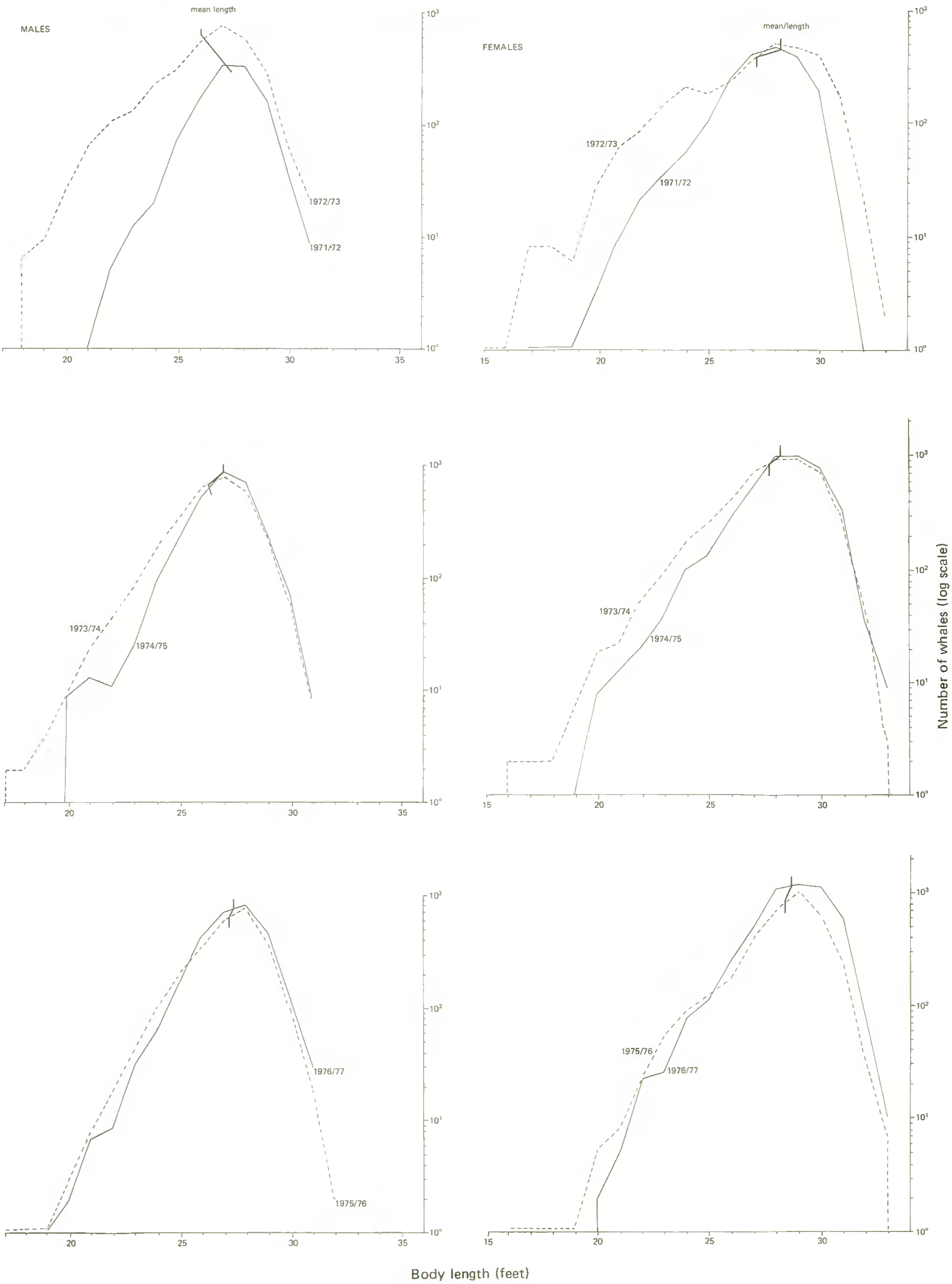

Fig. 2. Length frequency distributions of the catches of minke whales in the Antarctic, seasons 1971/72 through to 1976/77, with mean lengths indicated, for males and females.

Table 1

Proportion of body tissues by weight, in minke whales

Tissue	% Body weight
Meat	62.4
Blubber	15.0
Bones	14.2
Viscera	7.6

Compared with other balaenopterid whales, Ohsumi *et al.* (1970) observed that the minke whale carries the greatest proportion by weight of meat tissue, thus making it very valuable as a food source.

Although neither the formulae given here nor the data in Table 1 allow for seasonal variations in body weight associated with feeding, they can nevertheless be used to determine approximate catch biomass statistics and production.

REVIEW OF CATCH DATA

The length frequency distributions of the catches by sex between 1971 and 1977, are shown in Fig. 2. The data are taken from the published records of the Bureau of International Whaling Statistics.

In all seasons since 1971/72, except 1972/73 when the sex ratio of the catch was 1 : 1, males : females, the female catch has exceeded the male catch in the approximate ratio 3 : 2. Examination of the mean body length of the catches by sex shows that the females averaged 28.1 ft and the males averaged 26.9 ft.

During the whaling seasons of the 1960s, Ohsumi *et al.* (1970) and Ohsumi and Masaki (1975) reported that males were dominant in the catch, approaching 80% in Area IV. These variations in sex ratio in the pre- and post-1970 seasons have been regarded as an indication of sexual segregation geographically; the sex ratio being linked with the area of operation, since analysis of the foetal sex ratio indicates males : females = 1 : 1. The majority of sightings and catches have been within the Antarctic Convergence, and thus within the true Antarctic region.

Whaling for minke whales has taken place each season commencing 1971 in Area IV, unlike other Areas where operations have been intermittent or delayed. The CPUE data, shown in Table 2, show no consistent trend.

Table 2

Data on CPUE* for minke whales taken in Japanese operations, from Ohsumi (1977), and other catch data

Season	CPUE	% females in catch	Mean length in ft of catch ♂♂	Mean length in ft of catch ♀♀	% whales <25 ft in catch
1971/72	1.378	63.7	27.3	28.5	5.5
1972/73	1.366	49.5	26.3	27.1	18.7
1973/74	1.067	61.6	26.5	27.8	9.6
1974/75	0.803	61.0	26.9	28.3	4.7
1975/76	1.295	57.3	27.2	28.3	5.9
1976/77	1.143	63.9	27.4	28.7	2.9

*corrected for wind speed.

Two important influencing factors on CPUE are wind speed and visibility, mentioned by Ohsumi (1977). Another factor considered by Ohsumi (1976) is the latitudinal location of the pack-ice line, because minke whales are known to congregate at the ice edge. When the pack-ice line is far to the north, abundance of the whales is poor. In 1974/75, when CPUE was lowest, the pack-ice edge was farthest north of all preceding seasons.

Climatic conditions appear to affect the catch effort considerably. Referring to Table 2, there seems to be no correlation between CPUE, mean length and proportion of small whales in the catch and sex ratio. This suggests ready availability of all whales each season. An examination of the distribution of the total Antarctic catches by Series, illustrated in Fig. 3, indicates that the majority has been culled from Series B, 60°–70°S, although in recent seasons the actual percentage has fallen. Correspondingly, the percentage of the catches in Series C, 70°–80°S, has been increasing. In effect this means that the area of minke whaling has been moving southwards. None of this shifting of the whaling effort appears to have any correlation with catch data tabulated in Table 2, i.e. sex ratio, etc.

Since 1971, the size and sex distributions of minke whales in the catch have been fairly randomly selected on an annual basis, as the normal distributions in Fig. 2 illustrate. Apart from 1972/73, when the juvenile component approached 20% of the catch, the average proportion of small whales is only just statistically significant at 5% probability level. However, the mean length is biased to larger sized whales, for natural reasons such as the consequence of size lumping of animals of different year classes because their growth has either ceased or is slowing as maximum length is approached. Other reasons for slight bias to larger whales could be easier sighting and some selection on the part of whalers for a greater yield for effort.

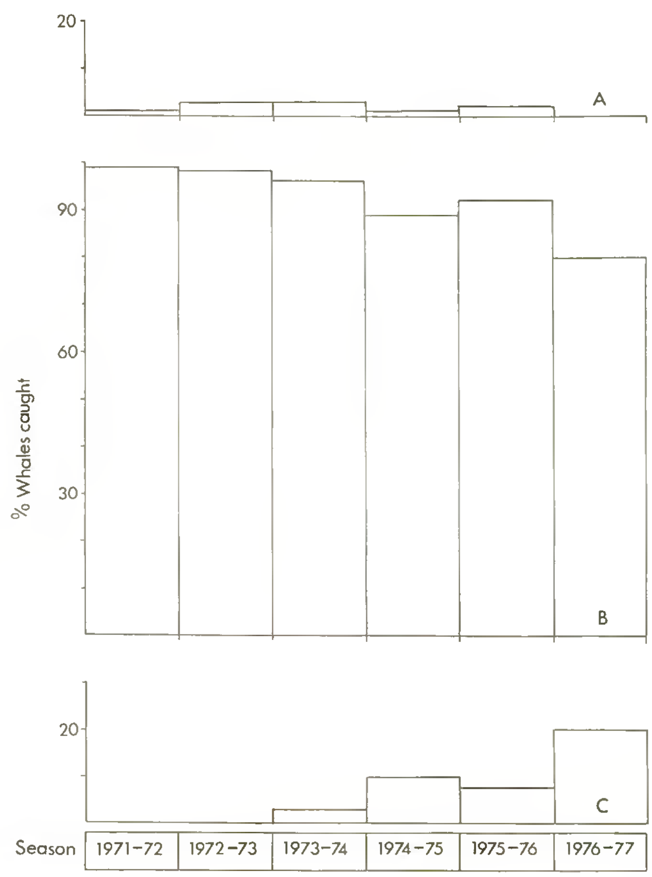

Fig. 3. Proportion of the total Antarctic minke whale catch taken in three latitudinal series. A: 50°– 60° S, B: 60°–70° S and C: over 70° S, by season.

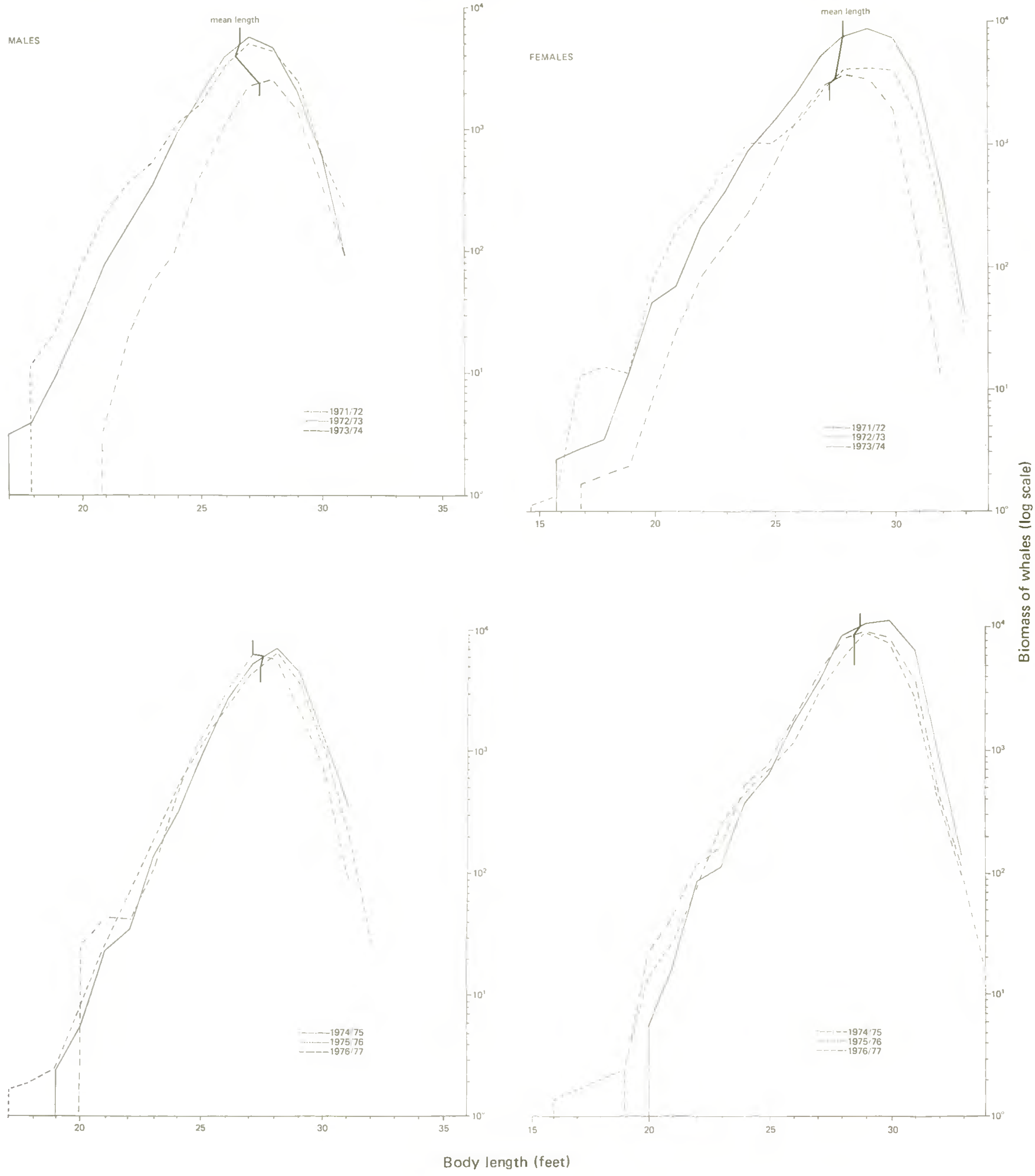

Fig. 4. Distribution of the biomass of the Antarctic minke whale catch by length, for seasons 1971/72 through to 1976/77, with mean lengths indicated, for males and females.

BIOMASS OF THE CATCH

In Fig. 4, the biomass at length and by sex of the seasons' catches are shown. The biomass distribution at length is similar in appearance to the number frequency distribution at length, and the mean body lengths of the catches from Fig. 2 are close to those calculated from mean body weight in Fig. 3. This is undoubtedly due to the fact that the size distribution of the catch has up to now been well balanced, with the mean length being fairly close to the predicted mean maximum lengths of the species. Ohsumi and Masaki (1975) have shown from mean length at age curves that these mean maximum lengths are about 28 ft for males and 29.5 ft for females.

CONSIDERATION OF A MINIMUM SIZE LIMITATION

At the present there is no minimum length limitation on the catch. This is perhaps unimportant at the moment, because few small whales are taken. However, should availability of whales decrease, or area of operation shift, particularly northwards, so that the likelihood of more small and hence young and immature whales enter the fishery, there may be a reason for setting a size limit.

While stocks of southern minke whales remain above MSY level, a minimum size limit may have no practical function. However, the MSY level has yet to be defined accurately by Area for this species. Long term management therefore might include a minimum size limit now as a precaution.

The possibility of imposing a size limit has been raised by the Infractions sub-Committee of the Technical Committee (IWC, 1978).

The purpose of a size limit should be to afford protection to certain whales in the stock, primarily in order to maintain high productivity in a balanced management plan.

In Fig. 5, the growth curves of weight at age have been derived from length at age curves (Ohsumi and Masaki, 1975). By the age of sexual maturity, about 6 years, when the length is 23.6 ft in males and 26.2 ft in females, the body weight is between 60% and 70% of the final body weight which is reached within approximately the next 12–16 years.

By age 10 years, equivalent in size to the current mean lengths of the catches (i.e. 27–28 ft), about 90% of the final body weight has been attained. Ohsumi and Masaki (1975) showed that over 90% of females are sexually mature by age 10 years.

If, for example, a size limit was set around 27 ft, virtually all the catch would be mature. Between 1971 and 1977 however, animals less than 27 ft comprised on average about 25% of the catches (males and females combined) and in terms of biomass this represents 17.5% of the catches. The 1972/73 season's catch comprised about 40% whales under 27 ft (the highest proportion), and that of 1976/77, about 15% (the lowest proportion); in terms of biomass, these catches comprised 28.5% and 10.5% respectively.

If the size limit was set at 25 ft, approximating the mean length at sexual maturity, the whales below this size limit only constituted about 8% of the catches in numbers, and less than 5% by biomass, during 1971–77.

By comparison with other balaenopterid species, for example fin and sei whales, the minimum size limits just discussed appear relatively high. The size limits for pelagic operations in the Southern Hemisphere are 57 ft for fin whales and 40 ft for sei whales. Both these values are less than the mean sizes at sexual maturity in these species, and are approximately × 2.7 the size at birth (Lockyer, 1977). By analogy one could set a size limit for minke whales based on an estimate derived from × 2.7 the birth size which according to Ivashin and Mikhalev (1978) would probably be about 2.8 m (about 9 ft). This would give a size limit of about 24 ft. At the present, a limit set at this value would have negligible practical effect as an average of only 4% of the catch would be excluded, and the argument for this size limit has no scientific basis, but is based more on tradition.

In order to exclude suckling calves or yearlings (not necessarily accompanied by other whales) from the catch, a size limit equivalent at least to the mean length at age one year would need to be set. By analogy with fin and sei whales (Lockyer, 1977), one might assume that the mean

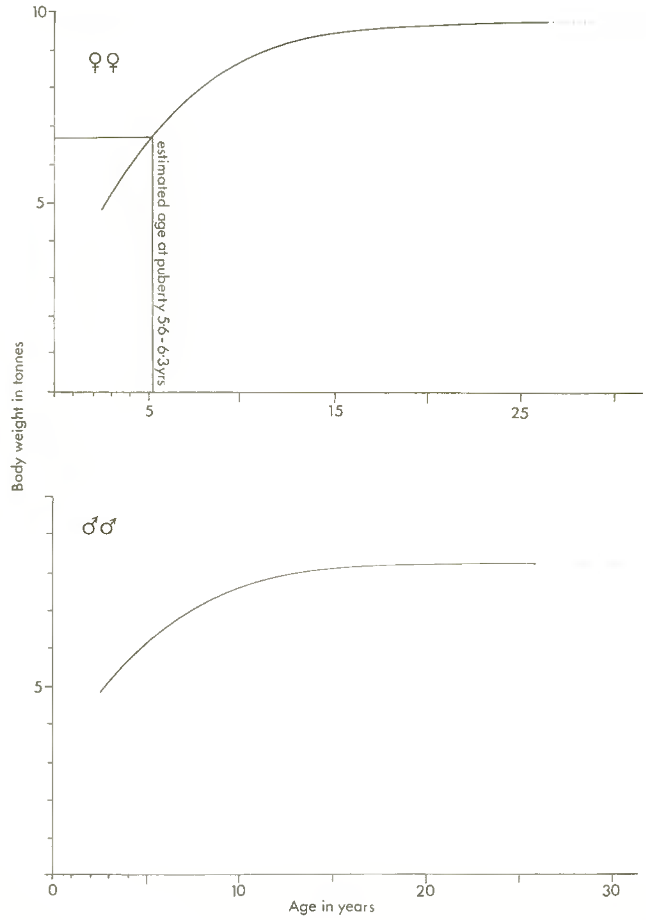

Fig. 5. Average growth in weight with age curves for southern minke whales, derived from growth in length with age curves from Ohsumi and Masaki (1975).

length at age one year would be approximately 21–22 ft in minke whales (× 2.3 – × 2.4 birth length). Length at weaning might similarly be assessed at 16 ft (× 1.8 birth length). Either of these limits might have a practical application should no other size limit be set, nor protection given to lactating cows with calves. The size limit set for sei whales for coastal operations is 35 ft which is close to the size at age one year in this species. A comparable size limitation on the catch of about 22 ft could be imposed on coastal minke whaling.

For pelagic whaling, the adoption of a 25 ft size limit for minke whales would afford protection to all calves and to the majority of the juvenile whales during the most rapid phase of growth prior to sexual maturity. The rate of growth falls off after maturity so that in terms of productivity mature whales at this size and just over are at their peak.

The disruption to the present fishery would be relatively minor, in that in terms of biomass, a statistically insignificant quantity (less than 5%) would be lost from the current pelagic 'free-for-all' system. This deficit could easily be more than compensated for in production by catching the biomass equivalent of fewer large whales, thus not deleteriously affecting CPUE. The larger size limit of 27 ft would undoubtedly prove impractical over a long period of time because many year classes are clustered around this length which is near the mean maximum length. The CPUE would eventually decline markedly. The social effects on the population in creating a gross age imbalance by removing only old and mature whales are unknown. Moreover, the inter-related effects of age specific natural mortality have not even been considered with regard to productivity.

Ohsumi and Masaki (1975) calculated that the current age of recruitment to the fishery is about 6 years so that there are both scientifically based management arguments and operational reasons for adopting a minimum size limit of about 25 ft for both sexes, not necessarily now, but at a future date when the 'surplus' over MSY has been culled.

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S10

Yearly Change of the Biological Parameters for the Antarctic Minke Whale

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ABSTRACT

The age at sexual maturity for the Antarctic minke whale can be estimated by means of four approaches, i.e. (i) change in rate of sexual maturity, (ii) relationship between age and corpora number, (iii) growth curve and body length at sexual maturity, and (iv) transition phase in the ear plug laminae.

Since regular catches of minke whales only began in the 1970s in the Antarctic, the yearly change in age at maturity cannot be estimated using approaches (ii) or (iii). Using the transition phase approach, the mean age at sexual maturity of animals of both sexes born prior to 1944 was approximately 14 years. It has been decreasing linearly each year since 1945 reaching about 6 years in the latter half of the 1960s. However, this change in age at maturity cannot be explained by a reduction in the population level of the Antarctic minke whale itself, but may be associated with the decline of the total biomass of the baleen whales.

The pregnancy rate of the Antarctic minke whale is estimated to be 95.1%–96.5%. There are small differences in pregnancy rate by Area, but no definite yearly trend in pregnancy rate has been observed during the seasons 1971/72–1976/77.

The male foetal sex ratio and mean litter size of the Antarctic minke whales are 45.9% and 1.006 respectively, for the whole area. No definite yearly trend in these two parameters has been observed during the seasons 1971/72–1976/77.

INTRODUCTION

When discussing intraspecific relationships of baleen whales, it has been generally assumed that some of the reproductive parameters may alter as a response to a change in population size. For instance, it is reported that a decrease in the age at sexual maturity and an increase in pregnancy rate is closely associated with a decline in the population of certain species (fin whales: Lockyer, 1972; Gambell, 1973; sei whales: Gambell, 1968, 1973; Lockyer, 1974). However, Gambell (1973) and Masaki (1976, 1977) reported that a decrease in age at sexual maturity and an increase in pregnancy rate of the Antarctic sei whale had already occurred prior to its exploitation and these facts were discussed at the IWC Special Meeting on Southern Hemisphere Sei Whales in Tokyo, April 1977 and by the IWC Scientific Committee in Canberra, June 1977. It was thought that the gross reduction of blue and fin whale stocks affected changes in the reproductive parameters of the sei whale, causing its population to increase. The same changes may have occurred in Antarctic minke whales.

There are few studies to date on yearly changes in the biological parameters which are necessary for the stock assessment of Antarctic minke whales. Most of the work deals with biological parameters for a single time period (Ohsumi *et al.*, 1970; Masaki, 1973; Ohsumi and Masaki, 1975; Williamson, 1975).

This study examines changes in four biological parameters: (1) age at sexual maturity; (2) pregnancy rate; (3) foetal sex ratio and (4) litter size. The biological data and materials used were obtained from the Japanese pelagic expeditions in the 1967/68 and 1971/72 to 1976/77 Antarctic whaling seasons.

1. AGE AT SEXUAL MATURITY

The best method for evaluating sexual maturity in cetaceans is to examine whether females have at least one corpus luteum or corpus albicans in the ovaries or by histological examination of testis tissue samples from males. The latter approach poses considerable practical difficulties where large numbers of samples are involved and in this study a testis weight of more than 0.4 kg was used as a standard criterion for maturity, based on histological data by Ohsumi *et al.* (1970) and Masaki (unpublished).

There are four possible approaches to the estimation of the age at sexual maturity:

(i) the age at which 50% of the whales examined of that age are mature (using the above criteria);
(ii) from the relationship between age and number of ovulations;
(iii) from the relationship between body length at sexual maturity and the growth curve;
(iv) from the transition phase of the ear plug.

(i) Age at sexual maturity based on the presence of at least one corpus luteum or corpus albicans in the ovaries or a testis weight of more than 0.4 kg

The age and sexual condition of 11,423 females and 7,729 males taken by Japanese expeditions in the 1967/68 and 1971/72–1976/77 seasons were determined in order to estimate the age at 50% sexual maturity for both sexes by season and by Area (Table 1).

Because of insufficient data on immature male whales and the practical problems involved in the age estimation of

Table 1

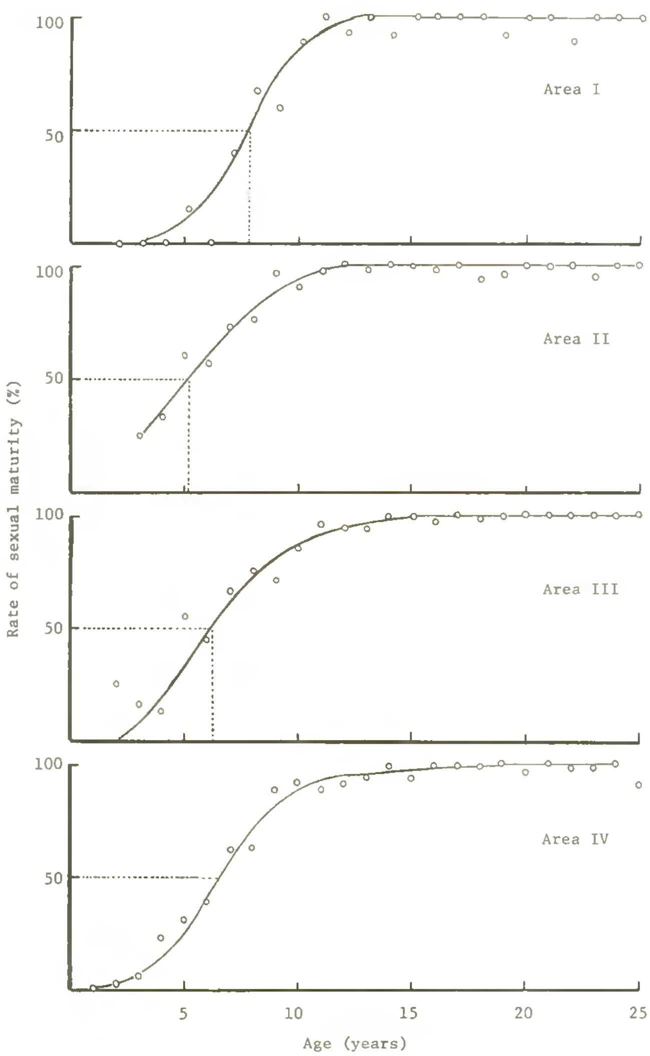
Yearly and Areal change in age at sexual maturity of Antarctic minke whales based on the presence of at least one corpus luteum or corpus albicans in the ovaries or a mean testis weight of 0.4 Kg

Sex	Area	1967/68	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	Total
Female	I	–	–	–	–	–	(6.5)	8.0	7.8
	II	–	–	–	(7.5)	(4.5)	(5.5)	–	(5.1)
	III	–	–	–	4.0	6.5	7.5	6.0	6.2
	IV	9.0	5.0	7.0	5.0	8.0	–	7.0	6.7
	V	–	–	–	–	(5.5)	6.5	(6.0)	(5.0)
	VI	–	–	–	–	–	–	(7.0)	(7.0)
Male	I	–	–	–	–	–	–	–	–
	II	–	–	–	–	–	–	–	–
	III	–	–	–	–	–	–	–	(2.2)
	IV	–	–	–	–	–	–	–	(2.8)
	V	–	–	–	–	–	–	–	–
	VI	–	–	–	–	–	–	–	–

immature males (which is more difficult than for immature females), the age at 50% sexual maturity could not be estimated from the percentage distribution of mature whales for each age group based on the above data. This may have been due to the Japanese whaling expeditions trying to take as large whales as possible. The core length of the ear plug is proportional to body length and in the Antarctic, male minke whales are shorter than females at sexual maturity.

As shown in Table 1, the age at 50% sexual maturity for females cannot be calculated for all Areas and seasons. The age at sexual maturity for females in Area IV, where minke whales have been taken by Japanese whaling expeditions for a relatively long period, ranges from five years to nine years although no definite trend has been observed (Table 1 and Fig. 1).

In Areas I, III and IV, the mean ages at sexual maturity in females over the time periods examined were estimated to be 7.8, 6.2 and 6.7 years respectively, and it was calculated to be 6.2 years for the whole area. This result is almost the same as that obtained for the Antarctic minke whale by Ohsumi *et al.* (1970) and Ohsumi and Masaki (1975).



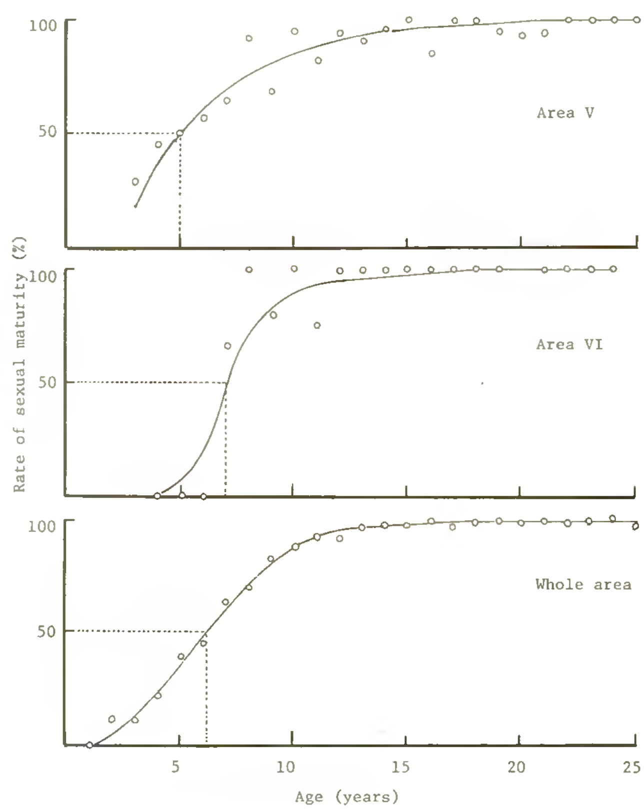


Fig. 1. Antarctic minke whales. Percentage of sexually mature females at each age.

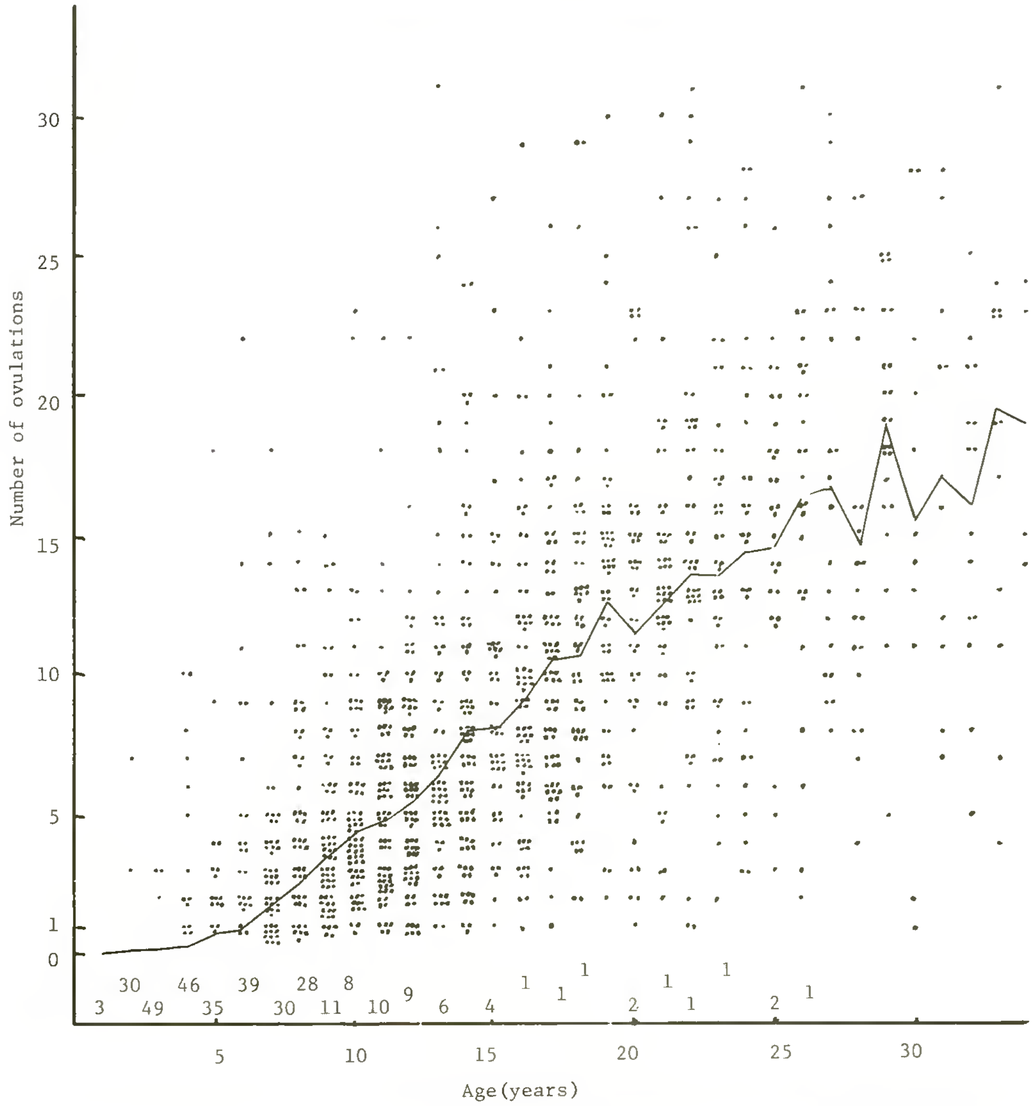


Fig. 2. Relationship between age and number of ovulations of Antarctic minke whales caught by Japanese whaling expeditions in Area IV during seasons 1967/68 and 1971/72 to 1976/77.

(ii) Age at sexual maturity based on the relationship between age and number of ovulations

For each Area in the Antarctic, the age at sexual maturity was calculated from the correlation between age and number of ovulations, as the age immediately after the first ovulation.

Fig. 2 shows the relationship between age and number of ovulations in Area IV (based on the data from 1967/68 and the 1971/72–1976/77 seasons). The solid line in Fig. 2 indicates the mean number of ovulations for each age group.

Fig. 3 shows age composition of animals for each number of ovulations. At the base of the composition, some data deviated from the smoothed composition curve and it may be that the ages for these whales were underestimated, thus in calculating the mean number of ovulations for each age group, these data were left out.

As was seen in Fig. 2 there is a refraction point of the regression line at about 20 years. It may also be that not too much reliance can be placed on ages estimated to be less than five years. It was felt that the regression formulae should be calculated in two separate analyses, and the author used a method which moved the first age from one year to ten years forward by one age group.

The regression formulae, age at sexual maturity (years) and reproductive cycle (months) are shown in Table 2. Age at sexual maturity in Area IV which was estimated from the data from five to twenty years of age was calculated to be 6.2 years and this figure is almost the same as that obtained from Approach (i) in this paper. The mean ages at sexual maturity in Areas I, II, III, V and VI were 6.5, 5.7, 6.5, 6.9 and 7.8 years respectively (Table 3).

Yearly changes in the age at sexual maturity could be examined in Areas III and IV using this approach (Table 3), but no yearly trend has been observed in either Area.

(iii) Age at sexual maturity estimated from the growth curve and body length at sexual maturity

In Areas where the ratio of the number of immature whales caught whose age could be estimated to the total catch number is low, the age at sexual maturity cannot be estimated by the two approaches above. The body length of Antarctic minke whales caught by Japanese whaling expeditions has been measured for each whale caught regardless of its sexual condition. Therefore the body length at sexual maturity can generally be estimated from the whales caught. If the relationship between age and body length (growth

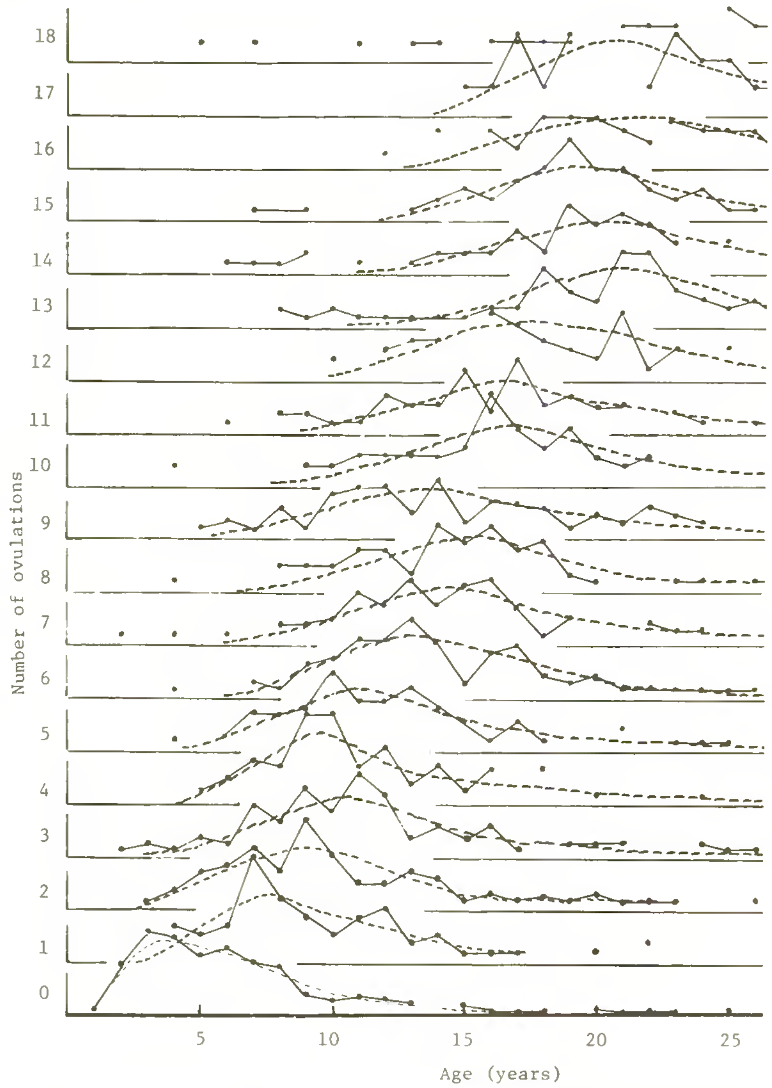
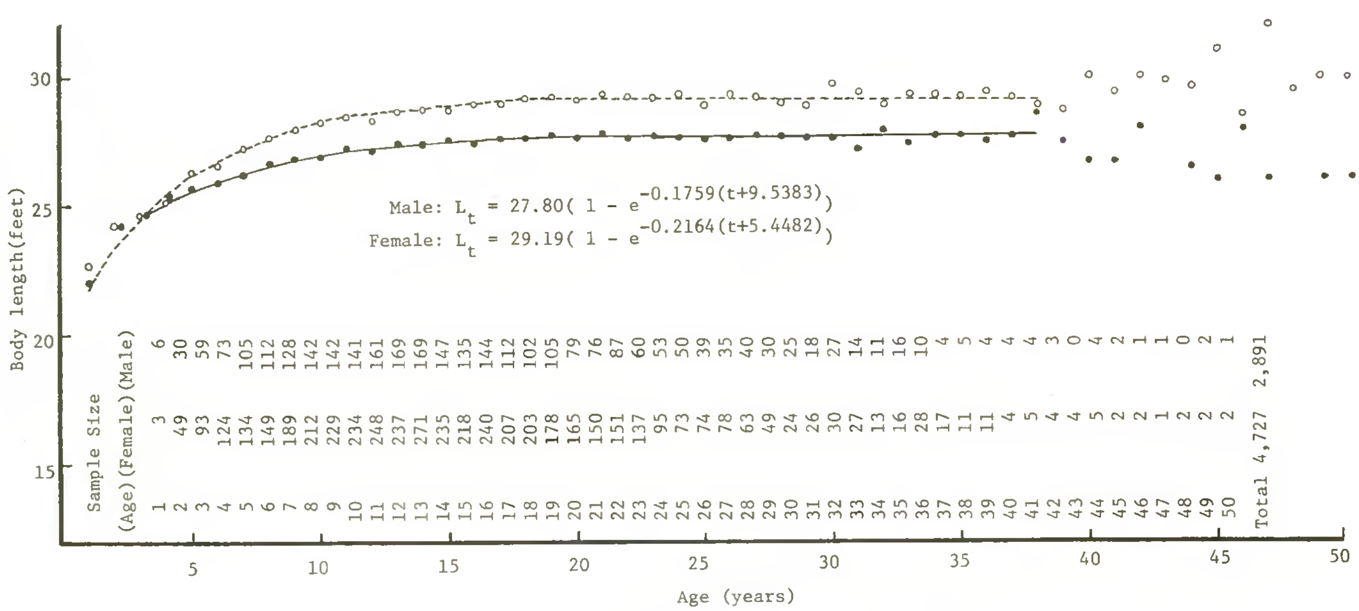


Fig. 3. Age composition by number of ovulations in Area IV in 1967/68 and from 1971/72 to 1976/77.



Sample Size

(Age)	(Female)	(Male)
1	3	6
2	49	30
3	93	59
4	124	73
5	134	105
6	149	112
7	189	128
8	212	142
9	229	142
10	234	141
11	248	161
12	237	169
13	271	169
14	235	147
15	218	135
16	240	144
17	207	112
18	203	102
19	178	105
20	165	79
21	150	76
22	151	87
23	137	60
24	95	53
25	73	50
26	74	39
27	78	35
28	63	40
29	49	30
30	24	25
31	26	18
32	30	27
33	27	14
34	13	11
35	16	16
36	28	10
37	17	4
38	11	5
39	11	4
40	4	4
41	5	4
42	4	3
43	4	0
44	5	4
45	2	2
46	2	1
47	1	1
48	2	0
49	2	2
50	2	1
Total	4,727	2,891

Fig. 4. Growth curve of the Antarctic minke whale.

○-----○ Females ●——● Males

Table 2

Age at sexual maturity and length of the reproductive cycle of the Antarctic minke whale by age based on the relationship between age and number of ovulations (1967/68, 1971/72–1976/77 seasons)

Area	Age range	Regression estimate	Reproductive cycle (months)	Age at sexual maturity
Area I	1–20	—	—	—
	2–20	Y=0.776 X–3.340	15.46	5.6
	3–20	Y=0.811 X–3.842	14.8	6.0
	4–20	Y=0.843 X–4.298	14.23	6.3
	5–20	Y=0.866 X–4.644	13.86	6.5
	6–20	Y=0.877 X–4.819	13.68	6.6
	7–20	Y=0.862 X–4.590	13.92	6.5
	8–20	Y=0.834 X–4.137	14.39	6.2
	9–20	Y=0.835 X–4.155	14.37	6.2
	10–20	Y=0.794 X–3.427	15.15	5.6
Area II	1–20	—	—	—
	2–20	—	—	—
	3–20	Y=1.032 X–4.348	11.63	5.2
	4–20	Y=1.059 X–4.753	11.33	5.4
	5–20	Y=1.080 X–5.059	11.11	5.6
	6–20	Y=1.090 X–5.222	11.01	5.7
	7–20	Y=1.090 X–5.217	11.01	5.7
	8–20	Y=1.074 X–4.964	11.17	5.6
	9–20	Y=1.061 X–4.749	11.31	5.4
	10–20	Y=1.101 X–5.414	10.90	5.8
Area III	1–20	—	—	—
	2–20	Y=0.953 X–4.128	12.59	5.4
	3–20	Y=0.997 X–4.753	12.04	5.8
	4–20	Y=1.036 X–5.324	11.58	7.1
	5–20	Y=1.068 X–5.805	11.24	6.4
	6–20	Y=1.092 X–6.167	10.99	6.6
	7–20	Y=1.094 X–6.218	10.97	6.6
	8–20	Y=1.095 X–6.222	10.96	6.5
	9–20	Y=1.102 X–6.333	10.89	6.7
	10–20	Y=1.054 X–5.540	11.39	6.2
Area IV	1–20	Y=0.717 X–2.463	16.74	4.8
	2–20	Y=0.748 X–2.893	16.04	5.2
	3–20	Y=0.777 X–3.313	15.44	5.6
	4–20	Y=0.802 X–3.681	14.96	5.8
	5–20	Y=0.820 X–3.948	14.63	6.0
	6–20	Y=0.834 X–4.167	14.39	6.2
	7–20	Y=0.835 X–4.180	14.37	6.2
	8–20	Y=0.835 X–4.172	14.37	6.2
	9–20	Y=0.835 X–4.173	14.37	6.2
	10–20	Y=0.848 X–4.398	14.15	6.4
Area V	1–20	—	—	—
	2–20	Y=0.825 X–3.680	14.55	5.7
	3–20	Y=0.865 X–4.250	13.87	6.1
	4–20	Y=0.901 X–4.787	13.32	6.4
	5–20	Y=0.931 X–5.231	12.89	6.7
	6–20	Y=0.952 X–5.557	12.61	6.9
	7–20	Y=0.968 X–5.803	12.40	7.0
	8–20	Y=0.964 X–5.736	12.45	7.0
	9–20	Y=0.934 X–5.259	12.85	6.7
	10–20	Y=0.973 X–5.904	12.33	7.1
Area VI	1–20	Y=1.096 X–5.803	10.95	6.2
	2–20	—	—	—
	3–20	—	—	—
	4–20	Y=1.223 X–7.604	9.81	6.2
	5–20	Y=1.283 X–8.604	9.35	6.2
	6–20	Y=1.353 X–9.569	8.87	7.8
	7–20	Y=1.401 X–10.318	8.57	8.1
	8–20	Y=1.467 X–11.372	8.18	8.4
	9–20	Y=1.602 X–13.577	7.49	9.1
	10–20	Y=1.679 X–14.861	7.15	9.4

X: age Y: number of ovulations

curve) can be estimated, the age at sexual maturity can be found by putting the body length at sexual maturity into the growth curve. However, growth curves by Area for the Antarctic minke whales caught by Japan cannot be obtained annually during seasons 1970/71–1976/77 through lack of sufficient data.

An estimated growth curve utilizing the Von Bertalanffy growth equation was made for 4,727 females and 2,891 male minke whales taken by Japanese whaling expeditions in the 1970/71–1976/77 Antarctic seasons (Fig. 4). The Von Bertalanffy growth curve equations for female and male whales were as follows:

$$\text{Females:}\quad L_t = 29.19\ [1 - e^{-0.2164\ (t + 5.4482)}]$$
$$\text{Males:}\quad L_t = 27.80\ [1 - e^{-0.1759\ (t + 9.5383)}]$$

As shown in Table 4, if we assume that the length at birth is 320 cm, the body length at weaning is twice as large as the length at birth and the period of lactation is about three months (see later), the estimated growth curve for both sexes can be determined from the calculated growth curve, with the length at birth and weaning as shown in Fig. 5.

The age of individuals under about five years tends to be underestimated, thus some of the mean body lengths of age classes under five years do not fit the estimated growth curve (Fig. 5). The body length at 50% sexual maturity is presented in Table 5 and shown in Fig. 6. No definite trend in the yearly change in body length at sexual maturity has been observed for either sex during seasons 1971/72–1976/77.

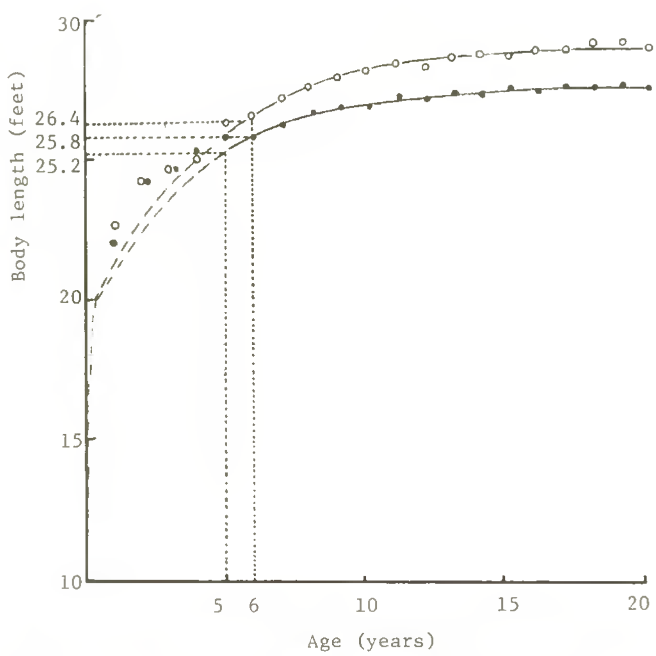


Fig. 5. Estimated growth curves of the Antarctic minke whale. ○—○ females, ●—● males.

Table 3

Age at sexual maturity and correlation formula which shows the relationship between age and number of ovulations of the Antarctic minke whales

in Area IV

(A)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)
1–20	—	—	—	—	—	—	Y=0.797 X−2.957	5.0	—	—	—	—	—	—
2–20	—	—	Y=0.786 X−3.088	5.2	Y=0.763 X−3.431	5.8	Y=0.835 X−3.488	5.4	Y=0.908 X−3.343	6.1	—	—	Y=0.835 X−3.369	5.2
3–20	—	—	Y=0.815 X−3.513	5.5	Y=0.800 X−3.967	6.2	Y=0.871 X−3.998	5.7	Y=0.745 X−3.884	6.6	—	—	Y=0.869 X−3.847	5.6
4–20	—	—	Y=0.839 X−3.859	5.8	Y=0.835 X−4.475	6.6	Y=0.901 X−4.447	6.0	Y=0.782 X−4.417	6.9	Y=0.971 X−4.617	6.2	Y=0.896 X−4.249	5.9
5–20	Y=0.728 X−4.810	8.0	Y=0.877 X−4.423	6.2	Y=0.863 X−4.899	6.8	Y=0.924 X−4.786	6.3	Y=0.814 X−4.901	7.2	—	—	Y=0.913 X−4.499	6.0
6–20	—	—	Y=0.897 X−4.733	6.4	Y=0.880 X−5.155	7.0	Y=0.937 X−4.985	6.4	Y=0.838 X−5.266	7.5	Y=0.775 X−2.772	4.9	Y=0.911 X−4.470	6.0
7–20	Y=0.781 X−5.581	8.4	Y=0.911 X−4.952	6.5	Y=0.884 X−5.221	7.0	Y=0.934 X−4.947	6.4	Y=0.846 X−5.390	7.6	Y=0.959 X−4.420	4.6	Y=0.897 X−4.252	5.9
8–20	Y=0.798 X−5.836	8.6	Y=0.917 X−5.048	6.6	Y=0.907 X−5.591	7.3	Y=0.931 X−4.890	6.3	Y=0.843 X−5.342	7.5	—	—	Y=0.883 X−4.033	5.7
9–20	Y=0.768 X−5.372	8.3	Y=0.949 X−5.579	6.9	Y=0.914 X−5.708	7.3	Y=0.877 X−4.016	5.7	Y=0.838 X−5.268	7.5	Y=0.891 X−3.327	4.9	Y=0.853 X−3.548	5.3
10–20	Y=0.667 X−3.761	7.1	Y=0.979 X−6.066	7.2	Y=0.938 X−6.100	7.6	Y=0.860 X−3.734	5.6	Y=0.862 X−5.665	7.7	Y=0.963 X−4.515	5.7	Y=0.810 X−2.819	4.7
	[1967/68 season]		[1971/72 season]		[1972/73 season]		[1973/74 season]		[1974/75 season]		[1975/76 season]		[1976/77 season]	

in Area III

(A)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)	(B)	(C)
1–20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2–20	—	—	—	—	—	—	—	—	Y=0.864 X−3.539	5.3	—	—	—	—
3–20	—	—	Y=0.772 X−2.819	4.9	—	—	—	—	Y=0.900 X−4.049	5.6	—	—	Y=0.953 X−4.698	6.0
4–20	—	—	—	—	—	—	Y=1.004 X−4.720	5.7	Y=1.167 X−6.561	6.5	Y=0.930 X−4.485	5.9	Y=0.994 X−5.293	5.3
5–20	—	—	Y=0.800 X−3.246	5.3	—	—	Y=1.027 X−5.078	5.9	Y=1.214 X−7.270	6.8	Y=0.949 X−4.773	6.1	Y=1.031 X−5.839	6.6
6–20	—	—	—	—	—	—	Y=1.025 X−5.448	6.1	Y=1.249 X−7.795	7.0	Y=0.950 X−4.786	6.1	Y=1.050 X−6.139	6.8
7–20	—	—	—	—	—	—	Y=1.050 X−5.416	6.1	Y=1.264 X−8.029	7.1	Y=0.953 X−4.832	6.1	Y=1.061 X−6.315	6.9
8–20	—	—	—	—	—	—	Y=1.087 X−6.018	6.5	Y=1.260 X−7.965	7.1	Y=0.933 X−4.520	5.9	Y=1.067 X−6.400	6.9
9–20	—	—	Y=0.786 X−2.201	4.4	—	—	—	—	—	—	Y=0.928 X−4.436	5.9	—	—
10–20	—	—	Y=0.784 X−3.084	5.2	—	—	—	—	—	—	Y=0.860 X−3.305	5.0	—	—
	[1967/68 season]		[1971/72 season]		[1972/73 season]		[1973/74 season]		[1974/75 season]		[1975/76 season]		[1976/77 season]	

(A): Range of age (B): Regression formula (C): Age at sexual maturity

Table 4

Foetal body length composition by ten-day period for the Antarctic minke whale (1971/72–1975/76)

Foetal body length (cm)	November			December			January			February			March
	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	Early
0– 9	4	18	147	105	72	53	41	27	28	18	24	9	
10– 19	1	14	255	276	114	135	96	68	61	30	27	7	1
20– 29		3	173	203	133	166	121	86	69	43	35	12	
30– 39			118	170	85	142	136	70	81	53	56	24	
40– 49			67	87	64	99	114	63	79	52	49	27	
50– 59			29	63	29	68	81	47	72	61	45	31	
60– 69			13	39	22	42	68	35	54	53	50	30	
70– 79			9	24	15	30	48	29	47	32	40	28	
80– 89			4	4	7	16	30	14	40	27	27	18	
90– 99				5	2	8	19	7	19	22	21	12	
100–109			1	3	1	9	16	11	15	18	24	19	
110–119					3	1	7	5	10	18	16	8	
120–129							2	4	12	9	19	8	1
130–139							3		5	4	12	5	
140–149					1			1	3	1	11	4	
150–159							1		5	3	7	4	
160–169								1		4	3	2	
170–179			1						1		2		
180–189										1	1		
190–199										1	1	1	
200–219								1					
220–239			2	1				1			1		
240–259		2	1	1		1	2			2			
260–279			1	3	2	1	1		1	1			
280–299			1	1		1	1	1					
300–319		1		3						1			
320–339			1										
Total	5	38	823	988	550	772	790	471	602	473	469	249	2
Average	7.0	31.2	26.0	31.4	31.5	37.0	45.3	44.1	53.0	58.7	66.3	69.3	70.0

Table 5

Yearly and Areal change in body length at sexual maturity of Antarctic minke whales based on the presence of at least one corpus luteum or corpus albicans in the ovaries or a mean testis weight of 0.4 Kg

Sex	Area	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	Total
Female	I	–	–	–	–	26.2	25.7	26.1
	II	–	–	26.4	26.1	26.1	–	26.1
	III	26.5		26.5	26.5	26.2	26.2	26.3
	IV	26.0	26.4	26.5	26.5	26.5	26.5	26.4
	V	–	–	–	26.5	26.9	25.8	26.4
	VI	–	–	–	–	26.5	26.0	26.2
Male	I	–	–	–	–	23.5	–	23.5
	II	–	–	–	–	23.3	–	23.3
	III	–	–	24.3	23.5	–	–	23.5
	IV	24.0	24.5	23.5	–	–	–	23.5
	V	–	–	–	(23.0)	(24.4)	–	23.2
	VI	–	–	–	–	(25.0)	–	(25.0)

Laws (1962) pointed out the possibility that a reduction in stock size leads to faster growth thus lowering the age at sexual maturity of the stock, and further, many authors have reported that the body length at sexual maturity differs according to stock units or Area for the Antarctic fin whale (Ohsumi and Shimadzu, unpublished), sei whale (Nasu and Masaki, 1970) and North Pacific sei whale (Masaki, 1976).

Fig. 6 and Table 5 show the body length at 50% sexual maturity of each sex for whales taken by Japanese expeditions in the Antarctic seasons of 1971/72–1976/77. The differences in body length at sexual maturity by Area in males is small (23.2–23.4 ft), and in females it ranges from 26.0 ft to 26.4 ft and is a little larger in Areas I, II and VI (26.0–26.2 ft) than that in Areas III, IV and V (26.3–26.4 ft). However, neither a decreasing nor increasing trend has been observed, at least during seasons 1971/72–1976/77.

From the estimated growth curves and body lengths of sexually mature whales for both sexes, the age at sexual maturity is estimated at between 2.7–2.9 years in males and 5.4–5.9 years in females. If we assume that the age at sexual maturity for recent year classes is six years of age for both sexes, the body lengths at sexual maturity of females and males taken from the estimated growth curve are 26.4 ft and 25.8 ft respectively (Fig. 5). Furthermore, supposing that the age at sexual maturity of males is lower than that for females and is five years, the body length at sexual maturity is no more than 25.2 ft long. It is possible that the standard value of 0.4 kg as a sexually mature testis weight is not correct, and so further examination of this standard is necessary.

(iv) Age at sexual maturity based on the transition phase in the ear plug laminae

A marked constriction in the breadth of ear plug laminae has been recognised in the ear plugs of fin whales (Lockyer, 1972), minke whales (Masaki, 1973) and sei whales (Lockyer, 1974) in the Antarctic, and fin whales (Masaki, 1973) and sei whales (Masaki, 1976) in the North Pacific. These constricted laminae have been termed the 'transition phase' by Lockyer (1972) who established in studies of the ear plugs of the Antarctic fin whale (1972) and sei whale (1974) that the number of laminae from the neonatal layer to this marked constriction (transition phase) indicates the age at sexual maturity.

The author examined yearly changes in the age at sexual maturity of the Antarctic minke whale on the assumption that a pair of bright and dark laminae indicates an annual growth layer, that these laminae are formed regularly throughout an animal's life and that the number of laminae from the neonatal layer to the transition phase indicates the age at sexual maturity. Ear plugs from 2,083 females and 1,286 males collected by Japanese whaling expeditions in the 1967/68 and 1971/72–1976/77 seasons were examined and the total number of growth layers and the number of layers to the transition phase noted for each ear plug. The year class of birth for each whale can be calculated from the total number of growth layers (= total age) and the date of capture, based on the assumption that one growth layer represents one year's growth. The individual and average transition counts for each year class by sex and Area are shown in Figs 7 and 8.

Females

The age data are few and lie scattered until the 1944 year class in Areas I, II, V and VI, and the mean age at sexual maturity ranges from 11 years to 18 years. There are also few data until the 1939 year class in Areas III and IV with a mean age at sexual maturity of 11.0 years and 22.5 years. In Areas III and IV, between the 1940 and 1944 year classes, the mean ages at sexual maturity are 12.5 years and 14.4 years of age respectively (Table 6). However, this difference was not significant at the 5% level using the t-test. The mean age at sexual maturity from an analysis of the transition phase in the ear plug for all Areas until the 1944 year class was 13.9 years.

After the 1945 year class the mean age at sexual maturity based on the transition phase declines linearly each year. This decreasing trend is common to all Areas. As shown in Table 6 the mean ages at sexual maturity after the 1965 year class are within the range 6.2 years to 6.6 years (except Area VI) and for all Areas is 6.4 years of age.

Males

As there are few data in Areas I, II, V and VI until the 1944 year class, it is not possible to compare the mean ages at sexual maturity for these Areas. However, the mean age at sexual maturity for the whole area up to the 1944 year class is calculated to be 13.8 years. This figure coincides

Table 6

Age at sexual maturity of the Antarctic minke whale by Area and by year class based on transition phase data

Sex	Area \ Year class	–1924	1925–29	1930–34	1935–39	1940–44	–1944	1945–49	1950–54	1955–59	1960–64	1965–69	Regression estimate (1945–70 year class)
Female	I	—	—	17.0	13.7	13.0	13.0	12.5	11.3	9.2	8.2	6.4	Y=–0.327 X+28.019
	II	—	14.0	14.5	13.8	11.5	12.9	12.2	10.4	9.1	7.7	6.2	Y=–0.328 X+27.821
	III	18.0	—	15.3	14.0	12.5	13.6	11.6	10.7	9.0	7.9	6.2	Y=–0.308 X+26.552
	IV	—	17.0	20.0	14.1	14.4	14.9	13.0	10.8	9.0	7.4	6.5	Y=–0.380 X+30.086
	V	—	—	14.5	12.7	12.9	13.1	12.1	10.5	9.2	8.0	6.6	Y=–0.290 X+25.811
	VI	—	—	16.0	—	13.7	14.3	12.0	13.7	7.8	9.0	6.0	—
Male	I	—	—	—	14.0	11.0	12.5	10.4	10.7	9.6	7.9	6.5	Y=–0.237 X+22.626
	II	—	—	—	—	12.3	12.3	—	11.0	8.8	7.1	5.0	Y=–0.422 X+33.021
	III	—	11.0	11.7	10.4	11.5	12.7	11.2	10.0	8.7	7.5	6.5	Y=–0.238 X+22.308
	IV	13.0	17.0	17.9	15.4	12.9	15.1	12.5	11.0	8.8	7.4	5.9	Y=–0.355 X+29.348
	V	—	—	10.3	14.8	13.5	13.2	11.3	10.1	8.3	7.4	6.4	Y=–0.264 X+23.741
	VI	—	—	15.0	11.5	13.0	12.8	11.0	8.3	8.9	8.0	6.0	Y=–0.224 X+20.798

Y: Average age at sexual maturity X: The later number in two figures of year class

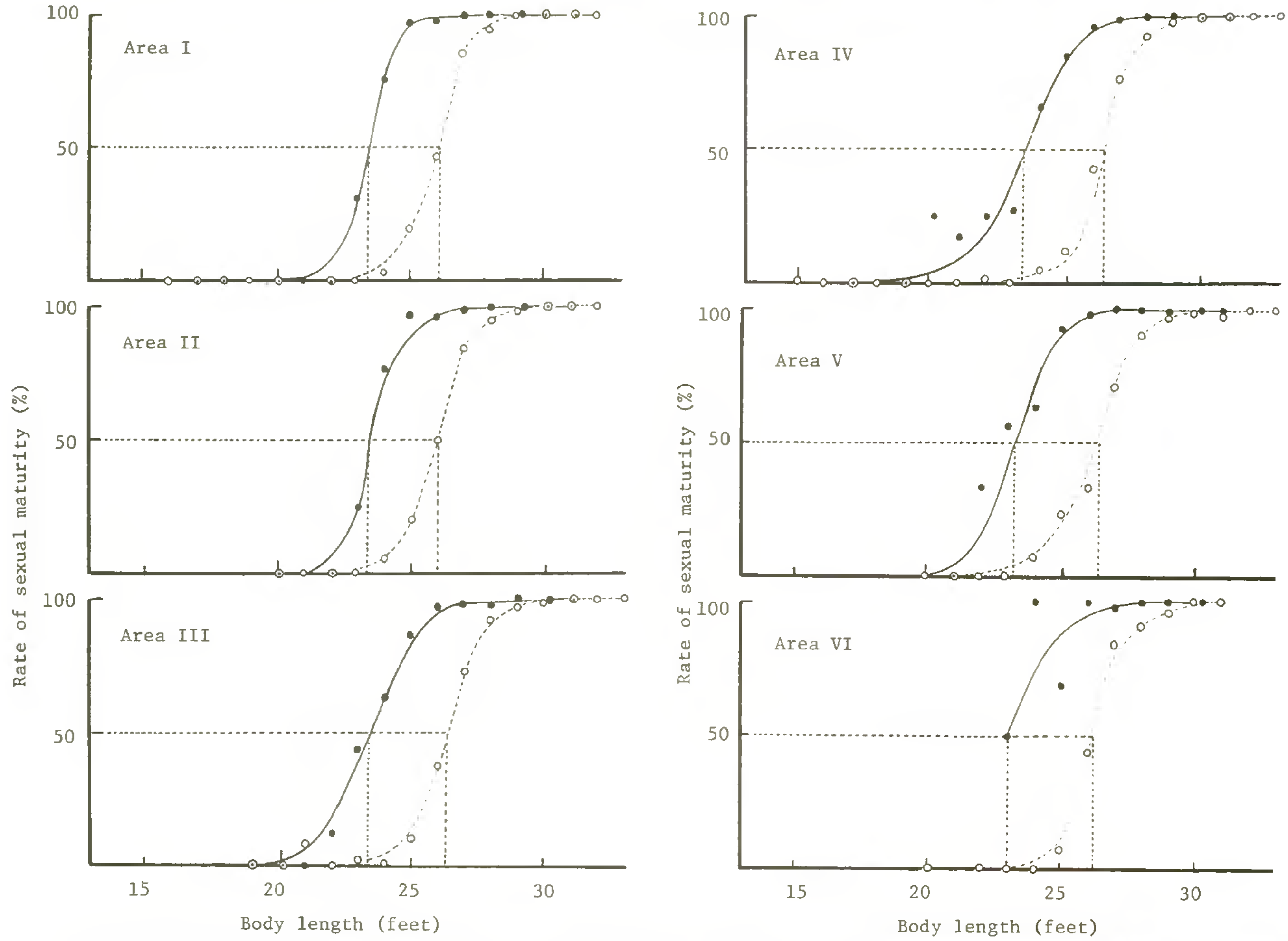


Fig. 6. Sexual maturity rate of the Antarctic minke whale as determined by the condition of the reproductive organs at each body length, by sex and by Area. ○---○ females, ●—● males.

with the female one of 13.9 years. Lacking sufficient data for Areas I, II, V and VI, the yearly change in the age at sexual maturity before the 1945 year class could not be examined. In Areas III and IV the mean age at sexual maturity for male minke whales decreases linearly each year as in the case of females (Fig. 8 and Table 6).

The mean age at sexual maturity in each Area after the 1965 year class varies from 5.0 years to 6.5 years, and for the whole area is 6.2 years. This figure is close to the female one of 6.4 years.

Figs 9 and 10 show the composition of the age at sexual maturity for males and females in the 1927–45, 1946–50, 1951–55, 1956–60 and 1961–65 year classes in Area VI. The range of ages at sexual maturity becomes narrower and the figure for the mode of the composition moves to a younger age or year class. Consequently, the mean age at sexual maturity gradually decreases. Furthermore, the shapes of the composition of the age at sexual maturity until the 1952–55 year classes show a roughly symmetrical form on the whole; after the 1956–60 year classes, the frequency distribution becomes somewhat distorted compared with those before the 1951–55 year classes.

Supposing that the latest maturing minke whales become mature at about 15 years of age and that the age samples were mainly collected during the seasons 1971/72 to 1976/77, the year class after 1955 may have a biassed representation in these seasons since only those animals maturing early can be recorded. Therefore, it is possible that the mean ages at sexual maturity calculated from the transition phase after the 1955 year class are underestimated.

However, if one assumes that a decrease in age at sexual maturity is caused by a decrease in the ratio of late maturing whales to sexually mature whales and an increase in the ratio of early maturing whales to sexually mature whales the ages at sexual maturity shown in Table 6 will be correct for each year class.

In both Approaches (i) and (ii), the age at sexual maturity is only estimated from individuals in recent year classes and therefore it is impossible to examine yearly changes in age at sexual maturity based on these approaches. Furthermore, in Approach (iii), it is doubtful that an estimate of the annual growth curve utilizing the limited data from commercial whaling is very accurate. Approach (iv) possesses a defect in the estimation of the age at sexual maturity for minke whales in recent year classes as mentioned above. Despite these reservations there is a close similarity in the values for age at sexual maturity for the Antarctic minke whale in recent year classes estimated by the four Approaches.

The yearly change in total biomass of baleen whales in the Antarctic (Gambell, 1975) and the age at sexual maturity based on the transition phase are shown in Fig. 8. The age at sexual maturity for the Antarctic fin and sei whales has fallen to about one-half and two-thirds of the values at the initial biomass level, respectively (Gambell, 1975). In the case of the Antarctic minke whale it appears to have fallen to about one-third of the age at the initial biomass level.

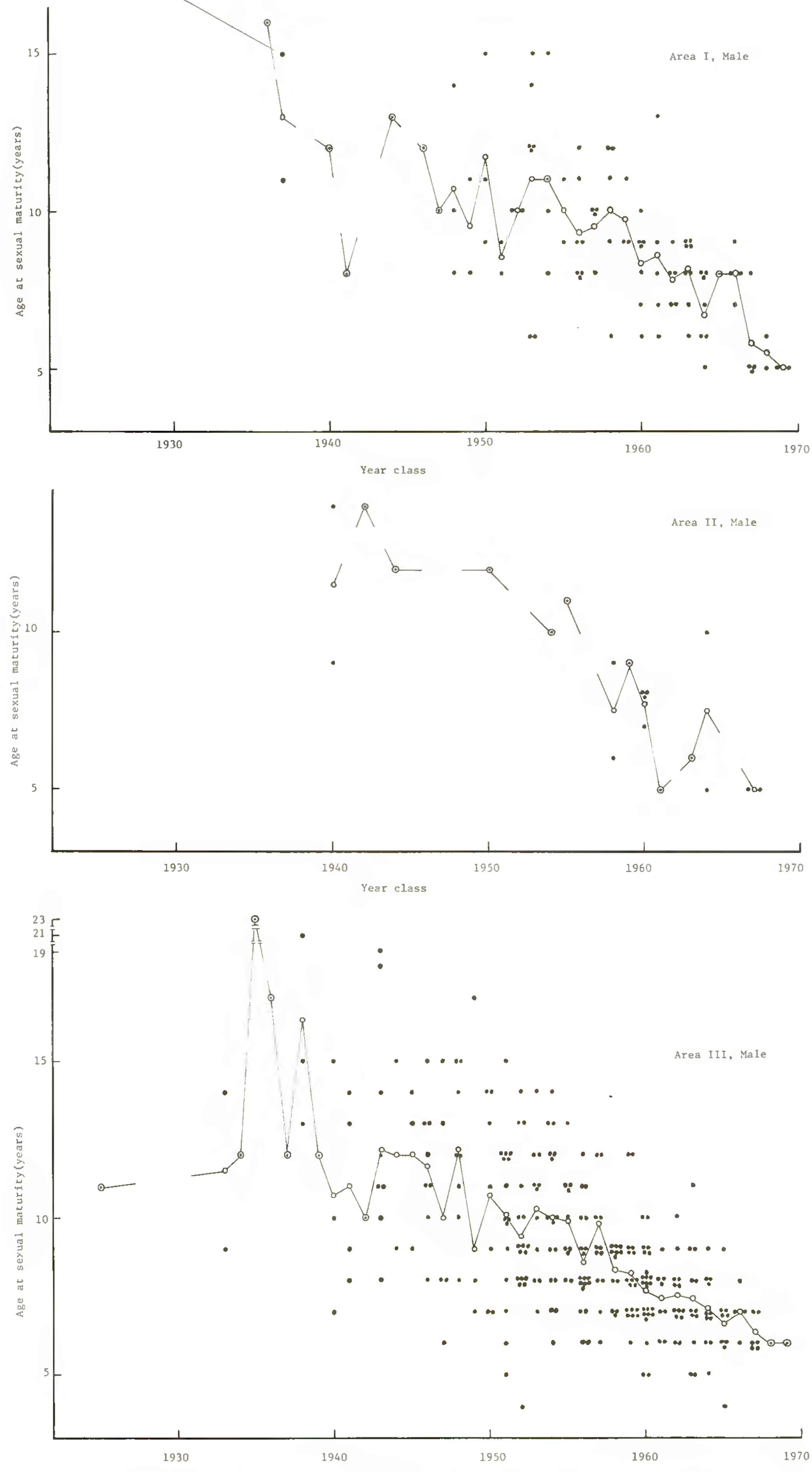
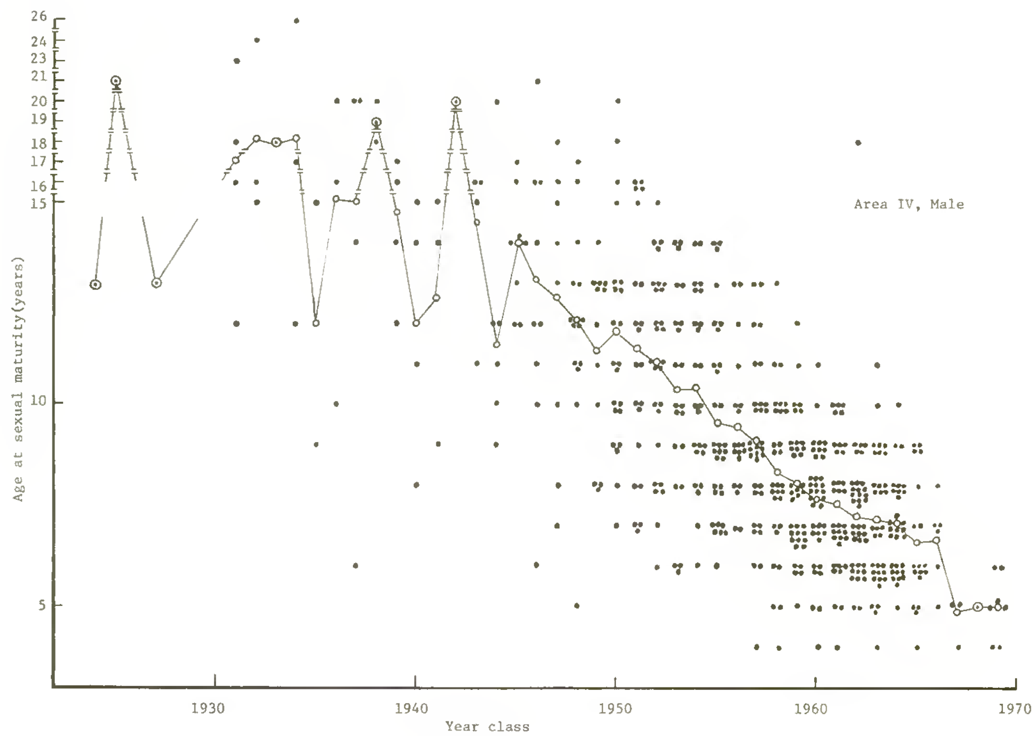


Fig. 7. Age at sexual maturity for each year class by sex as determined by the transition phase.



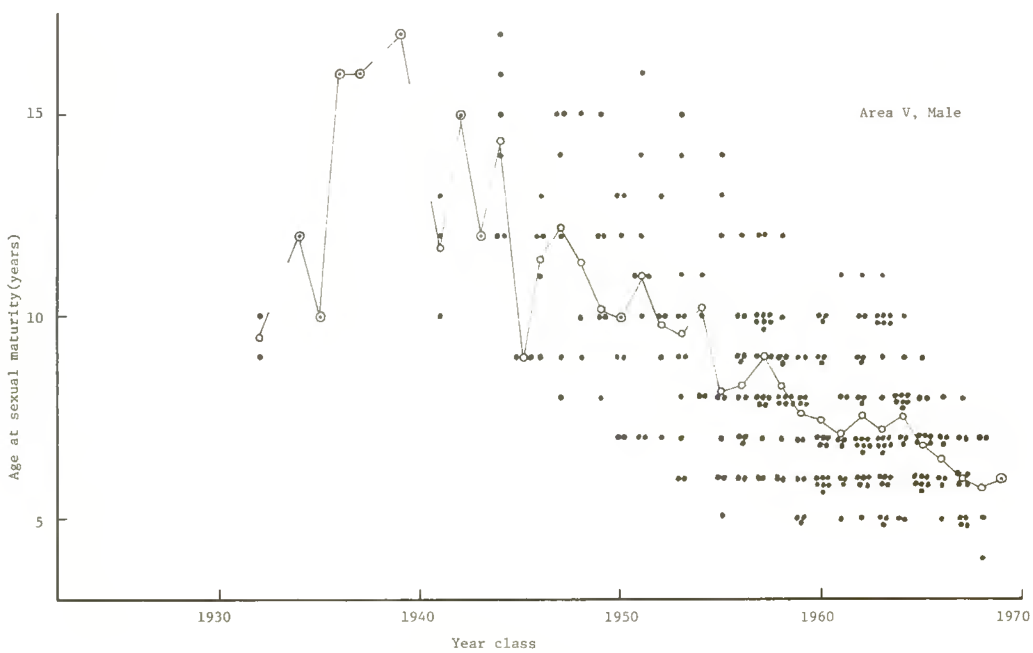
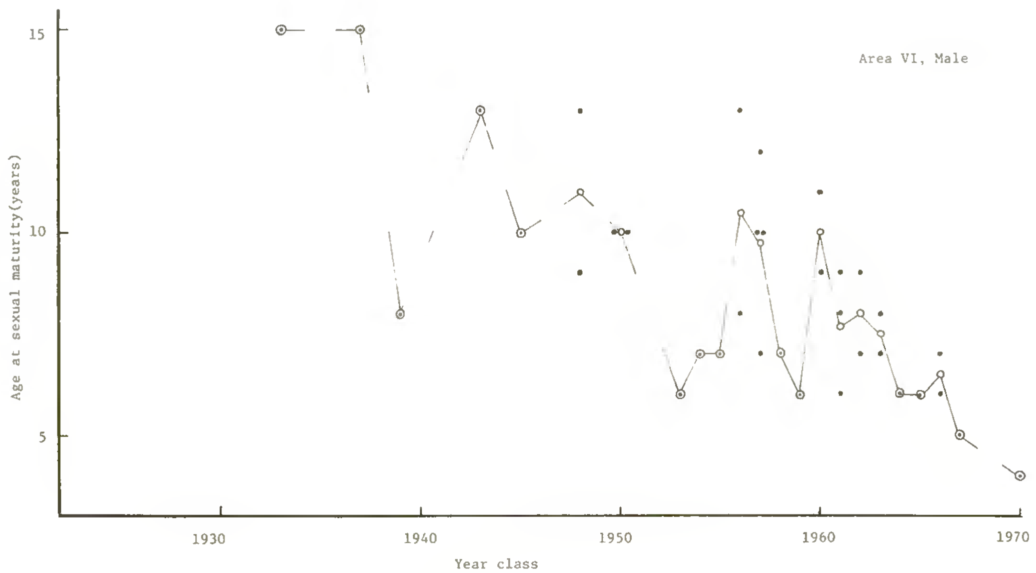


Fig. 7 (cont.). Age at sexual maturity for each year class by sex as determined by the transition phase.



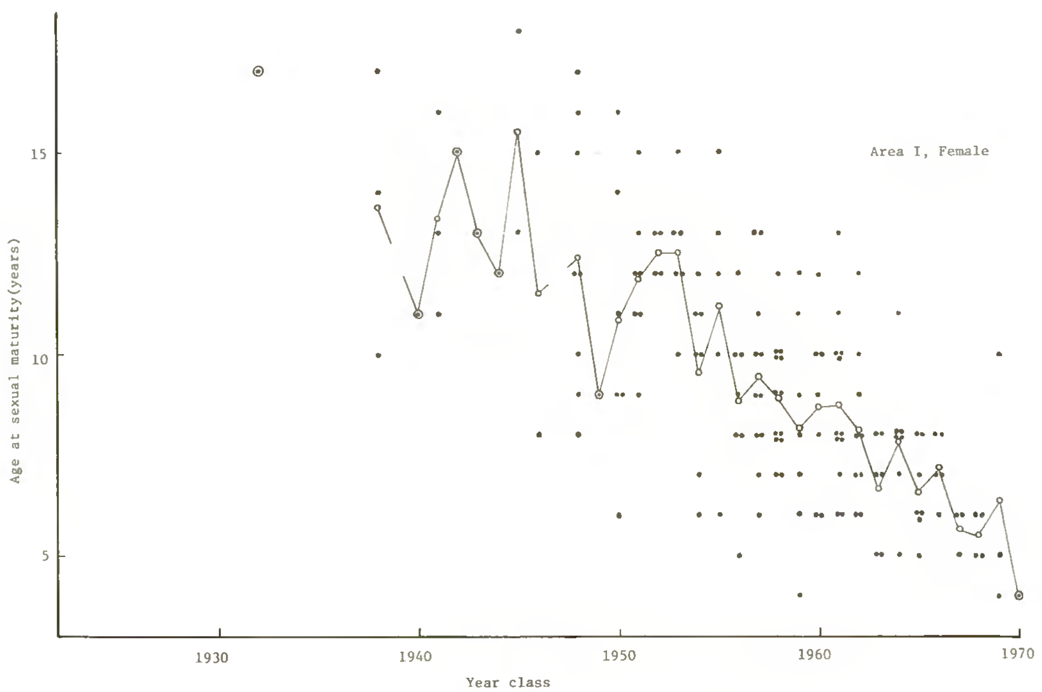
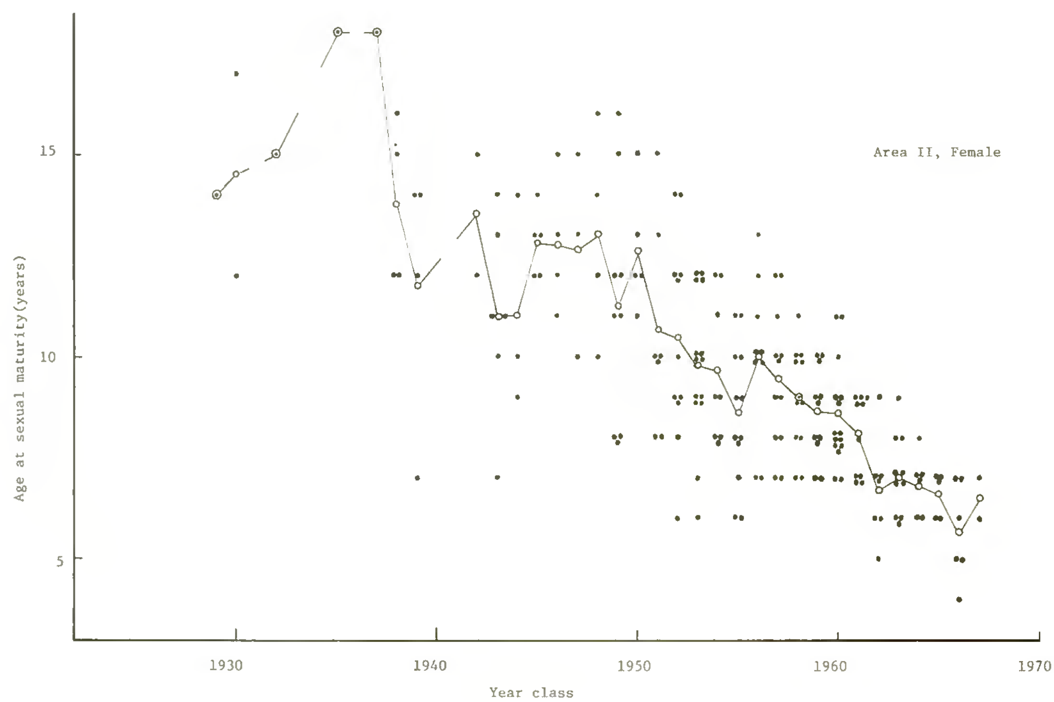


Fig. 7 (cont.). Age at sexual maturity for each year class by sex as determined by the transition phase.



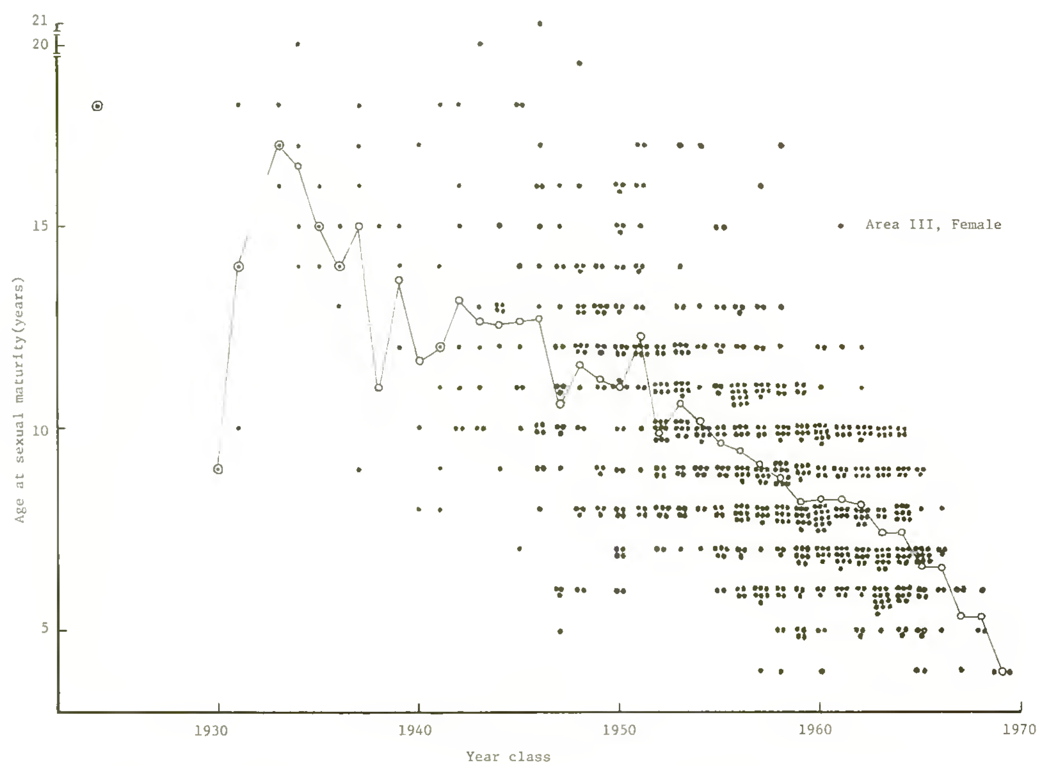
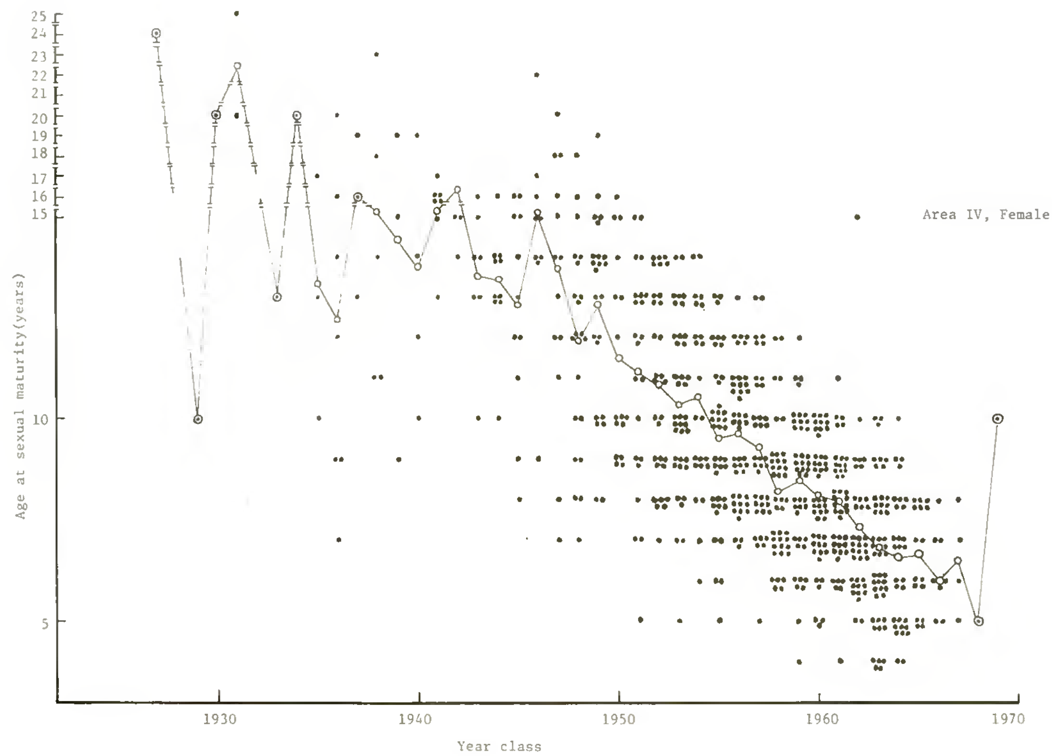


Fig. 7 (cont.). Age at sexual maturity for each year class by sex as determined by the transition phase.



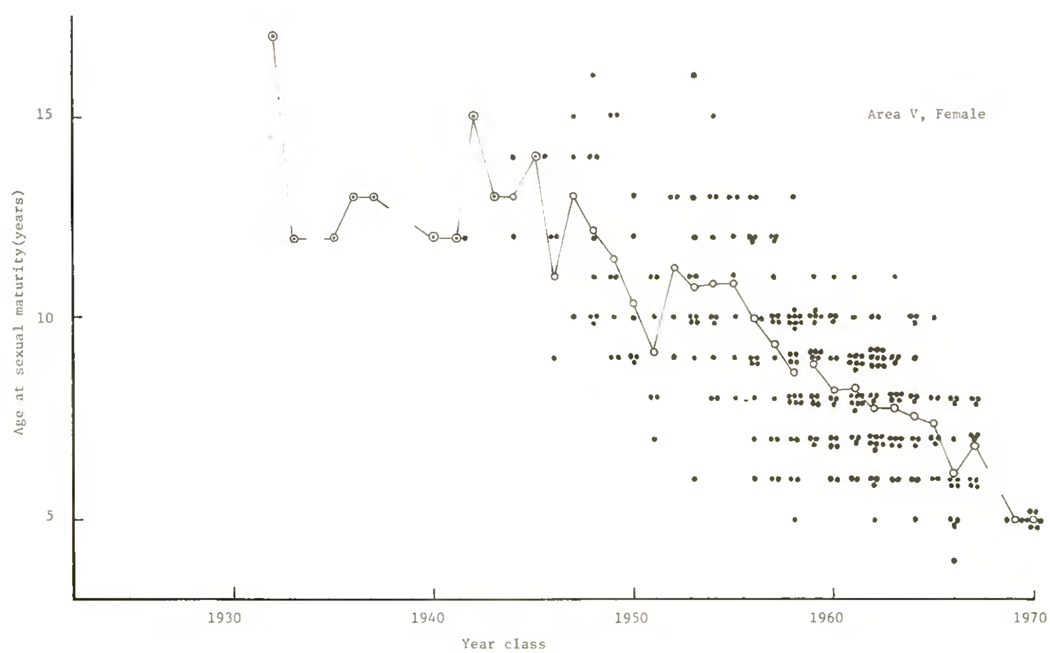


Fig. 7 (cont.). Age at sexual maturity for each year class by sex as determined by the transition phase.

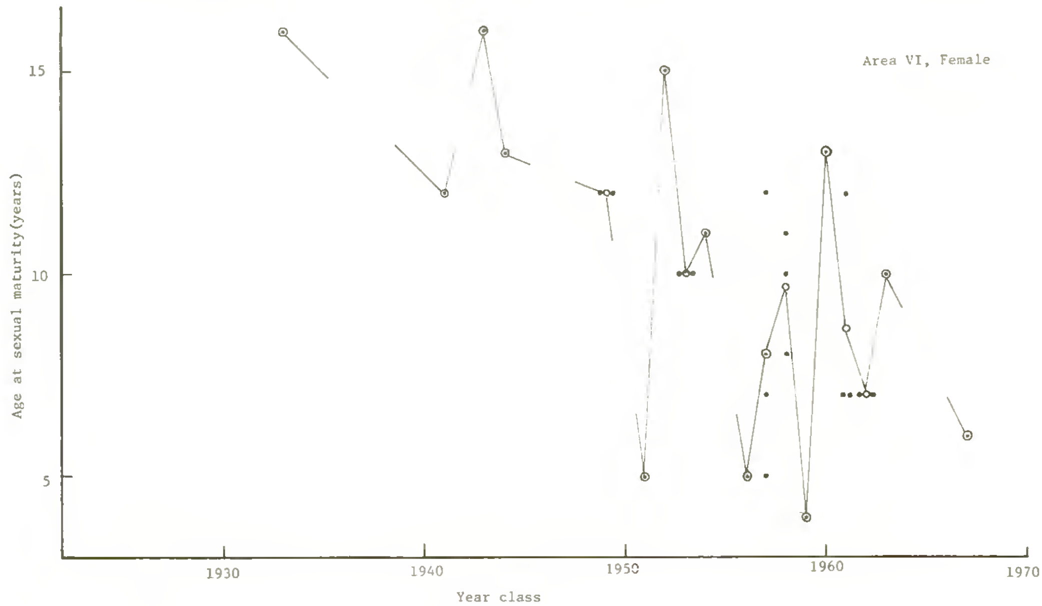


Fig. 7 (cont.). Age at sexual maturity for each year class by sex as determined by the transition phase.

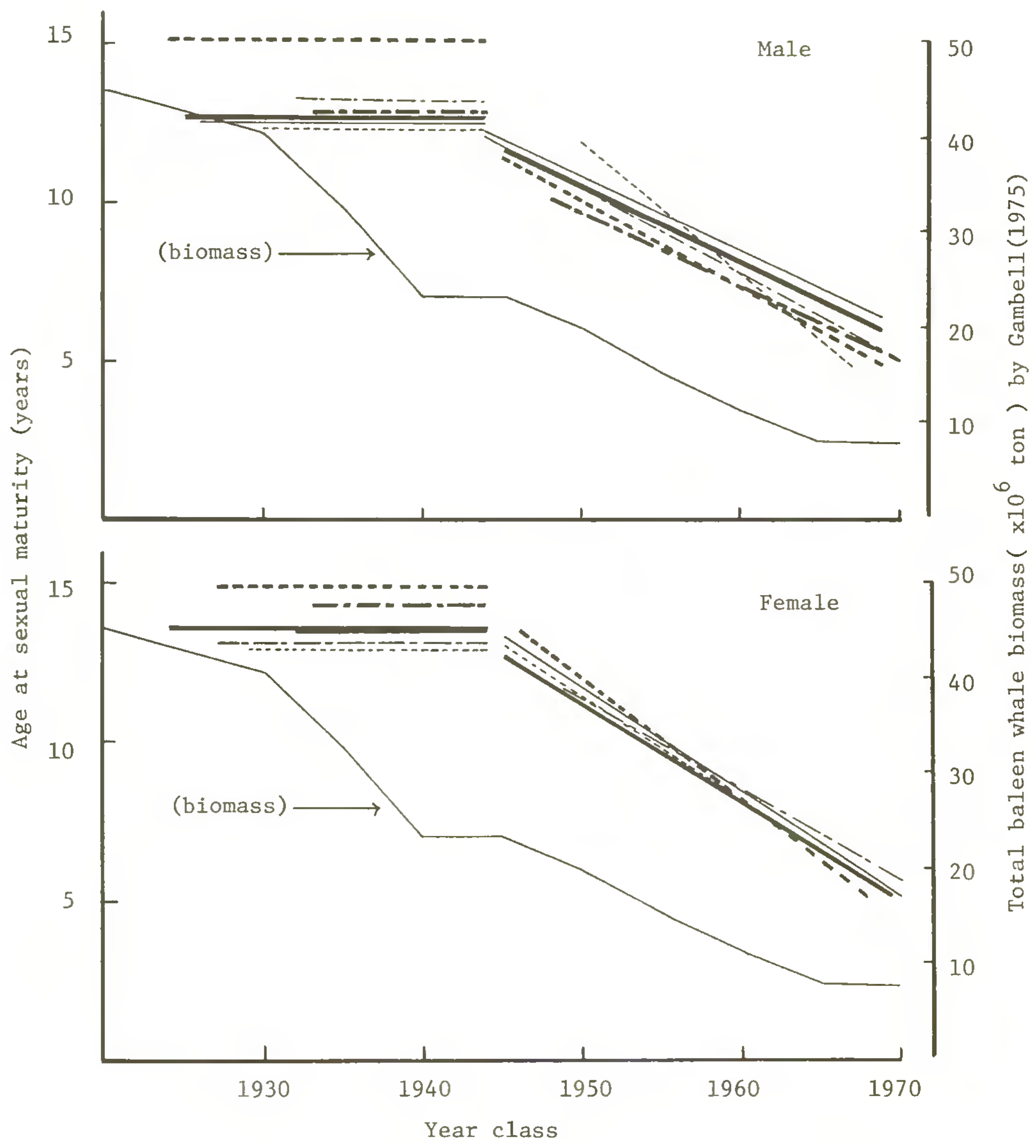


Fig. 8. Relationship between year class and age at sexual maturity as determined by transition phase of the ear plug. —— : Area I, - - - : Area II, —— : Area III, – – – : Area IV, –·– : Area V, –··– : Area VI.

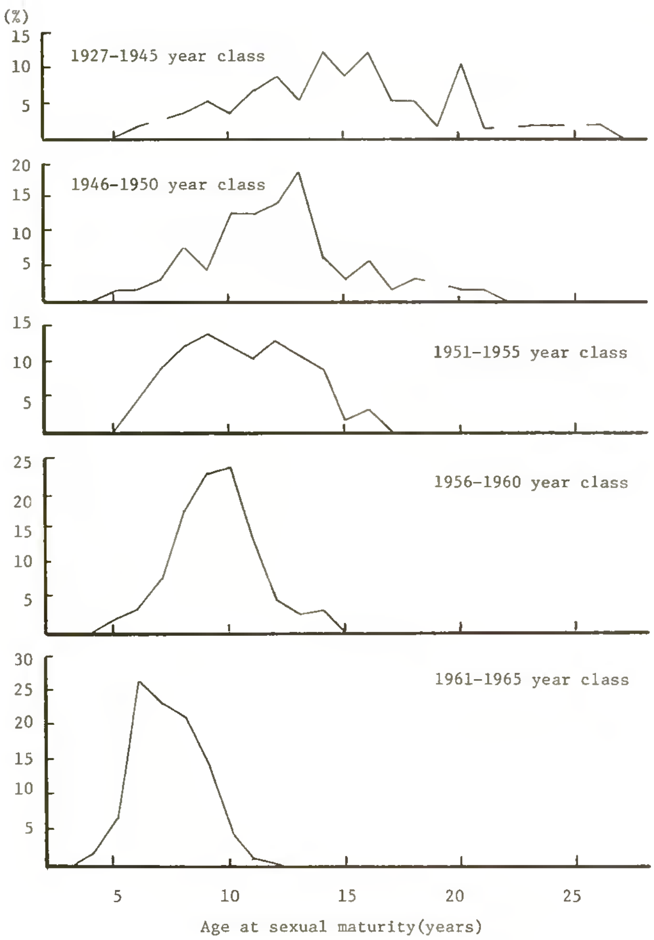


Fig. 9. Composition of age at sexual maturity as determined by the transition phase of males in Area IV.

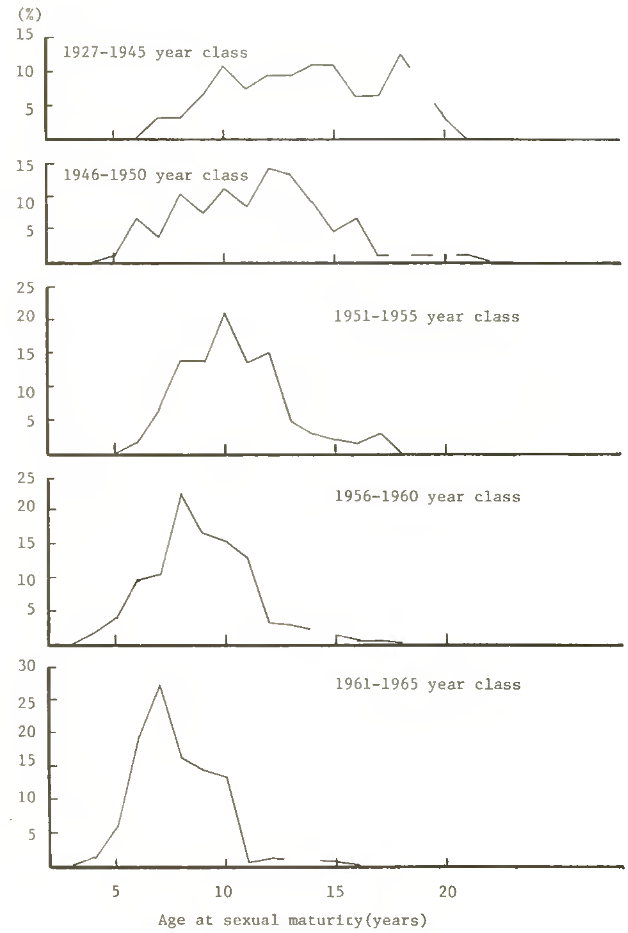


Fig. 10 Composition of age at sexual maturity as determined by the transition phase of females in Area IV.

2. PREGNANCY RATE

784 females of the minke whales caught by Japanese expeditions in the Antarctic during the period 1972/73–1976/77, were used to estimate the pregnancy rate. Table 7 shows the ratio of pregnant animals to sexually mature females (apparent pregnancy rate) by Zone, by Area and by month.

Table 7* shows the monthly change in the apparent pregnancy rate. The rate is highest in December (91.9%) and lowest in November and February (87.1%). This monthly change in the apparent pregnancy rate may substantiate the view that the pattern of migration differs with reproductive condition. The apparent pregnancy rates in Areas I to VI corrected by month are 86.3%, 94.9%, 90.5%, 89.4%, 91.8% and 80.0% respectively. No yearly change in apparent pregnancy rate from the 1972/73–1976/77 seasons has been observed (Table 8). The apparent pregnancy rate for the whole area is estimated to be 89.1%. This figure is lower than that of Jonsgard (1951) for the Atlantic minke whale (95.5%; including lactating whales), a little higher than that of Ohsumi *et al.* (1970: 78.9%–83.0%) and almost the same as that of Ohsumi and Masaki (1975) for the Southern Hemisphere minke whale (89.5%).

In the minke whale, reproductive segregation by age, by body length and by sexual condition must be considered; furthermore, detailed examination for the number and diameter of Graafian follicles, the diameter of corpora albicantia and the physiological condition of the mammary glands has not yet been thoroughly carried out. Therefore the above figures of apparent pregnancy rates should not be regarded as the true pregnancy rates. The true pregnancy

*p. 392.

Table 8

Yearly change of pregnancy rate of the Antarctic minke whale

Season	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
1972/73				88.5			88.5
1973/74		82.8	85.8	88.3			86.8
1974/75		93.8	92.5	82.8	91.2		91.3
1975/76	91.5	87.8	86.8	89.4	90.2	78.9	88.0
1976/77	77.1		90.8	91.0	86.2	75.0	87.4

Table 7

Pregnancy rate by month and by Area for the Antarctic minke whale, seasons 1972/73–1976/77

Area	November		December		January		February		Total	
	Preg./Mat.	Preg.(%)	Preg./Mat.	Preg.(%)	Preg./Mat.	Preg.(%)	Preg./Mat.	Preg.(%)	Preg./Mat.	Preg.(%)
Zone B (60°S–70°S)										
I	12/16	75.0	97/103	94.2	7/8	87.5	34/40	85.0	150/167	89.8
II					386/418	92.3	94/107	87.9	480/525	91.4
III	103/128	80.5	341/369	92.4	787/881	89.3	1,240/1,405	88.3	2,471/2,783	88.8
IV	725/826	87.8	1,565/1,706	91.7	231/258	89.5	17/22	77.3	2,538/2,812	90.3
V	553/630	87.8	131/144	91.0					684/774	88.4
VI					30/38	78.9			30/38	78.9
Total	1,393/1,600	87.1	2,134/2,322	91.9	1,441/1,603	89.9	1,385/1,574	88.0	6,353/7,099	89.5
Zone A (50°S–60°S)										
II							5/10	50.0	5/10	50.0
IV	8/9	88.9							8/9	88.9
VI							1/1	100.0	1/1	100.0
Total	8/9	88.9					6/11	54.5	14/20	70.0
Zone C (70°S–80°S)										
I							172/223	77.1	172/223	77.1
II							388/422	91.9	388/422	91.9
III							1/1	100.0	1/1	100.0
VI							57/76	75.0	57/76	75.0
Total							618/722	85.6	618/722	85.6
Total (50°S–80°S)										
I	12/16	75.0	97/103	94.2	7/8	87.5	206/264	78.3	322/390	82.6
II					376/418	92.3	487/539	90.4	873/957	91.2
III	103/128	80.5	341/369	92.4	787/881	89.3	1,241/1,406	88.3	2,472/2,784	88.8
IV	733/835	87.8	1,565/1,706	91.7	231/258	89.5	17/22	77.3	2,546/2,821	90.3
V	553/630	87.8	131/144	91.0					684/774	88.4
VI					30/38	78.9	58/77	75.3	88/115	76.5
Total	1,401/1,609	87.1	2,134/2,322	91.9	1,441/1,603	89.9	2,009/2,307	87.1	6,985/7,841	89.1

Table 9

Pregnancy rate by Area and by month of the Antarctic minke whale

Season	Area I	Area II	Area III	Area IV	Area V	Area VI	Total
1972/73 to 1976/77	94.2	95.6	96.2	96.9	80.0	86.9	95.1
	Nov.	Dec.	Jan.	Feb.	Total		
	96.3	96.7	94.5	93.1	95.1		

rate of the Antarctic minke whale is difficult to estimate in the same way as it is for Antarctic sei whales (Masaki, 1978). Gambell (1968) reported that the true pregnancy rate is equal to the annual ovulation rate in the case of the Antarctic sei whale.

An ovulating whale from which a corpus luteum is recognised in the ovaries but a foetus cannot be found in either uterine horn has not come within the category of pregnant whale up to now in this discussion. If we place ovulating whales in the same category as pregnant ones, monthly and Area pregnancy rates are calculated as shown in Table 9. As already calculated, the annual ovulation rates for Areas I to VI are 0.868, 1.090, 1.085, 0.830, 0.950 and 1.346, respectively. The mean annual ovulation rate (excluding Area VI) is estimated to be 0.965 and this figure is almost the same as the pregnancy rate (95.1%) based on data in which ovulating animals were regarded as pregnant. From these ovulation and pregnancy rates, the duration of one reproduction cycle of the Antarctic minke whale is calculated to be 12.44–12.62 months. The mean foetal growth curve derived from the date of capture of pregnant whales and the mean foetal body length for each ten-day period for Antarctic minke whales is shown in Fig. 11. If it is reasonable to adopt 320 cm as the length at birth then the gestation period is about 18 months using the above data.

On the other hand, Fig. 12 shows the composition by ten-day period within each range of foetal body length of the specimens as given in Table 4. Assuming it to be true that the value for the mode of the frequency distribution of the date of capture by ten-day period in each range of foetal body length indicates the time that the pregnant whale has just migrated to the main feeding grounds (between 60°S and 70°S) another mean foetal growth curve can be drawn as shown in Fig. 11. Using this growth curve, the length at birth (320 cm) and the 43 days of Laws' (1959) 't_0' mating and parturition times can be calculated

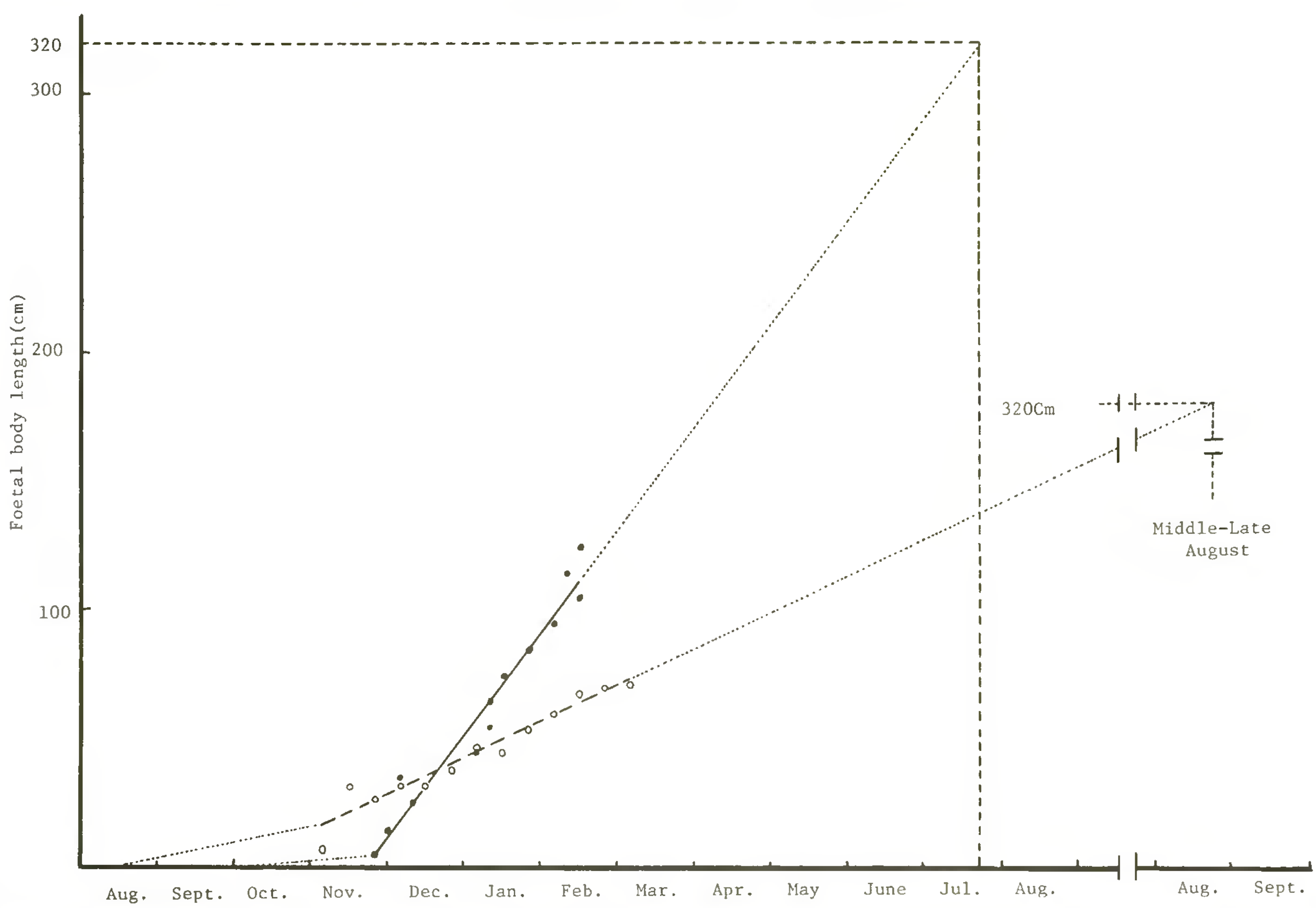


Fig. 11. Foetal growth curve of the Antarctic minke whale o---o: the mean foetal body length by the date (decade) of capture of pregnant whales, •——•: the figure of the mode of the composition by decade of the month captured.

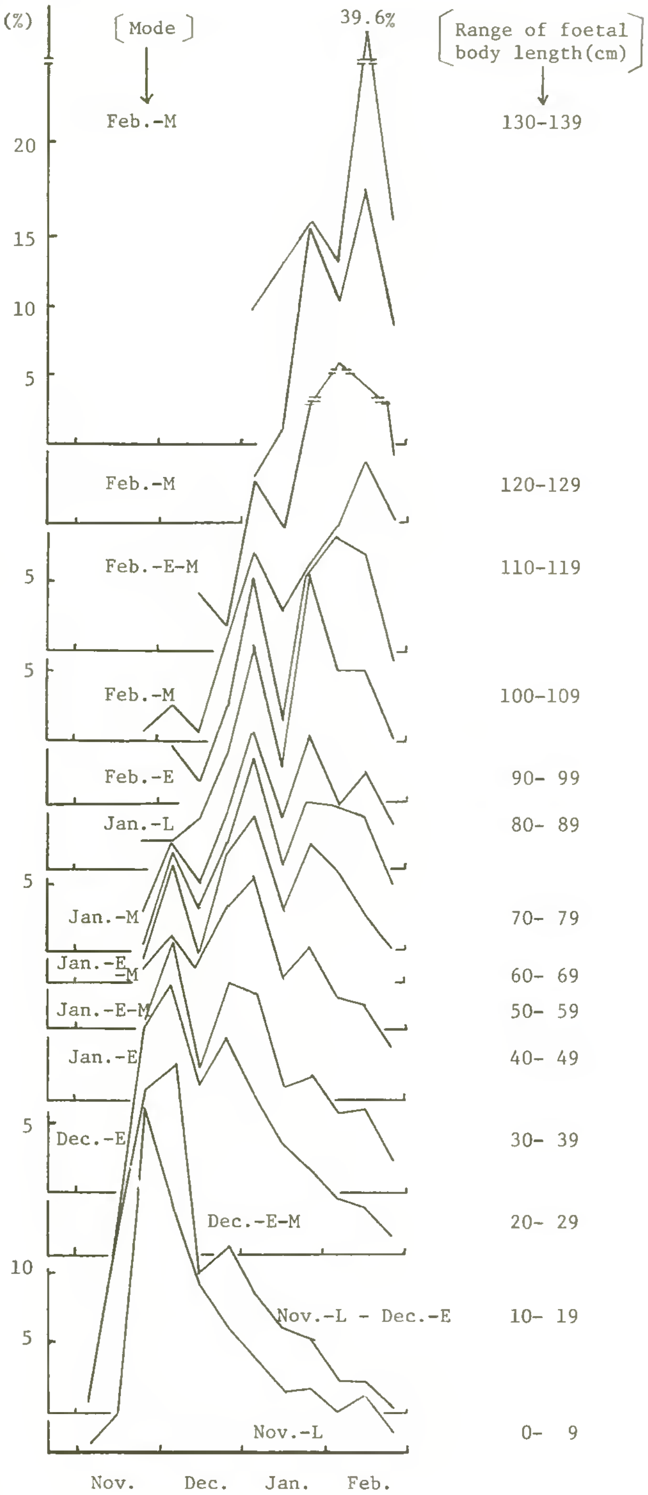


Fig. 12. Monthly frequency distribution of the range of foetal body lengths of the Antarctic minke whale.

to be early–mid October and late July respectively and thus the gestation period is almost 9.5 months for the Antarctic minke whale.

Assuming that lactation lasts three months, the duration of one reproductive cycle is estimated to be 12.5 months. This figure is almost the same as that (12.44–12.62 months) obtained from the ovulation and pregnancy rates mentioned above.

3. FOETAL SEX RATIO

The data used in this section were obtained by Japanese whaling expeditions in the Antarctic during the 1971/72–1976/77 seasons.

The yearly and Area changes in the male foetal sex ratio are shown in Tables 10 and 11. The mean foetal sex ratio of the 1971/72 to 1976/77 season was 45.9%. This figure is a little lower than that (48%) from Ohsumi and Masaki (1975). The ratios in Area I (53.8%) and Area VI (51.1%) are relatively high and that in Area IV (43.5%) is the lowest among the Antarctic Areas.

No definite trend of yearly change in male foetal sex ratio has been observed from 1971/72 to 1976/77 (Table 10).

4. LITTER SIZE

Of the minke whales caught by Japanese whaling expeditions in the Antarctic during seasons 1971/72–1976/77, 7,617 pregnant minke whales had a single foetus, 42 had twins and 3 had triplets. The mean litter size is 1.006 and this figure is a little lower than that (1.007) from Ohsumi and Masaki (1975).

Neither an increasing nor decreasing trend has been observed in the litter size of the Antarctic minke whale (Table 12).

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Table 10

Yearly change of foetal sex ratio by Area for the Antarctic

Area	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
I	–	–	–	–	52.3	54.8
II	–	–	52.6	49.7	50.0	–
III	48.4	–	46.3	41.5	45.2	50.7
IV	45.4	44.0	42.8	37.7	38.4	43.1
V	–	–	–	49.8	46.7	44.8
VI	–	–	–	–	46.7	52.6
Total	45.7	44.0	44.9	45.0	45.5	48.6

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Table 11

Foetal sex ratio, rate of multiplets and litter size of the Antarctic minke whale during seasons 1971/72–1976/77

Foetal sex \ Area	I	II	III	IV	V	VI	Total
Male	170	384	1,161	1,429	311	45	3,500
Female	146	379	1,338	1,856	355	43	4,117
Male sex ratio	53.8	50.3	46.5	43.5	46.7	51.1	45.9
Number of twins	2	7	11	19	3	0	42
Number of multiplets	0	1	2	0	0	0	3
Rate of multiplets	0.0063	0.0100	0.0052	0.0058	0.0045	0.0000	0.0059
Litter size	1.0126	1.0221	1.0112	1.0115	1.0090	0.0000	1.0121

Table 12

Yearly change of litter size by Area of the Antarctic minke whale

Area \ Season	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
I	–	–	–	–	1.0078	1.0053
II	–	–	1.0000	1.0098	1.0245	1.0073
III	1.0000	–	1.0062	1.0020	1.0106	1.0073
IV	1.0067	1.0077	1.0065	1.0000	1.0000	1.0035
V	–	–	–	1.0000	1.0000	1.0086
VI	–	–	–	–	1.0000	1.0000
Total	1.0061	1.0077	1.0060	1.0041	1.0095	1.0064

S12

Interspecies Relationships Among Some Biological Parameters in Cetaceans and Estimation of the Natural Mortality Coefficient of the Southern Hemisphere Minke Whale

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INTRODUCTION

The natural mortality coefficient (M) is one of the fundamental biological parameters necessary for the population assessment of living resources, and it is important to estimate the true value of this parameter as accurately as possible.

Ohsumi, Masaki and Kawamura (1970) first estimated the M value of the Southern Hemisphere minke whale to be 0.104 from the age distribution of the whales caught in the 1967/68 and 1968/69 seasons. Large scale exploitation of this stock started in the 1971/72 season and Ohsumi and Masaki (1975) re-examined age composition, corpora composition and ovulation rate using a large amount of biological data collected from this stock in 1971/72 and 1972/73. This resulted in a change in the estimated M value to 0.125.

The IWC Scientific Committee in June 1977, raised the point that catch curves will yield estimates of M which are biased upwards, if the minke whale population was increasing as hypothesized. In the light of several considerations of the real value of M, the Committee decided to proceed on the basis of M=0.09 in providing advice for 1977/78 (IWC, 1978).

Dr P.B. Best expressed his reservations about some of the conclusions on the assessment of the Southern Hemisphere minke whales made by the Committee. He pointed out that the fitting of a trend line to only two M values (for the fin and sei whales) could reveal little about the true value for the minke whale as assumptions had to be made about the relationship of M with body size. He felt that there was no good reason to accept M=0.09 over M=0.125 (IWC, 1978).

His reservation is worth examining further by use of previously reported M and body length values for as many species of cetaceans as possible. The existence of interspecific relationships between biological parameters in Cetacea has already been examined by some researchers. Laws (1956) examined the relationship between body length at physical maturity and body length at sexual maturity. Ohsumi (1966a) showed an allomorphosis between body length at sexual maturity and body length at birth. If there are some interspecific relationships among biological parameters concerning M, we can obtain a value of M for the Southern Hemisphere minke whale using other biological parameters which have been estimated independently.

Some papers have reported on interspecific relationships between M and other biological parameters in fish. Tauchi (1956) thought that M should be proportional to the reciprocal of the maximum life span (T), if fish have similar life tables, and he gave a formula to estimate the M value of unknown species of fish based on actual values of M and T. Tanaka (1960) confirmed Tauchi's theory by plotting known values of M and the reciprocal of T for five species of fish, and using these to estimate M values for several fish species with known T values.

Beverton and Holt (1959) showed that the maximum size (L) had a linear relationship with T in some fish groups. Mitani (1970) re-examined this relationship in fish groups, and confirmed a relatively clear relationship between L and T.

These reports suggest the possibility of similar interspecific relationships in Cetacea. I examine the following interspecies relationships: (a) between the reciprocal of T and M; (b) between L and M; (c) between L and T. After that, an M value for the Southern Hemisphere minke whale is estimated using these relationships.

PROBLEMS CONCERNING BIOLOGICAL PARAMETERS

The biological parameters examined in this paper are L, M and T. In practice, there are many problems concerned with obtaining values for these parameters in Cetacea.

Age determination

Age determination is fundamental to the estimation of biological parameters such as M and T, and is needed in the estimation of L. Techniques for determining the age of Cetacea have developed rapidly since the discovery of earplugs and teeth as age characters in the 1950s, and earlier methods, e.g. the utilisation of such characters as the baleen plates, have largely been superseded. Methods for the age determination of the large and commercial whale species have been developed more successfully than for non-commercial and smaller cetaceans. Several problems still remain however. It is difficult, for example, to read the earplug of the right whale or to read growth layers in teeth after the close of the pulp cavity, and there are problems regarding the accumulation rate of growth layers for the white whale.

Maximum body length (L)

There are large individual variations in the body lengths of whales. The maximum body length used in this paper is not the longest recorded body length, but the average body length of fully grown individuals. Growth ceases in cetaceans at a relatively early stage of their life span compared with fish. The physical maturity of cetaceans is identified by the full ossification of the epiphyses of the vertebral column, but it is laborious to examine the ossification of each whale caught. Usually L is estimated from the growth curve, drawn from age determination data of individuals caught. This is the best value to use for L_∞ in the Von Bertalanffy growth equation, if the equation can be used to describe the growth curve. A large sample size is needed to obtain a good growth curve. This parameter has been reported for a relatively large number of species of Cetacea compared with other biological parameters. Its value is often different for stocks even of the same species, e.g. Southern Hemisphere fin whales (Ohsumi and Shimadzu, 1970). On the other hand, there are some species such as the sperm whale for which different stocks have almost the same growth curve (Ohsumi, 1977b). It can be analogized that the L value may change with the change in population density or ecosystem, but there have been no reports of this phenomenon occurring in Cetacea.

Natural mortality coefficient (M)

Correct age determination and a large sample size are needed to estimate the value of this parameter. The natural mortality coefficient has usually been estimated as the gradient of the age distribution of whales caught from an unexploited population. However, the age distribution is often obtained from populations with a long history of exploitation. The gradient of the age distribution from such a population includes the fishing mortality coefficient. Even in the unexploited population the gradient does not always represent natural mortality itself as pointed out in the Introduction. If the population has been increasing, or age specific migration occurs, the gradient is larger than the true value of M, and if the population is decreasing or if age specific immigration occurs then the reverse is true. The gradient (total mortality coefficient, Z) is generally represented by the following equation:

$$Z = M + F + P + I$$

where, F is the fishing mortality coefficient, P is the population changing coefficient, and I is the age specific availability coefficient. If the population has a relatively short history of exploitation, F can be neglected if the gradient is calculated using the age distribution of older animals (Ohsumi, 1964).

There is a question as to whether the M value may change with age. A complete life table has not yet been obtained directly for cetaceans to check this, but it may be estimated that the M value remains constant, at least after sexual maturity, in Cetacea. The value of the juvenile natural mortality coefficient is almost impossible to estimate directly from the age distribution. For example, the maternal nursing behaviour towards calves and juveniles in toothed whales may be different from that in baleen whales. The former are usually gregarious, and thought to nurse their young for a relatively long time within the social school, hence the pattern of juvenile mortality rate in toothed whales may be different from that in baleen whales.

A further question is whether there is a difference in the value of M for males and females. There are some papers which show such a difference but this is perhaps due to differences in readability of age characters between the sexes. Although there may be some difference in M values between sexes, the detection of such differences is technically difficult at present and in this paper I assume that M values are the same for both sexes. Further study is needed to solve this problem.

Another problem is that this parameter may change with a change in species biomass or total biomass. It seems probable that this parameter is density dependent in the Cetacea, but no evidence for this has yet been found.

Where corpora distribution and ovulation rate have been obtained from other sources, the M value can be estimated from the gradient of the corpora distribution and ovulation rate (Ohsumi and Masaki, 1975). If there is doubt about the M value obtained from age distribution data it can usefully be checked by this approach.

Maximum life span (T)

As most Cetacea are oceanic and long lived, direct values of this parameter for individuals are almost impossible to obtain except for some of the smaller cetaceans which can be kept in aquaria (although there is the interesting case of 'Pelorus Jack').

In theory one should use the value for the oldest individual caught to estimate the value for this parameter, but a large sample size is needed to obtain a reliable figure, and in practice, the age determination of old animals is rather difficult. For example, the accumulation of dentine layers stops with the closure of the pulp cavity, and reading the cement layers is difficult, except in the case of *Platanista* (Kasuya, 1972b).

If corpora counts, ovulation rates, and age at sexual maturity based on a large sample size are known for a species, the T value can be estimated, although there is the problem of individual variation in ovulation rate and age at sexual maturity.

No evidence of large differences in T values between the sexes has been found yet for cetaceans. There is a possibility that this parameter is density dependent, but again no evidence has been reported.

REVIEW OF BIOLOGICAL PARAMETERS PREVIOUSLY REPORTED

California gray whales

The life history and ecology were studied by Rice and Wolman (1971). They calculated several values of M using age distribution based on growth layers in the earplug and corpora accumulation, and concluded that M was 0.08 in adults. As this stock was recovering until the 1960s, and recruitment had been increasing, the apparent value of M must be higher than the true one. The value of T was 69 years based on earplug growth layers, and was estimated to be 76–77 years based on maximum corpora number, ovulation rate and age at sexual maturity. L was estimated by the examination of vertebral epiphyses to be 13.0 m and 14.1 m for males and females, respectively.

North Pacific humpback whales

Nishiwaki (1959) constructed growth curves for this stock and from these L was estimated to be 13.4 m for males and 13.7 m for females. The oldest individual noted (and hence T) was 83 years. He also found that the age at sexual maturity was 11 growth layers and the maximum number of corpora in the ovaries was 30. From this data the ovulation rate was calculated to be 0.50 and T to be 71 years. Doi, Nemoto and Ohsumi (1967) reported a value of 0.05–0.08 for M based on age distribution data from earplugs.

Southern Hemisphere humpback whales

Chittleborough (1965) calculated L_{∞} in the Von Bertalanffy growth equation to be 13.0 m for males and 13.8 m for females. He estimated M, from the relationship between fishing effort and Z, as 0.05–0.09 (0.07 as the best estimate). According to Chittleborough (1959), the T value was 74 earplug layers.

North Pacific blue whales

From growth curves based on earplug layers, Ohsumi and Wada (unpublished), estimated L values of 23.4 m for males and 24.8 m for females, and gave a value for T of 91 years. They calculated total mortality coefficients from an age distribution based on earplug layers of 0.049–0.073 in 1957–65. Considering the long history of exploitation of this stock, the true value of M can be expected to be lower than this and I use 0.04 in this paper.

Southern Hemisphere blue whales
According to Mizue and Murata (1951), the ankylosis of the vertebral column is completed at body lengths of 24.4 m for males and 25.9 m for females. Lockyer (1976) showed that L_∞ in the Von Bertalanffy growth equation was 25.0 m and 26.2 m for males and females respectively. The variation in the estimates may be due to the difference of stocks in the Southern Hemisphere. No direct estimation of M has been made. The Committee of Three (1964) assumed it to be 0.05, the same as the fin whale. The sample size is not large enough to estimate T from earplug readings. According to Mizue and Murata (1951), the maximum corpora number was 40, and I calculated the ovulation rate from earplug data and corpora number for a limited number of animals in 1956/57–1958/59, as 0.40. The age at sexual maturity was estimated from the same data to be about 10 years. From this, T is estimated to be about 110.

Pygmy blue whales
According to Ichihara (1966), the L values were 20.4 m to 20.6 m for males and 21.6 m to 21.9 m for females. Ichihara and Doi (1964) estimated M to be 0.05 from age distribution data based on earplug layers in 1960/61 and 1961/62. The maximum number of earplug layers was 84.

North Pacific fin whales
Ohsumi, Nishiwaki and Hibiya (1958) estimated L to be 18.9 m for males and 20.1 m for females. Ohsumi (1964) estimated M to be 0.067, but Nemoto, Doi and Ohsumi (1968) re-estimated it as ranging from 0.037 to 0.052 with an average value of 0.046. Ohsumi *et al.* (1958) reported T as 101 earplug layers.

North Atlantic fin whales
According to Lockyer, Gambell and Brown (1977), the maximum age of fin whales off Iceland is 80, and from the growth curves, L values can be estimated as 18.9 m for males and 20.1 m for females. At the working group on North Atlantic whales (IWC, 1977), M was estimated as 0.04 which was interpolated from Z=0.07 by Rørvik, Jónsson, Mathisen and Jonsgård (1976). Ugland (1977) estimated M to be 0.035 by an equilibrium model.

Southern Hemisphere fin whales
L values of the Southern Hemisphere fin whale have been estimated by many researchers. Ohsumi and Shimadzu (1970) examined growth curves in each Area from large samples of earplugs and they found that L values differed between Areas, with Area II having the highest values (20.6 m for males and 22.2 m for females). Doi, Ohsumi, Nasu and Shimadzu (1969) estimated M using age distribution data from the 1930s from an age-length key and size distribution of the period, and estimated the mean value of M to be 0.042. It was agreed at the Special Meeting on Antarctic Fin Whale Stock Assessment in 1970 that an M value of 0.04 is the best present estimate of the average coefficient. The maximum corpora number was 53, according to Nishiwaki and Oye (1951). Ohsumi (1964) estimated the ovulation rate as 0.49, and the age at sexual maturity as 10–11 years. From these values T can be calculated to be about 120 years. This is almost the same as the value of 114 years obtained by Ohsumi (1964) based on the maximum number of earplug layers.

North Pacific sei whales
Masaki (1976) estimated body length at physical maturity as 14.3 m for males and 15.2 m for females. He also estimated M values from age distribution data based on earplug layers, as 0.054 for males and 0.060 for females. The maximum number of earplug layers recorded in the Far Seas Fisheries Laboratory is 67. According to Masaki (1976), the maximum corpora number was 32, the ovulation rate was 0.0604 and the age at sexual maturity was 7 years. From these data, T was estimated to be 60 years.

North Atlantic sei whales
Mitchell and Kozicki (1974) reported several biological parameters. According to them, L is 13.4–13.7 m for males and 14.0–14.3 m for females, and T is 71 years based on earplug layers. Lockyer (1977) estimated Z to be 0.0773 for males and 0.0727 for females, for the sei whales off Iceland. Considering these values, I use an M value of 0.07 in this paper. She further reports that L appears to be 13.4 m in males and 14.6 m in females, and that both sexes attain ages up to 50 growth layers. This may be lower than the real value of T, however, because of the low sample size.

Southern Hemisphere sei whales
There are many papers on the values of L. Considering the more recent reports, Lockyer (1977b) gives L values of 15.5 m for males and 16.5 m for females at South Georgia, and 14.8 m for males and 15.3 m for females at Durban. Best and Lockyer (1977) also reported L values of 14.8 m for males and 15.8 m for females taken at Donkergat. Ohsumi and Masaki (1978) obtained age-length keys for both sexes of sei whales in the Antarctic, and from these calculated the average lengths of individuals of 25 years and over. They found that the lengths differed by Area (14.9 m for males and 15.8 m for females in Area II and 14.6 m for males and 15.4 m for females in Area III). The M value of the Southern Hemisphere sei whale was first estimated by Doi, Ohsumi and Nemoto (1967) to be between 0.059 and 0.079 with a mean of 0.065. Lockyer (1977a) estimated M to be between 0.047 and 0.068 with an average of about 0.060. Ohsumi (1978) examined the total mortality coefficients by different approaches and concluded that M values in the early 1960s were 0.065 for males and 0.080 for females. At the Special Meeting on Southern Hemisphere Sei Whales in 1977 (IWC, 1978) M values of 0.07 for males and 0.08 for females were provisionally adopted while at the same time it was recognised that the sei whale population had been increasing before the beginning of exploitation in the early 1960s and that the true value of M would be lower than these values. The maximum number of earplug growth layers from data collected by my laboratory is 74.

North Pacific Bryde's whales
Body length at physical maturity can be estimated to be 13.1 m for males and 13.7 m for females from tables by Omura (1962). Ohsumi (1977c) reported L values of 12.8 m in males and 13.4 m in females. Doi, Nemoto and Ohsumi (1967) calculated the Z value to be 0.059–0.085. Considering the population level of this stock the Z value will not be very different from the M value. Ohsumi (1977a) estimated M as 0.080 for males and 0.091 for females and concluded that M was 0.085. According to Ohsumi (1977c), the maximum number of earplug layers found was 55.

Southern Hemisphere Bryde's whales
Best (1977) described two forms of Bryde's whale off

South Africa. From growth curves he estimated L for the inshore form to be 42–43 ft (12.8–13.1 m) for males and 45–46 ft (13.7-14.0 m) for females, and for the offshore form to be 45 ft (13.7 m) for males and 47–48 ft (14.3–14.6 m) for females. The maximum number of growth layers he found was 35 (for the offshore form). From his maximum corpora number (27) and ovulation rate for the offshore form (0.42) a T value of 71–74 years can be calculated, assuming an age at sexual maturity of 7–10 years. He made no estimation of M.

North Atlantic minke whales
Ugland (1977) estimated M to be 0.09 from his equilibrium model. Jonsgard (1951) estimated L to be 27 ft (8.2 m) for males and 29 ft (8.8 m) for females from Norwegian waters, but Ohsumi, Masaki and Kawamura (1970) thought these figures were too high compared to those for the Southern Hemisphere, and they proposed a value of 27.3 ft (8.3 m) for the females. Mitchell and Kozicki (1975) constructed a growth curve using L as 25 ft (7.6 m) for females from Newfoundland waters. There are no estimates of T to date.

Southern Hemisphere minke whales
Ohsumi, Masaki and Kawamura (1970) estimated L to be 8.3 m for males and 8.8 m for females. This was revised by Ohsumi and Masaki (1975) to be 8.5 m and 9.0 m respectively. Ohsumi *et al.* (1970) estimated T to be 47–48 years from the age at sexual maturity and the ovulation rate, and Ohsumi and Masaki (1975) gave a maximum number of earplug growth layers of 47. Ohsumi *et al.* (1970) estimated M to be 0.104, and Ohsumi and Masaki (1975) later revised this to 0.125.

North Pacific sperm whales
Nishiwaki, Ohsumi and Maeda (1963) and Berzin (1961) indicated L values of 52 ft (15.8 m) for males and 36 ft (11.0 m) for females. Ohsumi (1977b) reported the L value of males as 50.0 ft (15.2 m). Ohsumi (1966b) gave a maximum number of growth layers in the dentine of 77. Ohsumi, Kasuya and Nishiwaki (1963) and Ohsumi (1966b) estimated M to be 0.056 and 0.073 respectively.

Southern Hemisphere sperm whales
Best (1970) and Gambell (1972) report the same values of L: 50 ft (15.2 m) for males and 36 ft (11.0 m) for females. Best (1970) gave the maximum number of growth layers as 42, but Gambell (1972) recorded 62. Best (1970) adopted the same values of M (0.057–0.073) as Ohsumi (1966b), and Gambell (1972) used 0.06, the value adopted at the Meeting on Sperm Whale Stock Assessments in 1968 (IWC, 1969).

North Pacific Baird's beaked whales
Kasuya (1977) drew growth curves, and estimated L to be 10.7 m for males and 11.0 m for females. By counting growth layers in the cement, he estimated T to be 70 years. There are no estimates of M to date.

North Atlantic bottlenose whales
Christensen (1973) reports L values of 8.5 m for males and 7.5 m for females. He also reports a maximum number of growth layers of 37, although it is difficult to count layers after the pulp cavity has closed. Ugland (1977) estimates M as 0.085 from his equilibrium model.

Killer whales
Estimated from the size distribution given by Nishiwaki and Handa (1958) for the North Pacific, L is 24–25 ft (7.2–7.7 m) for males and 22 ft (6.7 m) for females. Jonsgard and Lyshoel (1970) estimated it as 8.5 m and 7.5 m for males and females respectively. There is an interesting record on the life span of a killer whale 'Old Tom' from New Zealand waters: Dakin (1934) reported that it lived to more than 50 years of age. There are no estimates of M values to date.

North Atlantic pilot whales
Sergeant (1962) reported several biological parameters of this species. From the growth curve given in his paper, L is 5.8 m for males and 4.6 m for females. He estimated T as 40–50 years and he calculated M from age distribution data from 1–8 year old animals to be 0.0445–0.0580, but I doubt that this age distribution represents a real mother population, as tooth layers were not counted for older ages. From his corpora distribution (from which a gradient can be obtained), and his estimate of the annual ovulation rate, a Z value of 0.090–0.136 can be calculated which will be almost the same as the M value.

North Pacific bottlenose dophins
According to Ohsumi (unpublished), L is 3.1 m for males and 2.9 m for females. The average annual ovulation rate is 0.62 and the maximum corpora number is 18. From these data and an estimated age at sexual maturity of 5 years, T can be calculated as 35 years.[1] No information on M is available.

North Atlantic bottlenose dolphins
According to Sergeant, Caldwell and Caldwell (1973), L is 2.6 m for males and 2.4 m for females, and the maximum number of growth layers is 26. From the age at sexual maturity, annual ovulation rate and maximum corpora number given in their paper, T is estimated to be 39. There are no estimates of M values to date.

North Pacific striped dolphins
Kasuya (1972a) gives L values of 235 cm for males and 222 cm for females and Miyazaki (1977) reports similar figures (238 cm and 225 cm respectively). Kasuya (1972a) estimated T as 26 years, but after re-examining cement layers, revised this to more than 45 years (1976). According to Miyazaki's (1977) growth curve, the maximum age was 29.5 years. The average of these three figures is 33.7 years. Kasuya and Miyazaki (1976) estimate total mortality coefficients in two ways. A Z value of 0.137 was obtained from the annual ovulation rate and gradient of corpora composition, and of 0.248 for males and 0.267 for females, from age-composition data based on tooth layers, but they took 0.07–0.08 as the M value after considering the degree of exploitation of this stock. Kasuya (1976) re-examined age composition by use of cement layers and the Z value was revised to be 0.146 for males and 0.126 for females.

[1] The famous 'Pelorus Jack' first appeared in French Pass, New Zealand, in about 1889, and disappeared in 1913. It was originally identified as a Risso's dolphin, but Gaskin (1972) examined its species, and thought it was in fact a bottlenose dolphin. However, Baker (1974) reports that it was definitely a Risso's dolphin.

A bottlenose dolphin, 'Love', is still living in an aquarium in Japan 20 years after capture (Hirosaki and Honda, 1977). It was caught in June 1957, when its body length was 275 cm, and was transported to the aquarium a year later. From this information it is evident that T is more than 24 years.

Although I have not had sufficient time to look critically at these results, I use 0.137 as the M value in this paper.

North Pacific spotted dolphins

Kasuya, Miyazaki and Dawbin (1974) and Kasuya (1976) studied the biological parameters of the stock on the Pacific side of Japan, and Perrin, Coe and Zweifel (1976) report these parameters for the offshore stock of the eastern tropical Pacific.

According to Kasuya (1976), L is 207 cm for males and 194 cm for females. Perrin *et al.* (1976) gave L as 201 cm and 187 cm respectively. Kasuya *et al.* (1974) reported the maximum number of tooth layers as 24, but Kasuya (1976), counting cement layers, estimated T to be 40–46 years. Perrin *et al.* gave a maximum number of layers of 18, but noted they become unreadable at older ages. The value I adopt here is 32 (the average of 24 and 40). Kasuya *et al.* calculated Z for both sexes combined to be 0.355 from age distribution data based on dentine layers, and estimated the value for females to be 0.077 from corpora composition and the annual ovulation rate. They thought the former value was too high because the age of physically mature animals is often underestimated by dentine reading. They estimated the Z value of males from the Z value of females and the change in the sex ratio by age as 0.161. Kasuya (1976) re-examined the Z value from age compositions based on cement layers and gave values of 0.078 for males and 0.114 for females. He regarded the Z value as almost the same as the M value since this stock of dolphin has been lightly exploited. I believe the value for females is too low because the average Z value for juveniles (up to 8 years) was calculated by Kasuya *et al.* and Kasuya to be 0.034 and 0.032 respectively.

North Pacific spinner dolphins

Perrin, Holt and Miller (1975) report L values of 175.5 cm for males and 170.6 cm for females. No other parameter values are available.

Harbor porpoises

Mohl-Hansen (1954) reported some biological investigation of this species from the Baltic Sea. From size distributions, L can be estimated as 147 cm for males and 162 cm for females. No other values of parameters are available.

North Pacific Dall's porpoises

From the size distribution given by Mizue, Yoshida and Takemura (1966), L can be estimated as 2.0 m for males and 1.9 m for females.

Ganges river dolphins

Kasuya (1962b) gave L values of 2.0–2.1 m for males and 2.5 m for females and a T value of over 28 years.

White whales

Sergeant and Brodie (1969) showed local variation in body size. Kleinenberg, Yablokov, Bel'kovich and Tarasevich (1964) gave L values for females of 335–360 cm from the Barents and Kara area and 390 cm from the Okhotsk Sea. From size distributions given in their book, L values for males of 430 cm from the northern area and 460 cm from the Far East can be estimated. Brodie (1971) estimates L as 427 cm for males and 362 cm for females from Baffin Island. Sergeant (1973) gives similar values. Sergeant (1959) notes the maximum number of growth layers as 50, and Sergeant (1973) reports a T value of 40–50 layers or 20–25 years. Khuzin (1961) estimated T as 40 years in males and 32 years in females. Sergeant (1973) calculated a mortality rate of 6.31–6.45%, assuming bi-annual accumulation of growth layers. If one layer is assumed to accumulate annually as in other cetaceans, M will be about 0.03.

Table 1 shows a list of L, T and M values taken from the above review as the basic data for the following examination of the natural mortality coefficient of the Southern Hemisphere minke whale.

THE RELATIONSHIP BETWEEN T AND M

In a stock with a constant natural mortality rate, M, where n is the number of animals of age x:

$$n = a e^{-Mx} \quad \text{where a is a constant}$$

$$\text{Thus } \ln n = -Mx + \ln a$$

As n approaches 1, x approaches T

$$\text{Thus } \ln 1 = MT + \ln a$$

$$MT = \ln a = \text{constant}$$

Thus M is inversely proportional to T, proving Tauchi's theory (1956)

It is interesting to see whether the present information on T and M values for various species of cetaceans can be applied to this theory. Fig. 1 shows the relationship between the M and reciprocal of T values from Table 1. Although there is individual variation, it can be seen that Tauchi's theory is applicable to Cetacea for both Mysticeti and Odontoceti. The MT value of 19 stocks of cetaceans (excluding the beluga) ranges from 3.20 to 5.84 with an average of 4.68 (s.d. 0.69).

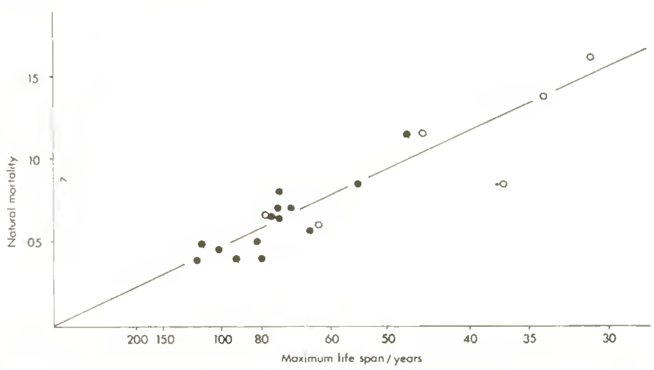

Fig. 1. Relationship between the reciprocal of the maximum life span and the natural mortality coefficient in cetaceans. ○: toothed whales. ●: baleen whales.

It can be concluded that cetaceans with long maximum life spans have lower natural mortality coefficients, and that the following equation is applicable to all cetaceans.

$$MT = 4.68 + 0.069 \qquad \ldots (1)$$

Either M or T can be obtained from this equation, if the other is known. Usually T is easier to estimate than M. Where both M and T are estimated for a cetacean species, it is possible to examine the accuracy of the values using this equation, and if the value of MT is far outside the range 3.99–5.37, the T and M values should be closely examined.

THE RELATIONSHIP BETWEEN L AND M

Three graphs were drawn to examine the relationship between L (in males) and M as shown in Fig. 2:

(a) M against L
(b) log M against L
(c) log M against log L.

Table 1
L, T and M values which have been reported for cetaceans

Species	Locality	L (m) Male	L (m) Female	T (yrs)	M
Gray whale	California	13.0	14.1	73	0.08
Humpback whale	N.P.	13.4	13.7	77	0.065
Humpback whale	S.H.	13.0	13.8	74	0.07
Blue whale	N.P.	23.4	24.8	91	0.04
Blue whale	S.H.	25.0	26.2	110	0.05
Pygmy blue whale	S.H.	20.5	21.7	84	0.05
Fin whale	N.P.	18.9	20.1	101	0.046
Fin whale	N.A.	18.9	20.1	80	0.04
Fin whale	S.H.	20.6	22.2	114	0.04
Sei whale	N.P.	14.3	15.2	64	0.057
Sei whale	N. West Atlantic	13.4	14.6	71	0.07
Sei whale	S.H.	14.9	15.8	74	0.065
Bryde's whale	N.P.	12.8	13.4	55	0.085
Bryde's whale	S.H. (offshore)	13.7	14.4	72	–
Minke whale	N.A.	7.8	8.3	–	0.09
Minke whale	S.H.	8.5	9.0	47	0.115
Sperm whale	N.P.	15.2	11.0	77	0.065
Sperm whale	S.H.	15.2	11.0	62	0.06
Baird's beaked whale	N.P.	10.7	11.0	70	–
Bottlenose whale	N.A.	8.5	7.5	>37	0.085
Ganges river dolphin	E. Pakistan	2.1	2.5	28	–
White whale	Arctic	4.3	3.6	23	0.06
Pilot whale	N.A.	5.8	4.6	45	0.115
Killer whale	Pacific	8.5	7.5	>50	–
Bottlenose dolphin	N.P.	3.1	2.9	35	–
Bottlenose dolphin	N.A.	2.6	2.4	32	–
Striped dolphin	N.P.	2.4	2.2	34	0.137
Spotted dolphin	N.P.	2.1	1.9	31	0.161
Spinner dolphin	N.P.	1.8	1.7	–	–
Harbor porpoise	Baltic	1.5	1.6	>13	–
Dall's porpoise	N.P.	2.0	1.9	–	–

N.P.: North Pacific N.A.: North Atlantic S.H.: Southern Hemisphere

From these it can be seen that graph (b) gives a straight line relationship described by

$$M = 0.1585\, e^{-0.06003\, L} \qquad \ldots(2)$$

with a correlation coefficient of 0.9415.

Fig. 3 shows the relationship between L (in females) and log M. As there is not such a good fit (correlation coefficient 0.6909) the L values for males are used in this paper.

L values can be obtained more easily and accurately than M and T values and if the above equation is true then M values can be estimated from L values.

THE RELATIONSHIP BETWEEN L AND T

Fig. 4 shows the relationship between L and log T (from the data in Table 1), which can be described by:

$$T = 31.277 e^{0.05480\, L} \qquad \ldots(3)$$

with a correlation coefficient of 0.9439.

A value of T can therefore be estimated from this equation if L is known.

We have seen in equation (1) that MT is constant. From equations (2) and (3)

$$MT = 4.96 e^{-0.00523\, L} \qquad \ldots(4)$$

If –0.00523 is regarded as 0 then equation (4) becomes

$$MT = 4.96$$

this is not so far from MT = 4.68 from equation (1) and the closeness of these values obtained by independent approaches strongly suggests the relationship is true.

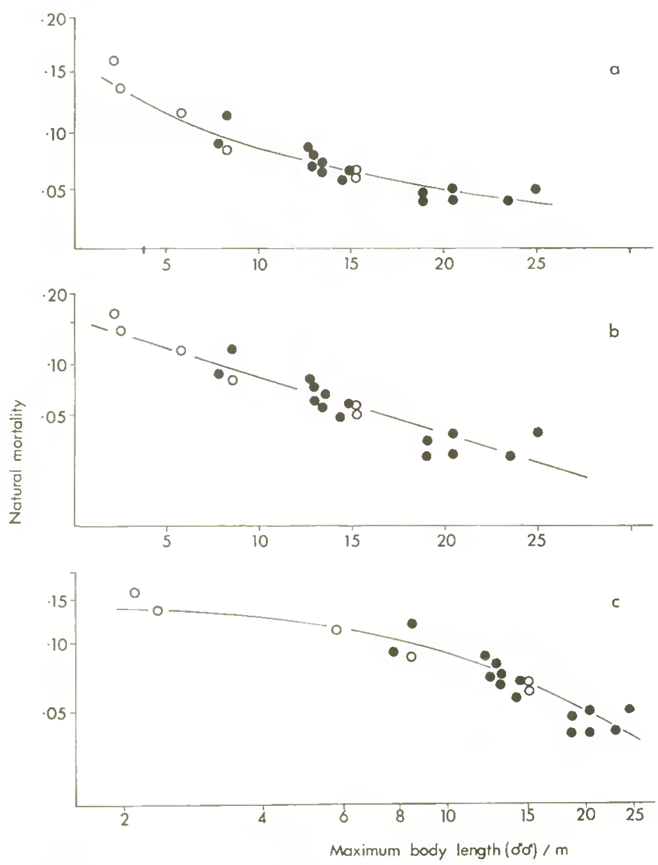

Fig. 2. Relationship between maximum body length (males) and natural mortality coefficient in cetaceans. ○: toothed whales, ●: baleen whales.

Table 2
Estimated values of M and T in Cetacea

Species	Locality	L	T1	T2	M1	M2
Gray whale	N.P.	13.1	64	64	0.073	0.073
Humpback whale	N.P.	13.4	65	66	0.071	0.072
Humpback whale	S.H.	13.0	64	64	0.073	0.073
Blue whale	N.P.	23.4	113	120	0.039	0.041
Blue whale	S.H.	25.0	123	134	0.035	0.038
Pygmy blue whale	S.H.	20.5	96	102	0.046	0.049
Fin whale	N.H.	18.9	88	92	0.051	0.053
Fin whale	S.H.	20.6	97	102	0.046	0.048
Sei whale	N.P.	14.3	69	70	0.067	0.068
Sei whale	N.W.Atlantic	13.4	65	66	0.071	0.071
Sei whale	S.H.	14.9	71	72	0.065	0.066
Bryde's whale	N.P.	12.8	63	63	0.074	0.074
Bryde's whale	S.H.	13.7	66	67	0.070	0.071
Minke whale	N.A.	7.8	48	47	0.099	0.098
Minke whale	S.H.	8.5	50	49	0.095	0.094
Sperm whale	N. & S.H.	15.2	72	73	0.064	0.065
Baird's beaked whale	N.P.	10.7	56	56	0.083	0.083
Bottlenose whale	N.A.	8.5	50	49	0.095	0.094
Ganges river dolphin	E. Pakistan	2.1	35	33	0.140	0.133
White whale	Arctic	4.3	40	38	0.122	0.118
Pilot whale	N.A.	5.8	43	42	0.112	0.109
Killer whale	Pacific	8.5	50	49	0.095	0.094
Bottlenose dolphin	N.P.	3.1	37	36	0.132	0.126
Bottlenose dolphin	N.A.	2.6	36	34	0.136	0.130
Striped dolphin	N.P.	2.4	36	34	0.137	0.131
Spotted dolphin	N.P.	2.1	35	33	0.140	0.133
Spinner dolphin	N.P.	1.8	35	33	0.144	0.136
Harbor porpoise	Baltic	1.5	34	32	0.145	0.138
Dall's porpoise	N.P.	2.0	35	33	0.141	0.134

L: L value of males in m.
T1: T value calculated by equation (3).
T2: T value calculated by equation (1) and M1 value.
M1: M value calculated by equation (2) and L value.
M2: M value calculated by equation (1) and T1 value.

ESTIMATION OF M AND T BY USE OF THE ABOVE EQUATIONS FOR THE SOUTHERN HEMISPHERE MINKE WHALE

The L value of the Southern Hemisphere minke whale can be estimated from a large sample size, and is more accurate than values of M and T.

Inserting 8.5 m as L into equation (2), yields an M value of 0.095. This figure is lower than those reported by Ohsumi *et al.* (1970, 0.104) or Ohsumi and Masaki (1975, 0.125).

Putting the same value into equation (3), T is estimated to be 49.8 years. This figure is a little higher than Ohsumi *et al.* (47–48 years) or Ohsumi and Masaki (47 years).

Inserting 49.8 years as T into equation (1), gives an average M value of 0.094 ranging from 0.080 to 0.108 by use of the standard deviation. This is almost the same as that estimated from equation (2). Putting the estimated M value (0.094) into equation (1), gives a T value of 49.3 years.

Similarly the North Atlantic minke whale's M value is estimated to be 0.098–0.099 as shown in Table 2. As the same species may have a similar value of M, it can be concluded that the M value for the minke whale is 0.10.

ESTIMATED VALUES OF M AND T IN CETACEA

If equations (1), (2) and (3) are true for all cetacean species, and if the reported value of L for males is accurate for all species, then M and T values can be estimated. Table 2 shows the results of such calculations.

It can be estimated that the T value of cetaceans ranges from about 30 years in the smallest species to about 130 years in the largest species. On the other hand, M values are about 0.15 in the smallest species and 0.035 in the largest species.

DISCUSSION

There are many problems in the estimation of values of biological parameters as discussed in the second chapter of this paper. The most serious problem is the difficulty of age determination, followed by small sample sizes of age characters for the estimation of M and T values, especially for smaller cetaceans.

Sergeant (1973) reports that the T value for the white whale is 40–50 layers or 20–25 years. The present results suggest an annual layer formation, as in other species rather than a bi-annual formation, as the estimated T value is 38–40 years. However, Sergeant (1973) also reports the M value as 0.06 assuming a bi-annual formation of tooth layers which would become 0.03 in the case of annual formation, a value far from the present result of 0.118–0.122. This difference is probably caused by using only a small

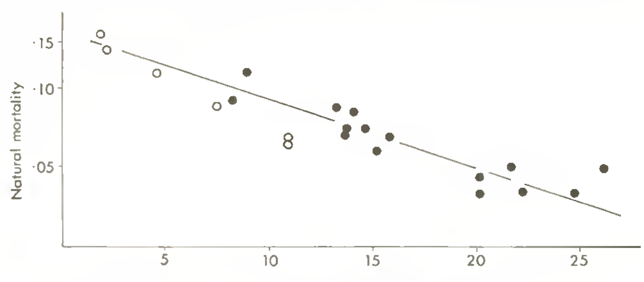

Fig. 3. Relationship between maximum body length (females) and natural mortality coefficient in cetaceans. ○: toothed whales ●: baleen whales.

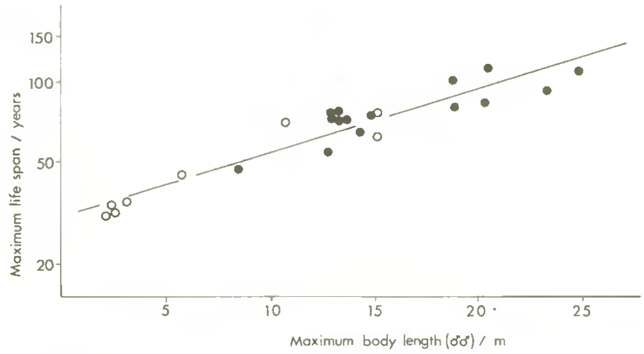

Fig. 4. Relationship between maximum body length (males) and maximum life span in cetaceans. ○: toothed whales, ●: baleen whales.

sample size for obtaining the age distribution. Another problem is that it becomes impossible to determine the age of a tooth after the close of the pulp cavity. Kasuya (1976) uses cemental layers instead of dentine layers for the age determination of striped and spotted dolphins, and estimates T as 49–50 and 40–46 years respectively, as opposed to the present results of 34–36 and 33–35 years, respectively. The T value based on dentine layers for the striped dolphin was 25–26 years (Kasuya, 1972) and 24 years in the spotted dolphin (Kasuya *et al.* 1974). It is true that we must use cemental layers, but I think further study is needed to confirm the accumulation rate of the cemental layers, especially for older ages.

Although I have assumed in this paper that there is no difference in the M value between the sexes, it is possible that such a difference exists. The poor correlation between the L values for females and M compared with that for males may be due to this.

Kasuya (1976) reported a large difference in the M values for male (0.114) and female (0.078) spotted dolphins. In this paper the M value was estimated to be 0.133–0.140, i.e. somewhat larger than Kasuya's value for males and very much larger than his value for females. He also estimated M for female striped dolphins to be 0.07–0.08, and believes the difference between Z (0.126) and M is due to the fishing coefficient, F, which is therefore 0.046–0.056. As both species are closely related and the M values for the females of both species are almost the same, it could be assumed that the M values for the males would also be the same, and therefore about 0.114. This would make the Z value for male striped dolphins 0.16–0.17 (M + F). However, the actual Z value for males was found to be 0.146, lower than the estimated value.

As there is no large difference in the Z values for male and female striped dolphins (0.146 and 0.126, respectively) and the fishing coefficients for both sexes will be similar (as the male and female catches are almost identical), then there will be very little difference in the M values for both sexes. In my experience, the F value does not usually appear in the age composition, and thus the Z value is similar to the M value. In this paper M for the striped dolphin is estimated as 0.131–0.137 which is within the range of the Z values. This suggests that the M values of the spotted dolphin need to be re-examined using a larger sample size.

The same pattern of relationships between L, T and M values is found to apply in both the Mysticeti and Odontoceti. The reported figures on these parameters for odontocetes are sparse and not sufficient for the examination of any differences of pattern between mysticetes and odontocetes. The development of population studies, especially on smaller cetaceans, to estimate these biological parameters would be welcome.

It was found that for Southern Hemisphere minke whales the estimated M value (0.095) in this study was lower than the Z value (0.125) given by Ohsumi and Masaki (1975). If the present figure of 0.095 represents the real M value, Ohsumi and Masaki's previous estimate includes an increasing coefficient of population size as assumed in the last annual meeting of the Scientific Committee. Although no direct evidence is available on an increase in population size, Masaki (1979) reports a yearly change in the age at sexual maturity prior to serious exploitation of the Southern Hemisphere minke whale. This phenomenon suggests the possibility of population increase in this stock before the beginning of exploitation. If this is true the Z value which was estimated from age distribution data is larger than the true M value.

This study is merely a rough approach to the estimation of M and T values for cetaceans. The individual variation in any law suggests that the real M value of each cetacean stock may differ from the relationship between three parameters dealt with in this study. Therefore, it is important to obtain a true M value for each individual stock using a more direct method than that used in this study.

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Population Assessment of the Antarctic Minke Whale

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INTRODUCTION

The catch history of the Southern Hemisphere minke whale has been reviewed by Ohsumi, Masaki and Kawamura (1970) and Mitchell (1975).

Japanese pelagic whaling first took minke whales in the Antarctic in the 1963/64 season but the minke whale catch was not of prime importance until 1970/71 as shown in Table 1. Before then the highest catch was 597 in 1967/68.

The first full-scale Japanese minke whale operation was carried out by the small factory ship *Jinyo Maru* in the 1971/72 Antarctic season. Table 2 shows the name and composition of each expedition, the number of operating days and the catch of minke whales since then. The *Jinyo Maru* and *Chiyo Maru* expeditions operated solely for minke whales from 1971/72 to 1974/75. Ordinary whaling expeditions took minke whales as well as other whale species.

The catch quota system was first established for the Southern Hemisphere minke whale in 1972/73, and applied only to pelagic whaling in the Antarctic until 1974/75. Since 1975/76, the total quota has been allocated for both pelagic whaling and coastal whaling in the Southern Hemisphere. The quotas were set for minke whales in the combined Areas in 1974/75, and for each Area since 1975/76.

operations by two Japanese whaling expeditions in 1976/77.

The abundance of minke whales in the Antarctic renders the information usually provided by scouting boats unnecessary and during the period of minke whaling, these boats independently investigate other whaling grounds.

When the expedition arrives on the whaling ground, the manager, after discussing such factors as the weather forecast and the processing condition of the whale carcases with his staff, gives an operation schedule to the catcher boats detailing how and how many whales are to be taken the next day. The minke whales are too abundant for catcher boats to take them at full capacity due to the limited processing capacity of a factory ship, and the number of catchers is therefore regulated during minke whaling. For example, some catcher boats arrive in the Antarctic after the first period of minke whaling and leave before the final period; other catcher boats act as scouting boats during minke whale operations. The manager allows operating catchers to tow whales to the factory ship even during recognised 'catching time' to aid the processing of as fresh carcases as possible, and sometimes allows boats to rest during daylight as it is not difficult to take the required number of whales in a short time. In order to prevent damage to the meat, cold grenades are used to kill the whales and two or more large buoys are used to float the carcases rather than compressed air, as the latter lowers the quality of the meat. Most catcher boats operate towing carcases alongside.

Table 1

Catch of minke whales by Japanese pelagic whaling in the Antarctic until 1977/78

	Area						
Season	I	II	III	IV	V	VI	Total
1963/64	–	–	1	94	1	–	96
1964/65	–	2	–	–	–	–	2
1965/66	–	–	–	–	–	–	–
1966/67	–	–	1	–	–	–	1
1967/68	–	–	–	597	–	–	597
1968/69	–	–	–	41	1	–	42
1969/70	–	–	–	–	–	–	–
1970/71	–	–	4	–	–	–	4
1971/72	–	–	354	2,659	–	–	3,013
1972/73	–	–	–	2,092	–	–	2,092
1973/74	–	163	1,494	2,043	–	13	3,713
1974/75	–	800	1,359	841	500	–	3,500
1975/76	577	405	1,021	435	420	159	3,017
1976/77	456	–	1,385	950	1,010	149	3,950
1977/78	–	–	1,012	481	668	239	2,400

OPERATIONS

The pelagic whaling grounds for the Southern Hemisphere minke whale are usually found in the waters south of 60°S, many days sailing from the whaling grounds for sei and sperm whales. Since the introduction of the Area quota system, the time taken in travelling between the whaling grounds has been increasing. Fig. 1 shows an example of

MEASUREMENT OF FISHING EFFORT

We have collected the data on operation hours for the minke whale fishery in the Antarctic since the beginning of full-scale exploitation in 1971/72, because in order to control

Table 2

Japanese whaling fleets engaged in minke whaling in the Antarctic since 1971/72

Season	Factory ship	Catcher boats	Operation days	Number caught
1971/72	*Jinyo maru**	4	85	3,013
1972/73	*Chiyo maru**	4	48	2,092
1973/74	*Kyokusei maru*	6	26	800
1973/74	*Chiyo maru**	3	99	2,900
1973/74	*Tonan maru No. 2*	6	12	13
1974/75	*Kyokuyo maru No. 3*	6	21	650
1974/75	*Chiyo maru**	3	86	2,350
1974/75	*Tonan maru No. 2*	6	12	500
1975/76	*Kyokuyo maru No. 3*	6	34	905
1975/76	*Nissin maru No. 3*	7	17	1,207
1975/76	*Tonan maru No. 2*	5	29	905
1976/77	*Nissin maru No. 3*	9	38	2,335
1976/77	*Tonan maru No. 2*	7	30	1,615
1977/78	*Nissin maru No. 3*	7	45	2,400

*taking minke whales only.

the catch, the resting time can be a relatively large proportion of day time as noted above. The catcher's hour's work (CHW) of a catcher boat per day is the time from the start of operations to the end of operations excluding the resting time during the day, and thus includes the time engaged in searching, chasing, handling and towing. It is rare for other whale species to be taken during the minke whaling period, and thus the CHW for minke whales can be regarded as almost pure. As scouting boats operate independently in other whaling grounds during this period, they are excluded in the measurement of fishing effort.

Detailed records of the operation of most catcher boats taking minke whales have been collected for the following items on each day:

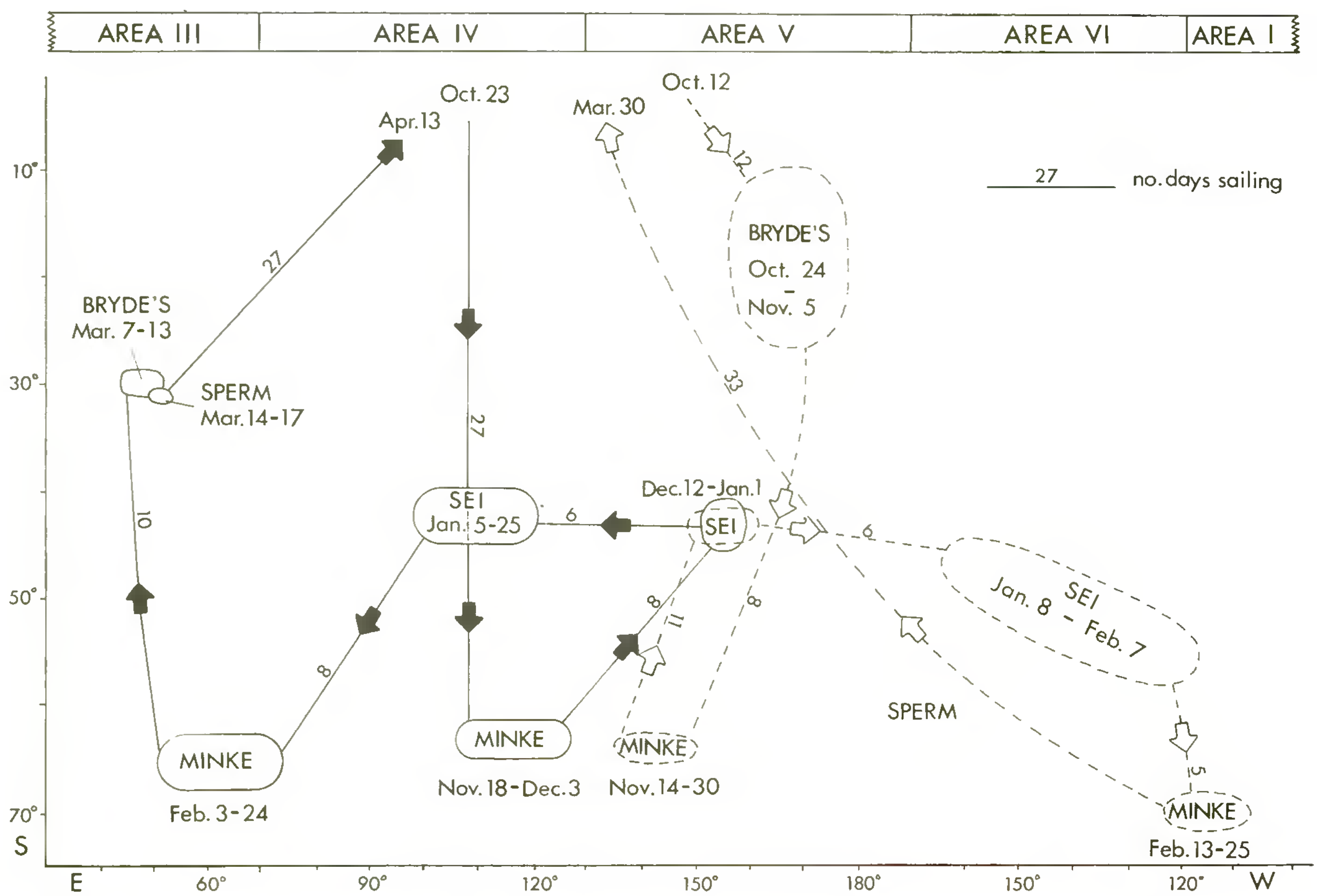

Fig. 1. The Japanese whaling expeditions in the 1976/77 season. Solid line: *Nissin maru No. 3*. Broken line: *Tonan maru No. 2*. Circles: whaling grounds.

1. Date
2. Time of the start of operation
3. Time of cessation of operation
4. Towing time
5. Species and name of boat which found it*
6. School size*
7. Time of finding*
8. Time of hit*
9. Time of end of handling*
10. Time of death*
11. Sighting of whales (species, school number, school size)

*for each whale.

Table 3

Average operation time per catcher boat per day to take minke whales by Japanese fleets in the Antarctic in 1976/77 season

Items	November		December	February			Total
	Middle	Late	Early	Early	Middle	Late	
A. Nissin maru No. 3 fleet							
Area	IV	IV	IV	IV,III	III	III	
Number of boats	4	4	4	3	3	3	4
Total days (CDW)	12	40	8	22	30	12	124
Total catch	68	321	64	212	290	102	1,057
Catch per day	5.67	8.03	8.00	9.64	9.67	8.50	8.52
Time per boat per day (hrs)							
Searching	12.89	9.04	9.24	3.70	2.44	5.58	6.39
Chasing	1.81	2.65	3.95	3.94	3.73	3.73	3.25
Handling	1.50	1.89	2.59	2.11	2.09	1.96	1.99
Towing	2.18	2.22	1.85	3.25	4.42	2.68	2.95
Resting	5.62	8.20	6.37	11.00	11.32	13.95	9.42
Time per whale caught (hrs)							
Searching	2.28	1.13	1.15	0.38	0.25	0.66	0.75
Chasing	0.32	0.33	0.49	0.41	0.39	0.44	0.38
Handling	0.26	0.24	0.32	0.22	0.22	0.23	0.23
Towing	0.39	0.28	0.23	0.34	0.46	0.32	0.35
Resting	0.99	1.02	0.80	1.14	1.17	1.64	1.11
Number of whales caught per hour							
Searching	0.44	0.89	0.87	2.61	3.96	1.52	1.33
Chasing	3.13	3.03	2.03	2.45	2.59	2.28	2.62
Handling	3.78	4.25	3.09	4.57	4.63	4.34	4.28
Towing	2.60	3.62	4.32	2.97	2.19	3.17	2.89
Resting	1.01	0.98	1.26	0.88	0.85	0.61	0.90
Operation (CHW)	0.31	0.51	0.45	0.74	0.76	0.85	0.58
B. Tonan maru No. 2 fleet							
Area	V	V			I	I, VI	
Number of boats	7	7			6	6	7
Total days (CDW)	49	70			48	30	197
Total catch	296	704			371	234	1,605
Catch per day	6.04	10.06			7.73	7.80	8.15
Time per boat per day (hrs)							
Searching	8.72	3.95			6.00	6.59	6.04
Chasing	2.76	3.59			3.68	3.23	3.35
Handling	2.34	3.17			2.35	2.57	2.67
Towing	2.10	4.15			3.55	3.70	3.43
Resting	8.08	9.14			8.42	7.91	8.52
Time per whale caught (hrs)							
Searching	1.44	0.39			0.78	0.84	0.74
Chasing	0.46	0.36			0.48	0.41	0.41
Handling	0.39	0.32			0.30	0.33	0.33
Towing	0.35	0.41			0.46	0.47	0.42
Resting	1.34	0.91			1.09	1.01	1.05
Number of whales caught per hour							
Searching	0.69	2.54			1.29	1.18	1.35
Chasing	2.19	2.80			2.10	2.41	2.43
Handling	2.58	3.17			3.29	3.04	3.05
Towing	2.88	2.42			2.18	2.11	2.38
Resting	0.75	1.10			0.92	0.99	0.96
Operation (CHW)	0.38	0.68			0.50	0.48	0.53

The chasing time is the period between the time a whale is found and the time it is hit, and the handling time is the period between the time it is hit and the time handling ceases. The period between the start of operations or the end of handling and the time of finding is the searching time. The sum of these times gives the total operation time per day.

Table 3 gives examples of the duration of each operational process for catcher boats taking minke whales from two expeditions during the 1976/77 Antarctic season.

The searching time per whale varies greatly by 10-day period (decade). It is long when few whales are caught and short when many whales are caught in a day. Therefore, it is natural to consider that the number of whales caught per unit of searching time is largely related to the density or availability of whales, as examined by Ohsumi (1979) for the North Pacific sperm whale.

The chasing, handling and towing times per whale are mostly constant although they vary somewhat by expedition and by decade. This means that these kinds of operational processes are not concerned with the density of whales, but with the number of whales caught. A similar examination has been made by Ohsumi (1979), although he estimated that the towing time may be somewhat related to the density of whales in the case of the sperm whale. For the Antarctic minke whale, the towing time per whale was almost constant. This means that the minke whale whaling ground is localised around the factory ship, and that separation of the whaling ground from the factory ship does not occur.

Resting time is concerned with length of daylight, if the catching operation is not regulated, as whaling is impossible at night (apart from towing or streaming). Thus, resting time is directly related to the position of the whaling ground and the season in such a case. Resting time is also concerned with the condition and processing capacity of an expedition. This factor is especially important in minke whaling. As shown in Table 3 there is a large variation in the resting time and it is long on the days when many whales were caught, as it was used as a method of regulating the catch. However, it is not as proportional as chasing, handling and towing times. Ohsumi (1979) pointed out that the resting time has become longer in association with the improvement of labour conditions for the crews.

There are three kinds of indicator of fishing effort in whaling. The traditional one is CDW, and Japan has collected CHW for the minke whale. The latest is searching time as suggested by Ohsumi (1979). They include the following operational processes:

$$\text{CDW} = S + C + H + T + R$$
$$\text{CHW} = S + C + H + T$$
$$\text{CSW} = S$$

where, S is searching time, C is chasing time, H is handling time, T is towing time, R is resting time and CSW is catcher's searching hour's work.

The definition of fishing effort is a problem. It may mean the total operation of a fishing vessel and CDW includes all the operational processes. However, if the object of measuring the fishing effort is to calculate catch per unit of effort in order to obtain an estimate of the density of a population, then CDW and CHW may include much wasted time, compared with CSW. Ideally the CPUEs calculated by means of these three kinds of fishing effort would be compared with the real density of the population, but there is no material which represents the real density of population.

Table 4 shows the CPUEs calculated for these three kinds of fishing effort for the minke whales in Area IV. The patterns of yearly fluctuation are similar, although they are somewhat different in detail.

CSW is used as fishing effort in this paper. There are no data on the searching time in some expeditions and in some years. In such cases the average times of C + H + T per whale were calculated from the detailed operation times which were recorded. If such data were available for the same expedition in the same year, they were used for the estimation of CSW for that expedition. If only CHW was available for an expedition, the average value of C + H + T of the expedition in a nearby year was used to estimate CSW. With a given value of C + H + T and catch for each day:

$$\text{CSW} = \text{CHW} - n\,(C + H + T)$$

where, n is the number of whales caught in a day, and C + H + T is the average time spent chasing, handling and towing per whale.

Table 4

Comparison of yearly change in CPUE for the three kinds of fishing effort from the minke whales caught in Area IV

Year	Raw CDW	Raw CHW	Raw CSW
1971/72	9.22	0.945	1.76
1972/73	11.55	0.943	1.76
1973/74	7.43	0.555	0.87
1974/75	5.79	0.400	0.60
1975/76	10.88	0.733	1.50
1976/77	9.49	0.508	0.83
1977/78	10.65	0.627	1.75

CATCH EFFICIENCY

Size of catcher boat

It is important to use catch and effort data for operating catcher boats which belonged to the same expedition in the same year to estimate catch efficiency, because operating conditions differ by expedition and by year.

Table 5 shows the correlation coefficient and two kinds of coefficient for the relationship between tonnage and CPUE for each catcher boat in the same expedition and the same year. There were only three or four operating catcher boats in the *Jinyo Maru* and *Chiyo Maru* expeditions, and these data were excluded as there were not enough boats to examine the relationship. CPUE was calculated as the total number of minke whales caught per total raw CHW for each boat during minke whaling.

Among the eight cases, three have minus values for the correlation coefficient: the overall range is from –0.554 to +0.434 with an average of –0.015. Considering the small sample size, it may be concluded that there is no correlation between tonnage and catch efficiency for minke whales. According to the information from crews of catcher boats, larger boats are rather less efficient for minke whaling.

Asdic

All catcher boats which engaged in minke whaling were equipped with Asdic, and therefore there is no need to consider the yearly change in efficiency due to changing ratios of boats with Asdic. I discussed with some catcher boat crews the use of Asdic in minke whaling. The following information was obtained from the discussions.

It is generally more efficient to chase a minke whale slowly and quietly, because minke whales are apt to escape quickly and to swim in a complex pattern when chased by a catcher boat at high speed. If Asdic is used for chasing a

Table 5

Relationship between tonnage and CPUE based on raw CHW for minke whaling in the Antarctic

Year	Expedition	Number of boats	Range of tonnage	Correlation coefficient	a	b
1973/74	*Kyokusei*	6	618.6–701.1	–0.3994	0.509	0.740
1974/75	*Tonan No. 2*	6	752.8–917.0	–0.5539	0.252	0.747
1974/75	*Kyokuyo No. 3*	6	618.6–738.0	0.2490	0.657	0.129
1975/76	*Kyokuyo No. 3*	6	618.6–812.1	0.2225	2.980	–1.715
1975/76	*Tonan No. 2*	5	737.8–917.0	–0.3055	–0.136	–0.531
1975/76	*Nissin No. 3*	7	636.2–758.3	0.0610	0.711	0.607
1976/77	*Tonan No. 2*	7	737.8–917.0	0.4340	1.424	–0.282
1976/77	*Nissin No. 3*	9	696.0–812.1	0.1729	0.411	0.196

CPUE = a T/1000 + b   T = Tonnage

minke whale: it swims faster and in a very complex way at the water surface; a whale school divides; and minke whales often escape into pack ice. Therefore as a rule Asdic is not used for chasing minke whales as it increases the chasing time. However, Asdic is used when a single minke whale dives for a long time in water with bad transparency. It is not used for a school even in such conditions in order to prevent the division of the school. Asdic is used in minke whaling to find the whale by driving it to the water surface by the stimulation of the sonic wave produced by the Asdic. Another reason not to use Asdic in minke whaling is that the drifting pack-ice blocks damage the protruding Asdic apparatus when used in the minke whaling ground near the pack-ice edge.

EFFECT OF WEATHER CONDITIONS

Among weather and sea conditions the wind force and visibility have been recognised as affecting the whaling operation.

Fig. 2 shows the relationship between visibility and wind force in the minke whaling period from the 1971/72 to 1976/77 Antarctic seasons. It can be estimated from this figure that there is no relationship between visibility and wind force, and therefore it is necessary to examine both factors independently for the correction of fishing effort with weather conditions.

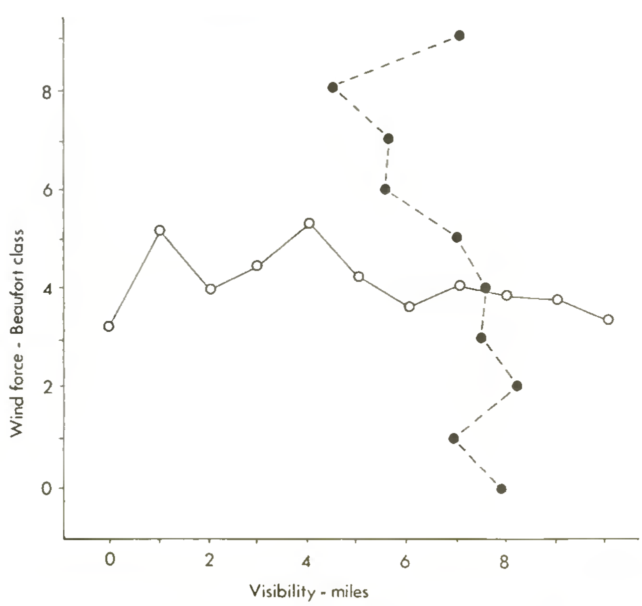

Fig. 2. Relationship between wind force and visibility. ○: average wind force at each visibility, •: vice-versa.

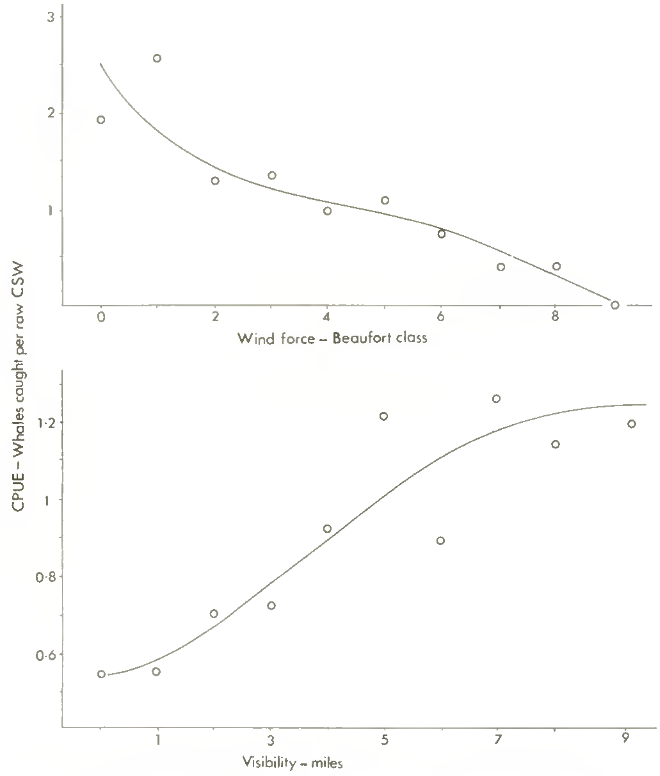

Fig. 3. Relationship between wind force or visibility and CPUE based on raw CSW.

Wind force

Catch and raw CSW data were summed and the average CPUE was calculated for each wind force class. CPUE decreases gradually with the increment of wind force (Fig. 3a). This means that the catch efficiency decreases with an increase in wind force. Table 6a shows the efficiency coefficient for each wind force class estimated from this figure.

Visibility

The relationship between visibility and CPUE was examined in the same manner as noted in the previous section. It was found that catch efficiency increases with an increase in visibility (Fig. 3b). Table 6b shows the efficiency coefficient in each visibility class for the correction of fishing effort with visibility.

Weather-corrected CSW

The raw CSW of operating catcher boats for each day was corrected using the records of wind force and visibility at

Table 6a

Correction factor of wind force in each Beaufort class

Class	0	1	2	3	4	5	6	7	8	9
Factor	2.49	1.82	1.44	1.21	1.07	0.94	0.77	0.54	0.30	0.00

Table 6b

Correction factor of visibility in each mile class

Miles	0	1	2	3	4	5	6	7	8	9
Factor	0.54	0.57	0.67	0.78	0.89	1.01	1.11	1.18	1.22	1.25

the noon position of the mother ship for each expedition in each year:

Weather-corrected CSW = w x v x raw CSW

where, w is correction coefficient of wind force as shown in Table 6a, and v is that of visibility as shown in Table 6b.

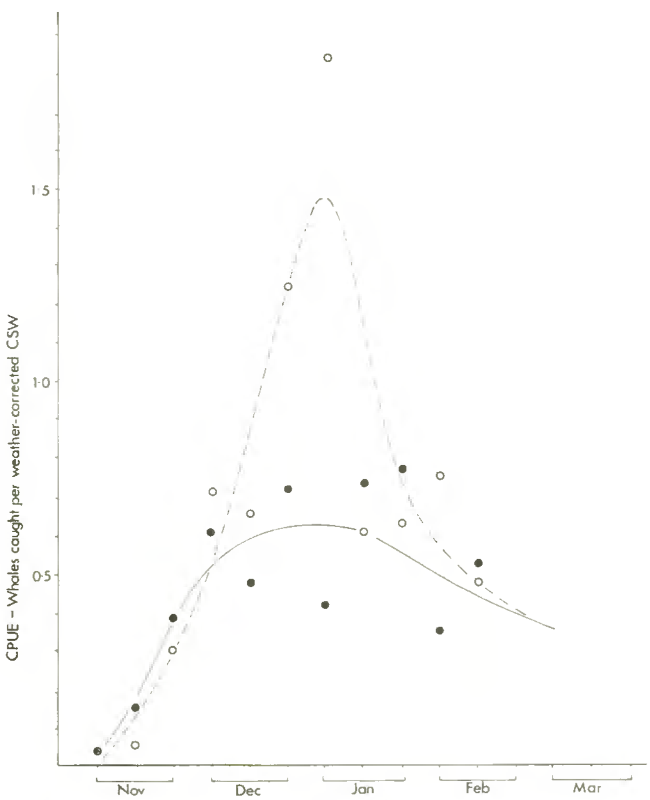

Fig. 4. Seasonal change in CPUE based on weather corrected CSW in Area IV: •—• males, o---o females.

EFFECT OF WHALING SEASON

As whaling is not carried out at the same time every year, it is necessary to consider the effect of season, if the density of whales or their availability changes with season in the whaling ground. CPUEs of male and female minke whales were calculated for each month and decade using the catch and weather-corrected CSW. Fig. 4 shows the result in Area IV.

The minke whaling ground begins to form from the beginning of November in the Antarctic. Males arrive earlier than the females on the Antarctic whaling grounds. The density of female minke whales increases rapidly, and the density becomes higher than that of males after the first decade of December. The density of both sexes reaches a maximum in the first decade of January and the density of females decreases rapidly after then. By contrast, the density of males does not decrease as rapidly. Considering the large seasonal changes in density for the two sexes, different parameter values for each sex should be used when correcting for whaling season. The parameters which were used in this paper are shown in Table 7.

Weather and season corrected CSW is calculated for each decade in each expedition in each year from the following formula:

Corrected CSW = s x weather corrected CSW

where, s is seasonal correction factor as shown in Table 7. The results are shown in Table 8 by sex and year for the operation in each Area.

YEARLY CHANGE IN CPUE

Table 8 shows the catch, corrected CSW and CPUE of the minke whales caught in the Antarctic by Japanese expeditions from 1971/72 to 1977/78. Yearly change in CPUE is shown in Fig. 5. The yearly change in CPUE based on raw CDW is also shown in the same figure for comparison with the CPUE based on the corrected CSW.

Table 7

Correction factor of season in each month and decade

Decade	Male	Female	Decade	Male	Female
November, Early	0.02	0.01	January, Middle	0.60	1.13
November, Middle	0.17	0.11	January, Late	0.56	0.74
November, Late	0.38	0.28	February, Early	0.49	0.57
December, Early	0.51	0.51	February, Middle	0.44	0.48
December, Middle	0.58	0.86	February, Late	0.39	0.42
December, Late	0.62	1.23	March, Early	0.34	0.34
January, Early	0.63	1.48			

Area I
Data are only available for two years, and it is difficult to estimate the yearly trend of CPUE. Both types of CPUE are similar.

Area II
There are not enough data to estimate a trend in CPUE. The CPUE of males is constant through three years, but that of females decreased in the 1975/76 season. Both types of CPUE are similar.

Area III
Data are available for six years. Although the CPUE based on raw CDW seems to be constant for both sexes throughout the years, there is an increasing trend in the CPUE based on corrected CSW, especially after 1974/75.

Area IV
The largest and longest data sets are available from this Area. In the case of females, the CPUE based on raw CDW has been constant over the seven years, but the CPUE based on corrected CSW has been increasing in the last three years. The CPUE of males based on raw CDW looks to have a somewhat decreasing tendency, but the CPUE based on corrected CSW has been constant over the seven years.

Area V
Data are available for four years. The CPUE based on corrected CSW fluctuates more than that based on raw CDW. It is difficult to estimate the trend of CPUE in this Area.

Area VI
Data are available for four years, but were limited in 1973/74. There is no clear trend of yearly change in CPUE, although it may seem to have been increasing.

ESTIMATION OF POPULATION DENSITY BY MEANS OF WHALE SIGHTING

Another source of information for the estimation of population density are sightings data. We have been collecting whale sighting data from the scouting boats and operating catcher boats. As the main whaling ground of the minke whale is found in the waters south of 60°S, these data will be examined in this paper.

Whale sighting by scouting boats
A data collection system from scouting boats was established in 1965/66, but data from the waters south of 60°S are relatively sparse because the main objects of Japanese pelagic

Table 8

Catch, effort and CPUE of the minke whales caught by Japanese whaling expeditions

Year	Catch		Corrected CSW		CPUE	
	Males	Females	Males	Females	Males	Females
Area I						
1975/76	338	239	337.5	319.1	1.002	0.749
1976/77	145	311	218.5	238.4	0.663	1.304
1977/78	–	–	–	–	–	–
Area II						
1973/74	25	138	74.3	90.3	0.337	1.528
1974/75	74	726	263.0	343.4	0.281	2.111
1975/76	159	246	424.1	465.8	0.356	0.528
1976/77	–	–	–	–	–	–
1977/78	–	–	–	–	–	–
Area III						
1971/72	170	184	157.7	183.4	1.078	1.003
1972/73	–	–	–	–	–	–
1973/74	320	1,174	837.7	1,488.0	0.366	0.789
1974/75	554	805	976.8	1,612.9	0.567	0.499
1975/76	417	604	185.2	184.7	2.251	3.271
1976/77	445	940	212.9	237.6	2.090	3.956
1977/78	398	614	122.5	132.5	3.249	4.635
Area IV						
1971/72	929	1,728	1,071.5	1,663.9	0.867	1.038
1972/73	1,116	974	729.3	1,115.8	1.530	0.873
1973/74	761	1,282	973.8	1,078.0	0.781	1.189
1974/75	430	410	734.1	599.5	0.586	0.684
1975/76	198	237	151.2	147.2	1.310	1.610
1976/77	518	432	400.6	373.9	1.293	1.155
1977/78	128	353	116.2	150.9	1.103	2.339
Area V						
1974/75	190	310	158.7	138.6	1.197	2.237
1975/76	260	160	234.8	191.4	1.107	0.836
1976/77	515	495	197.1	138.3	2.613	3.579
1977/78	330	338	693.1	840.1	0.476	0.402
Area VI						
1973/74	10	3	29.2	30.3	0.343	0.099
1974/75	–	–	–	–	–	–
1975/76	92	67	324.9	429.4	0.283	0.156
1976/77	51	98	37.1	40.0	1.373	2.450
1977/78	156	83	296.0	254.5	0.527	0.326

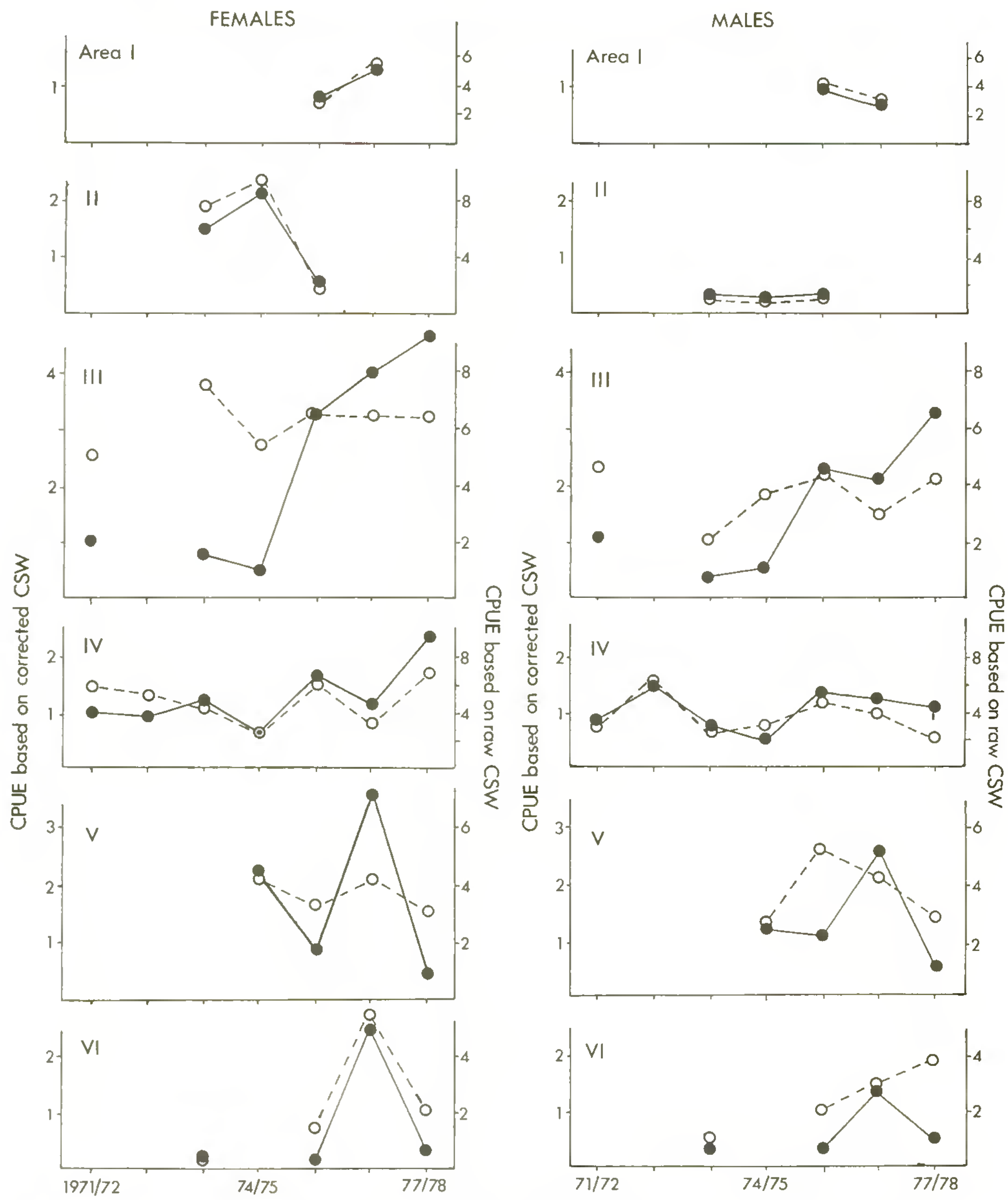

Fig. 5. Yearly change in CPUE calculated from raw CDW and corrected CSW for minke whales caught by Japanese expeditions. Closed circle and solid line: CPUE based on corrected CSW, open circle and broken line: CPUE based on raw CDW.

whaling were sei, fin and sperm whales for which the main whaling grounds are in general in the waters north of 60°S.

Table 9 shows the number of miles steamed and the number of minke whales sighted during the navigation. Although it is desirable to correct this by weather and season, as for searching time, the raw data were used in this paper because of the shortage of time available to examine these effects. The density of the minke whale population is represented as the number of whales sighted per 10,000 miles steamed. It is impossible to separate the whales by sex from whale sighting data.

Fig. 6 shows the distribution of minke whales sighted per mile by scouting boats during years 1967/68–1976/77 in the waters south of 60°S. The density of minke whales is high in Areas II, III and IV, but is low in Areas I, V and VI. However, it is necessary to consider the topography of the pack-ice edge and the Antarctic Convergence. Fig. 6 shows the topography of Antarctica and the pack-ice edge in February and the Antarctic Convergence. It has been shown that the minke whale is most densely distributed near the pack-ice edge and this is located more to the south in Areas I, V and VI than in Areas II, III and IV. There is more open sea in the former Areas than the latter Areas, and therefore the average density is more diluted in the former Areas.

Whale sighting by operating catcher boats

Operating catcher boats have recorded the whales sighted during their operation time. As a catcher boat cannot take all the whales found, the whales found per fishing effort will represent the density of the whale population better than the CPUE. Scouting boats do not always operate in the minke whaling ground as noted previously, whereas the sightings data from operating catcher boats are mainly provided from the minke whaling ground.

Table 10 shows the minke whales sighted, raw CDW and minke whales found per CDW. It may be better to use corrected CSW rather than raw CDW, but this is not available for all the data, because some were obtained on operation days when other whale species were caught besides minke whales, and records of CHW or CSW were not noted on

Table 9
Yearly change in the number of minke whales sighted by scouting boats in the waters south of 60° S

Area	Year	Navigation (miles, A)	Whales sighted (B)	B/A (per 10^4 miles)
I	1973/74	1,216	382	3,141
	1974/75	936	0	0
	1975/76	11,693	341	292
	1976/77	1,314	34	259
	Total	15,159	757	499.3
II	1973/74	2,058	388	1,885
	1974/75	437	55	1,259
	1975/76	2,057	97	472
	1976/77	165	20	259
	Total	4,717	560	1,187.2
III	1971/72	673	13	193
	1972/73	3,135	698	2,226
	1973/74	2,572	2,189	8,511
	1975/76	6,385	2,472	3,872
	1976/77	3,177	317	1,212
	Total	15,942	5,689	3,568.9
IV	1967/68	3,053	391	1,281
	1969/70	1,537	49	319
	1971/72	1,065	171	1,606
	1972/73	2,455	195	794
	1973/74	1,149	44	383
	1974/75	2,988	466	1,560
	1975/76	3,805	420	1,104
	1976/77	7,760	1,474	1,879
	Total	23,812	3,210	1,348.1
V	1967/68	4,191	133	317
	1972/73	10,421	395	379
	1974/75	1,225	78	637
	1976/77	2,545	133	523
	Total	18,382	739	402.0
VI	1967/68	1,340	22	164
	1968/69	4,418	7	16
	1972/73	9,847	294	299
	1973/74	12,093	137	113
	1974/75	4,049	80	198
	1975/76	4,427	171	386
	1976/77	1,247	173	1,387
	Total	37,421	884	236.2

these days. Correction for weather and season was not made because of the short time available for examination.

Comparison of the yearly change in three indices of population density

Three independent minke whale population density indices were available: CPUE, whale sighting by scouting boats, and whale sighting by operating catcher boats. Fig. 7 compares the yearly change in population density which is represented by these three indices. For convenience the CPUE of both sexes of minke whales caught per raw CDW are used here for comparison with other sources in which raw effort data were used.

Area I: Sightings data for four years are available from the records of scouting boats. It is difficult to estimate any trend in density from these data because of the large fluctuations. The whales sighted by operating catcher boats (B) and the CPUE (C) increased from 1975/76 to 1976/77.

Area II: The number of whales sighted by scouting boats (A) shows a decreasing trend over four years. B and C also show a decrease from 1974/75 to 1975/76, but there are insufficient data for a serious examination. The USSR has been operating in this Area, and according to Ohsumi (1978), a remarkable increasing trend in CPUE has been seen in Soviet expeditions.

Area III: Excluding the extremely large figure of A in 1973/74, all data suggest an increasing trend in population density in this Area.

Area IV: Both B and C have been constant, but A shows an increasing trend, which if weather and season corrected effort is used in B and C, may be confirmed.

Area V: A, B and C show an increasing trend.

Area VI: All sources of data show an increasing trend in this Area, especially in the two most recent years.

ESTIMATION OF RECRUITMENT RATE

Table 11 shows the catch of minke whales in the Southern Hemisphere from 1971/72 to 1977/78.

We have seen from the previous sections that there is no evidence to suggest that the Southern Hemisphere minke whales have been decreasing despite the fact that about 50,000 whales have been caught. This phenomenon suggests

Table 10
Yearly change in the number of minke whales sighted by operating catcher boats in the waters south of 60° S

Area	Year	CDW (A)	Whales sighted (B)	B/A
I	1975/76	158	922	5.84
	1976/77	72	3,978	55.25
	Total	230	4,900	21.30
II	1973/74	18	912	50.67
	1974/75	78	3,993	51.19
	1975/76	212	2,979	14.05
	1976/77	–	–	–
	Total	308	7,884	25.60
III	1971/72	36	731	20.30
	1972/73	–	–	–
	1973/74	153	7,619	49.80
	1974/75	150	5,846	38.97
	1975/76	93	5,026	54.04
	1976/77	149	9,765	65.54
	Total	581	28,987	49.87
IV	1971/72	288	8,997	31.24
	1972/73	184	4,798	26.08
	1973/74	273	8,030	29.41
	1974/75	134	2,119	15.81
	1975/76	40	1,276	31.90
	1976/77	131	2,717	20.74
	Total	1,050	27,937	26.61
V	1972/73	42	221	5.26
	1973/74	–	–	–
	1974/75	76	1,310	17.24
	1975/76	55	1,420	25.82
	1976/77	126	3,737	29.66
	Total	299	6,688	22.37
VI	1972/73	56	302	5.39
	1973/74	84	44	0.52
	1974/75	6	0	0.00
	1975/76	58	692	11.93
	1976/77	36	998	27.72
	Total	240	2,036	8.48

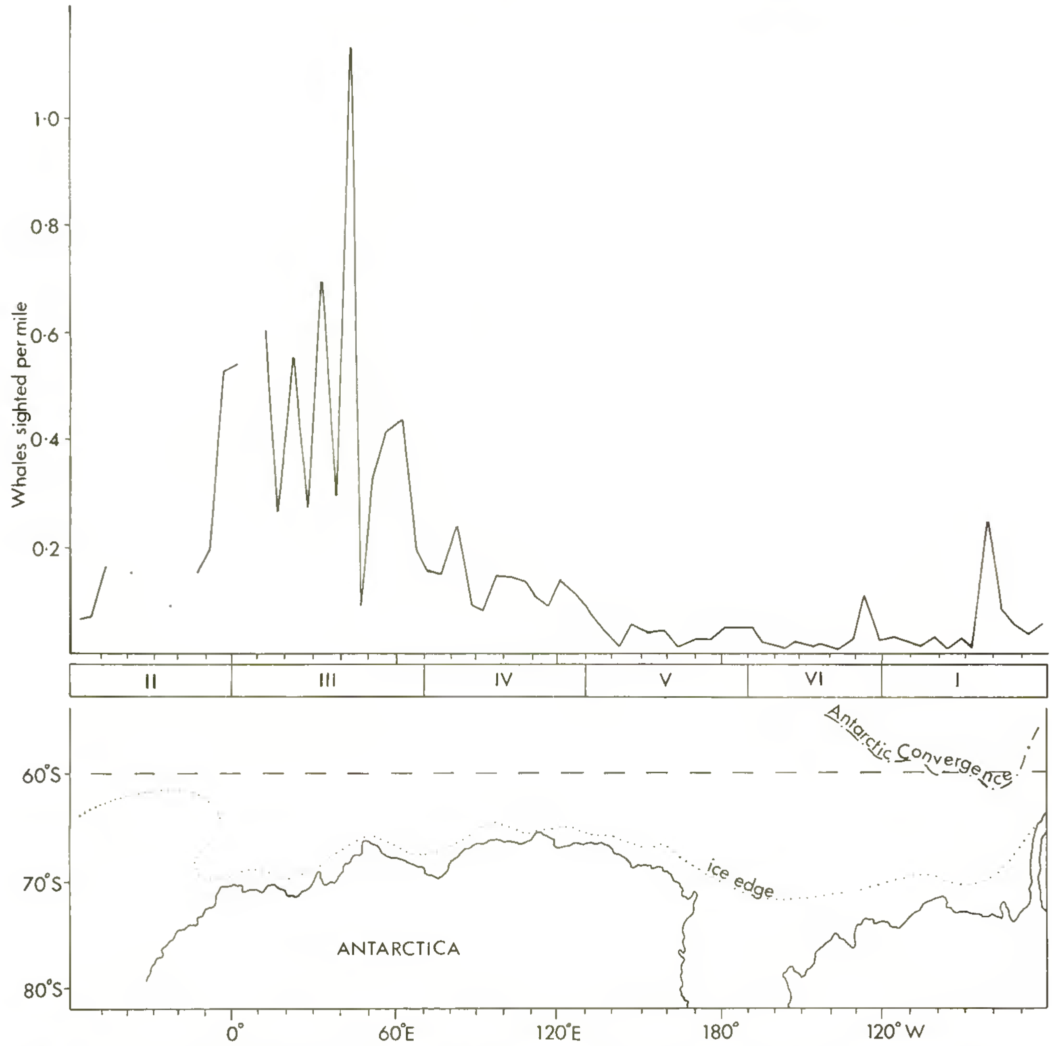

Fig. 6. Longitudinal distribution of minke whales sighted by scouting boat per mile in the waters south of 60° S and topography of Antarctica, pack ice edge in February and the Antarctic Convergence.

two possibilities, that the population size is too large for the catch to affect the indices of density, and that the population has a potential for increasing.

Table 12 shows the total mortality coefficients (Z) calculated from age distributions. The Z value in the total Antarctic is 0.154 in females and 0.144 in males.

Ohsumi (1979) estimates the natural mortality coefficients (M) of the Antarctic minke whale to be 0.094 from his investigation of the interspecies relationships of biological parameters. If this value represents the true value of M, then Z is larger than M. This means that Z includes the population growth coefficient. Masaki (1979) gives evidence which suggests that the age at sexual maturity had decreased prior to full scale exploitation. This in turn suggests that the recruitment rate was increasing before exploitation.

The following equation is considered:

$$Z = M + I \qquad \ldots(1)$$

where, I is population growth coefficient or net recruitment rate. Then

$$I = r - M \qquad \ldots(2)$$

where, r is recruitment rate.

Inserting equation (2) into equation (1),

$$\begin{aligned} Z &= M + (r - M) \\ &= r \end{aligned}$$

This means that the r value is the same as the Z value.

Raw growth curves were constructed from the age determination of minke whales, although they possess a bias arising from the practical difficulties in collecting, preparing and reading earplugs, especially for the younger animals. Ideal age-length keys were made for each sex in each Area from the body length at birth, the age and length at sexual maturity and the age and length at physical maturity using the method of Ohsumi and Masaki (1978). From these ideal age-length keys, the size distributions of the minke whales caught were converted into age distributions using the TAGK programme of Allen (1977a), and the total proportion of recruits in the catch (r_{II}), T (the ratio between the survival rate of the recruited part of the younger year classes and that of older animals) and the average age at recruitment were estimated by use of the age distributions and the CPOP programme of Allen (1977b). The results are shown in Table 13. According to Allen (1966), the T value should be near unity. Therefore reliable values of r_{II} were selected based on T values of 0.75–1.25. The average value of these was calculated for each sex and in each Area, and the average of the averages was then calculated. It is 0.164 in females and 0.140 in the males, values which are close to the Z value obtained in Table 12.

The values of r differ greatly by sex and by Area, probably because of a shortage of data. I use the average of the r values in the total area in this paper (0.159 for females and 0.142 for males). A value of 0.151 is used for the examination of both sexes combined.

Table 11

Catch of minke whales in the Southern Hemisphere

Year	Area I		Area II		Area III		Area IV		Area V		Area VI		Total	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
1971/72	–	–	330	570	306	252	929	1,728	–	–	–	–	1,565	2,550
1972/73	–	–	233	469	583	739	2,410	2,146	–	–	–	–	3,226	3,354
1973/74	764	493	242	584	516	1,307	1,761	2,808	–	–	10	3	3,293	5,243
1974/75	931	939	326	1,241	623	851	907	1,323	259	475	–	–	3,046	4,829
1975/76	569	476	755	1,447	876	1,388	429	452	317	314	92	67	3,038	4,144
1976/77	294	649	512	1,127	759	2,117	917	683	597	870	51	98	3,132	5,544
1977/78	147	316	110*	252*	531	1,270	251	712	357	527	325	202	1,721*	3,279*

*Excluding catches in Brazil.

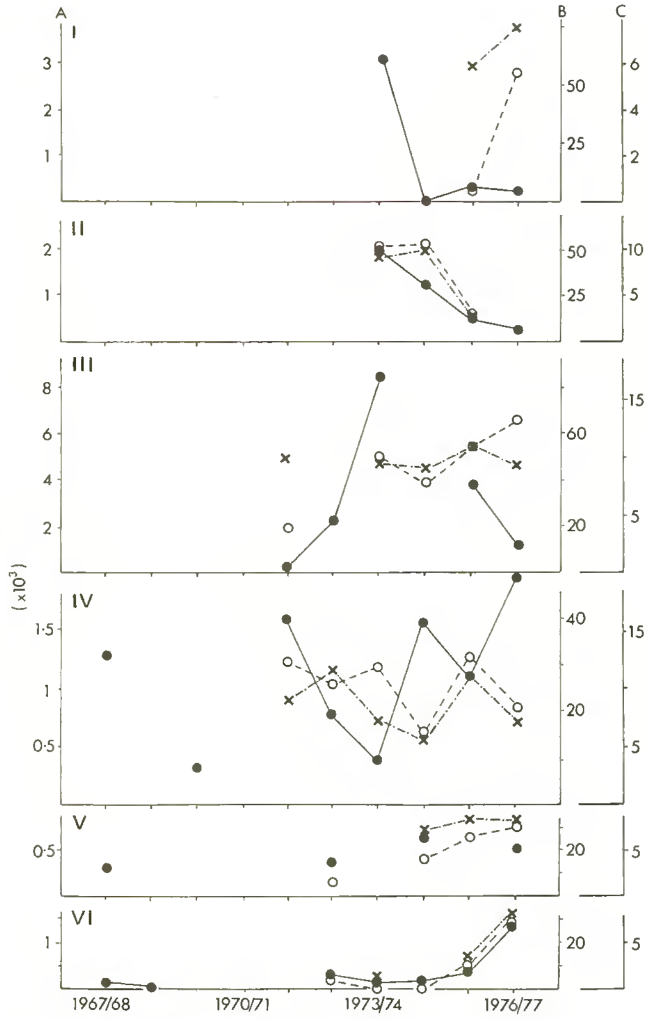

Fig. 7. Comparison of yearly change in population density of minke whales in waters south of 60°S.
A ●—● minke whales sighted per 10,000 miles by scouting boats.
B ○---○ minke whales sighted per 10,000 miles steamed by scouting boats.
C X---X minke whales caught per day.

Table 12

Estimation of total mortality coefficients by means of age distributions obtained from the whales caught in the years, 1971/72–1976/77

Area	Females		Males	
	Z	c	Z	c
I	0.101	–0.868	0.103	–0.933
II	0.151	–0.939	0.107	–0.843
III	0.139	–0.947	0.115	–0.957
IV	0.135	–0.976	0.138	–0.975
V	0.139	–0.957	0.112	–0.895
VI	0.064	–0.668	0.084	–0.878
Total	0.154	–0.981	0.144	–0.983

ESTIMATION OF POPULATION SIZES IN OTHER AREAS

Table 14 shows the average values of indices of population density from whale sightings by scouting and operating catcher boats and CPUEs of both sexes based on corrected CSW. Although there are large Area differences in the

Table 13

Estimation of recruitment rate using the CPØP programme. Average: Average of values with an asterisk.

Area	Year	Females			Males		
		r	T	x_r	r	T	x_r
I	1974/75	−0.558	−0.093	4.00	−0.271	−0.100	3.78
	1975/76	0.154	0.963*	6.25	0.111	0.871*	7.23
	1976/77	0.080	0.310	0.00	0.078	−0.022	0.00
	Average	0.154	0.963	6.25	0.111	0.871	7.23
II	1974/75	0.199	1.107*	7.74	0.127	1.138*	7.64
	1975/76	0.072	0.901*	4.54	−0.074	0.575	5.49
	1976/77	−0.185	0.385	2.78	−0.160	0.149	3.31
	Average	0.136	1.004	6.14	0.127	1.138	7.64
III	1972/73	0.278	1.087*	6.60	0.244	1.090*	7.66
	1973/74	−0.151	0.010	4.68	0.045	1.038*	4.14
	1974/75	0.236	1.088*	6.69	0.161	1.058*	7.63
	1975/76	−0.112	0.545	4.61	−0.073	0.149	3.31
	1976/77	0.017	0.967*	3.88	−0.023	0.669	5.16
	Average	0.177	1.047	5.72	0.150	1.062	6.48
IV	1972/73	0.367	1.089*	5.64	0.312	1.130*	6.53
	1973/74	−0.032	0.653	2.80	−0.027	0.702	2.46
	1974/75	0.192	1.204*	7.48	0.028	0.940	4.92
	1975/76	−0.186	0.406	5.81	0.012	0.969*	5.69
	1976/77	0.146	0.967*	5.72	0.086	1.062*	8.51
	Average	0.235	1.128	6.92	0.138	1.026	6.41
V	1975/76	0.201	1.096*	6.52	0.067	0.951*	7.26
	1976/77	0.032	0.956*	3.79	0.141	1.193*	7.52
	Average	0.117	1.026	5.16	0.104	1.072	7.39
VI	1976/77	−0.027	0.690	6.03	0.207	1.012*	7.70
	Average				0.207	1.012	7.70
Average of average		0.164			0.140		

r: Total proportion of recruits in catch
T: Estimated annual T
x_r: Average age at recruitment
*: Reliable value of T

indices of density from whale sightings, the CPUEs are not so different by Area apart from both sexes in Area VI and males in Area II. As noted previously, a catcher boat cannot take all the whales found in searching, and thus the CPUE in the waters where large schools are found is relatively small compared to that in waters where a single animal or small schools are distributed, and therefore the CPUE values become similar wherever the whales are abundant. This means that the CPUE is not suitable for the comparison of population density among Areas.

The average of the two indices of population density obtained by whale sightings is shown for each Area, and they are used for the extrapolation of population sizes.

In order to convert the population density index into the index of abundance the surface area of each statistical Area is needed. As noted, the surface area of waters south of 60°S should be used because the density is lower in the larger Areas. The surface area was estimated for each Area, allowing for the pack-ice edge (Table 14).

The population size in each Area can be estimated from that in Area IV by the following equation:

$$N_g = \frac{N_{IV}}{D_{IV} A_{IV}} \times D_g \times A_g$$

where, N is population size, g is Area, D is index of population density and A is size of Area. The results are shown in Table 14.

ESTIMATION OF POPULATION SIZE IN AREA IV

The largest and longest series of data are available from Area IV and it is therefore reasonable to assume that the most reliable population assessment will be for this Area and that this estimated population size can be used as the standard for extrapolation to other Areas.

The yearly change in CPUE based on corrected CSW shows that the male population in Area IV has been constant. If this is true, the following equation will hold:

$$N = (N - \overline{C})\, e^{-M} + (1 - e^{-r})\, N \qquad \ldots (3)$$

where, N is the population size, $\overline{C}$ is average annual catch, and r is r_{II}.

Using the average catch of males from 1971/72 to 1976/77 (1,226), M as 0.094 and r as 0.142, N is calculated to be 26,400. The CPUE based on corrected CSW for females has been increasing somewhat, especially in recent years, but if it is regarded as constant, the female population size can be estimated as 24,200 by putting M (0.094), r (0.159) and $\overline{C}$ (1,523) into equation (3). This is lower than the estimated population size of males. The estimated female population size is lower than the actual one, because it was regarded as constant, although the CPUE has been increasing.

Thus an exploitable population size of both sexes in Area IV of 52,800 (26,400 x 2) can be reasonably estimated.

Using this method the population size of the Southern Hemisphere minke whale is found to be larger than pre-

Table 14

Estimation of population density, population size and replacement yield in each Area.

Items	Area I	II	III	IV	V	VI	Total
Average density							
Sighting by							
Scouting[a)]	499	1,187	3,569	1,348	402	236	
Operating[b)]	21.30	36.17	49.87	26.61	22.37	8.48	
CPUE[c)]							
Males	0.869	0.339	0.924	0.977	0.981	0.450	
Females	0.987	1.234	1.126	1.056	0.996	0.233	
Relative density							
Sighting by							
Scouting	0.37	0.88	2.65	1.00	0.30	0.18	
Operating	0.80	1.36	1.87	1.00	0.84	0.32	
CPUE							
Males	0.89	0.35	0.95	1.00	1.00	0.46	
Females	0.93	1.17	1.07	1.00	0.94	0.32	
Average density[d)]	0.59	1.12	2.26	1.00	0.57	0.25	
Size of Area[e)]	860.5	621.5	837.8	546.0	791.2	859.9	
Population size[f)]	49.1	67.3	183.1	52.8	43.6	20.8	416.7
RY	2,700	3,700	10,070	2,900	2,400	1,140	22,920

a): Whales sighted per 10,000 miles
b): Whales sighted per day
c): Whales caught per corrected CSW
d): Average relative density (data from scouting and catcher boats)
e): Thousand square miles
f): Thousand whales

viously estimated, with a total population size in recent years of 416,700.

ESTIMATION OF REPLACEMENT YIELD

The replacement yield (RY) is determined as the catch which maintains the population size in the next year at the same level as in the first year. Therefore:

$$N = (N - RY)\, e^{-M} + (1 - e^{-r})\, N$$

$$RY = (e^{-M} - e^{-r})\, N / e^{-M} \qquad \ldots (4)$$

Putting the values of M (0.094) and r (0.151) into equation (4), RY is calculated to be 5.5% of the population size. The RY in each Area is then calculated from this and the population size as shown in Table 14.

The RY in Area IV is estimated to be 2,900 and the average annual catch is 2,749 in this Area, which although lower than the RY is similar to it. The index of population density has been increasing somewhat, especially in the most recent years when the annual catches were much less than the estimated RY. In Area III the estimated RY (10,070) greatly exceeds the annual catches. Although the annual catch has been increasing rapidly, CPUE has been increasing remarkably in this Area. These phenomena confirm that the estimated values of RY are reasonable.

ESTIMATION OF CHANGE IN CARRYING CAPACITY

Gambell (1975) estimated the yearly change in the biomass of baleen whales in the Antarctic. Fig. 8 shows the total biomass of the blue, fin and humpback whales which are considered to have close inter-relationships with the minke whale. The biomass of these species decreased greatly until the middle of the 1960s and then started to recover. The catch of these whales species will be re-opened when each stock recovers to the population level at which the IWC will permit the catch, and each stock will maintain its optimum population level under proper management by the IWC. The broken line in the upper figure of Fig. 8 shows the assumed future population trend.

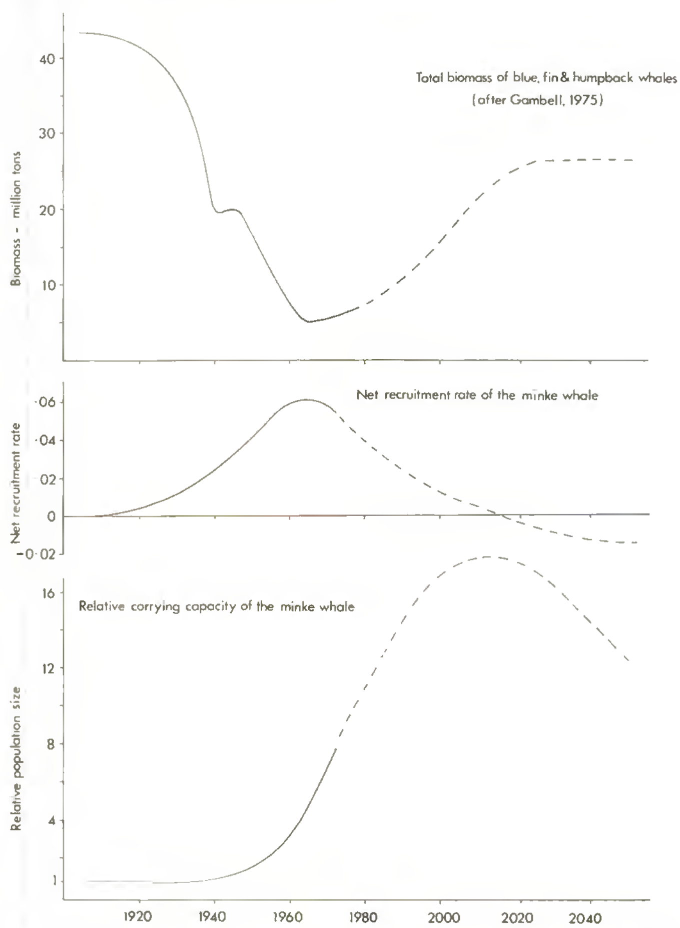

Fig. 8. Estimation of population growth of the Southern Hemisphere minke whale associated with the change in biomass of blue, fin and humpback whales.

The net recruitment rate of minke whales is considered to have changed and to have been increasing with the reduction of the biomass of the blue, fin and humpback whales. It is also thought that the net recruitment rate started to decrease when the other baleen whales began to recover. It is natural to consider the minke whale weaker than the other baleen whales in the interaction, and there is a possibility that the new recruitment rate of the minke whales will become a minus value when the other baleen whales recover to a certain population level. Fig. 8b shows an assumed yearly change in the net recruitment rate of the minke whale. It would be zero at the beginning of this century, gradually increase until the middle of the 1960s, and reach 0.06 considering the recent actual value (0.055). After this it would start to decrease, and it may become a negative value after the mid-1990s.

The yearly change in population size can be calculated if the original population size and the net recruitment rate in each year are available, using the following equation:

$$N_{t+1} = (1 + p) N_t$$

where, p is the net recruitment rate, N is the population size and t is a given year. Fig. 8c shows the yearly change in population size under the assumption that the original population size is one, and the net recruitment rate changes yearly as shown in Fig. 8b.

If this is true, the original population size of the Southern Hemisphere minke whale at the beginning of this century would be about one-eighth of that at the beginning of the 1970s. As the population size in recent years was estimated to be 416,700, the original population size then becomes 52,100. Thus the present situation of the Southern minke whale must be regarded as one of over-population. To ensure the recovery of the populations of blue, fin and humpback whales, it will be necessary to reduce the minke whale population, and for this purpose the catch quota of the minke whale should be larger than the present RY.

The carrying capacity will continue to rise until the net recruitment rate reaches zero, but after that it must start to decrease, if the net recruitment rate becomes negative associated with the populations of other baleen whales recovering to a certain level. Thus, the carrying capacity of the Southern Hemisphere minke whale will not be saturated in future until it reaches a level which will be above but near the original carrying capacity. Therefore, the setting of a quota based on the future carrying capacity would be unrealistic in the management of the minke whale population.

A conservative management strategy would be set to the catch quota at the presently estimated RY for several years, and monitor any population changes during the period. There will be no danger to the population, as rational management suggests it should be reduced for the benefit of the baleen whales as a whole.

The scientific management of the minke whale population should maintain the highest net productivity by stimulating reproduction through continuing exploitation of the population.

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S15

External and Biochemical Characters as an Approach to Stock Identification for the Antarctic Minke Whale

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ABSTRACT

Three external characters: (1) the relationship between the end of the ventral grooves and the umbilicus, (2) flipper coloration, and (3) the proportion of the black band in the baleen plate, and three biochemical characters: (1) 6-phosphogluconate dehydrogenase (6-PGD), (2) sorbitol dehydrogenase (SDH), and (3) glutamate oxaloacetate aminotransferase (GOT), were examined to identify the stock units in the Antarctic minke whales.

The present data on three external characters were inadequate for stock identification since they showed no coincidental results among the observers which were considered to arise from variation in their classification criteria.

Genetic control and molecular conformation on three enzymatic proteins were demonstrated by horizontal starch gel electrophoresis and four genetically isolated stocks were recognized: (1) the Atlantic and the western Indian Ocean, (2) the eastern Indian Ocean, (3) the western Pacific, and (4) the eastern Pacific.

INTRODUCTION

Since the beginning of pelagic whaling for the Antarctic minke whale by Japanese expeditions, biological investigation into many items including observations on external characters and sampling of biochemical characters (Ohsumi, 1972) has been carried out. Three particular characters of the minke whale: (1) the relationship between the end of the ventral grooves and umbilicus, (2) flipper coloration, and (3) the proportion of the black band in the baleen plate, were observed and recorded systematically and sufficient data are now available for analysis.

Biochemical studies on whale stock identification have been proceeding in Japan, and out of forty enzymes, eight polymorphic enzymes have been selected which are considered useful for this kind of investigation (Wada, 1976). In 1977, mass screening of enzyme types was performed using three enzymes, 6-phosphogluconate dehydrogenase (6-PGD), sorbitol dehydrogenase (SDH) and glutamate oxaloacetate aminotransferase (GOT).

This paper deals with the results of stock identification analysis by means of external and biochemical characters.

EXTERNAL CHARACTERS

1. Materials and methods

The external characters of minke whales have been systematically recorded for almost all whales caught by Japanese expeditions since the 1971/72 whaling season. (Observations were not made on 57 whales for character (1), 7 for character (2) and 113 for character (3) (Figs 1–3). The recording of each item was made by observers on board according to the following standard (Figs 4–6).

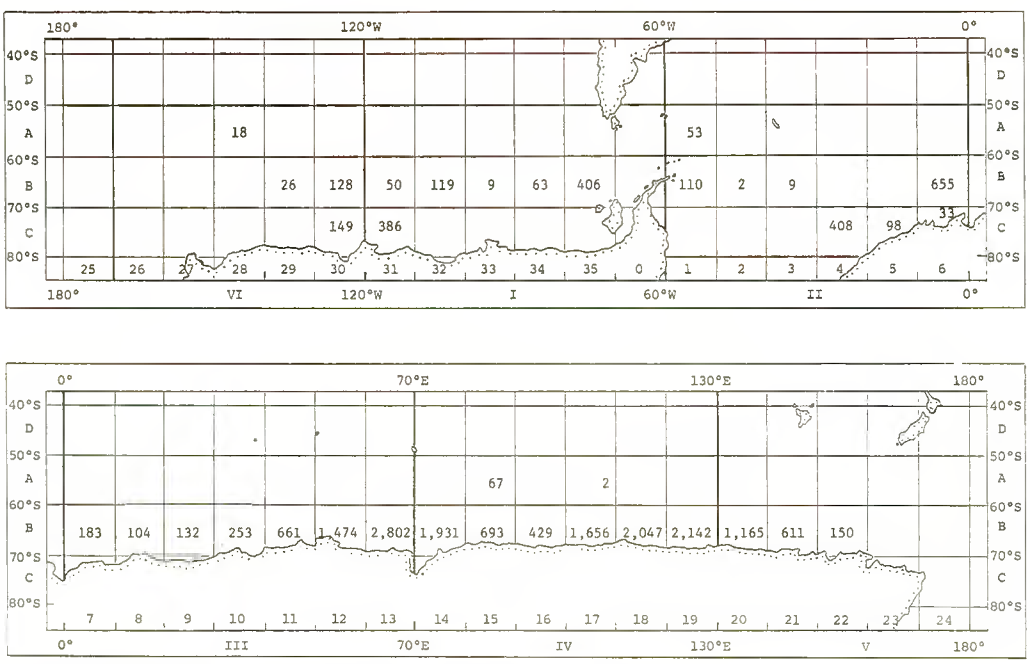

Fig. 1. Collection localities and the number of whales observed on item 1.

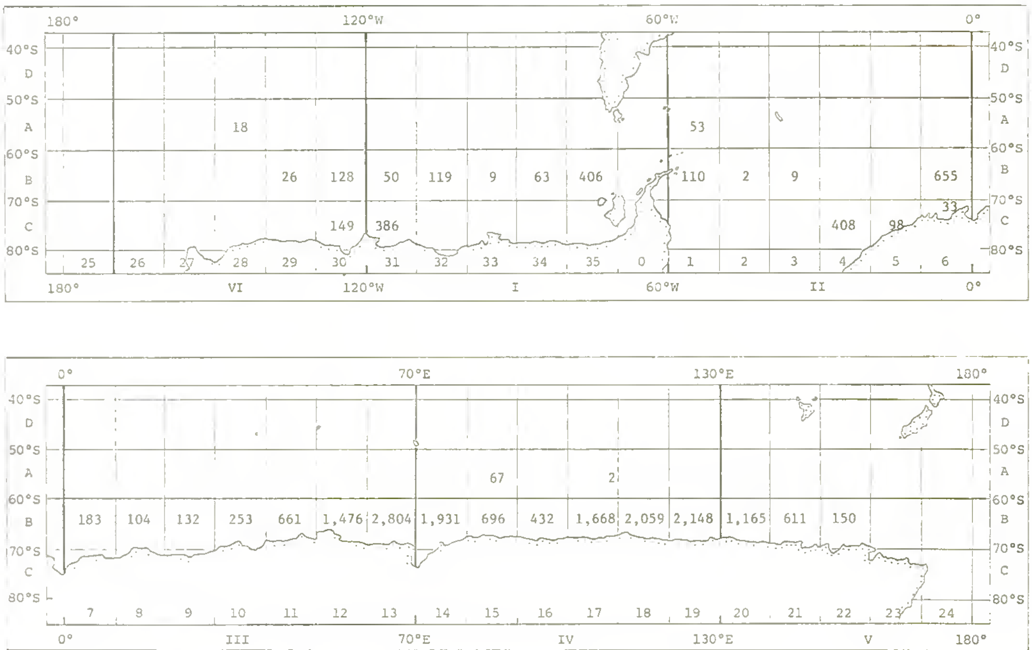

Fig. 2. Collection localities and the number of whales observed on item 2.

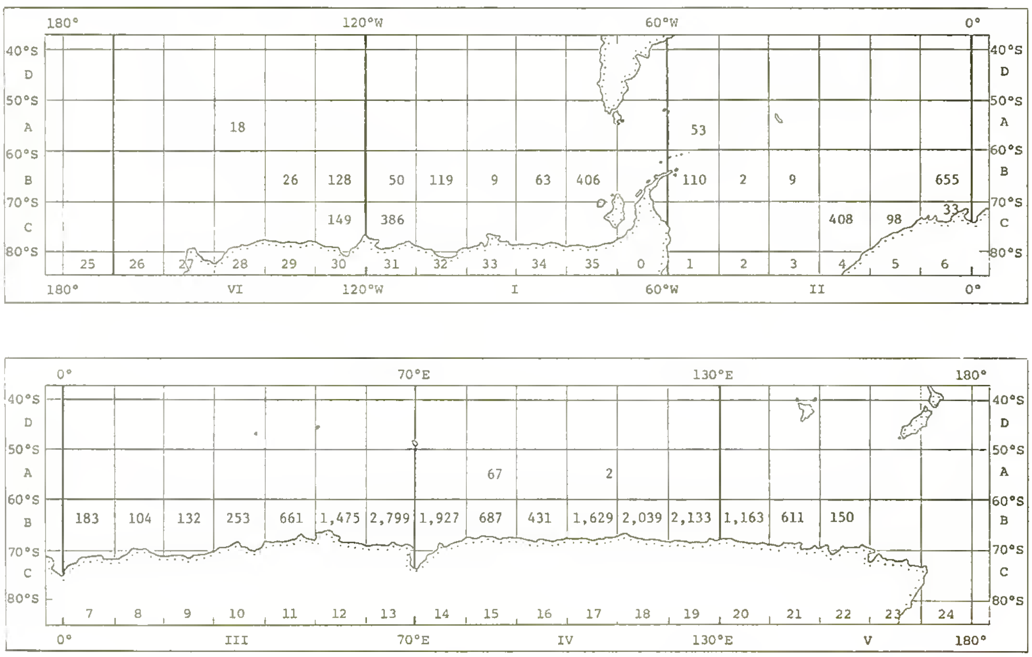

Fig. 3. Collection localities and the number of whales observed on item 3.

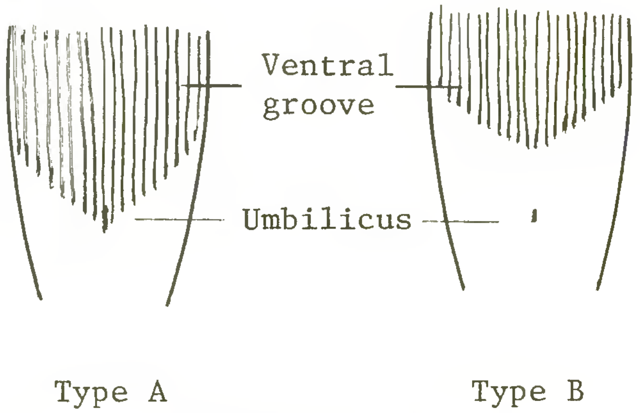

Fig. 4. Two types of relationship between the end of the ventral grooves and the umbilicus.

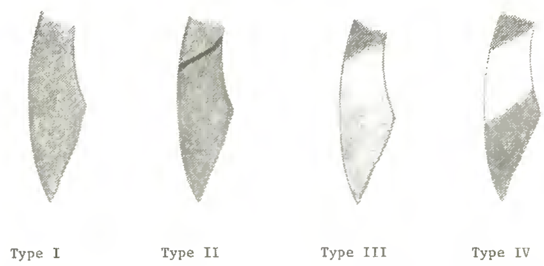

Fig. 5. Four types of flipper coloration.

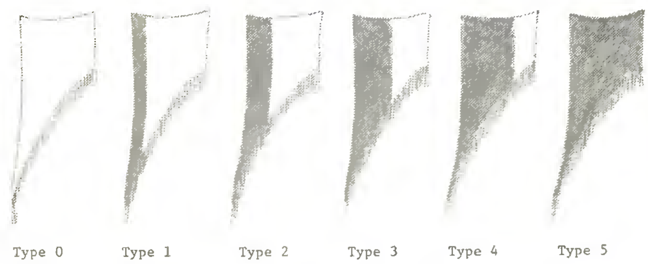

Fig. 6. Six types of baleen plate.

(1) *Relationship between the end of the ventral grooves and the umbilicus*
Type A: Ventral grooves reaching umbilicus
Type B: Ventral grooves not reaching umbilicus

(2) *Flipper coloration*
The minke whales were classified into four types according to the surface coloration of the flippers.
Type I: Uniformly black
Type II: With dark line
Type III: With faint greyish band
Type IV: With clear white band

(3) *Proportion of the black band in the baleen plate*
The largest baleen plate from each individual was examined with respect to the proportion of the black band, and was classified into six types.
Type 0: All faint amber
Type 1: Black band occupies 1/4 area of baleen plate
Type 2: Black band occupies 1/3 area of baleen plate
Type 3: Black band occupies 1/2 area of baleen plate
Type 4: Black band occupies 2/3 area of baleen plate
Type 5: All black

2. Results and discussion

The number of whales classified were tabulated in Table 1* (sex and month combined) by season and by expedition. It is noteworthy that Type 5 (the so-called *Balaenoptera bonaerensis* type) was recorded although there were not many examples. Type 0 was even more rarely observed. Types A, I and 3 were the dominant characters. No relationship between external characters and sex was observed (Table 1) but considerable variation in the observed frequency patterns between expeditions was found. Figs 7–9 which show the longitudinal distribution of observed frequencies in 10° squares by season, by expedition and by sex combined illustrate this problem. The data from *Jinyo Maru* (50°E–130°E) are reliable as they were provided by a scientist, but they show no clear trend although the fluctuation is very small. As Japanese expeditions have operated for several seasons in Area IV (70°E–130°E), there are sufficient data from this Area for comparison, but results from the different expeditions did not tend to coincide. Apart from this the figures show remarkable variation even within the same 10° square by expedition or by season. Consequently, we must conclude that the data on three

*The Tables (1–7) for this paper are on pp. 428–32.

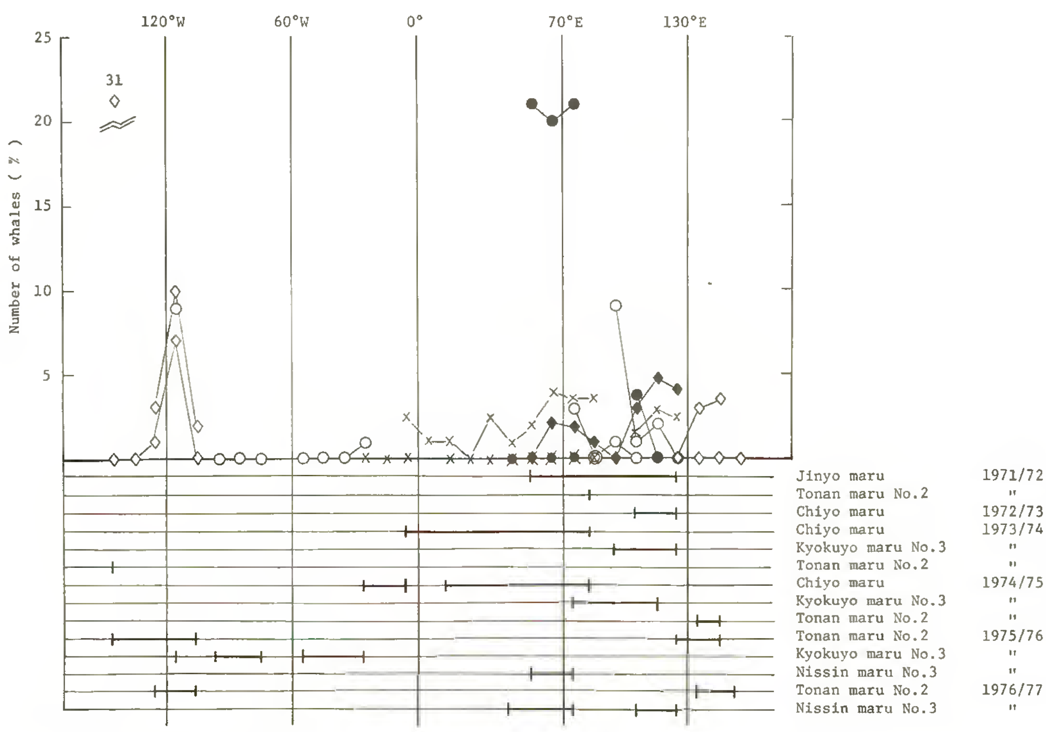

Fig. 7. Longitudinal distribution of the rate of Type A.

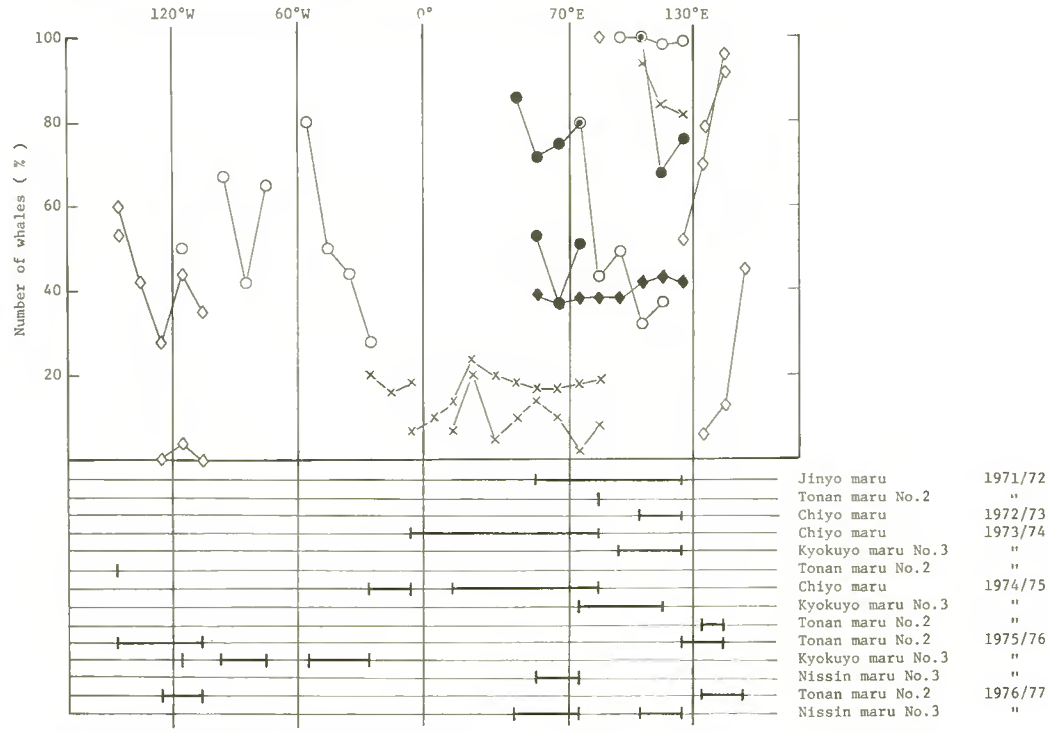

Fig. 8. Longitudinal distribution of the rate of Type I.

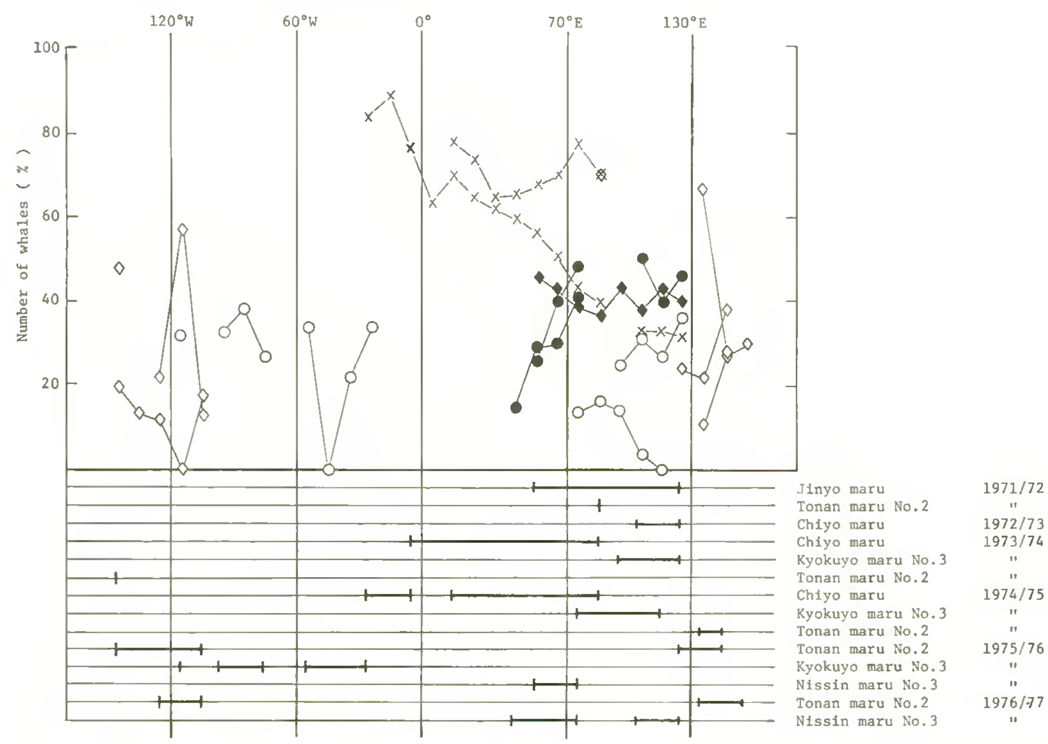

Fig. 9. Longitudinal distribution of the rate of Type 3.

external characters include some bias arising from variation in the classification criterion among the observers, and that they are inadequate for stock identification or that the external characters of minke whales do not reflect stock units. Before this can be determined it is essential to unify the criterion classification technique of each observer.

BIOCHEMICAL CHARACTERS

1. Materials and methods

A great many liver samples were collected for this study from the Antarctic minke whales taken in the 1975/76 and 1976/77 whaling seasons (Figs 10–12). Mass screening to detect enzyme polymorphs was performed easily and efficiently using cell-lysates produced by the thawing process as a crude extract (Numachi, 1971). After being soaked into a piece of filter paper (6mm x 4 mm) the cell-lysates were subjected to horizontal starch gel electrophoresis (250 mm x 125 mm x 6 mm) at 3 mA per cm for about 5 hours with enforced cooling by ice block. The buffer system described by Clayton and Tretiak (1972) was applied but with a slight modification in concentration. After the completion of electrophoresis, the gel was sliced horizontally into 1 mm thick slices and then incubated in the reaction mixture (Shaw and Prasad, 1970) in order to visualise the enzyme activities.

2. Results and discussion

As shown in Figs 10–12, the number of samples in each 10° square ranged from five to five hundred. Furthermore, these samples were collected from only twenty-one 10° squares in the Antarctic during the period from November to March. It is, of course, desirable to analyse the data by 10° square by month. However, if this is done the sample error increases to the extent that no significant difference between samples can be detected. Therefore, the samples are classified into five tentative blocks as noted below in order to minimise sample errors.

Group A:	The Atlantic	1
Group B:	The western Indian Ocean	12 13 14
Group C:	The eastern Indian Ocean	17 18 19
Group D:	The western Pacific	20 21 22
Group E:	The eastern Pacific	28 29 30 31 32 33 34 35

Nine different phenotypes were recognised in the 6-PGD zymogram from 2,418 samples analysed (Fig.13). Designating these nine phenotypes as C, CS, CN, CF, S, SN, SF, N, and NF, it is quite definite from the subunit theory (Markert, 1963) that minke whale 6-PGD is a dimeric enzyme and is controlled by four codominant alleles (6-PGD^c, 6-PGD^s, 6-PGD^n and 6-PGD^f) at the 6-PGD locus.

In SDH, the 2,418 samples were classified into eleven phenotypes, SN, SF, SR, N, NF, NR, NE, F, FR, FE and R (Fig. 14). Five codominant alleles (SDH^s, SDH^n, SDH^f, SDH^r and SDH^e) were detected from these eleven phenotypes. The number of isozymes and their staining intensity in hetero-variant types such as SN, SF, SR, NF, NR, NE, FR and FE indicate a tetramic structure of minke whale SDH.

A total of 2,431 samples were examined for the GOT isozyme pattern. Including the several strong minor components, the zymogram of GOT showed slightly more complex

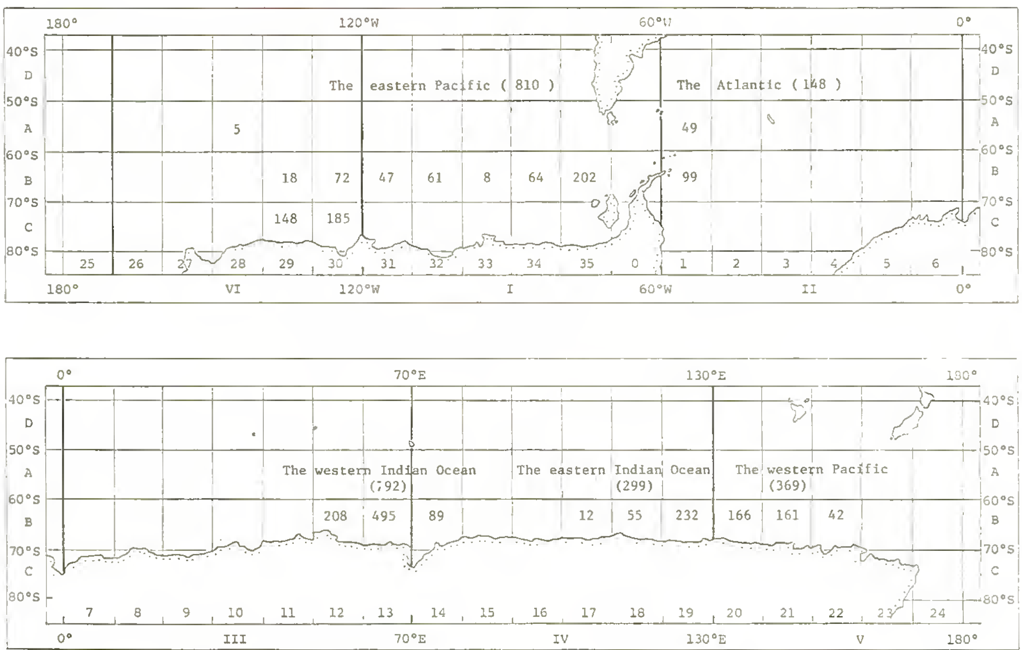

Fig. 10. Collection localities and the number of samples analysed for 6–PGD.

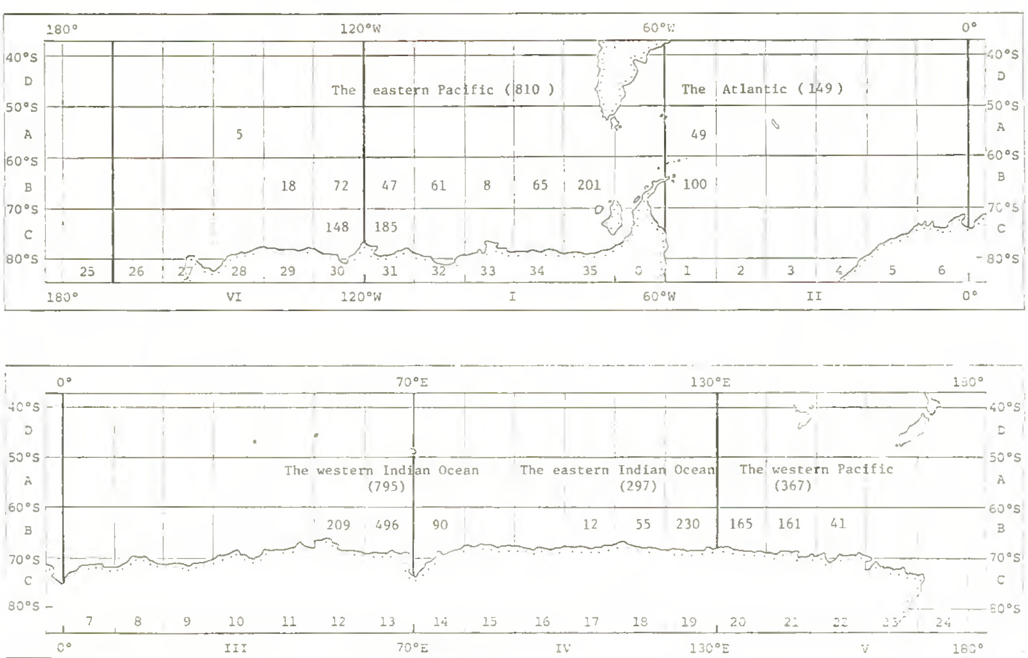

Fig. 11. Collection localities and the number of samples analysed for SDH.

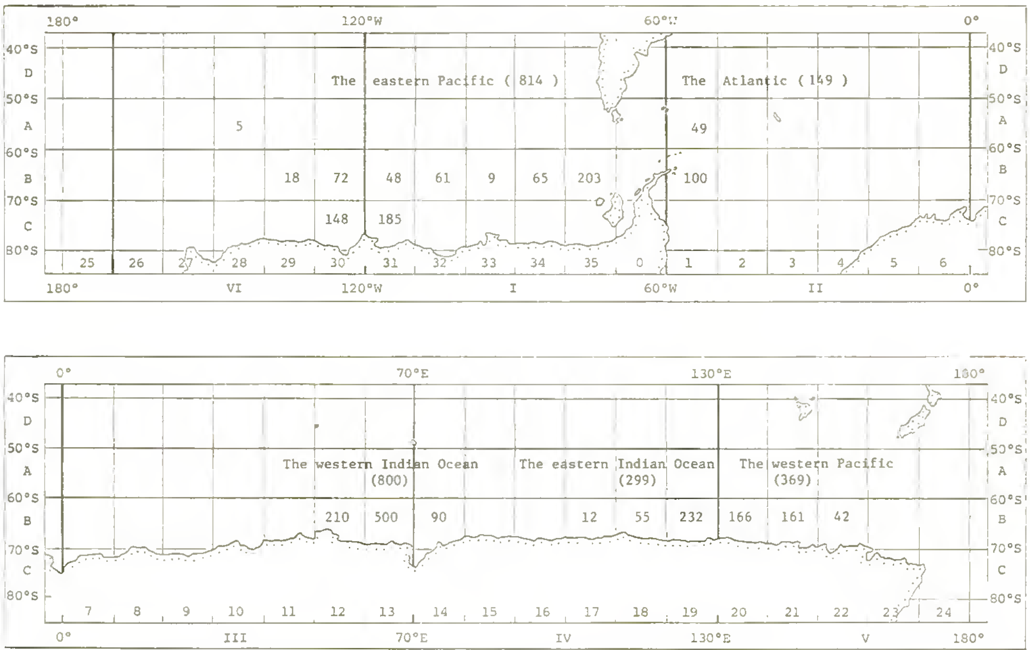

Fig. 12. Collection localities and the number of samples analysed for GOT.

patterns than in 6-PGD and SDH (Fig. 15), but, if minor components are removed from Fig. 15 (on the assumption that they are not produced under genetic control) the subunit theory can be applied for GOT as it has been for 6-PGD and SDH. From seven phenotypes (SN, N, NF, NR, NE, F and R) detected, five codominant alleles (GOT^s, GOT^n, GOT^f, GOT^r and GOT^e) were counted.

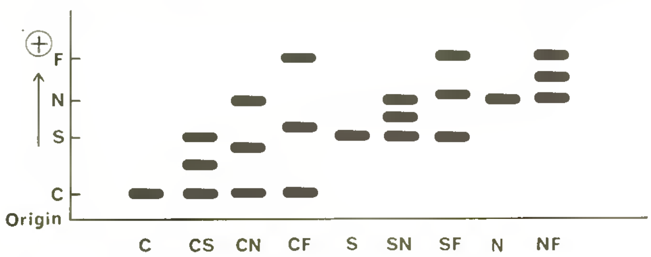

Fig. 13. Electrophoretic patterns and phenotypes in 6-PGD.

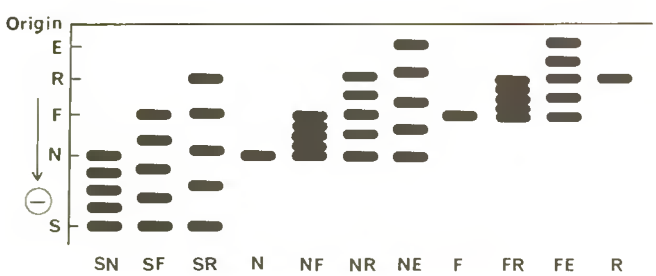

Fig. 14. Electrophoretic patterns and phenotypes in SDH.

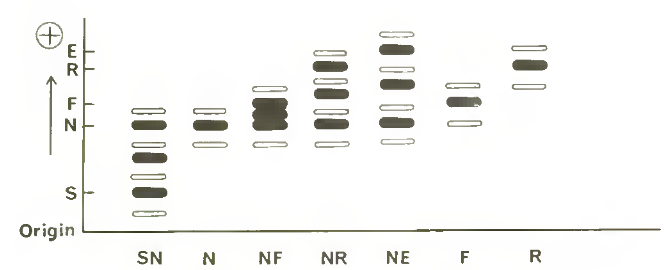

Fig. 15. Electrophoretic patterns and phenotypes in GOT.

The observed frequencies were tested for goodness of fit to the expected distributions according to the Hardy-Weinberg theorem (Tables 2–4). Every Chi-square value calculated was less than that corresponding to a probability of 0.05, thus showing that all alleles equilibrate in each whale group. Chi-square values representing a significant difference of allele frequency between two arbitrary groups are given by the following formula:

$$\chi^2 = \frac{\Sigma\, 2N_i(P_i - P_T)^2}{P_T\,(1 - P_T)} \qquad \text{(d.f.} = 1)$$

P_i : Allele frequency in i group
P_T : Combined allele frequency in two groups
N_i : Number of whales in i group

The results of the calculations are given in Tables 5–7 (the significant level is shown by asterisks). Four genetic characters, 6-PGD^s, 6-PGD^n, 6-PGD^f and SDH^s, indicated a significant difference in allele frequencies between Groups C and D. Apart from these 6-PGD^n and 6-PGD^s, together with GOT^r, also represented significant differences between the Groups B and C, and SDH^n and SDH^f were significant between the Groups C and E. 6-PGD^f was significant between Groups B and D and between D and E. Group A was separated from Group E by SDH^n only. Among fourteen characters, seven characters, 6-PGD^c, SDH^r, SDH^e, SDH^s, GOT^n, GOT^f and GOT^e were found to be unsuitable as genetic markers since they were found in similar frequencies in the five groups.

Groups C and D are composed from a series of six 10° squares, differences in the genetic composition in these two groups were detected, and the Chi-square value for 6-PGD^n between the Groups C and D is further increased if Squares 19 and 20 are regarded as an area of intermingling and the data from them is excluded from the calculation. Therefore, it can safely be said that two distinct whale stocks exist on either side of 130°E and that they intermingle around that line.

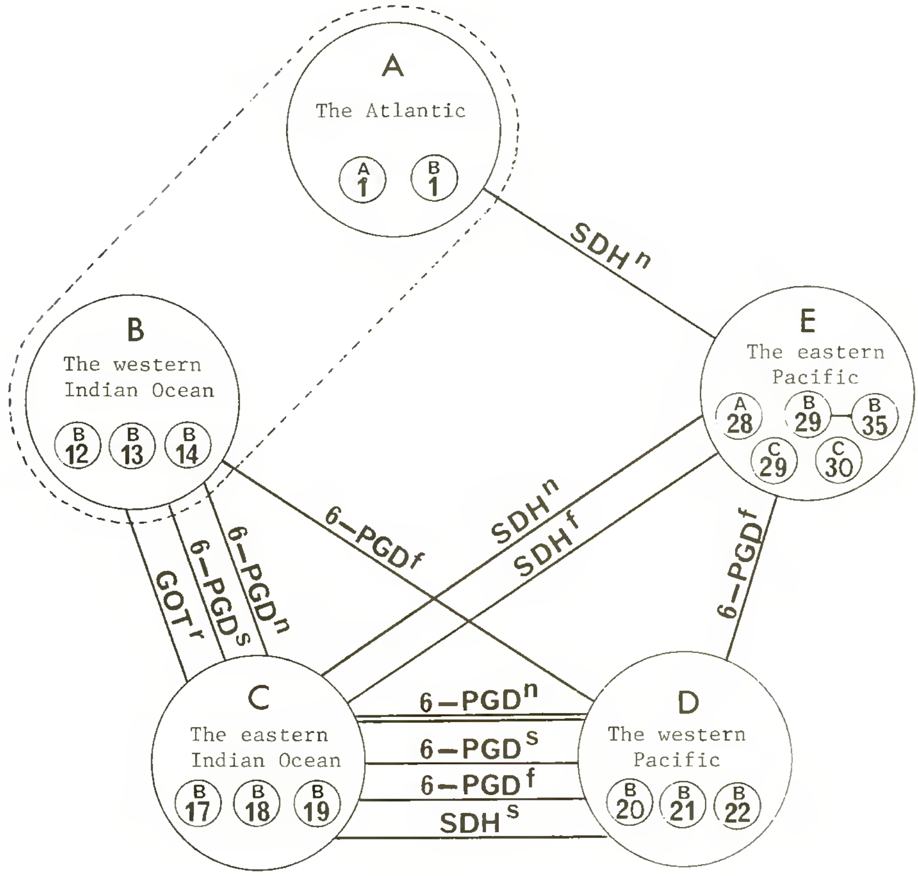

Fig. 16. Schematic figure showing the significant differences among five groups. = : at 1% significant level. – : at 5% significant level. Figures in small circles: 10° square.

There are no genetic characters separating Group A from Group B. Even if the data from Group A is included with that from Group B, the relationships B–C, B–D, and B–E remain unchanged. Hence, at present, it can also be safely said that Group A and Group B come from the same stock. From Fig. 16, illustrating the results obtained from this study, it seems almost certain that four groups (A+B, C, D and E) are from different stocks.

Unfortunately, allele frequency differences of these three enzymes in the Antarctic minke whale are generally not very large. Only the 6-PGD^n gene showed the difference between Groups C and D at the 1% significant level, and apart from this the allele frequency differences are detected only at the 5% significant level. As shown in Figs 10–12, there remain a large number of 10° squares which have not been examined for genetic characters. It is essential to obtain samples from these areas to clarify the number and borders of stock units in the whole Antarctic. A thorough study dealing with these problems will be carried out using new samples and new genetic markers in addition to the present results.

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[Tables 1–7 are on the following pages].

Table 1
Results of the observation on three external characters (Upper: real number, Lower: percentage)

Season	Expedition	Item 1		Item 2				Item 3					
		A	B	I	II	III	IV	0	1	2	3	4	5
1971/72	Jinyo maru	74	2,873	1,204	1,784	–	–	–	51	568	1,165	1,108	3
		2.5	97.5	40.3	59.7	–	–	–	1.8	19.6	40.2	38.3	0.1
1971/72	Tonan maru No. 2	–	13	13	–	–	–	–	–	4	9	–	–
		–	100.0	100.0	–	–	–	–	–	30.8	69.2	–	–
1972/73	Chiyo maru	51	2,039	1,781	92	202	14	–	143	865	746	330	5
		2.4	97.6	85.2	4.4	9.7	0.7	–	6.8	41.4	35.7	15.8	0.3
1973/74	Chiyo maru	68	2,832	492	61	2,330	17	–	141	927	1,533	292	7
		2.3	97.7	17.0	2.1	80.3	0.6	–	4.9	32.0	52.9	10.1	0.1
1973/74	Kyokuyo maru No. 3	11	789	793	7	–	–	–	97	411	256	36	–
		1.4	98.6	99.1	0.9	–	–	–	12.1	51.4	32.0	4.5	–
1973/74	Tonan maru No. 2	4	9	7	3	3	–	–	–	8	5	–	–
		30.8	69.2	53.8	23.1	23.1	–	–	–	61.5	38.5	–	–
1974/75	Chiyo maru	–	2,350	309	334	1,656	51	–	13	155	1,737	441	4
		–	100.0	13.1	14.2	70.5	2.2	–	0.6	6.6	73.9	18.8	0.1
1974/75	Kyokuyo maru No. 3	8	641	349	270	30	–	–	187	384	72	4	2
		1.2	98.8	53.8	41.6	4.6	–	–	28.8	59.2	11.1	0.6	0.3
1974/75	Tonan maru No. 2	–	500	413	84	3	–	12	14	165	271	35	3
		–	100.0	82.6	16.8	0.6	–	2.4	2.8	33.0	54.2	7.0	0.3
1975/76	Kyokuyo maru No. 3	4	901	513	348	44	–	–	106	470	284	43	2
		0.4	99.6	56.7	38.5	4.8	–	–	11.7	51.9	31.4	4.8	0.2
1975/76	Tonan maru No. 2	16	884	530	365	5	–	–	170	482	199	41	5
		1.8	98.2	58.9	40.6	0.5	–	–	19.0	53.7	22.2	4.6	0.5
1975/76	Nissin maru No. 3	245	962	537	423	178	69	5	200	337	446	213	6
		20.3	79.7	44.5	35.0	14.7	5.8	0.4	16.6	27.9	37.0	17.6	0.5
1976/77	Tonan maru No. 2	47	1,568	221	39	1,351	4	1	128	1,121	316	47	2
		2.9	97.1	13.7	2.4	83.7	0.2	0.1	7.9	69.4	19.6	2.9	0.1
1976/77	Nissin maru No. 3	4	2,331	1,772	193	345	25	5	209	1,206	792	113	10
		0.2	99.8	75.9	8.3	14.8	1.0	0.2	9.0	51.6	33.9	4.8	0.5
Total	Total	532	18,692	8,934	4,003	6,147	180	23	1,459	7,103	7,831	2,703	49
		2.8	97.2	46.4	20.8	31.9	0.9	0.1	7.6	37.1	40.9	14.1	0.2
	Male total	198	7,502	4,053	1,536	2,074	47	9	685	3,000	2,966	992	29
		2.6	97.4	52.6	19.9	26.9	0.6	0.1	8.9	39.1	38.6	12.9	0.4
	Female total	334	11,190	4,881	2,467	4,073	133	14	774	4.103	4,865	1,711	20
		2.9	97.1	42.2	21.4	35.3	1.1	0.1	6.7	35.7	42.4	14.9	0.2

Table 2
Phenotype and allele frequencies of 6-PGD in the Antarctic minke whale

Group		Phenotypes										Total	Alleles				X^2
		C	CS	CN	CF	S	SN	SF	N	NF	F		c	s	n	f	
A	Obs.	2	5	29	1	4	28	0	77	2	0	148	.132	.138	.720	.010	2.107
	Exp.	2.6	5.4	28.1	0.4	2.8	29.5	0.4	76.6	2.2	0.0						
B	Obs.	20	27	153	7	15	143	2	399	26	0	792	.143	.128	.707	.022	4.307
	Exp.	16.3	28.9	160.5	5.0	12.9	142.8	4.5	396.0	24.7	0.4						
C	Obs.	5	17	57	5	9	61	2	135	8	0	299	.149	.164	.662	.025	5.408
	Exp.	6.6	14.6	58.9	2.2	8.0	64.9	2.5	131.1	9.9	0.2						
D	Obs.	6	21	70	1	5	60	0	201	5	0	369	.141	.123	.728	.008	7.576
	Exp.	7.3	12.8	75.7	0.8	5.6	66.2	0.7	195.4	4.4	0.0						
E	Obs.	21	31	164	4	16	151	2	393	28	0	810	.149	.133	.697	.021	3.616
	Exp.	17.9	32.1	168.0	5.1	14.4	150.5	4.5	393.4	23.7	0.4						

(d.f. = 6)

Table 3
Phenotype and allele frequencies of SDH in the Antarctic minke whale

Group		Phenotypes											Total	Alleles					X^2
		SN	SF	SR	N	NF	NR	NE	F	FR	FE	R		s	n	f	r	e	
A	Obs.	2	0	0	104	34	7	0	2	0	0	0	149	.007	.842	.128	.023	–	1.774
	Exp.	1.8	0.3	0.1	105.6	32.1	5.8	0.0	2.4	0.9	0.0	0.1							
B	Obs.	14	1	1	529	190	27	6	26	0	1	0	795	.010	.814	.153	.018	.005	11.480
	Exp.	12.9	2.4	0.3	526.8	198.0	23.3	6.5	18.6	4.4	1.2	0.3							
C	Obs.	10	1	1	206	69	4	1	5	0	0	0	297	.020	.835	.135	.008	.002	9.321
	Exp.	9.9	1.6	0.1	207.1	67.0	4.0	1.0	5.4	0.6	0.2	0.0							
D	Obs.	2	2	0	248	84	10	3	16	2	0	0	367	.005	.811	.163	.016	.004	11.027
	Exp.	3.0	0.6	0.1	241.4	97.0	9.5	2.4	9.8	1.9	0.5	0.1							
E	Obs.	18	3	0	497	231	28	8	22	1	0	2	810	.013	.790	.172	.020	.005	17.404
	Exp.	16.6	3.6	0.4	505.5	220.1	25.6	6.4	24.0	5.6	1.4	0.3							

(d.f. = 10)

Table 4
Phenotype and allele frequencies of GOT in the Antarctic minke whale

Group		Phenotypes							Total	Alleles					X^2
		SN	N	NF	NR	NE	F	R		s	n	f	r	e	
A	Obs.	0	135	6	8	0	0	0	149	–	.953	.020	.027	–	0.328
	Exp.	0.0	135.3	5.7	7.7	0.0	0.1	0.1							
B	Obs.	4	715	25	50	2	1	3	800	.003	.944	.017	.035	.001	8.906
	Exp.	4.5	712.9	25.7	52.9	1.5	0.2	1.0							
C	Obs.	0	276	12	11	0	0	0	299	–	.962	.020	.018	–	0.458
	Exp.	0.0	276.7	11.5	10.4	0.0	0.1	0.1							
D	Obs.	0	333	11	24	1	0	0	369	–	.951	.015	.033	.001	1.081
	Exp.	0.0	333.7	10.5	23.2	0.7	0.1	0.4							
E	Obs.	1	744	28	38	1	1	1	814	.001	.956	.018	.024	.001	3.293
	Exp.	1.6	743.9	28.0	37.4	1.6	0.3	0.5							

(d.f. = 10)

Table 5

Chi-square values for 6-PGD showing the significant difference of allele frequencies between the two groups

1. 6-PGD[c]

Group	A	B	C	D
B	0.234			
C	0.462	0.113		
D	0.139	0.006	0.163	
E	0.566	0.218	0.000	0.258

2. 6-PGD[s]

Group	A	B	C	D
B	0.212			
C	1.018	4.724*		
D	0.423	0.102	4.566*	
E	0.043	0.169	3.444	0.436

*: 5% significant level
**: 1% significant level

3. 6-PGD[n]

Group	A	B	C	D
B	0.201			
C	3.065	4.143*		
D	0.066	1.081	6.829**	
E	0.626	0.375	2.489	2.348

4. 6-PGD[f]

Group	A	B	C	D
B	1.773			
C	2.239	0.107		
D	0.070	5.641*	6.163*	
E	1.516	0.000	0.297	5.060*

Table 6

Chi-square values for SDH showing the significant difference of allele frequencies between the two groups

1. SDH[s]

Group	A	B	C	D
B	0.190			
C	2.125	3.393		
D	0.107	1.348	6.345*	
E	0.625	0.564	1.385	3.054

2. SDH[n]

Group	A	B	C	D
B	1.318			
C	0.068	1.281		
D	1.379	0.019	1.286	
E	4.221*	2.899	5.536*	1.362

3. SDH[f]

Group	A	B	C	D
B	1.229			
C	0.080	1.095		
D	2.002	0.365	2.006	
E	3.525	2.110	4.371*	0.279

4. SDH[r]

Group	A	B	C	D
B	0.275			
C	3.454	2.793		
D	0.570	0.043	1.638	
E	0.089	0.085	3.754	0.367

5. SDH[e]

Group	A	B	C	D
B	1.208			
C	0.570	0.570		
D	0.000	0.000	0.192	
E	0.000	0.000	0.569	0.000

*: 5% significant level

Table 7

Chi-square values for GOT showing the significant difference of allele frequencies between the two groups

1. GOT^s

Group	A	B	C	D
B	0.709			
C	0.000	1.098		
D	0.000	1.441	0.000	
E	0.000	0.805	0.000	0.000

2. GOT^n

Group	A	B	C	D
B	0.360			
C	0.395	2.868		
D	0.013	0.445	0.931	
E	0.042	2.415	0.360	0.262

3. GOT^f

Group	A	B	C	D
B	0.104			
C	0.000	0.137		
D	0.312	0.046	0.465	
E	0.033	0.000	0.066	0.176

4. GOT^r

Group	A	B	C	D
B	0.460			
C	0.755	4.248*		
D	0.226	0.022	2.886	
E	0.075	3.331	0.668	1.512

5. GOT^e

Group	A	B	C	D
B	0.000			
C	0.000	0.000		
D	0.000	0.000	0.000	
E	0.000	0.000	0.000	0.000

*: 5% significant level

SC/30/Doc 29

Further Examination on Population Assessment of Southern Minke Whales in Area IV.

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INTRODUCTION

Drs J. Beddington and S. Holt criticised Paper S.14 (Ohsumi, 1979) which I presented to the Seattle meeting on the population assessment of the Southern minke whale and raised several points:

(1) The wasted time (chasing, handling and towing) per whale caught in 1977/78 was exceptionally high and therefore the catch and effort data for that year should be excluded.

(2) The assumption of seasonal changes in density in the whaling ground is doubtful, and therefore consideration of the seasonal factor is unnecessary in the standardisation of fishing effort.

(3) The population density in Area IV has been decreasing since the beginning of exploitation, although I estimated there was no decreasing trend.

In this paper I re-examine the above problems using additional data.

OPERATIONAL PROCESS IN 1977/78

The effort data in 1977/78 used in Paper S.14 was obtained by telegram from *Nissinmaru No. 3* during her homeward voyage. The original records of the Expedition are now available and a re-examination of the operation processing times was carried out. Table 1 shows the times of each operational process in 1977/78 in the same way as Table 3 of Ohsumi (1979). A new operational process was added to the records in 1977/78, the 'confirming time' which is the time taken to confirm the species, school size, condition of the whales (eg. cow and calf) and body length, as being suitable to catch, i.e. the time between the finding of the school and the start of chasing. This operational process had not been clearly defined until the previous year, and it was thought to be included in the searching time. However, it was found that it was excluded from the searching time in the reported data from the Expedition.

Table 2 shows the comparison of the results of processing times in 1977/78 with those in 1976/77 for the data from Area IV. The chasing time per whale caught is 0.12 hours longer in 1977/78, the handling times are almost the same and the towing time is 0.14 hours shorter in 1977/78. The total times of chasing, handling and towing are almost the same in 1977/78 (0.89 hours) and 1976/77 (0.92 hours). The larger figure which Dr Beddington obtained is derived from data adding the confirming time.

The CHW and CSW values were recalculated from 1977/78 to include the confirming time. The CSW including con-

Table 1

Average operation times per catcher boat per day to take minke whales by the *Nissin maru No. 3* Expedition in the Antarctic 1977/78.

Month	November	December				February				
Decade	Late	Early		Middle		Early	Middle		Late	Total
Area	VI	VI	V	V	IV	IV	IV	III	III	
Boats	7	7	7.1	7	7	6	7	6.7	7	7
CDW	28	14	57	56	14	24	14	47	49	303
Catch	113	120	214	438	150	231	100	518	494	2,378
Catch per day	4.04	8.57	3.75	7.82	10.71	9.63	7.14	11.02	10.08	7.85
Time per boat per day										
Searching	10.58	8.73	13.27	7.56	7.79	5.24	2.56	1.68	1.87	6.73
Confirming	0.66	1.90	0.66	1.03	1.00	1.25	0.93	1.00	1.06	0.98
Chasing	1.89	3.72	1.63	2.93	3.67	5.16	3.87	3.65	3.55	3.09
Handling	0.96	1.95	0.84	1.68	2.17	2.43	1.96	2.40	2.46	1.80
Towing	1.20	1.17	1.00	1.09	2.16	1.51	1.19	1.77	1.98	1.42
Resting	8.71	6.53	6.60	9.71	7.21	8.41	13.49	13.50	13.08	9.98
Time per whale caught										
Searching	4.04	1.02	3.54	0.97	0.73	0.54	0.36	0.15	0.19	0.86
Confirming	0.16	0.22	0.18	0.13	0.09	0.13	0.13	0.09	0.11	0.12
Chasing	0.47	0.43	0.43	0.37	0.62	0.54	0.54	0.33	0.35	0.39
Handling	0.24	0.23	0.22	0.21	0.20	0.56	0.27	0.22	0.24	0.23
Towing	0.36	0.14	0.27	0.14	0.20	0.16	0.17	0.16	0.20	0.18
Resting	2.16	0.76	1.76	1.24	0.67	0.87	1.89	1.23	1.30	1.27

firming time (0.68 hours) per whale caught was shorter than that in the previous year (1.24 hours). The difference between the two figures was due to the higher availability of whales in 1977/78. This resulted in a shorter searching time (5.20 hours) and longer resting time (9.46 hours) compared with 9.43 hours and 7.61 hours in the previous year, respectively. The high CPUE value based on CDW supports high availability in 1977/78.

It can therefore be concluded that there is no reason to exclude the catch and effort data in 1977/78.

Table 2

Comparison of average operation times of the *Nissin maru No. 3* Expedition in Area IV in 1977/78 with those in 1976/77

Year	1976/77	1977/78
Number of boats	4	7
CDW	64	52
Total catch	487	481
Catch per day	7.61	9.25
Searching	603.2	270.5
Confirming	–	57.0
Chasing	175.3	229.5
Handling	121.1	116.1
Towing	149.3	83.1
Time per day per boat		
Searching	9.43	5.20
Confirming	–	1.10
Chasing	2.74	4.41
Handling	1.89	2.23
Towing	2.33	1.60
Resting	7.61	9.46
Time per whale caught		
Searching	1.24	0.56
Confirming	–	0.12
Chasing	0.36	0.48
Handling	0.25	0.24
Towing	0.31	0.17
Resting	1.00	1.02

SEASONAL CHANGE IN DENSITY DISTRIBUTION

Ohsumi (1979) examined the monthly variation in CPUE of the minke whale in Area IV, and showed that the density distribution of the minke whale in the Antarctic whaling ground changes seasonally and reaches a maximum in the first decade of January. He emphasised that this must be taken into account in the standardisation of fishing effort, because whaling is not carried out at the same time every year (Fig. 1).

Dr Beddington examined Japanese catch and effort data and pointed out that there was no clear seasonal change in CPUE in Area III, and he considered the seasonal correction of effort unnecessary if the data from early and middle decades of November were excluded.

As the whale sighting by scouting boats is an independent measure of the distribution and density from the catch and effort data, it is useful to examine this problem using sightings data, although this does not allow comparison of the sexual differences in seasonal changes in density and distribution.

Fig. 2 shows the monthly change in the number of minke whales sighted per 10 miles steamed by scouting boats in the waters south of 60°S in Areas III and IV. A seasonal change in density is clearly shown in both Areas, and it is at

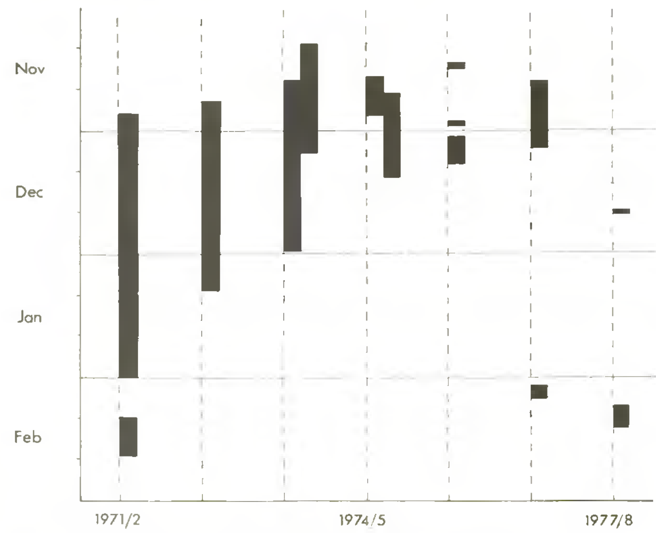

Fig. 1. Length of the minke whale season in the Antarctic, Area IV, Japanese expeditions.

a maximum in January. This phenomenon coincides with the seasonal change in CPUE noted by Ohsumi (1979), who also showed a large seasonal change in density between the sexes. If the sex of the minke whale could be identified in sightings data the seasonal change in density of the female could be more clearly defined.

It can be concluded that a seasonal change in density distribution of the minke whale in the Antarctic whaling ground is confirmed and that correction of season is needed to standardise the fishing effort. Further study is needed to obtain better figures for the seasonal correction factor, but the figures given in Table 7 by Ohsumi (1979) should be at least used for the minke whales in Area IV.

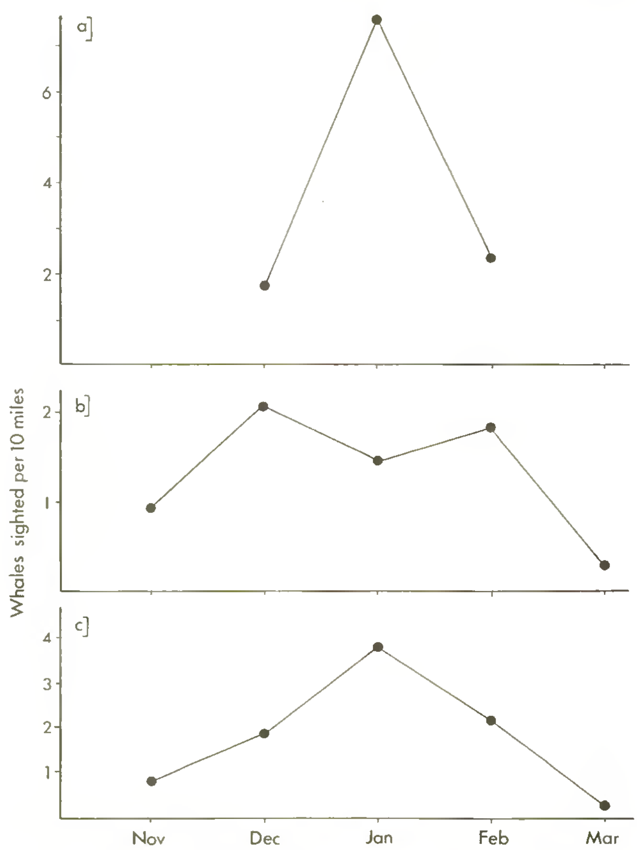

Fig. 2. Monthly change in the number of whales sighted per 10 miles by scouting boats in the waters south of 60°S during seasons 1965/66–1976/77. a: Area III; b: Area IV; c: Area III + IV.

CPUE TRENDS IN AREA IV

Fig. 3 shows the yearly change in CPUE for the minke whales in Area IV, based on four kinds of fishing effort from 1971/72 to 1977/78. The CSW in 1977/78 was revised by adding the confirming time to the searching time. The trends of CPUE vary with the effort indices. Although the CPUE based on raw CDW and on raw CSW seem to show a somewhat decreasing trend, the CPUE based on weather-corrected CSW is almost steady (with a large yearly fluctuation). When weather and season corrected CSW is used as the index of fishing effort, there is a clear, increasing trend throughout the 7 years.

It has been recognized that it is better to use CSW than CDW, and that a weather correction factor should be used in the standardisation of effort. It was also confirmed in the previous section that a seasonal factor should be incorporated to obtain a more reliable effort. Therefore, the yearly change in CPUE based on weather and season corrected CSW represents the most reliable trend of population density among the four kinds of CPUE.

The yearly change in the number of minke whales sighted per unit steamed by scouting boats, which is an independent measure of density distribution, shows a clear, increasing trend thereby supporting the existence of the above trend obtained from weather and season corrected CSW (Table 9 in Ohsumi, 1979). The CPUE of the Soviet expeditions in Area IV also shows an increasing trend, and thus all the independent measures of density in Area IV coincide with each other. Such a synthesis is the most reasonable way to estimate a trend in the density of fisheries resources as it uses all the available information. The available information on the population density of the minke whale in Area IV at least denies the possibility of any decrease in the years since 1971/72.

Fig. 4 shows the yearly change in CPUEs by sex based on raw, weather corrected and weather and season corrected CSW. The CPUE of the female shows a clear, increasing trend, and that of the male has been almost steady.

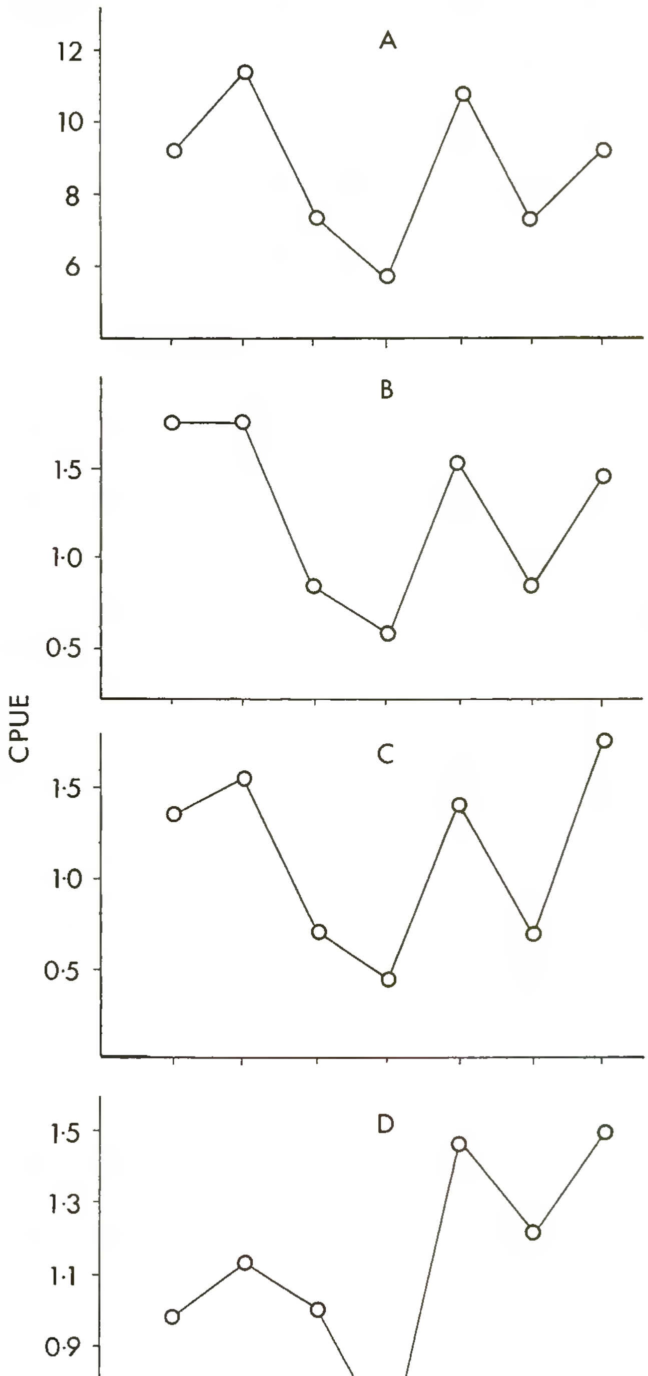

Fig. 3. Yearly change in CPUEs based on four kinds of fishing effort for the minke whale in Area IV.
A: Raw CDW, B: Raw CSW, C: Weather corrected CSW, D: Weather and season corrected CSW.

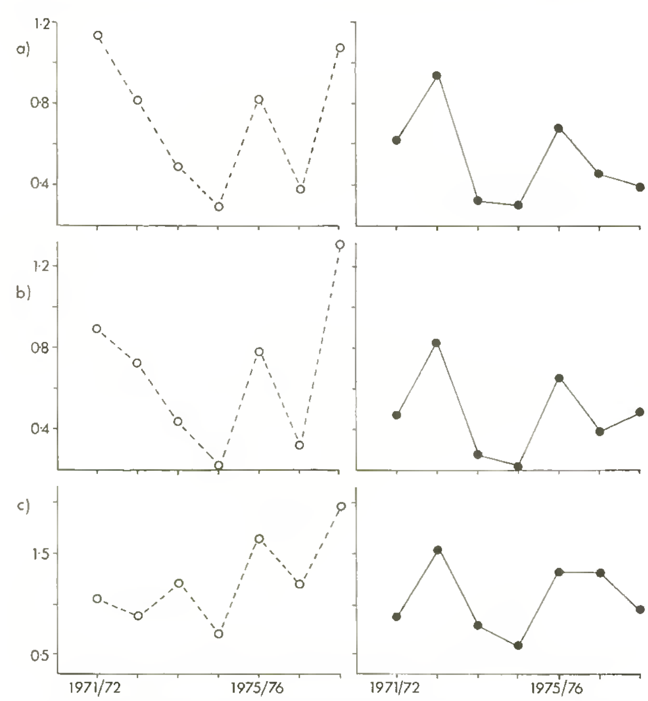

Fig. 4. Yearly change in CPUE (for three types of fishing effort) for minke whales in Area IV
O----O females, •—• males. a: raw CSW; b: weather corrected CSW; c: weather and season corrected CSW.

POPULATION SIZE IN AREA IV

The estimated population size differs greatly depending on which population trend is recognised. Ohsumi (1979) estimated the population size of the minke whale in Area IV to have been 52,800 in recent years, based on the estimated values of the natural mortality coefficient, recruitment rate

Table 3
Yearly change in population sizes of the minke whale in Area IV based on the supposed population size in 1971/72

		Case 1				Case 2				Case 3			
	C	N	R	E	RY	N	R	E	RY	N	R	E	RY
Males													
1971/72	929	8,000	1,107	0.116	420	26,000	3,598	0.036	1,366	35,000	4,844	0.027	1,840
1972/73	2,410	7,537	1,043	0.320	396	26,398	3,653	0.091	1,387	35,828	4,959	0.063	1,884
1973/74	1,761	5,705	790	0.309	300	25,468	3,525	0.069	1,339	35,349	4,892	0.050	1,858
1974/75	907	4,377	606	0.207	230	25,084	3,472	0.036	1,319	35,437	4,904	0.026	1,862
1975/76	429	3,762	521	0.114	198	25,459	3,523	0.017	1,338	36,306	5,025	0.012	1,909
1976/77	917	3,552	492	0.258	187	26,285	3,638	0.035	1.382	37,652	5,211	0.024	1,979
1977/78	251	2,888	400	0.087	152	26,708	3,696	0.009	1,403	38,618	5,345	0.006	2,030
1978/79		2,798				27,756				40,236			
Females													
1971/72	1,728	8,000	1,107	0.216	420	26,000	3,598	0.067	1,366	35,000	4,844	0.049	1,840
1972/73	2,146	6,811	943	0.315	358	25,671	3,553	0.084	1,349	35,102	4,858	0.061	1,845
1973/74	2,808	5,185	718	0.542	273	24,947	3,453	0.113	1,312	34,828	4,820	0.081	1,830
1974/75	1,323	2,880	399	0.459	153	23,586	3,264	0.056	1,239	33,939	4,697	0.039	1,784
1975/76	452	1,815	251	0.249	95	23,509	3,254	0.019	1,236	34,358	4,755	0.013	1,806
1976/77	683	1,491	206	0.458	78	24,222	3,352	0.028	1,272	35,589	4,926	0.019	1,871
1977/78	712	941	130	0.757	49	24,758	3,427	0.029	1,302	36,670	5,075	0.019	1,927
1978/79		338				25,294				37,775			

C: Catch N: Population size R: Recruitment E: Exploitation rate RY: Replacement yield of Type II, average annual catch and the assumption that the population has at least been steady in recent years. However, at the Seattle Meeting, Dr Holt calculated that the mean population size in Area IV from 1971/72 to 1976/77 was 12,000–13,000, using a calculated value for the fishing mortality coefficient. These two estimations differ widely from each other.

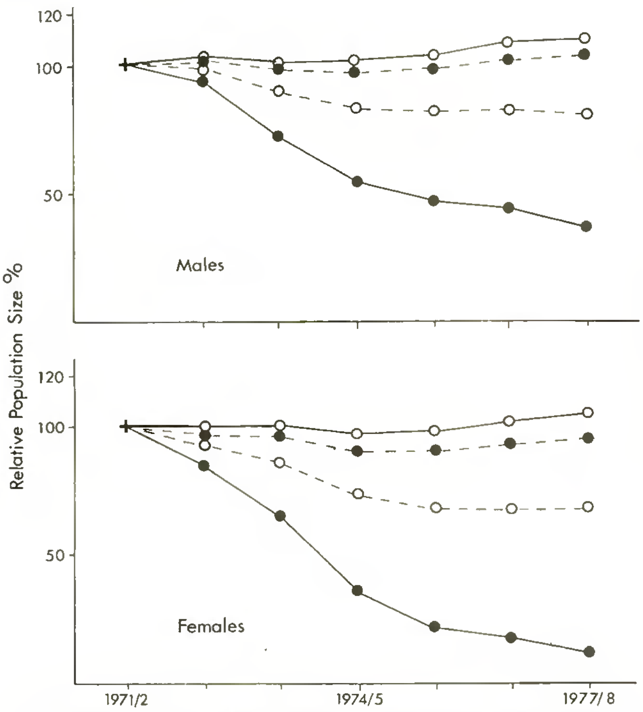

Fig. 5. Comparison of yearly changes in relative population sizes of Area IV minke whales based on different assumptions of population in 1971/72:
●—● 8,000; ○----○ 15,000; ●----● 26,000; ○—○ 35,000.

A population changes according to the following equation:

$$N_{t+1} = (N_t - C_t)\, e^{-M} + (1 - e^{-r})\, N_t$$

where, N is the exploitable population size, C is the total catch in a year, M is the natural mortality coefficient, r is the recruitment rate to the exploitable population and t is a given year.

The values of M and r were recognised to be 0.095 and 0.149, respectively, at the Seattle Meeting of the Scientific Committee. C in each year is obtained directly from catch statistics. If N in 1971/72 is assumed, the population size in the following years can be calculated using the above equation. Three assumed values of $N_{1971/72}$ of each sex are used in this examination: 8,000, 26,000 and 35,000. The first is near the estimation by Dr Holt and the second comes from Ohsumi (1979). Table 3 shows the results of the calculation of yearly changes in N values.

If 8,000 is correct as the initial population size of each sex, the population in 1977/78 would have decreased to only 11.8% of its initial size in the females and the exploitation rate in 1977/78 becomes extremely high (75.7%). After such a large reduction in population size, a remarkable change should appear in CPUE and age structure, and whalers would find their operations very difficult. However, in practice, these phenomena have not occurred in the Area. Therefore, the assumption of an initial population size of 8,000 (16,000 for both sexes combined) in 1971/72 is clearly unrealistic and should not be considered. If 26,000 is correct then the male population has remained almost steady but the female population has decreased somewhat. When the initial population of females is assumed to be 35,000, the population size in 1977/78 becomes 104.8% of the initial size. Considering the increasing trend in population density during the years, there is a possibility that the female population size was larger than 35,000 in 1971/72.

At the Seattle Meeting, the mean age at recruitment was estimated to be 6–7 years, and the minke whale population was recognised to have gradually increased, at least until the beginning of exploitation, and therefore recruitment should have been increasing at least until 1977/78. However, as shown in Table 3, the calculated number of recruits would have decreased rapidly if we assume an initial population size of 8,000 for both sexes. This is not supported by the observed trend of recruitment and again refutes the assumption that 8,000 is the initial population size in Area IV. The assumption of 35,000 can explain the yearly change in the number of recruits more reasonably.

Ohsumi (Paper S.14) estimated the replacement yield in Area IV to be 2,900. Table 3 also shows the estimated RY for each sex in each year for the three population sizes. If the population size in recent years is estimated to be 52,000–70,000, then the RY will be 2,700–3,700.

REFERENCE

Ohsumi, S. 1979. Population assessment of the Antarctic minke whale. Paper S.14 (published in this volume).

SC/30/Doc 31

Theoretical Aspects Analysed by Introducing Age-Specific Maturity and Age-Specific Availability into Population Analysis of Minke Whales in the Antarctic

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ABSTRACT

The Scientific Committee of the IWC usually carries out stock assessments using catch per unit effort data. However, I believe that, generally speaking, catching efforts are one of the most insignificant, arbitrary and vague concepts not only in whaling, but in all other fisheries. In this paper I endeavour to analyse populations without using effort. In addition I introduce an age-specific maturity function and age-specific availability function into the analysis. The mathematical model is very simple. The population size in each year by each age can be estimated; recruitment can be computed; and the replacement yield in future years can be obtained. Initially the analysis used a variable pregnancy rate but here I present the results using a constant pregnancy rate. The estimated results for female minke whales in Area IV in the Antarctic for the 1977 season are as follows:

Total population: 41,500 Exploitable population: 19,000 Mature population: 16,300 Replacement yield: 1,170

INTRODUCTION

In past reports on the stock assessment of whale populations, there are many incomplete or unrealistic parameters and data which should be examined both theoretically and against real data, such as catching efforts, age at first capture, age at maturity etc. In this paper I present some theoretical aspects obtained from introducing both an age-specific maturity function instead of age at maturity and an age-specific availability function instead of age at first capture, in order to attempt to reconcile an analytical hypothesis with actual features of the biology and fishery of female minke whales. Moreover, I do not use effort data (which are extremely difficult to elaborate when considering actual whaling operations under natural, biological and industrial circumstances) in any form. In other words, if we use any kind of effort data, the results obtained seem to be uncertain and unbelievable somewhere. In particular any analysis using catch per unit effort is apt to be unreliable because of the wide fluctuations in the estimates.

HOW TO CHANGE NATURAL MORTALITY, MATURITY, AVAILABILITY AND PREGNANCY RATE BY AGE

In this paper I use the following notations:

Age: x

Coefficient of natural mortality: $M(x) = \begin{cases} M' \text{ at } 0<x<a \\ M \text{ at } a<x \end{cases}$

Maturity function: $MTR(x) = \begin{cases} 0 \text{ at } x \leqslant b \\ \text{linear at } b<x<c \\ 1 \text{ at } e \leqslant x \end{cases}$

Availability function: $Q(x) = \begin{cases} 0 \text{ at } x \leqslant d \\ \text{linear at } d<x<e \\ 1 \text{ at } e \leqslant x \end{cases}$

Pregnancy rate: p

Schematic models for the above equations are shown in Fig. 1. The natural mortality function is a step function changing at age a. The age-specific maturity function is linear between age b when the first whale is mature and age c when all whales are mature. Similarly the age-specific availability function is linear between first availability at age d and full availability at age e. The values of a, b, c, d, e and p adopted in this paper are given in Table 1. In the original paper, I carried out the analysis using a variable

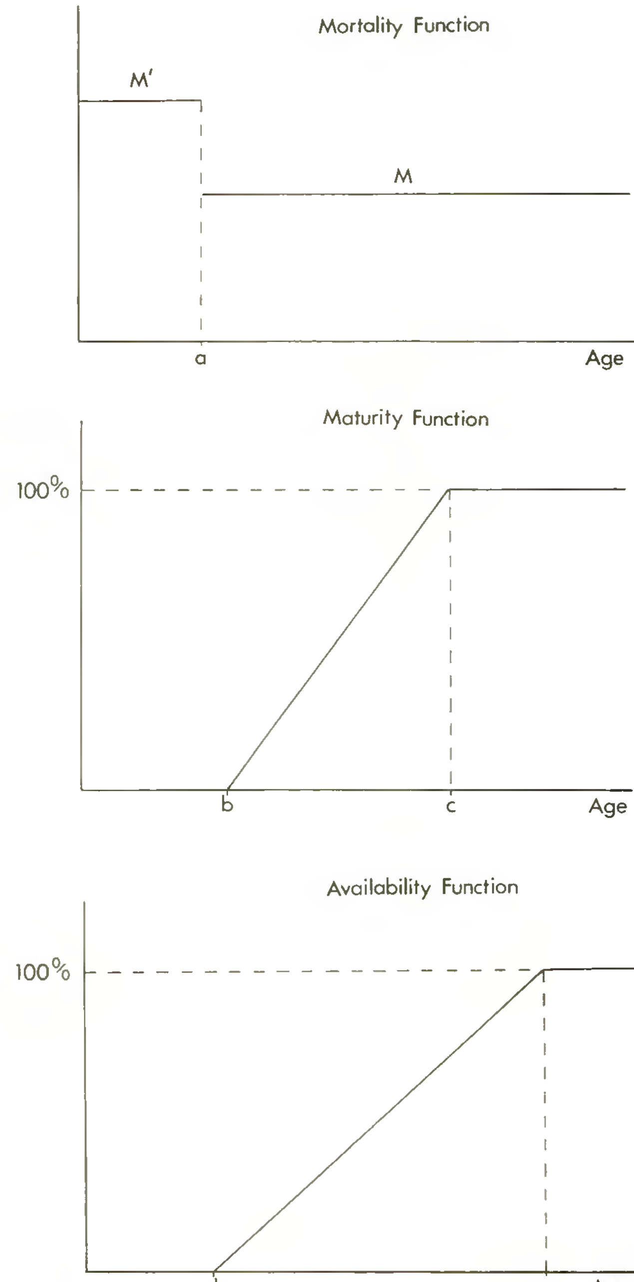

Fig. 1. Change in natural mortality, maturity and availability with age.

Table 1
Changes in natural mortality, maturity, availability pregnancy rate

Year	a	b	c	d	e	p
1904	1	8	17	1	10	0.75
1905–13	1	8	17	1	10	0.75
1914–23	1	7	16	1	10	0.75
1924–33	1	6	15	1	10	0.75
1934–43	1	5	14	1	10	0.75
1944–53	1	4	13	1	10	0.75
1954–63	1	3	12	1	10	0.75
1964–71	1	2	11	1	10	0.75
1972–77	1	2	11	1	10	0.75

Notes:
(1) Notations a, b, c, d and e are represented in Fig. 1.
(2) Values are mainly from Masaki (1979a), IWC (1979a) and IWC (1979b).

pregnancy rate which changes linearly and gradually from 0.75 in 1904 to 0.85 at the present time, but in this paper I adopt a constant pregnancy rate of 0.75 as shown in Table 1. A generalised population distribution pattern by age which shows the mature population by age is presented in Fig. 2.

POPULATION MODEL

By using the maturity function and the availability function mentioned above, a population model can be easily set up logically and biologically as follows:

$N_i(x)$: number of x-age in year i
$C_i(x)$: catch of x-age in year i
$B_i(x)$: available number of x-age in year i
$A_i(x)$: mature number of x-age in year 1

$A_i(x)$: $N_i(x)\,MTR(x)$
$B_i(x)$: $N_i(x)\,Q(x)$
Total number of available stock $B = \sum_x B_i(x)$
Total number of mature stock $A = \sum_x A_i(x)$

For the next year:

$$N_{i+1}\ (x+1) = [N_i(x) - C_i(x)]\ e^{-M(x)}$$

assuming a short period of catching whales in one year. The number of 0-age in year (i + 1) is:

$$N_{i+1}\,(o) = \sum_x p[\{N_i(x) - C_i(x)\}\,MTR(x)]\ e^{-M}$$

EQUILIBRIUM CONDITION WITH NO CATCH

Assuming the population to be stable in the initial year, 1904, when modern whaling in the Antarctic began, there should be a relationship between the above population parameters. The equilibrium condition can be derived from the following process.

$$A = \sum_x A(x) = \sum_x N(x)\,MTR(x)$$

$$= N_o \sum_x [e^{-\sum^x M(x)}\,MTR(x)]$$

$$N_o = \frac{A}{2}\,p\,e^{-M}$$

$$= \tfrac{1}{2} N_o p e^{-M} \sum_x [e^{-\sum^x M(x)} MTR(x)]$$

$$\therefore \quad \tfrac{1}{2} p e^{-M} \sum_x [e^{-\sum^x M(x)} MTR(x)] = 1$$

This is the equilibrium condition for minke whales. Calculated results are shown in Table 2† under the conditions a = 1, b = 8 and c = 17 in 1904. The natural mortality coefficient of juvenile whales, M′, should be larger than that for adults, M, and therefore, those figures marked with an asterisk are reasonable and those without an asterisk are not.

In the following calculations in this paper I adopt the values of M = 0.095 and M′ = 0.0153 in Table 2, because M was accepted to be 0.095 by the Scientific Committee (IWC, 1979a, from Ohsumi, 1979b).

YEARLY CHANGE IN POPULATION, NUMBER AVAILABLE, NUMBER MATURE AND RECRUITS BY AGE

I carried out calculations on the female stock in Area IV (between 70°E and 130°E) in the Antarctic. Yearly changes in the population, the available (exploitable) number and the number mature can be calculated successively and transiently from the population model described in the previous section. In addition, recruitment and rate of recruitment are easily obtained. In the calculation an assumption about the available number in the initial year (1904) is necessary, and I chose five situations: 2,000, 4,000, 6,000, 8,000 and 10,000 female minke whales in the equilibrium state in the initial year, 1904. The results obtained are summarised in Table 3, from Phase 2 of DOIPOP. Looking at the age composition obtained from Phase 2 of DOIPOP, some values for the exploitable population by age are negative for recent years, if a small number of exploitable whales is assumed for the initial year, 1904. (Negative values cannot be obtained in Table 2 because the figures are not broken down into age; in 1975, negative values are found in Table 4.) This is unreasonable and unrealistic and initial abundances giving rise to such situations must be rejected. Comparisons of theoretical age compositions with the actual age distribution of the catch is one verification method for DOIPOP.

†The calculation programme in this report is called DOIPOP. Table 2 is Phase 1 of DOIPOP.

Table 2
Relationship between maturity, pregnancy, and natural mortality
(PHASE 1 of DOIPOP)

Natural mortality coefficient	Pregnancy rates									
	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.085	0.0586	0.1063*	0.1498*	0.1898*	0.2269*	0.2614*	0.2936*	0.3240*	0.3525*	0.3796*
0.090	0.0037	0.0514	0.0949*	0.1349*	0.1719*	0.2064*	0.2387*	0.2690*	0.2976*	0.3246*
0.095	−0.0499	−0.0022	0.0413	0.0813	0.1184*	0.1529*	0.1851*	0.2155*	0.2440*	0.2711*
0.100	−0.1021	−0.0545	−0.0110	0.0291	0.0661	0.1006*	0.1329*	0.1632*	0.1918*	0.2188*
0.105	−0.1532	−0.1056	−0.0620	−0.0220	0.0150	0.0495	0.0818	0.1121*	0.1407*	0.1677*

*Acceptable juvenile mortality rates

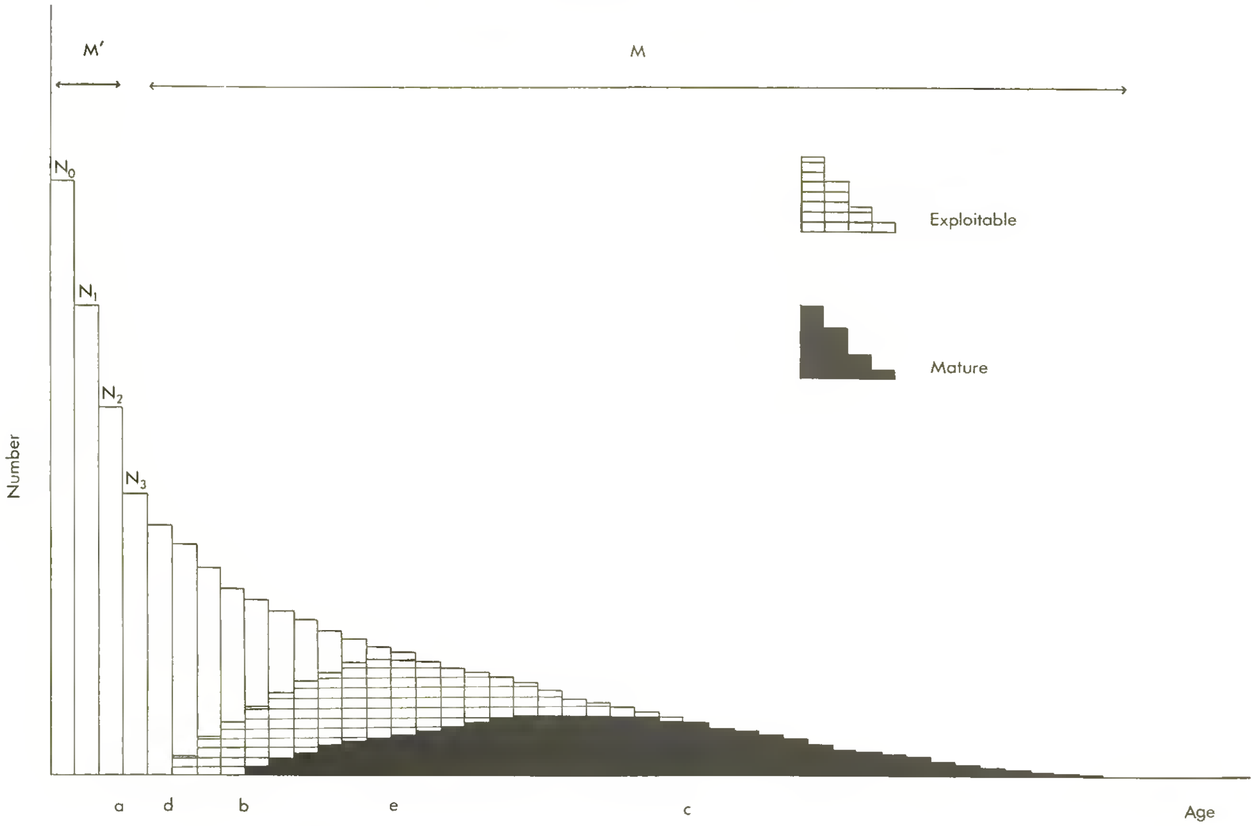

Fig. 2. Generalised population composition showing the mature population and the exploitable population, and parameters as given in Fig. 1.

Table 3

Yearly change of population size by age
(from PHASE 2 of DOIPOP)

(A) Initial available number is 2,000 (situation 2000)

Year	Whole number	Available number	Mature number	Recruit	Recruitment rate
1904	3,490	2,000	1,027	182	0.0908
1914	3,490	2,000	1,129	182	0.0908
1924	3,708	2,068	1,252	198	0.0965
1934	4,123	2,241	1,473	224	0.1010
1944	4,846	2,558	1,836	268	0.1065
1954	6,065	3,096	2,451	342	0.1128
1964	8,162	4,010	3,542	468	0.1201
1971	10,730	5,030	4,413	617	0.1272
1972	11,126	5,217	4,574	643	0.1279
1973	9,476	3,971	3,357	793	0.1520
1974	7,199	2,722	2,177	1,061	0.2673
1975	3,927	823	381	897	0.3294
1976	2,221	205	−186	581	0.7063
1977	1,425	167	−173	393	1.9186

(B) Initial available number is 4,000 (situation 4000)

Year	Whole number	Available number	Mature number	Recruit	Recruitment rate
1904	6,981	4,000	2,053	363	0.0908
1914	6,981	4,000	2,259	363	0.0908
1924	7,415	4,135	2,503	397	0.0965
1934	8,247	4,482	2,945	448	0.1010
1944	9,692	5,116	3,672	537	0.1065
1954	12,130	6,193	4,902	683	0.1128
1964	16,324	8,020	7,048	936	0.1201
1971	21,460	10,061	8,826	1,235	0.1272
1972	22,252	10,434	9,148	1,286	0.1279
1973	21,012	9,384	8,101	1,462	0.1402
1974	19,161	8,342	7,100	1,758	0.1874
1975	16,332	6,658	5,491	1,622	0.1944
1976	15,087	6,261	5,120	1,331	0.2000
1977	14,772	6,450	5,334	1,169	0.1867

Table 3 (continued)

(C) Initial available number is 6,000 (situation 6000)

1904	10,471	6,000	3,080	545	0.0908
1914	10,471	6,000	3,388	545	0.0908
1924	11,123	6,202	3,755	595	0.0965
1934	12,370	6,723	4,418	672	0.1010
1944	14,538	7,674	5,508	805	0.1065
1954	18,195	9,289	7,354	1,025	0.1128
1964	24,486	12,030	10,626	1,403	0.1201
1971	32,190	15,091	13,238	1,852	0.1272
1972	33,378	15,651	13,722	1,929	0.1279
1973	32,549	14,798	12,845	2,132	0.1362
1974	31,123	13,961	12,022	2,455	0.1659
1975	28,737	12,493	10,601	2,347	0.1681
1976	27,953	12,316	10,426	2,081	0.1666
1977	28,118	12,732	10,840	1,945	0.1579

(D) Initial available number is 8,000 (situation 8000)

1904	13,962	8,000	4,106	726	0.0908
1914	13,962	8,000	4,517	726	0.0908
1924	14,830	8,270	5,007	794	0.0965
1934	16,494	8,964	5,891	896	0.1010
1944	19,385	10,232	7,344	1,073	0.1065
1954	24,260	12,385	9,805	1,367	0.1128
1964	32,647	16,040	14,169	1,817	0.1201
1971	49,920	20,121	17,651	2,470	0.1271
1972	44,504	20,869	18,296	2,573	0.1279
1973	44,084	20,211	17,589	2,802	0.1343
1974	43,085	19,581	16,945	3,152	0.1560
1975	41,142	18,328	15,710	3,073	0.1569
1976	40,819	18,372	15,731	2,831	0.1545
1977	41,464	19,015	16,347	2,721	0.1481

(E) Initial available number is 10,000 (situation 10000)

Year	Whole number	Available number	Mature number	Recruit	Recruitment rate
1904	17,452	10,000	5,133	908	0.0908
1914	17,452	10,000	5,647	908	0.0908
1924	18,538	10,337	6,259	992	0.0965
1934	20,617	11,205	7,363	1,121	0.1010
1944	24,231	12,790	9,180	1,341	0.1065
1954	30,324	15,481	12,256	1,709	0.1128
1964	40,809	20,050	17,711	2,339	0.1201
1971	53,650	25,151	22,064	3,087	0.1272
1972	55,630	26,086	22,870	3,216	0.1279
1973	55,620	25,625	22,333	3,471	0.1331
1974	55,048	25,200	21,867	3,849	0.1502
1975	53,548	24,163	20,820	3,798	0.1507
1976	53,685	24,428	21,037	3,581	0.1482
1977	54,810	25,297	21,853	3,497	0.1432

ESTIMATION OF POPULATION SIZE

The population size can be estimated by verification of one of the assumed values adopted as the initial number in 1904 by the method described above. For this I chose the age distribution of the 1975 catch as it was larger than the catch in 1976 or 1977, and should give a sufficiently accurate age distribution of the population.

Table 4 shows the age distribution of the actual catch and the age composition of the theoretical number of exploitable whales for each situation obtained from the output of Phase 2. Table 5 shows the results (all the situations are adjusted to the same value for the age interval 5–9). It can clearly be seen that the pattern for situation 8000 best fits the actual distribution.

Consequently considering the population trend of the exploitable stock during seasons 1972 to 1977, the available number decreases rapidly in situations 2000 and 4000, and is almost stable in situations 8000 and 10000 as shown in Table 3. Any theoretical variation or trends shown in Table 3 are also useful for verification, if we have any other independent information available such as sightings data from non-whaling vessels.

From the results described above, situation 8000 is the most reasonable. This suggests that the exploitable number of female minke whales in Area IV has been approximately 20,000 in recent years.

FUTURE PREDICTIONS AND REPLACEMENT YIELDS

In Phase 2 of DOIPOP for the female minke whale, calculations are carried out from the 1904–1977 seasons. The next problem is to predict changes in the future population

Table 4
Comparison of actual catch with theoretical available number in 1975

Age interval	Actual catch	Available number				
		Situation 2000	Situation 4000	Situation 6000	Situation 8000	Situation 10000
0–4	71	561	1,208	1,855	2,501	3,148
5–9	499	816	2,777	4,739	6,701	8,662
10–14	337	–65	1,444	2,952	4,461	5,969
15–19	163	–233	569	1,370	2,172	2,973
20–24	82	–160	251	662	1,074	1,485
25–29	42	–74	153	381	608	835
30–34	23	–37	84	205	326	447
35–39	11	–13	56	126	195	264
40–44	5	–1	37	76	114	152
45–49	4	2	25	47	70	92
Total	1,237	796	6,604	12,413	18,222	24,027

Table 5
Comparison of adjusted theoretical age composition with the actual one in 1975
(Adjusting is done at 5–9 age interval from Table 4)

Age interval	Actual catch	Situation 4000	Situation 6000	Situation 8000	Situation 10000
5–9	499	499	499	499	499
10–14	337	259	312	332	344
15–19	163	102	145	162	171
20–24	82	45	70	80	86
25–29	42	27	61	45	48
30–34	23	15	22	24	26
35–39	11	10	13	15	15
40–44	5	7	8	8	9
45–49	4	4	5	5	5

Note:
Situation 2000 was rejected because of its negative age composition.

arising from catches after 1978. Assuming various values for the exploitation rate I easily calculated the theoretical population sizes of the 1978 and 1979 seasons on the basis of the population model. The results are shown in Table 6 (Phase 3 of DOIPOP). The replacement yield and sensible exploitation rate can be easily found from this by selecting the rate at which the available numbers do not change widely from 1977 to 1979.

The estimated replacement yield for each situation is shown in Table 7 and from this it can be concluded that the best estimate for the replacement yield is 1,170 under an exploitation rate of 0.06.

DISCUSSION

(1) *Accuracy of biological parameters*
There is some uncertainty about the values for the biological parameters such as a, b, c, d, e, p, especially for the early period from 1904 to 1940 due to a lack of data. However, as it is impossible to obtain these data at the present time, 'intelligent guesses' were made for these values.

(2) *Comparison with results using a variable pregnancy rate*
In the original paper presented to the IWC Scientific Committee at Cambridge in June, 1978, calculations were carried

Table 6
Effect on catch in this year on the population level in next year
(PHASE 3 of DOIPOP)

(A) Situation 4000

Available number in 1976/77 season = 6,450 Population level after the season = 14,286

Rate of exploitation	1977/78 Season			1978/79 Season			1979/80 Season
	Available number	Catch	Population	Available number	Catch	Population	Available number
0.00	6,393	0	14,652	6,869	0	15,141	7,282
0.02	6,393	128	14,508	6,776	136	14,829	7,090
0.04	6,393	256	14,364	6,684	267	14,521	6,901
0.06	6,393	384	14,220	6,592	395	14,217	6,715
0.08	6,393	511	14,076	6,499	520	13,918	6,532
0.10	6,393	639	13,931	6,407	641	13,623	6,352
0.12	6,393	767	13,787	6,314	758	13,332	6,175
0.14	6,393	895	13,643	6,222	871	13,046	6,002
0.16	6,393	1,023	13,499	6,130	981	12,764	5,831
0.18	6,393	1,151	13,355	6,037	1,087	12,487	5,663
0.20	6,393	1,279	13,211	5,945	1,189	12,213	5,499

Parameters: p, a, b, c, d, e are assumed to be the same in 1976/77 season

Table 6 (continued)

(B) Situation 6000

Available number in 1976/77 season = 12,732 Population level after the season = 28,131

Rate of exploitation	1977/78 Season Available number	Catch	Population	1978/79 Season Available number	Catch	Population	1979/80 Season Available number
0.00	12,910	0	29,014	13,628	0	30,040	14,292
0.02	12,910	258	28,718	13,433	269	29,404	13,899
0.04	12,910	516	28,422	13,239	530	18,776	13,513
0.06	12,910	775	28,126	13,045	783	28,158	13,133
0.08	12,910	1,033	27,830	12,851	1,028	17,548	12,760
0.10	12,910	1,291	27,534	12,657	1,266	16,949	12,393
0.12	12,910	1,549	27,238	12,463	1,495	26,359	12,033
0.14	12,910	1,807	26,942	12,268	1,718	25,778	11,679
0.16	12,910	2,066	26,646	12,074	1,932	25,206	11,332
0.18	12,910	2,324	26,350	11,880	2,138	24,644	10,992
0.20	12,910	2,582	26,054	11,686	2,337	24,090	10,658

Parameters: p, a, b, c, d, e are assumed to be the same in 1976/77 season

(C) Situation 8000

Available number in 1976/77 season = 19,015 Population level after the season = 41,976

Rate of exploitation	1977/78 Season Available number	Catch	Population	1978/79 Season Available number	Catch	Population	1979/80 Season Available number
0.00	19,426	0	43,377	20,386	0	44,939	21,302
0.02	19,426	389	42,929	20,090	402	43,978	20,708
0.04	19,426	777	42,481	19,794	792	43,031	20,124
0.06	19,426	1,166	42,033	19,499	1,170	42,099	19,551
0.08	19,426	1,554	41,585	19,203	1,536	41,180	18,987
0.10	19,426	1,943	41,137	18,907	1,891	40,276	18,434
0.12	19,426	2,331	40,689	18,611	2,233	39,386	17,890
0.14	19,426	2,720	40,241	18,315	2,564	38,509	17,357
0.16	19,426	3,108	39,793	18,019	2,883	37,648	16,834
0.18	19,426	3,497	39,345	17,722	3,190	36,801	16,320
0.20	19,426	3,885	38,897	17,427	3,485	35,967	15,817

Parameters: p, a, b, c, d, e are assumed to be the same in 1976/77 season

(D) Situation 10000

Available number in 1976/77 season = 25,297 Population level after the season = 55,821

Rate of exploitation	1977/78 Season Available number	Catch	Population	1978/79 Season Available number	Catch	Population	1979/80 Season Available number
0.00	25,943	0	57,739	27,145	0	59,839	28,312
0.02	25,943	519	57,139	26,747	535	58,553	27,512
0.04	25,943	1,038	56,540	26,350	1,054	57,287	26,736
0.06	25,943	1,557	55,940	25,952	1,557	56,039	25,969
0.08	25,943	2,075	55,340	25,554	2,044	54,811	25,215
0.10	25,943	2,594	54,740	25,157	2,516	53,602	24,475
0.12	25,943	3,113	54,140	24,759	2,971	52,412	23,748
0.14	25,943	3,632	53,540	24,361	3,411	51,242	23,035
0.16	25,943	4,151	52,940	23,963	3,834	50,090	22,335
0.18	25,943	4,670	52,340	23,566	4,242	48,957	21,649
0.20	25,943	5,189	51,740	23,168	4,634	47,844	20,977

Parameters: p, a, b, c, d, e are assumed to be the same in 1976/77 season

out using a variable pregnancy rate (0.75 in 1904 to 0.86 at the present time) instead of a constant pregnancy rate. The results were as follows:

a. Situations 6000 and 8000, (i.e. initial numbers of 6,000 and 8,000 females in 1904) both fitted the actual catch patterns in 1975.
b. The present exploitable female population in Area IV was estimated to be 22,000–33,000 in 1977.
c. The replacement yield for 1978 to 1979 was estimated to be 2,000.

As would be expected, these values are higher than those in this paper which uses a constant pregnancy rate.

Table 7

Estimated replacement yield in each situation

Initial available number / Situation	Present available number	Rate of exploitation E	Replacement yield (present)	Note
2000	167			Rejected clearly by negative age distribution.
4000	6,450	0.10	640	Rejected by comparing age distribution with the actual one.
6000	12,732	0.06	780	Rejected by comparing age distribution with the actual one.
8000	19,015	0.06	1,170	Acceptable.
10000	25,297	0.06	1,560	Rejected by comparing age distribution with the actual one.

(3) *Development of biological methods without CPUE*

We should not blindly believe that population analysis is limited to arithmetical calculations on catching effort and catch per unit effort. There are problems in standardising effort data and in determining either increasing or decreasing trends in CPUE with time from an insufficient data base. This can result in fruitless discussions between people with directly opposing interpretations of the same raw data. Important parameters such as age data for each year, availability, maturity, mortality, etc. should not be ignored and we must endeavour to establish biological methods such as DOIPOP. These do not exclusively use effort and CPUE data which always contain very wide uncertainties.

SUMMARY

1. The population model, DOIPOP, is simple and logical. It does not require the use of catching efforts which are always uncertain in whaling, and thus any regression analysis concerning effort and CPUE can be excluded.
2. Phase 1 of DOIPOP is the relationship between the natural mortality of juvenile and adult whales. Phase 2 is the yearly change of the whale population, the exploitable population, the mature population and the number of recruits etc. Phase 3 concerns predictions and replacement yields.
3. Verification can be carried out by comparing the actual age distribution (in the catch) with the theoretical age composition of the exploitable population.
4. The calculations were made for female minke whales in Area IV in the Antarctic. The age-specific availability function, age-specific maturity function, mortality function and pregnancy rate are shown in Fig. 1 and Table 1.
5. The output of Phase 1 is given in Table 2, summarised results from Phase 2 are given in Table 3, and the output of Phase 3 is given in Table 6. Calculations were made for five situations: the initial available number in 1904 as 2,000, 4,000, 6,000, 8,000 and 10,000.
6. Situation 2000 was clearly rejected because it gave a negative age composition in recent catching seasons. Situation 8000 seems to be appropriate because of the favourable comparison of the actual age composition with the theoretical one as shown in Table 5.
7. The estimated exploitable stock sizes and replacement yields are as follows:

Situation	Available number in 1977	Replacement yield
(4000)	(6,450)	(640)
(6000)	(12,732)	(780)
8000	19,015	1,170
(10000)	(25,297)	(1,560)

Rejected situations are parenthesised

8. Sightings data not associated with catching operations, are another independent method of verification.
9. From the above results, the status of the exploitable female minke whale population in Area IV of the Antarctic seems to be situation 8000, i.e. the exploitable population in 1977 is 19,000 and the replacement yield is 1,170.

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SC/30/Doc 32

The Effect of Meteorological Factors on the Catch of the Minke Whale in the Antarctic

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ABSTRACT

CPUE (catch per CSW, catcher's searching hour's work) of minke whaling are examined with relation to two meteorological factors: wind force and visibility. The two coefficients estimated using a multiple regression analysis (additive form) showed highly significant values. Combination of the two factors into nine categories gives correcting indices for effort data. To compare these indices with those calculated using a multiplicative model, two separate regression lines are fitted. The highly significant correlation means that there is no contradiction between the two methods.

INTRODUCTION

In pelagic operations, meteorological factors such as wind force and visibility greatly affect sightings and therefore catching efficiency. At the request of the IWC *Ad Hoc* Scientific Committee Meeting in 1961, Kurogane and Nemoto (1963) analysed this problem for fin and sei whales.

Ohsumi (1979) examined this effect for Japanese pelagic expeditions taking minke whales in the Antarctic. Since he dealt with the two factors separately in a multiplicative model, I analyse the same data (including data for the 1977/78 season) by an ordinary multiple regression analysis, and compare the two methods.

MATERIALS AND METHOD

Data collected by Japanese whaling fleets from 1971/72 to 1977/78 include visibility in miles and wind force on the Beaufort scale, measured at noon on board the factory ship. The CPUE values are calculated using raw CSW (catcher's searching hour's work) as the basis for effort.

Let the independent variables X_1 be the wind force and X_2 be the visibility,

$$X_1 = 0, 1, 2, .., 9$$

$$X_2 = 0, 1, 2, .., 9$$

the largest class includes values of 9 and over. These figures are shown in Table 1, together with the number of observations. The total number of observations, 554, is the number of operating days for minke whales during those seasons. The CPUE values are calculated as,

pooled catch/pooled CSW

for each combination and they are equivalent to weighted means. Mean figures for each class of X_1 and X_2 are also calculated in this manner and are shown in Table 1.

Table 1

CPUE (catch/CSW) in relation to wind force and visibility

	Wind force (X_1)										
	0	1	2	3	4	5	6	7	8	9	Mean
0	0.637*	0.668*	0.092*	0.439	0.293	0.392	0.144*		4.228*		0.398
	1	2	1	6	4	3	1		1		19
1			2.137	0.377	1.018	0.640	1.378	0.402	0.000*		0.807
			4	4	7	6	3	4	1		29
2	1.163*	1.565*		1.020	0.548	0.234	0.883				0.709
	1	1		6	6	4	6				24
3		2.645*	5.036*	1.455	0.412	1.471	0.572	0.000*			0.878
		2	1	3	6	6	6				25
4	8.492*		0.807*	0.945	1.217	0.863	0.804	0.532	0.000*		0.928
	1		2	6	4	5	7	3	1		29
5	1.442*		1.762	1.915*	2.138	0.750	0.425	1.154	0.000*		1.232
	1		3	2	8	6	3	3	1		27
6	1.540*	3.295*	0.625*	1.199	0.809	2.411*	0.526		0.197*		0.893
	2	1	1	5	9	2	6		1		27
7	11.111*	2.433	3.107	0.906	1.142	0.463	0.531			0.000*	0.978
	3	4	3	8	12	6	5			1	42
8	1.951	4.575*	0.676	1.369	1.863	1.986	0.704	0.194			1.167
	5	1	5	7	9	6	11	3			47
9	2.026	2.856	1.394	1.994	1.227	1.283	1.238	0.300	0.000*		1.454
	16	13	38	75	84	44	8	6	1		285
Mean	2.145	2.407	1.304	1.428	1.111	1.033	0.739	0.413	0.182	0.000	
	30	24	58	122	149	88	56	20	6	1	554

Lower figures: number of observations

*Values excluded from the multiple regression analysis

To calculate the multiple regression, taking CPUE as the dependent variable Y:

$$Y = a + b_1X_1 + b_2X_2$$

i.e. the usual additive model without an interaction term. For this calculation I excluded CPUEs based on two observations or less and the value (X_1=0,X_2=7) from the 77 values in Table 1, leaving 51 values available for the analysis.

RESULTS

The correlation coefficients are,

$r_{X_1X_2}$ = –0.189 (not significant)

r_{X_1Y} = –0.618**(significant at the 1% level)

r_{X_2Y} = +0.358**(significant at the 1% level)

It is quite easy to understand these results: there is no obvious relationship between wind force and visibility; an increase in visibility results in higher CPUE, while an increase in wind force results in the reverse. Kurogane and Nemoto (1963) reported similar results.

The calculated multiple regression is:

$$Y = 1.668 - 0.216X_1 + 0.067X_2 \quad \ldots(1)$$

Comparing the two coefficients, b_1 and b_2, wind force has the dominant effect on the CPUE. The CPUE will increase by about 0.07 with an increase in visibility of one mile, while it will decrease by about 0.22 with an increase of wind force of 1 on the Beaufort scale.

The test of the significance of the regression is shown in Table 2.

Table 2

Variance analysis table to test significance of regression

Source of variation	df	Sum of squares	Mean square	F
Regression (b_1)	1	8.562	8.562	31.080**
(b_2)	1	2.762	2.762	10.027**
Residual	48	13.222	0.276	
Total	50	24.547		

**Significant at the 1% level.

Thus the above analysis proved significance at the 1% level for b_1 and b_2 and we can use the multiple regression (1) to explain the minke whale CPUE with two meteorological factors, wind force and visibility. However, the multiple correlation coefficient is rather small and its square value (R^2) is 11.324/24.547 = 0.4613. In other words, only 46.13% of the total variance can be explained by the above model.

Kurogane and Nemoto (1963) examined data based on CDW and they took another variable, day length, which, since they treated their data by month, showed only one significant value in twelve cases. The multiple correlation coefficients they obtained for the three variable model, wind force, visibility and day length are 0.530, 0.605, 0.695 for fin whales in January, February and March, respectively and 0.724 for all baleen whales taken in March. Almost the same degree of variation (R = 0.526, 0.601, 0.682 and 0.723, respectively) could be explained by the two variable model, wind force and visibility. The R^2 values in their two variable model are 0.281, 0.366, 0.483 and 0.524, respectively. Consequently these two analyses showed almost the same degree of ability to explain the variation of CPUE with two meteorological factors, despite the difference in species. However, one other important factor which affects the CPUE of the minke whale has not been taken into account: the monthly change in population density within the same whaling ground.

The comparison of the two regression coefficients b_1 and b_2 (Table 3), shows that in minke whaling the wind force has the dominant effect on CPUE while in fin and sei whaling the two meteorological factors have almost the same effect. (Since correlation coefficients r_{X_1Y} and r_{X_2Y} showed significance for fin (January) and fin (February), I took these two cases for comparison.)

Table 3

Comparison of regression coefficients

	Minke (this report)	Fin (Jan.) (Kurogane and Nemoto (1963))	Fin (Feb.)	Fin (March)	All (March)
b_1	−0.216	−3.2	−2.1	−4.6	−5.8
b_2	0.067	3.0	2.5	0.85	1.5

It is, then, quite reasonable to consider the difference of height and duration of blow between fin and minke whales.

Doi (1971) gave values of 3.23 seconds for the minke whale blow and 4.57 seconds for the fin whale blow, based on data collected by Japanese whaling fleets in the Antarctic Ocean. Experienced whalers also say that the blow of the minke whale is much lower and thinner than that of the fin whale.

CORRECTING INDICES FOR THE MINKE CPUE

For practical use it is convenient to classify the wind force and visibility into suitable categories. Kurogane and Nemoto (1963) used nine categories: for X_1 = 0–3, 4–6, 7–10, and for X_2 = 0–1, 2–4, 5–9. I also chose nine categories and tried to balance the number of observations in each category, since the minke whale data had a much wider range:

Wind force X_1 = (0–2), (3–5), (6–9)

Visibility X_2 = (0–2), (3–5), (6–9)

Then the weighted estimates of CPUE were calculated for each category:

$$\Sigma\Sigma Y_{ij}/\Sigma\Sigma n_{ij}$$

where n_{ij} is the number of observations for each combination of wind force and visibility.

These nine estimates are converted into indices taking the most frequent category (X_1=3–5, X_2=6–9; weighted CPUE = 1.408) as the standard. The results are shown in Table 4, together with indices calculated directly from the data.

Table 4

Correcting indices for minke whale effort data

	Wind force		
Visibility	0–2	3–5	6–9
0–2	1.023 (0.777)	0.639 (0.405)	0.247 (0.526)
3–5	1.666 (1.409)	0.743 (0.791)	0.388 (0.444)
6–9	1.404 (1.247)	1.000 (1.000)	0.581 (0.404)

( ) from original data.

The correlation coefficient between these nine pairs of values is highly significant (r = 0.863**).

MULTIPLICATIVE MODEL

Ohsumi (1979) estimated correcting factors for minke CPUE using a multiplicative model. He plotted the mean CPUE for each wind force class and smoothed the relationship. This was also done for visibility. Then he applied these estimates in the multiplicative form:

$$(\hat{Y}[X_1]) \cdot (\hat{Y}[X_2]) \cdot$$

I also calculated the relationship between CPUE and wind force and between CPUE and visibility but for a straight line, not a smoothed curve. The mean CPUE values for each wind force are given in Table 1. With these figures the calculated regression line is,

$$Y = 2.208 - 0.251X_1$$

The slope, b, is significant at the 1% significance level.

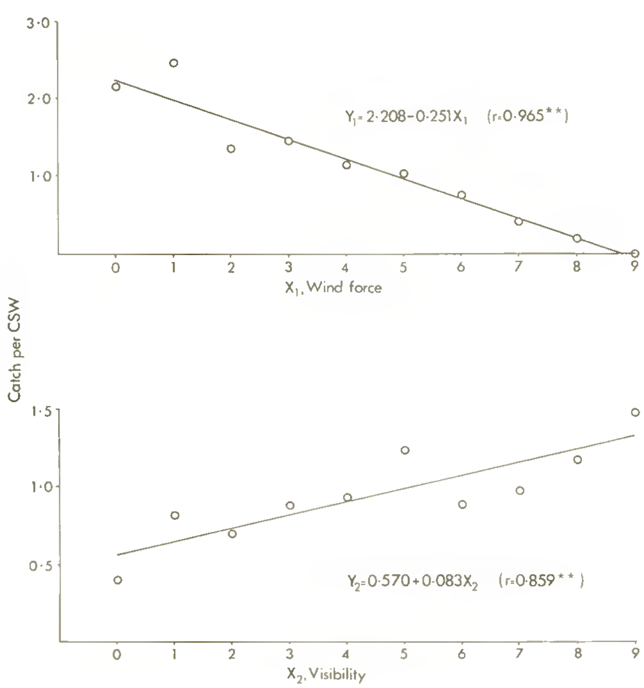

Fig. 1. Relationship between CPUE and meteorological factors.

The regression line between CPUE and visibility was also calculated using the same procedure (mean CPUE values for each visibility class are given in Table 1). The regression line is,

$$Y = 0.570 + 0.083X_2$$

and the slope was also highly significant (Fig. 1).

Estimated correcting indices calculated using a similar method to that used for the multiple regression analysis, are shown in Table 5.

Table 5

Correcting indices (multiplicative model)

	Wind force		
Visibility	0–2	3–5	6–9
0–2	0.756	0.506	0.248
3–5	1.066	0.668	0.334
6–9	1.530	1.000	0.450

The weighted estimate of CPUE for the category (X_1=3–5, X_2=6–9) is 1.586, which is to be compared with that of 1.408 for multiple regression analysis.

The correlation coefficient between the values in Table 4 and Table 5 are highly significant (0.965**) although the values are slightly smaller in Table 5. In conclusion the multiplicative model does not contradict the multiple regression model, probably due to the poor correlation between the two meteorological factors.

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SC/30/Doc 53

Further Considerations on the Assessments of Southern Hemisphere Minke Whales

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ABSTRACT

The paper presents further analyses of data considered at the Special Meeting on Minke Whales, Seattle, May 1978, and presents calculations which were completed by the author on that occasion but which were not included in the Report of that meeting for lack of time to consider them. Some of the considerations outlined were taken into account at the June 1978 meeting of the Scientific Committee in Cambridge and London; other matters were left pending further study, including the method of calculating the eventual abundances towards which minke whale stocks were increasing prior to their pelagic exploitation in the early 1970s and the evidence, from catch distributions, that the six Southern Hemisphere Areas may not adequately define management stocks, which is presented in an Appendix.

1. ESTIMATION OF q

Values of F obtained for Area IV at the Special Meeting on Minke Whales (IWC, 1979) can, with corresponding measures of total annual effort, F, be used to calculate q (coefficient of efficiency) from the equation:

$$F = qf \quad (F = Z - 0.095)$$

The correct values of whaling effort to be used are the averages of pairs of successive pelagic efforts in the two seasons from which the Z values are calculated (to which would be added, if Areas II and III were being considered, the land station effort in the season between). The data are given in Table 1.

Area IV and also for the other Areas, with appropriate corrections. An alternative method of estimating q, which does not in principle require a prior knowledge of M (only an assumption that M is constant) is to calculate the linear regression of Z on effort, thus:

$$Z = M + qf$$

The 10 data pairs available (5 for each sex) give an estimate:

$$M = 0.08$$
$$q = 0.89 \times 10^{-4}$$

but the correlation is low:

$$r = +0.17$$

Table 1

	F			f	$q \times 10^{-4}$		
Seasons	♂	♀	♂ + ♀	(EJCSW)	♂	♀	♂ + ♀
1971/72–1972/73	0.043	0.938	0.491	2,048	0.210	4.580	2.397
1972/73–1973/74	0.473	−0.371	0.051	3,910	1.210	−0.949	0.130
1973/74–1974/75	0.337	1.076	0.707	4,420	0.762	2.434	1.600
1974/75–1975/76	−0.018	−1.046	−0.532	2,041	−0.088	−5.125	−2.607
1975/76–1976/77	−0.076	0.922	0.423	1,272	−0.597	7.248	3.325
Means	0.247	0.401	0.324	2,738	0.299	1.638	0.969
$\Sigma F/\Sigma f = {}_{\Sigma}q$					0.902	1.464	1.183

The variation of q is evidently very great, as are the differences between $\bar{q}$ and an overall ${}_{\Sigma}q$ calculated by dividing the mean whaling mortality over the period by the mean effort.

This variability is an indication of the extent to which the measures of effort are unsatisfactory; variability is even greater for other measures of effort tried – CSW[1] and 'Ohsumi'. The appearance of negative values in the more recent years, and of negative values frequently in the estimates for Area III and for Areas III and IV combined, suggest that q might in fact have been increasing over at least part of the period. $q_♀$ and $q_♂$ are not very closely correlated; the difference between their means is in the expected direction, and $q_♀$ and $q_♂$ are in a reasonable ratio (1.60), considering the preponderance of females in the catches (females/males = 1.24).

In the following sections values of ${}_{\Sigma}q$ are used to calculate values of F from series of seasonal effort data for

This is certainly not a sensitive method for the estimation of M, with such variable data, but the general concordance is such as slightly to enhance confidence in the analysis carried out.

2. COMPARISON OF DENSITIES OF EXPLOITED STOCKS AS BETWEEN AREAS

The average catches per unit effort, over the period 1971/72–1976/77, relative to that in Area IV are given in Table 2 (both sexes combined). However, since minke whaling was not carried out in each Area in every year of the period, except in Area IV, and since the estimates obtained for F, M and i indicate that the numbers of whales in Area IV declined during this period, the simple comparison may not be strictly valid. An alternative approach is to compare only for the years in which whaling took place in the Area concerned. Such comparison would eliminate the effects of any

Table 2

	Area						
Effort measure	I	II	III	IV	V	VI	Average
CSW	0.76	0.64	1.20	1.00	0.68	0.32	0.77
CSW[1]	0.76	0.78	1.06	1.00	0.94	0.39	0.82
'Ohsumi'[1]	0.78	0.72	1.32	1.00	1.61	0.65	1.01
CSW (inc. 1977/78)[2]	0.75	0.64	1.34	1.00	0.58	0.35	0.78

[1] The average for the 'Ohsumi' effort data is excessively high because of the strong seasonal 'correction', based on Area IV data which has been applied to the other Areas.
[2] The essential difference is in Area III where extremely high catch rates were reported in 1977/78.

general trend in q due for example to technological changes not accounted for, or to a general increase in knowledge, on the part of whalers, of the behaviour of the southern minke whale. It could, on the other hand, for an Area where whaling has been conducted only towards the end of the period, lead to underestimates of the comparable density in that Area, if the knowledge of minke distribution had not yet been perfected but was by then well known for Area IV. The results of all such possible comparisons are given in Table 3, only for the CSW effort measures. The average values including and excluding 1977/78 data are about the same but they are somewhat higher than those given in Table 2. If these values are now extrapolated back to the 'initial' year 1971/72 initial relative densities can be computed. For this however, it is necessary to calculate the trends of any change of stock in each Area. This is done in the next sections.

3. ESTIMATION OF 'INITIAL' AND 'CURRENT' DENSITIES IN EACH AREA

This can be done by two methods. The first is based on a calculation of the approximate trend of density in Area IV by the regression of ln (CPUE) on time. The results are given in Table 4. In Table 5 the estimates given in Table 3 are corrected by multiplying them by the averages given in the five right hand columns of Table 4.

These calculations assume there were no changes in density in the Areas other than Area IV between 1971/72 and the mean year of comparison. The regressions of ln CPUE on time in Area III indicate an *upward* trend, at an exponential rate of +0.2823 yearly if 1977/78 data are *excluded*, and +0.3365 if 1977/78 data are *included*. Absolute initial populations cannot be calculated from these trends because they are much steeper than the net rates of increase

$$i = (Z' - M)$$

calculated from age compositions; the value of i for all Areas (both sexes) is

$$0.149 - 0.095 = 0.054$$

and for Area III data alone is

$$0.129 - 0.095 = 0.034$$

This regression therefore gives absurd results on the assumptions made (constant M and i) and parameter estimates agreed during the Special Meeting; it is noteworthy, however, that if they are used to back-calculate the Area III stock in 1971/72, relative to its level in the mean year of comparison, then the factors of initial density compared with Area IV become:

0.38 instead of 0.94 (1977/78 excluded)

and

0.33 instead of 1.25 (1977/78 included)

The other Areas, where whaling was conducted by Japanese vessels in fewer years, show variations in CPUE which may indicate increases in Areas I, V and VI and decreases in Area II, but it would hardly be valid to extrapolate these for the present purpose. If we assume constancy in all Areas we can also calculate the *present* (beginning of 1978/79 season) density ratios. These are given in Table 6. It is evident that the densities of exploited stocks in other Areas (with the exception of Area VI) may be expected now to be higher than, or at least approaching, that in Area IV. This swing in the densities is presumably attracting whaling effort relatively into Areas other than IV, but this effect cannot be analysed because of the institution of quotas by Area.

A more precise way of calculating the relative initial (and present) densities would be to simulate the changes in Area IV – and possibly in other Areas – on the basis of estimates made of q, M and i and the observed total whaling effort. The simulations for Area IV are given in Table 7. It will be seen that they lead to substantially lower current

Table 3

	I	II	III	IV	V	VI	Average
1977/78 excluded	1975/76, 1976/77	1973/74, 1974/75, 1975/76	All except 1972/73		1974/75, 1975/76, 1976/77	1973/74, 1975/76, 1976/77	
	0.84	0.76	1.29	1.00	1.06	0.34	0.88
1977/78 included			+1977/78	+1977/78	+1977/78	+1977/78	
	0.84	0.76	1.43	1.00	0.83	0.37	0.87

Table 4

Calculation from regressions of 1n (catch/CSW) on time

	Area IV		Average for years of comparison with				
	Excl. 1977/78	Incl. 1977/78	I	II	III	V	VI
ln slope	−0.1222	−0.0415					
'Initial' stock	13,700	20,700					
Relative stock							
1971/72	1.000	1.000					
1972/73	0.885	0.959					
1973/74	0.783	0.920					
1974/75	0.693	0.883					
1975/76	0.613	0.847					
1976/77	0.543	0.813					
Mean	0.753	–	0.578	0.696	0.726	0.616	0.646
1977/78	0.480	0.780					
Mean	–	0.886	0.830	0.833	0.874	0.831	0.840

Table 5

Relative 'initial' densities (1971/72) from Tables 3 and 4

	I	II	III	IV	V	VI	Average
Excluding 1977/78 data	0.49	0.53	0.94	1.00	0.65	0.22	0.64
Including 1977/78 data	0.70	0.63	1.25	1.00	0.69	0.24	0.75

Table 6

Current relative densities (from Tables 4 and 5)

	I	II	III	IV	V	VI
Excluding 1977/78 data	1.02	1.10	1.96	1.00	1.35	0.46
Including 1977/78 data	0.90	0.81	1.60	1.00	0.88	0.31

Table 7

Simulations of Area IV exploited stock density

		$q = 1.183 \times 10^{-4}$		$q = 0.969 \times 10^{-4}$	
Beginning of Season	Effort (EJCSW)	i = 0.149 – 0.095 = 0.054	i = 0.137 – 0.095 = 0.042	0.054	0.042
1971/72	1,510	1.00	1.00	1.00	1.00
1972/73	3,905	0.88	0.87	0.91	0.90
1973/74	5,268	0.59	0.57	0.66	0.64
1974/75	3,696	0.33	0.32	0.42	0.40
1975/76	568	0.23	0.22	0.31	0.29
1976/77	1,919	0.22	0.21	0.31	0.29
Mean	2,811				
1977/78	549	0.19	0.17	0.27	0.25
Mean	2,487				
1978/79		0.19	0.17	0.27	0.25
$\bar{F}$		0.294		0.241	

stock densities than does that in Table 4 (left hand column), even when the lower value of $\bar{q}$ is used. A reduction to 27% over 7 years for

$$q = 0.969 \times 10^{-4} \text{ and } i = 0.954$$

is equivalent to the action of a constant F of 0.24 over that period. The equivalent from the regression slope of 0.1222 is F = 0.18, which would correspond with

$$q = 0.73 \times 10^{-4}$$

The higher F derived from the analysis of age-structure to give Z is however well within the probable limits of the regression method; the slope of the 90% confidence limit is –0.3157 corresponding with

$$F = 0.37 \text{ for } i = 0.054$$

and

$$F = 0.36 \text{ for } i = 0.0415$$

Values for the 95% confidence limit are, of course, even higher.

In order not to *underestimate* the densities in other Areas we use the simulation for

$$q = 0.969 \times 10^{-4} \text{ and } i = 0.054$$

which, of the four, gives the smallest rate of change of stock. The 'initial' and 'current' density ratios thus obtained are given in Table 8.

or as given by the values of Z′ in Table 12 of Ohsumi (1978). However, the effort in each Area was not deployed over equal geographical areas, and a correction has to be made for this; an explanation is given in section 4 below. I have used the first two rows of Table 12 to calculate, for each Area and each season:

$$F = q.f/a$$

where a is the effective size of an Area relative to Area IV. These give two series of F values – in these it is assumed that either:

(A) there are no whales belonging to the stock within the Area but outside the sub-areas in which there has been whaling, i.e. either the whales in those non-exploited sub-areas are at negligible density, or they do not mix with and have therefore not been significantly affected by the whaling in that Area; or, alternatively,

(B) that there are whales in all sub-areas south of 55°S and that there is complete mixing so that whaling in only a few sub-areas affects the density of whales in each entire Area.

The calculated values of F are given in Table 10. These have been used to simulate the course of stock changes in each Area (Table 11) using in each case the mean i value for

Table 8

'Initial' and 'current' relative densities

From Tables 3 and 7 ($q = 0.969 \times 10^{-4}$ and $i = 0.054$)

	I	II	III	IV	V	VI	All
'Initial'							
Excluding 1977/78	0.26	0.35	0.64	1.00	0.37	0.15	0.46
Including 1977/78	0.26	0.35	0.66	1.00	0.27	0.14	0.45
'Current'							
Excluding 1977/78	0.96	1.30	2.37	1.00	1.36	0.54	1.26
Including 1977/78	0.96	1.30	2.45	1.00	1.01	0.53	1.21

A further step is to simulate the changes in stocks in other Areas. For this purpose we first tabulate the EJCSW on the basis of Japanese effort data and the ratio of total to Japanese catches, by Areas and seasons (Table 9). In Table 10 are given the derived stock densities by assuming

$$q = 0.969 \times 10^{-4}$$

and i is either equal to the average in all Areas, i.e.

$$0.149 - 0.095 = 0.054$$

all Areas, or the appropriate i value for each Area, from Ohsumi's Table 12, assuming M = 0.095. It should be noted that it has been assumed for this purpose that in any stock reduced by whaling there has not yet been time for incoming recruits to be affected by such reduction.

Where it is assumed that all whales are in the exploited Areas (or if there are any others outside them they do not mix) – Case (A) in Table 11 – substantial reductions in density are predicted over the period except in Area VI.

Table 9

EJCSW in areas other than Area IV

Season / Area	I	II	III	V	VI
1971/72 [+ 1972]	0	[959]	268 + [155]	0	0
1972/73	0	[888]	485 + [55]	0	0
1973/74	(1,212)	155 + [1,045]	1,299 + [132]	0	47
1974/75	(1,805)	435 + [561]	1,363 + [115]	644	0
1975/76	1,149	2,896 + [1,931]	571 + [29]	1,464	592
1976/77	786	(2,113) + [2,488]	896	1,022	117
Mean 1971/72–1976/77	825	2,245	895	522	126
1977/78	(447)	(884) + [?2,488]	288	1,560	913
Mean	771	2,406?	808	670	238

Table 10

Whaling mortality rate by areas and seasons
(From Tables 9 and 12 with $q = 0.969 \times 10^{-4}$)

F	I		II		III		V		VI	
Season	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
1971/72 and 1972	0	0	0.143	0.068	0.068	0.032	0	0	0	0
1972/73	0	0	0.132	0.063	0.087	0.041	0	0	0	0
1973/74	0.173	0.095	0.179	0.086	0.231	0.107	0	0	0.005	0.004
1974/75	0.257	0.142	0.148	0.071	0.239	0.111	0.160	0.056	0	0
1975/76	0.164	0.091	0.720	0.344	0.097	0.045	0.364	0.128	0.067	0.051
1976/77	0.112	0.062	0.686	0.328	0.145	0.067	0.254	0.089	0.013	0.010
Mean										
1977/78	0.064	0.035	0.503	0.240	0.047	0.022	0.166	0.058	0.104	0.078
Mean										

Considerable variability is introduced by using the i values specific to each Area, and it is probably more satisfactory to consider the common i value = 0.054. The mean of the Area i values given by Ohsumi is 0.021, assuming M constant = 0.095, i.e. considerably less than the average value of 0.054; these Area values may be underestimates resulting from applying to the individual catch curves a regression procedure in which the earliest age of full recruitment has been underestimated. The reductions indicated are not evident in the corresponding catch per unit effort series, but cannot all be ruled out by these data. Furthermore, the effective Area ratios for Case (A) are overall rather close to those obtained from data on sightings by scouting vessels (cf. first and last rows of Table 12 and footnote); this would seem to support this approach to the Area estimation. A more optimistic picture appears in Case (B) of Table 11 where the existence of a 'reservoir' of whales in the unexploited parts of each Area is assumed, with full mixing. Thus it seems that little change would be expected in Areas I and III, an increase in Area VI, but substantial declines in Areas II and V which would already bring these two stocks into the 'protected' category by a naive application of the New Management Procedure. In particular it should be remembered that land station whaling was being carried out in Area II for some years before the 1971/72 Antarctic season.

4. DETERMINATION OF EFFECTIVE WHALING AREA WITHIN EACH STOCK AREA

A first approach to this problem is to assume that by now there has been some whaling, at least in one of the possible 7 seasons, everywhere that minke whales occur in sufficient density. Only in Areas I and V have there been significant catches in Series A (north of 60°S). Judging from detailed

Table 11

Simulations of stock density changes

(A) Whales only in exploited areas

Area	I		II		III		V		VI	
i =	0.054	0.007	0.054	0.034	0.054	0.032	0.054	0.031	0.054	–0.021
1971/72	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1972/73	1.06	1.01	0.91	0.97	0.99	0.96	1.06	1.03	1.06	0.98
1973/74	1.11	1.01	0.85	0.94	0.95	0.91	1.11	1.06	1.11	0.96
1974/75	0.99	0.86	0.75	0.89	0.80	0.75	1.18	1.10	1.17	0.94
1975/76	0.81	0.67	0.68	0.86	0.66	0.61	1.06	0.97	1.23	0.92
1976/77	0.72	0.57	0.35	0.63	0.64	0.57	0.78	0.69	1.21	0.84
Mean										
1977/78	0.68	0.51	0.19	0.47	0.58	0.51	0.64	0.55	1.27	0.81
Mean										
1978/79	0.67	0.50	0.12?	0.38	0.59	0.50	0.57	0.48	1.20	0.72
(B) Whales also in unexploited areas and mixing										
1971/72	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1972/73	1.06	1.01	0.99	0.97	1.02	1.00	1.06	1.03	1.06	0.98
1973/74	1.11	1.01	0.98	0.94	1.04	0.99	1.11	1.06	1.11	0.96
1974/75	1.07	0.92	0.95	0.89	0.98	0.92	1.18	1.10	1.17	0.94
1975/76	0.98	0.81	0.93	0.86	0.93	0.85	1.06	1.07	1.24	0.92
1976/77	0.94	0.74	0.70	0.63	0.94	0.84	0.78	0.97	1.29	0.85
Mean										
1977/78	0.93	0.70	0.53	0.47	0.92	0.81	0.64	0.78	1.29	0.83
Mean										
1978/79	0.95	0.68	0.44?	0.38	0.95	0.82	0.57	0.76	1.26	0.75

Japanese catch data these were practically all taken south of 55°S, i.e. in sub-area As.

Within the B Series (50°S–60°S) no minke whales have been taken by Japanese vessels in I w, II e, III w, V e or VI w northward of 65°S. Large catches by the USSR in I w have been taken in the north as well as the south. There have been no Soviet catches in VI w; some of the substantial USSR catches in II e and III w might have been taken north of 65°S. Roughly speaking, there has been pelagic whaling, south of 55°S in:

Area I	4 sub-areas out of a possible 7
Area II	6 sub-areas out of a possible 8
Area III	3 sub-areas out of a possible 6 (or 7 if Cn III w included)
Area IV	4 sub-areas out of a possible 5
Area V	1 sub-area out of a possible 6
Area VI	4 sub-areas out of a possible 8

These fractions, multiplied by the sector angle of each Area relative to the IV-angle, give a first approximation to the effective relative areas of whaling. There are, however, two other considerations:

(a) There are vacant localities – statistical squares in which no whaling has taken place, near the boundaries of II w and II e, and V w and VI e. Thus, all catches in As II w have been within 10° of the boundary of Areas I and II, and catches in Bn II w have been within 10° of that boundary. Likewise, catches in Bs and Cn II e have all been in the eastern halves of those sub-Areas.

(b) Statistical squares to the northward have larger areas than those to the southward, in the approximate ratios:

As	1.4
Bn	1.2
Bs	1.0
—	
Cn	0.8

These can be used as factors if minke whales are assumed to be distributed more or less throughout the most northerly squares. This seems to be true for Bn, but possibly not for As, for which a reduced factor of 1.3 has been used.

Taking account of the relative sizes, the angular widths and the fraction of possible sub-areas in which whaling has been carried out I have calculated the following effective area adjustments, relative to Area IV;

Table 12

		I	II	III	IV	V	VI	Sum
(A)	Area exploited	0.68	0.65	0.60	1.00	0.39	0.85	4.17
(B)	Available area S of 55°S	1.23	1.36	1.29	1.00	1.11	1.13	7.12
	Ohsumi (area between 60°S and ice-edge in February)	1.58	1.14	1.53	1.00	1.45	1.57	8.27
	Sightings[1]	0.51	0.62	0.94	1.00	0.71	0.47	4.25

[1] The last row gives the estimates calculated by Best (Japan, 1978) at the Special Scientific Meeting, from the areas where the number of whales sighted by Japanese scouting vessels exceeded a certain threshold density of sightings per 1,000 miles traversed. It will be seen that although there are some Area to Area differences, notably for Areas V and VI, the sum (last column) is very close to the estimate of total exploited area relative to Area IV.

5. RECALCULATION OF 'INITIAL' AND 'CURRENT' STOCKS

We are now in a position, using the simulations in Table 11, the area dispositions in Table 12, and the first estimates of densities in Table 8 (which assumed no stock changes in Areas other than IV) to calculate refined stock estimates for Areas other than IV. To do this we first calculate the average density (relative to 'initial') in each Area in the years for which CPUE comparisons were made with Area IV (shown in the heading of Table 3) and divide this into the corresponding density ratios given in the top two rows of Table 8. The results are shown in Table 13, first two rows. The last two rows are similarly obtained by dividing the average densities in the comparison years into the 1978/79 values given in the last rows of Table 11 (A) and (B).

It will be seen that inclusion of the 1977/78 comparison data has made, at this stage, only slight differences to the results. For the next step I have used the values that exclude the 1977/78 data. This step is to multiply the values in Table 13 by the corresponding Area adjustments given in Table 12. This has been done for the (A) and (B) assumptions; the results are given in Table 14.

The final step is the calculation, from Table 14, of the absolute numbers of minke whales, in each Area, at the beginning of the 1971/72 season and at the beginning of the 1978/79 season. The mean stock size in Area IV over the period 1971/72–1976/77 is estimated as:

$$\overline{C}/\overline{F} = 2{,}749/0.229 = 12{,}004$$

The mean density over that period was, from Table 7

$$(q = 0.969 \times 10^{-4} \text{ and } i = 0.054)$$

= 60% of the 'initial' (beginning of 1971/72 season) density so the 'initial' stock in Area IV is

$$12{,}004/0.60 = 20{,}007$$

The 'current' stock (beginning of 1978/79 season) is, from the same column of Table 7,

$$20{,}007 \times 0.27 = 5{,}402$$

From these two estimates Table 15 is derived.

Replacement yields are roughly 5.4% of the estimates of current stock, and total 1,030 for the (A) assumption and 1,520 for the (B) assumption, as compared with the 1977/78 quota of 5,690.

6. NATURAL GROWTH OF MINKE WHALE STOCKS

As a guide to classification of stocks in a dynamically changing situation, it may be useful to attempt a simulation of the course of increase expected in the stocks if intensive pelagic whaling and increased land station whaling had not begun in 1971/72. For this purpose we assume that the minke stocks were in balance before the increase noted in the early age-composition data from Japanese pelagic whaling, that is before about 1950. Then at that time,

$$r_1 = M = 0.095$$

We further assume that the yield curve at that time could be approximated by a modified logistic, with MSYL = 60% of the stock level at that time. In the next few years food rapidly became more available, either as a result of the decline in blue and fin whales, or because of a natural change in krill productivity, or a combination of these causes. After a recruitment delay a new value

$$r_1' = 0.149$$

Table 13
'Initial' and 'current' densities, relative to Area IV
(corrected for simulated changes in all stocks over the period of exploitation; i = 0.054 in all Areas)

	I		II		III		V		VI		All	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
'Initial'												
1977/78 data excluded	0.34	0.27	0.46	0.37	0.79	0.65	0.37	0.29	0.13	0.12	0.52	0.45
1977/78 data included	0.34	0.27	0.46	0.37	0.86	0.68	0.37	0.29	0.12	0.11	0.53	0.45
'Current'												
1977/78 data excluded	0.84	0.67	0.21	0.16	1.73	1.43	0.77	0.77	0.55	0.54	0.85	0.76
1977/78 data included	0.84	0.67	0.21	0.16	1.88	1.49	0.63	0.63	0.53	0.52	0.85	0.75

Table 14
Stock abundances, relative to Area IV

	I	II	III	IV	V	VI	All
'Initial'							
(A)	0.23	0.30	0.47	1.00	0.14	0.11	2.25
(B)	0.33	0.50	0.84	1.00	0.32	0.14	3.13
'Current'							
(A)	0.57	0.14	1.04	1.00	0.30	0.47	3.52
(B)	0.82	0.22	1.84	1.00	0.85	0.61	5.34

Table 15
Estimates of stock abundance (to nearest hundred)
(from Tables 14 and 7)

		I	II	III	IV	V	VI	All
Assumption:								
(A)	'Initial'	4,600	6,000	9,400	20,000	2,800	2,200	45,000
	'Current'	3,100	800	5,600	5,400	1,600	2,500	19,000
(B)	'Initial'	6,600	10,000	16,800	20,000	6,400	2,800	62,600
	'Current'	4,400	1,200	9,900	5,400	4,600	3,300	28,800

is established, which leads to the observed $i = 0.054$ in the age-compositions; in Area IV and elsewhere the stocks increase until they reach to calculated value of 20,000 in Area IV and corresponding levels in other Areas. Thus the Area IV stock might have numbered about 12,000 whales in 1960. Evidently the high level of r' cannot continue indefinitely; as the food supply per whale is reduced, both by the increase in minke whales themselves and possibly the increases in other predators, r' will be gradually reduced until it is again equal to $M = 0.095$.

If the reduction in food is density dependent, we can estimate the new asymptotic population if r_o, the maximum recruitment rate in small populations with unlimited food supply, can be estimated, and if we assume that with the increased food supply the population now moves on a higher level modified logistic of the same form. If the age at sexual maturity cannot be reduced much below the present value of six years, nor the pregnancy rate of mature females exceed about 80%, and if the juvenile mortality rate is assumed equal to the adult rate, we would expect r_o to be approximately 0.20. I take this value for the following calculation.

It can readily be shown that the ratio U of the new to the original asymptotic stock level is given by:

$$U = \left(\frac{r_o - r_1}{r_o - r_1'}\right)^{1/2.39}$$

For the values given we find $U = 1.35$. A total 35% increase in stock is very small considering the apparent establishment of a 5.4% rate of increase over a decade or more. This suggests either that r_o is less than 0.20, or that the abundance of minke whales is limited more by the other influences on food availability (including other whales) than by its own density. In the former case r_o would necessarily be less than 0.16 if the new asymptotic abundance were to be expected to reach double or more the original abundance. In the latter case we have no basis for estimating the new asymptote unless the main competitors can all be identified and estimated.

If the new asymptote would be double the original one, then the new MSYL[1] is 20% higher than the original asymptotic level. This suggests that an appropriate management regime might seek to maintain the stocks at roughly the level that they had attained at the beginning of the period of their exploitation by pelagic whaling.

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Appendix

DISTRIBUTION OF MINKE WHALE CATCHES BY LATITUDE AND LONGITUDE

Detailed Japanese catch data presented to the Special Scientific Meeting on Southern Hemisphere minke whales show that

(a) there was, in most years, both before and after the institution of quotas by Areas a strong grouping of catches near the boundary of Areas III and IV between about 53° and 57°S.

(b) there were several extensive localities in which minke whales have never been caught by Japanese vessels.

These data permit a sub-division of Areas, within Series, as follows:

An and Bn – the northerly 5° of Series A and B
As and Bs – the southerly 5° of Series A and B

In addition the Areas can each be divided into western and eastern parts in such a way that few, if any, whales were caught near to the east/west boundaries in most Areas, thus:

Sub-Area	Squares	Latitude
Iw	31 – 33	90°W
Ie	34, 35, 0	60°W
IIw	1 – 3	30°W
IIe	4 – 6	0
IIIw	7 – 10	40°E
IIIe	11 – 13	70°E
IVw	14 – 17	110°E
IVe	18, 19	130°E
Vw	20 – 23	170°E
Ve	24, 25	170°W
VIw	26, 27	150°W
VIe	28 – 30	120°W

In particular, there were discontinuities in catch distributions between VIw and VIe, IIw and IIe, IVw and IVe, and Vw and Ve. These were particularly marked in Area II. Thus the minke whales caught in IIw As were all taken between 55°W and 60°W; those in IIw Bn between 45°W and 60°W; those in IIe Bs between 0° and 10°W; and those in IIe Cn between 0° and 20°W (see Appendix Table I).

In general the latitude of Japanese minke whale catches varies significantly from Area to Area (Table II), being much more northerly in IV and V than in the others.

Table II

North-south catch distributions, by Area, 5° latitude
All years 1971/72–1976/77 – both sexes – Japanese catches

	Percentage of total in Area					
	I	II	III	IV	V	VI
An				0.1		
As		3.7		0.6		5.6
Bn	2.3	7.9	24.8	81.8	100.0	6.7
Bs	97.7	49.4	75.2	17.5		41.7
Cn		39.0	–			46.4
Total	100.0	100.0	100.0	100.0	100.0	100.0
Mean latitude °S	67.4	68.7	66.3	63.3	62.5	68.9

Notes:

(1) In sub-Areas where whaling has been conducted in two or more years, the relative distribution of catches is a consistent pattern; in particular, the north-south distributions in Series B, in Areas III and IV.

(2) In most years catches are 'clumped' in a small part of the total area; in particular *in all years* in which whaling took place in Areas III and IV (5 out of 6) catches are around the boundary of the two Areas and latitudinally at mid-series of B.

Table 1

Distribution of Japanese minke whale catches, by latitude and longitude. Totals 1971/72–1976/77, both sexes. = Discontinuities in distribution.

		VI		I								V		
	Series	W	E	W	E	W	E	W	E	W	E	W	E	All areas
50°S	An	0	0	0	0	0	0	0	0	13	0	0	0	13
60°S	As	0	18	0	0	53	0	0	0	56	0	0	0	127
	Bn	0	20	0	15	112	0	0	1,354	3,137	4,652	1,930	0	11,220
70°S	Bs	0	134	178	454	9	652	672	3,587	1,236	0	0	0	6,922
	Cn	0	149	380	0	240	310	1	0	0	0	0	0	1,080
	170°W	150°W	120°W	90°W	60°W	30°W	0°	40°E	70°E	110°E	130°E	170°E	170°W	
	All	0	321	558	469	414	962	673	4,941	4,442	4,652	1,930	0	19,362
	% caught N of 55°S	0	0	0	0	0	0	0	0	0.3	0	0	0	0.07
	% caught N of 60°S	–	5.6	0	0	12.8	0	0	0	1.5	0	0	0	0.72
				0		6.0		0		0.7		0		

Data are not available to examine the Soviet catches by finer sub-division than 10° latitude. The BIWS data by statistical 'squares' permit, however, a review of Japanese and Soviet catches by longitudinal sub-divisions (Table III). The changes in the pattern, all Series combined, are illustrated by Table IV.

Table III

Distribution of Soviet minke whale catches, years 1972/73–1976/77, both sexes

( ) = Total Japan and USSR

Area	VI		I		II		III		IV		V
Series	w	e	w	e	w	e	w	e	w	e	w
A	0	0 (18)	0 (0)	0 (0)	6 (59)	0 (0)	54 (54)	46 (46)	45 (114)	3 (3)	0 (0)
B	0 233	288 (442)	2,112 (2,290)	1,509 (1,978)	13 (134)	1,466 (2,118)	639 (1,311)	4,063 (10,016)	8,543 (13,247)	457 (5,795)	661 (3,205)
C	0 (0)	0 (149)	927 (1,307)	0 (0)	0 (240)	751 (1,061)	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)
All series	233	(609)	(3,597)	(1,978)	(433)	(3,179)	(1,366)	(10,062)	(13,361)	(5,762)	(3,205)

Table IV

Longitudinal distribution of minke catches (both sexes), Japanese plus USSR

( ) = Additional land station catches

Area	VI		I		II		III		IV		V	
Season	w	e	w	e	w	e	w	e	w	e	w	e
1971/72					(702)		(204)	354	1,922	735		
1972/73					(605)		625 (135)	562	2,463	2,094		
1973/74		13	640	617	13 (765)	162	652 (173)	1,047	4,545	655		
1974/75			1,729	141	6 (1,029)	800	89 (115)	1,270	2,230	0	734	
1975/76		159	575	470	414 (776)	990	0 (110)	2,154	632	249	631	
1976/77		149	653	289	0 (1,000)	865	2 (0)	2,874	756	922	1,010	
1977/78	233	288	0	463	0 (?)	362	0 (0)	1,801	813	150	980	38

SC/30/Doc 60

Stock Estimate of Minke Whales in the Svalbard-Norway-British Isles Area from Markings and Recoveries 1974–77

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ABSTRACT

A total of 204 minke whales were reported effectively marked in 1974–76. Twelve marks were recovered in 1975–77 from a total catch of 4,931 whales. The best population estimate from these data is 50,592 whales with a 95% confidence interval ranging from 26,895 to 100,172. An annual catch of 1,790, which is the quota for this area in 1977 and 1978 implies an exploitation rate of 3.5% with a 95% confidence interval ranging from 1.8% to 6.7%.

INTRODUCTION

On the basis of markings in 1974–75 and mark recoveries and catches in 1975 and 1976 Christensen and Rørvik (1978) estimated the number of minke whales *(Balaenoptera acutorostrata)* in the Svalbard-Norway-British Isles area to be 48,216. The present report updates this estimate from the additional marking of 15 minke whales in 1976, the recovery of 5 marks in 1977 and the catch statistics for 1977.

MATERIALS AND METHODS

A total of 204 minke whales were marked with small 'Discovery'-type marks (Benjaminsen *et al.*, 1976) in 1974, 1975 and 1976. The markings are summarised in Table 1. Seven recoveries from these markings reported in 1975 and 1976, were given in a previous paper (Christensen and Rørvik, 1978) and five additional recoveries reported in 1977 are listed in Table 2. None of the marks were recovered in the year of marking because in each year the whales were marked after the close of the whaling season.

Table 1

Geographical distribution of minke whales marked in 1974, 1975 and 1976
The markings are arranged according to statistical area used in Norwegian fisheries statistics (Christensen, 1977)

Area	Locality	Number of whales 1974	1975	1976	
03	Østbanken	1	–	–	
11	Gåsbanken	3	–	–	
15	Sentralbanken	–	4	–	
20	Bjørnøya	20	132[1]	2	
20	Storfjorden	11	–	2	
23	Hopen	15	–	–	
23	East of Edgeøya	–	–	8	
23	Southeast of Edgeøya	–	–	3	
25	Spitsbergen	1	–	–	
42	Shetland	2	–	–	
	Total	53	136	15	204

[1] One known to be double marked.

Of the 10 whales marked in Area 20 in 1975 and later caught, one was double marked (Table 2, Christensen and Rørvik, 1978). The marking in this area was exceptionally intensive in 1975 (Table 1), and with the lack of evidence to the contrary it is assumed that double marking did not occur in 1974 and 1976. Correcting for the assumed number of double markings in Area 20, an estimate of the number of whales marked in 1975 is given by:

$$132 \times (10/11) + 4 = 124$$

Total catches of minke whales in the area from the British Isles, along the coast of Norway, in the Barents Sea and at Svalbard were 1,374 in 1975, 1,860 in 1976 and 1,697 in 1977. The number of marked whales caught in each of the years 1975, 1976 and 1977 are 1, 5 and 5 respectively.

The stock estimate was made as in last year's report (Christensen and Rørvik, 1978) using the direct multiple sample census method described by Chapman (1952):

$$\hat{N} = \Sigma n_j T_j / (\Sigma t_j + 1)$$

where

$\hat{N}$ = estimated stock size
T_j = number of marked whales alive at the beginning of season j,
t_j = number of marked whales caught in season j,
n_j = number of whales caught in season j.

Applying this method it is assumed that:

(1) N is constant throughout these years.
(2) The recovery rate is 100%.
(3) The natural mortality rate is 0.10 (= M).
(4) Marked and unmarked whales are completely mixed.

The number of marked whales alive before each whaling season (T_j) were calculated:

$$T_{1975} = 53 \times e^{-M} = 48$$
$$T_{1976} = (48 - 1 + 124)e^{-M} = 155$$
$$T_{1977} = (155 - 5 + 15)e^{-M} = 149$$

STOCK ESTIMATE

The stock size estimated from these data is $\hat{N}$ = 50,592. The 95% confidence interval calculated by approximating Σt_j with a Poisson distribution, range from 26,895 to 100,172.

The present estimated stock of 50,592 whales is nearly the same as the previous estimate of 48,216 animals based on seven recoveries (Christensen and Rørvik, 1978). However, the lower and upper 95% confidence limits have been changed from 20,251 and 130,955 to 26,895 and 100,172 respectively by the additional five recoveries in 1977.

Table 2

Marked minke whales recaptured in Norwegian catches in 1977

	Marked			Recovered		
Mark No.	Date	Position	Area	Date	Position	Distance from marking position
N 1059	16.8.75	N74°16′ E18°08′	20	28.5.77	N74°35′ E17°50′	20 n. mil
N 1061	10.8.75	N74°20′ E17°25′	20	15.5.77	N74°30′ E16°30′	18 n. mil
26209	15.8.75	N74°12′ E18°40′	20	27.6.77	N74°50′ E17°30′	42 n. mil
27142	4.8.75	N74°47′ E17°36′	20	30.6.77	N73°55′ E17°50′	52 n. mil
27147	5.8.75	N74°55′ E18°00′	20	21.6.77	N74°35′ E18°00′	20 n. mil

Catch quotas for 1977 and 1978 were set at 1,790 for the assumed Svalbard-Norway-British Isles stock, equal to the average annual catches in the period 1966–75. If this quota is taken, it gives an annual exploitation rate of 3.5% with 95% confidence limits of 1.8% and 6.7%.

CONCLUDING REMARKS

No whales were marked in 1977, but two catchers are now being chartered for new markings cruises after the close of this year's season in July 1978.

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SC/30/Doc 61

Preliminary Catch Statistics for Minke Whales (*B. acutorostrata*) Caught by Norway in 1977

I. Christensen, Å. Jonsgård and C. J. Rørvik.

In 1977 the Norwegian catch of whales included 1,772 minke whales and 7 killer whales. The information given in the Tables is based upon data obtained from forms filled out by the whalers. The forms were introduced in 1938, when whaling participation was made dependent by licences. However, two years ago the forms were revised, and data based upon the altered forms were for the first time presented to the IWC Scientific Committee at its annual meeting last year in Canberra.

The North Atlantic minke whale quotas set by the IWC for 1977 were as follows (Norwegian quotas according to allocation agreements with Iceland and Denmark in brackets):

Canadian East Coast	48
West Greenland	325 (75)
East Greenland-Iceland-Jan Mayen	320 (120)
Svalbard-Norway-British Isles	1,790

Table 5 shows that no minke whales were caught by Norway in the East Greenland-Iceland-Jan Mayen area. Usually Norwegian whaling vessels operate in these waters in July and August. However, in the 1977 season, so many whales were taken in May and June that the market for whale products became poor. Because of this, the Norwegian Government decided to stop all whaling from 1st July onwards except for one vessel operating off West Greenland. The Government decision also explains why the quota set for Svalbard-Norway-British Isles was not fully attained.

Table 1

Participating vessels grouped according to length of vessels in feet and engine power in HP

Length of vessels in feet	Number of vessels	Engine power in HP	Number of vessels
30–39.9	2	Below 100	1
40–49.9	13	100 – 199	12
50–59.9	18	200 – 299	30
60–69.9	26	300 – 399	32
70–79.9	14	Above 400	12
80–89.9	6		
90–99.9	3		
100–109.9	2		
110–119.9	2		
120 and above	1		

Table 2

Number of vessels grouped according to minke whales taken

Number of vessels	Number of whales per vessel
22	Below 10
24	10–19
19	20–29
13	30–39
7	40–49
2	50 and above
Total 87	

Table 3

Number of small whales caught in seasons 1961–1977

Species	1961	1962	1963	1964	1965	1966	1967	1968	1969
Minke	3,219	3,286	3,233	2,732	2,467	2,153	2,175	2,733	2,391
Bottlenose	87	321	267	307	682	340	264	384	485
Killer	111	124	90	77	104	161	36	86	231
Pilot	295	43	71	54	32	339	117	31	27
	3,712	3,774	3,661	3,170	3,295	2,993	2,592	3,234	3,134

Species	1970	1971	1972	1973	1974	1975	1976	1977
Minke	2,307	2,330	2,650	2,055	1,820	1,788	2,146	1,772
Bottlenose	535	213	17	3	0	0	0	0
Killer	246	57	28	1	6	2	0	7
Pilot	43	0	0	0	1	0	0	0
	3,131	2,600	2,695	2,059	1,827	1,790	2,146	1,779

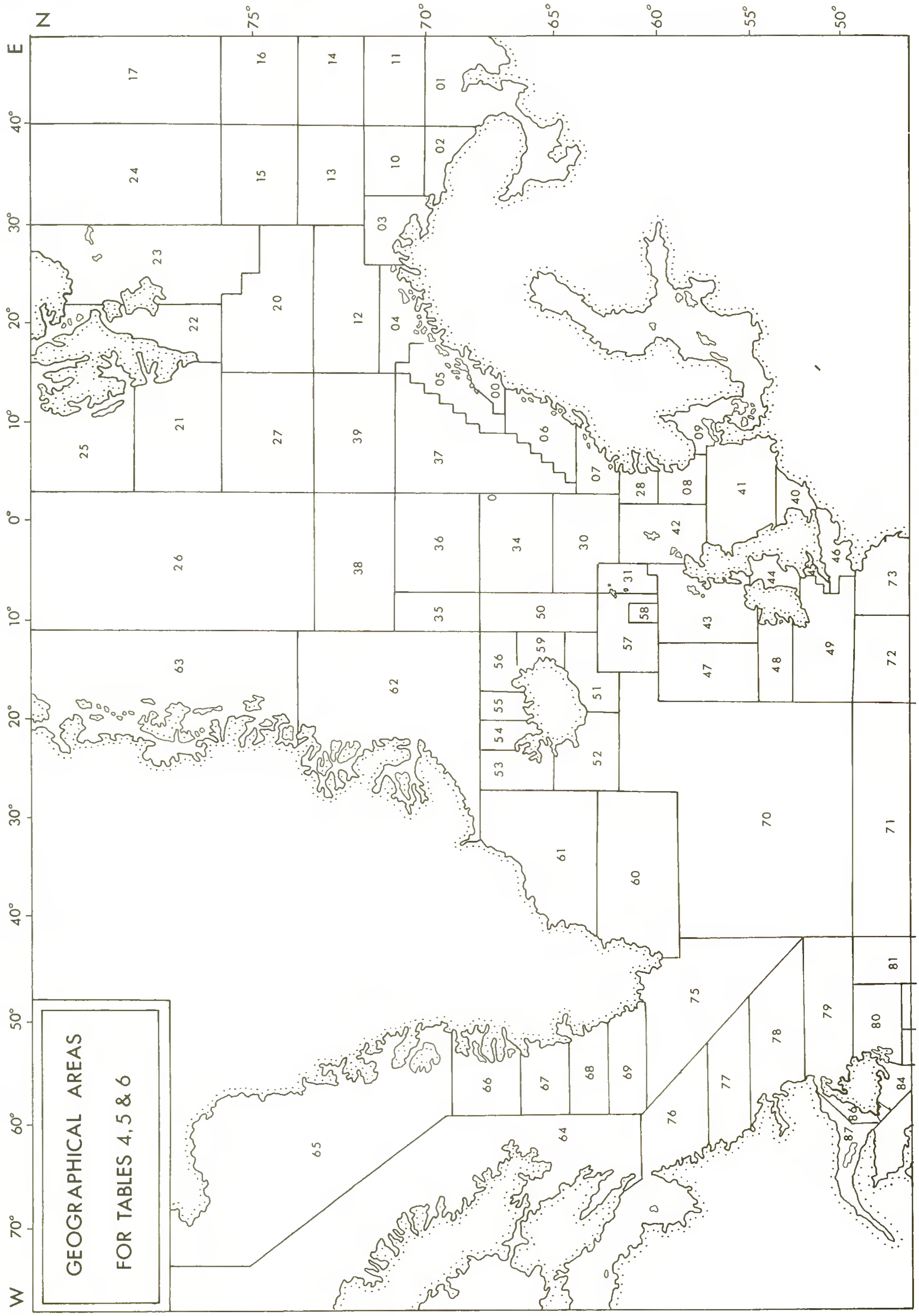
GEOGRAPHICAL AREAS
FOR TABLES 4,5 & 6

Table 4

Number of minke whales (including 4 killer whales caught in area 00 and 3 in area 05) caught in different areas and months

		April	May	June	July	August	Not given	Total
00	Vestfjorden	9	32	38			1	80
01	Kaninbanken		6	122	1			129
02	Murmanskkysten		93	55			21	169
03	Øst-Finnmark		53	160			7	220
04	Vest-Finnmark		51	56	2			109
05	Røstbanken til Malangsgr.	2	9	17				28
08	Egersundbanken		28	1				29
10	Skolpenbanken		30	14				44
11	Gåsebanken			35	1			36
12	Nordkappbanken		9	18				27
13	Thor Iversenbank			1				1
14	Britoinfeltet			2				2
20	Bjørnøya		236	459				695
21	Vest-Spitsbergen			28				28
23	Hopen			2				2
27	Syd-vest av Spitsbergen			15				15
28	Vikingbanken		8	44				52
37	Norskehavet		2					2
41	Sentrale Nordsjø		9	2				11
49	Sørvest av Irland		12	13				25
65	Disko				4	6		10
66	Hellefiskbank			9	21	35		65
Total								1,779

Table 5

Number of vessels which have caught minke whales in different areas and months. Some vessels have operated in more than one area in the same month. Seven killer whales included in the table

		April	May	June	July	August	Not given
00	Vestfjorden	5	12	8			1
01	Kaninbanken		3	16	1		
02	Murmanskkysten		15	17			
03	Øst-Finnmark		24	32			
04	Vest-Finnmark		5	15	1		
05	Røstbanken til Malangsgr.	2	4	3			
08	Egersundbanken		3	1			
10	Skolpenbanken		15	6			
11	Gåsebanken		11	1			
12	Nordkappbanken		8	9			
13	Thor Iversenbank			1			
14	Britoinfeltet			1			
20	Bjørnøya		23	36			
21	Vest-Spitsbergen			8			
23	Hopen			2			
27	Syd-vest av Spitsbergen			7			
28	Vikingbanken		2	6			
37	Norskehavet		1				
41	Sentrale Nordsjø		4	1			
49	Sørvest av Irland		2	2			
65	Disko				1	1	
66	Hellefiskbank			1	1	1	
	Not given		8	6			

Table 6

Number of days in which minke whales have been caught in different areas and months

		April	May	June	July	August	Not given
00	Vestfjorden	6	16	17			1
01	Kaninbanken		4	25	1		
02	Murmanskkysten		17	9			
03	Øst-Finnmark		16	28			
04	Vest-Finnmark		10	13	I		
05	Røstbanken til Malangsgr.	2	6	8			
08	Egersundbanken		8	1			
10	Skolpenbanken		14	7			
11	Gåsebanken			13	1		
12	Nordkappbanken		4	5			
13	Thor Iversenbank			1			
14	Britoinfeltet			2			
20	Bjørnøya		28	27			
21	Vest-Spitsbergen			8			
23	Hopen			2			
27	Syd-vest av Spitsbergen			6			
28	Vikingbanken		3	13			
37	Norskehavet		1				
41	Sentrale Nordsjø		4	2			
49	Sørvest av Irland		5	4			
65	Disko				4	2	
66	Hellefiskbank			4	8	12	
	Not given		7	8			

Table 7

Visibility at time of minke whale harpooning (including 7 killer whales)

Visibility		Whales caught
1.	Fog	47
2.	Poor visibility	143
3.	Moderate visibility	324
4.	Good visibility	624
5.	Very good visibility	421
6.	Variable visibility	185
	Not given	35
		1,779

Table 8

Wind speed at time of minke whale harpooning (including 7 killer whales)

Beaufort number		Whales caught
0	– Calm	203
1	– Light air	238
2	– Light breeze	425
3	– Gentle breeze	471
4	– Moderate breeze	260
5	– Fresh breeze	104
6	– Strong breeze	50
7	– Moderate gale	7
8	– Fresh gale	10
9	– Above fresh gale	9
	Not given	2
		1,779

SC/30/Doc 62

Norwegian Minke Whales Fishery in 1976 and 1977

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INTRODUCTION

Whaling for small whales in Norway has been regulated by licence since 1938. The licensees were required to fill in a form containing biological and product information for each whale taken. In an additional form, introduced in 1965, date, position, weather and catch were recorded by whalers operating in distant waters (Jonsgård, 1968). A new reporting system was introduced for all whalers in 1976. The new form includes all the above information and the licensees also have to record position and weather every day at sea, whether whales were caught or not. The present report is based on data from this new reporting system.

RESULTS

Catch and effort statistics for the Norwegian minke whale *(Balaenoptera acutorostrata)* fishery in 1976 and 1977 are given in Tables 1 and 2. The tables give by area and month the number of ships participating, the number of minke whales caught, and the catch per ship. Also included is the number of ship-days, which is the pooled number of days the ships have been in the area, and the catch per ship-day (CPUE). (Area divisions are given by Christensen, 1977).

The influence of weather on minke whale whaling is demonstrated in Figs 1 and 2, which show for every day, the wind, visibility and catch per ship-day in the Barents Sea in June of 1976 and 1977. Fig. 3 shows the weather and catches for June 1977 in the Svalbard area.

The present measure of effort, ship-days, does not allow for variable weather conditions, but the intention is to use the data from the new reporting system to improve the effort measurements by correcting for recorded weather observations.

Tables 3 and 4 give the number and percentages of male and female minke whales caught in different areas by month in 1976 and 1977. The percentage of females in total minke whale catches in the Svalbard-Norway-British Isles area in the period 1960–77 is shown in Fig. 4.

In 1976, 67.5% of the catch in this area were females (Table 1), but in 1977 the percentage of females was reduced to 56% (Table 2). If whaling in 1977 had continued until the end of the whaling season (1st September), the ratio of males to females in the total catch from the Svalbard-

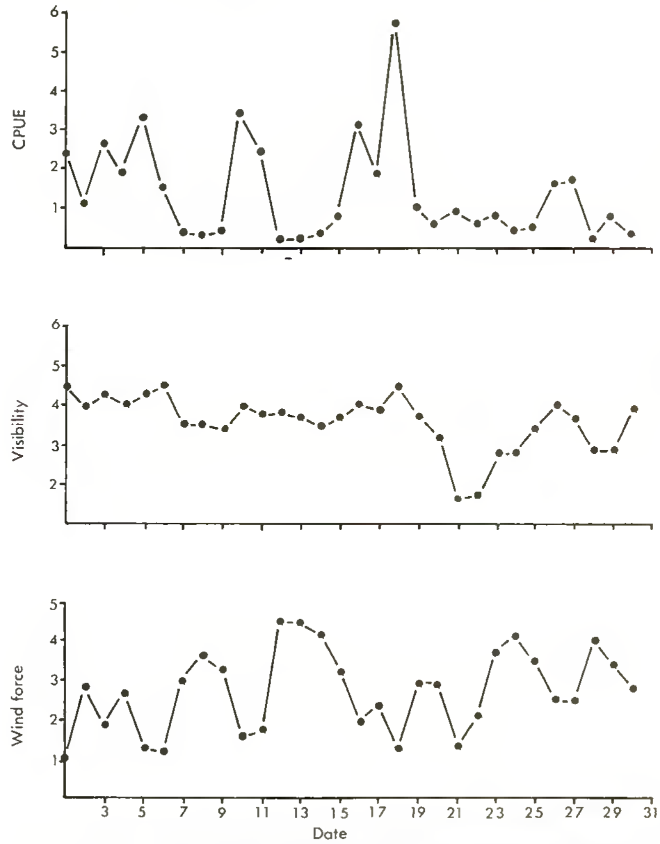

Fig. 1. Catch per unit effort, wind force and visibility for the minke whale fishery in the Barents Sea, June 1976. Wind force is measured on the Beaufort scale. Visibility: 1 = fog, 2 = poor, 3 = moderate, 4 = good, 5 = very good.

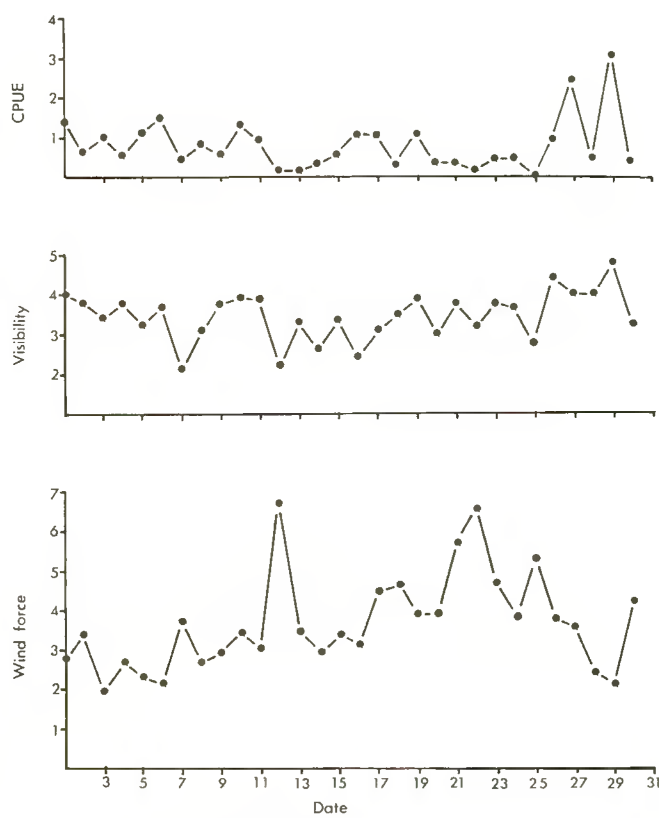

Fig. 2. CPUE, wind force and visibility for the minke whale fishery in the Barents Sea, June 1977. Units as in Fig. 1.

Norway-British Isles area probably would have been closed to 50–50. The percentage of females in the north-east Atlantic catches has tended to increase after 1972 (Fig. 4). This is explained by Fig. 5 which shows that during the last ten years an increasing part of the minke whale catch has been taken in the northern areas where females dominate in April and May (Fig. 6).

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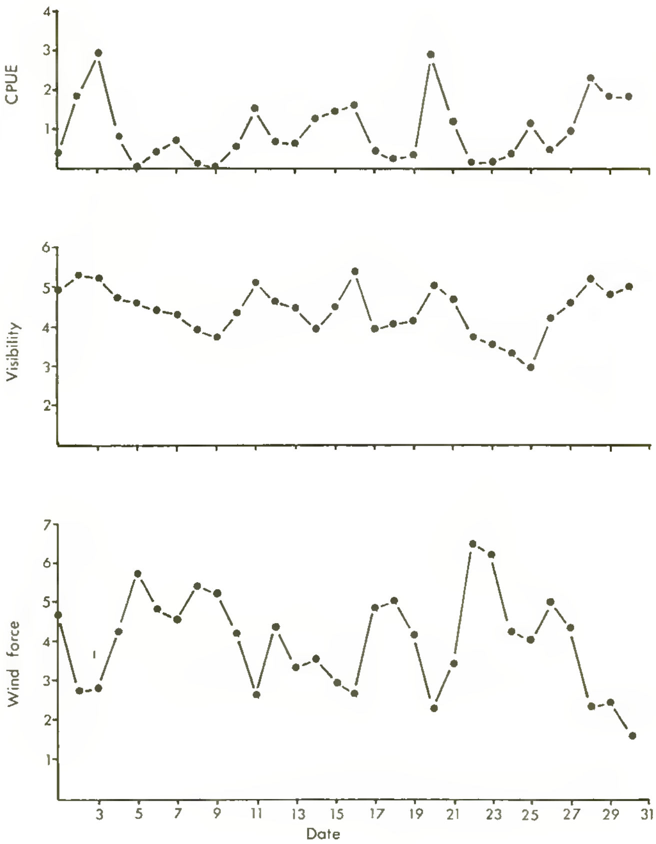

Fig. 3. CPUE, wind force and visibility for the minke whale fishery at Svalbard, June 1977. Units as in Fig. 1.

Fig. 4. The percentage of females in the total catch of minke whales in the Svalbard-Norway-British Isles area in the period 1960–77.

Fig. 5. The distribution on sub-areas of the total Norwegian catch of minke whales in the Svalbard-Norway-British Isles area in the period 1960–77. (1) Barents Sea, Svalbard and Coast of Finnmark. (2) Coast of Nordland. (3) North Sea, Ireland-Faroe Islands.

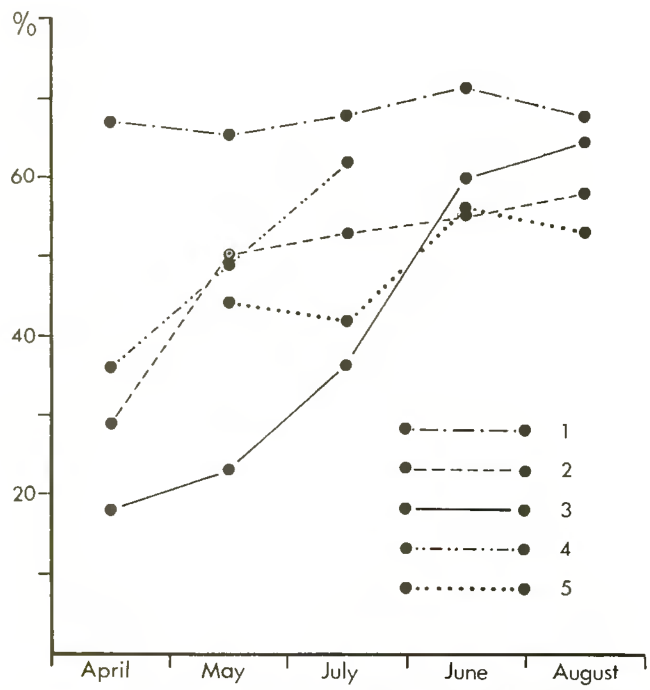

Fig. 6. The percentage of males by month and sub-area in Norwegian catches of minke whales in the Svalbard-Norway-British Isles area in the period 1960–77. (1) Ireland-Faroe Islands – West Coast of Norway. (2) Coast of Nordland. (3) Barents Sea and Svalbard. (4) Coast of Finnmark. (5) Skagerak.

Table 1

The catch and effort in the Norwegian minke whale fishery in different areas in North Atlantic in 1976

Area	Month	No. of ships	No. of whales	Catch per ship	Ship-days	Catch/ ship-days
Barents Sea (01, 02, 10, 11, 13, 14, 15, 16, 17, 18)	May	20	162	8.1	220	0.74
	June	34	903	26.6	624	1.45
	Total	34	1,065	31.3	844	1.26
Svalbard (12, 20, 21, 22, 23, 24, 27, 39)	May	14	164	11.7	191	0.86
	June	18	219	12.2	132	1.66
	Total	20	383	19.1	323	1.19
Coast of Finnmark (03, 04)	May	19	22	1.2	81	0.27
	June	26	40	1.5	109	0.37
	Total	29	62	2.1	190	0.33
Coast of Nordland (00, 05, 06, 37)	April	7	7	1.0	37	0.19
	May	16	36	2.3	157	0.23
	June	10	18	1.8	68	0.27
	July	9	9	1.0	21	0.43
	August	14	18	1.3	69	0.26
	Total	19	88	4.6	352	0.25
Møre (07, 30)	July	3	1	0.3	5	0.60
North Sea (08, 09, 28, 40, 41, 42)	April	6	4	0.7	29	0.14
	May	6	30	5.0	84	0.36
	June	8	18	2.3	95	0.19
	July	11	11	1.0	52	0.21
	August	11	66	6.6	96	0.69
	Total	12	129	10.8	356	0.36
Ireland-Faroe Islands (31, 43, 47, 48, 49, 57, 58)	May	1	7	7.0	4	1.75
	June	3	11	3.7	7	1.57
	August	2	18	9.0	10	1.80
	Total	7	37	5.3	21	1.76
Iceland-Jan Mayen (26, 34, 35, 36, 38, 50, 51, 54, 55, 56, 59, 62, 63)	May	1	3	3.0	8	0.37
	June	1	1	1.0	5	0.20
	July	5	5	1.0	12	0.42
	Total	7	9	1.3	25	0.38
Denmark Strait (52, 54, 60, 61, 70)	July	8	28	3.5	49	0.57
	August	6	56	9.3	81	0.69
	Total	8	84	10.5	130	0.64
W. Greenland (65, 66, 67, 68, 69, 75)	June	1	39	39.0	13	3.00
	July	4	15	3.8	37	0.41
	August	4	116	29.0	119	0.97
	Total	4	170	42.5	169	1.01
Position not given by the whalers	Total	34	78	2.3	325	0.24
Svalbard-Norway-British Isles Total	April–August	–	1,764	–	2,105	0.84
Denmark Strait-Iceland-Jan Mayen	May–August	–	93	–	172	0.54
W. Greenland	June–August	–	170	–	169	1.01
All areas		–	2,105	–	2,771	0.76

Note: Effort not given for 41 whales.

Table 2
The catch and effort in the Norwegian minke whale fishery in different areas in North Atlantic in 1977

Area	Month	No. of ships	No. of whales	Catch per ship	Ship-days	Catch/ship-days
Barents Sea (01, 02, 10, 11, 13, 14, 15, 16, 17, 18)	May	23	129	5.6	197	0.65
	June	26	225	8.7	292	0.77
	Total	28	356	12.7	489	0.73
Svalbard (12, 20, 21, 22, 23, 24, 27, 39)	May	20	245	12.3	339	0.72
	June	32	522	16.3	507	1.03
	Total	33	767	23.2	842	0.91
Coast of Finnmark (03, 04)	May	32	105	3.3	145	0.72
	June	36	221	6.1	394	0.56
	Total	41	326	8.0	539	0.61
Coast of Nordland (00, 05, 06, 37)	April	6	11	1.8	53	0.21
	May	14	41	2.9	161	0.26
	June	10	50	5.0	129	0.39
	Total	15	102	6.8	343	0.30
North Sea (08, 09, 28, 40, 41, 42)	May	5	45	9.0	69	0.65
	June	7	47	6.7	91	0.52
	Total	8	92	11.5	160	0.58
Ireland-Faroe Islands (31, 43, 47, 48, 49, 57, 58)	May	1	12	12.0	31	0.39
	June	2	13	6.5	15	0.87
	Total	2	25	12.5	46	0.54
W. Greenland (65, 66, 67, 68, 69, 75)	June	1	9	9.0	19	0.47
	July	1	25	25.0	31	0.81
	August	1	41	41.0	26	1.58
	Total	1	75	75.0	76	0.99
Svalbard-Norway-British Isles Total	April–June		1,668		2,419	0.69
Total all areas	April–August		1,743		2,495	0.70

Note: Effort not given for 29 whales caught from the Svalbard-Norway-British Isles areas.

Table 3
The sex composition by month and area of minke whales in Norwegian catches in 1976

Area	Month	Males		Females	
		Number	%	Number	%
Barents Sea (01, 02, 10, 11, 13, 14, 15, 16, 17, 18)	May	42	24.7	122	75.3
	June	242	27.2	648	72.8
	Total	284	26.9	770	73.1
Svalbard (12, 20, 21, 22, 23, 24, 25, 27, 39)	May	23	14.2	139	85.8
	June	76	35.5	138	64.5
	Total	99	26.3	277	73.7
Coast of Finnmark (03, 04)	May	17	77.3	5	22.7
	June	26	65.0	14	35.0
	Total	43	69.4	19	30.6
Coast of Nordland (00, 05, 06, 37)	April	1	14.3	6	85.7
	May	11	33.3	22	66.7
	June	7	41.2	10	58.8
	July	5	62.5	3	37.5
	August	13	72.2	5	27.8
	Total	37	44.6	46	55.4

	Month	Males Number	Males %	Females Number	Females %
North Sea	April	0	0.0	4	100.0
(08, 09, 28, 40, 41, 42)	May	10	33.3	20	66.7
	June	8	44.4	10	55.6
	July	8	72.7	3	27.3
	August	52	80.0	13	20.0
	Total	78	60.9	50	39.1
Ireland-Faroe Islands	May	4	57.1	3	42.9
(31, 43, 47, 48, 49, 57, 58)	June	6	54.5	5	45.5
	August	12	66.7	6	33.3
	Total	24	63.2	14	36.8
Iceland-Jan Mayen (26, 34, 35,	May	0	0.0	2	100.0
36, 38, 50, 51, 54, 55, 56, 59,	June	1	100.0	0	0.0
62, 63)	July	3	60.0	2	40.0
	Total	4	50.0	4	50.0
Denmark Strait	July	22	78.6	6	21.4
(52, 53, 60, 61, 70)	August	37	68.5	17	31.5
	Total	59	72.0	23	28.0
W. Greenland	June	3	7.9	35	92.1
(65, 66, 67, 68, 69, 75)	July	4	28.6	10	71.4
	August	24	21.2	89	78.8
	Total	31	18.8	134	81.2
Position not given by the whalers	Total	37	41.1	53	58.9
Total Svalbard-Norway-British Isles		565	32.5	1,176	67.5
E. Greenland-Iceland-Jan Mayen		63	70.0	27	30.0
W. Greenland		31	18.8	134	81.2
Total all areas		696	33.2	1,390	66.7

Note: Sex not given for 60 whales.

Table 4

The sex composition by month and area of minke whales in Norwegian catches in 1977

Area	Month	Males Number	Males %	Females Number	Females %
Barents Sea (01, 02, 10,	May	42	30.7	95	69.3
11, 13, 14, 15, 16, 17, 18)	June	76	33.0	154	67.0
Note: Sex not given for 14 whales	Total	118	32.2	249	67.8
Svalbard (12, 20, 21,	May	67	27.3	178	72.7
22, 23, 24, 25, 27, 39)	June	213	40.9	308	59.1
Note: Sex not given for 1 whale	Total	280	36.6	486	63.4
Coast of Finnmark	May	62	59.0	43	41.0
(03, 04)	June	156	70.3	66	29.7
Note: Sex not given for 2 whales	Total	218	66.7	109	33.3
Coast of Nordland	April	6	60.0	4	40.0
(00, 05, 06, 37)	May	26	63.4	15	36.5
	June	26	53.1	23	46.9
Note: Sex not given for 3 whales	Total	58	58.0	42	42.0
North Sea	May	26	57.8	19	42.2
(08, 09, 28, 40, 41, 42)	June	31	66.0	16	34.0
	Total	57	62.0	35	38.2

	Month	Males		Females	
		Number	%	Number	%
Ireland-Faroe Islands (31, 43, 47, 48, 49, 57, 58)	May	4	33.3	8	66.7
	June	8	61.5	5	38.5
	Total	12	48.0	13	52.0
W. Greenland (65, 66, 67, 68, 69, 75)	June	0	0.0	9	100.0
	July	2	8.0	23	92.0
	August	19	46.3	22	53.7
	Total	21	28.0	54	72.0
Total Svalbard-Norway-British Isles	April–June	743	44.0	934	56.0
Total all areas	April–August	764	43.6	988	56.4

Note: Sex not given for 20 whales

Feeding Habits of the Minke Whale in the Antarctic

Seiji Ohsumi
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Ohsumi, Masaki and Kawamura (1970) have reported the food species and some feeding habits of the minke whale in the Antarctic.

The minke whale began to be exploited on a large scale in the Antarctic in the 1971/72 season. Japanese biologists, inspectors and whalers have recorded stomach contents as well as other biological data and have made collections from minke whales since then. I was on board the factory ship *Jinyo Maru* in the 1971/72 season, and engaged in biological research including an examination of minke whale feeding. Food samples have been collected for each season, and Dr Akito Kawamura of the University of Hokkaido has been examining these samples and will be reporting on his work soon.

Some feeding habits of Antarctic minke whales are presented in this paper from biological data collected by my laboratory.

HEART WEIGHT RATIO AND FEEDING RATE

Sergeant (1969) found that the heart weight, expressed as a proportion of the body weight, is equal to about 11% of the feeding rate, which is defined as the weight of food ingested daily expressed as a percentage of the body weight.

Ohsumi (1979) presents body and weight data for 56 Southern Hemisphere minke whales. Fig. 1 shows the relationship between body length and the heart weight ratios.

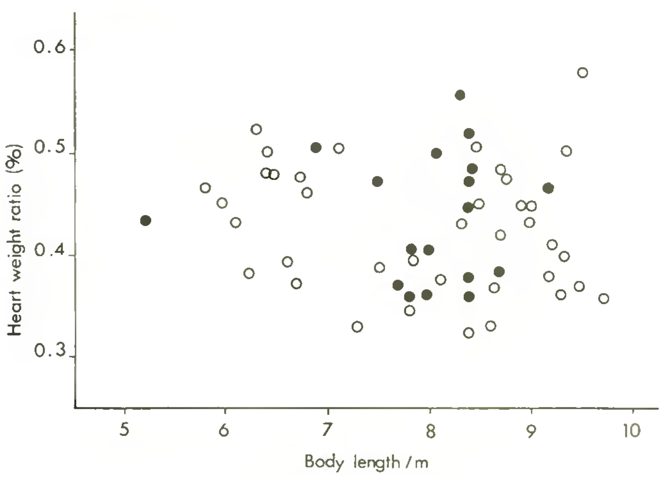

Fig. 1. Relationship between body length and heart weight ratio for the minke whale in the Antarctic, 1971/72.

There is no clear trend showing the change in the ratio with body length, and no sex difference in the ratio, as had been found by Kawamura (1974) for the Southern Hemisphere sei whale. The heart weight ratios range from 0.323% to 0.578%, and the average is 0.430% with a standard deviation of 0.061%. Slijper (1958) and Sergeant (1969) reported 0.51% and 0.475%, respectively, for the minke whale. Kawamura (1974) gave the heart weight ratio of the Southern Hemisphere minke whale as 0.422%. These figures fall within the range of the present estimate.

If the heart weight ratio is 11% of the feeding weight, the feeding rate of the Southern Hemisphere minke whale becomes 3.96% of the body weight. Sergeant (1969) has reported that the feeding rate is 4% for adult rorquals, and Kawamura (1974) has reported it as 3.84% in the minke whale. These figures are almost the same as the present result.

The average body length of Southern Hemisphere minke whales caught by the Japanese whaling fleets in the 1976/77 season was 8.43m. Ohsumi (1979) presents a formula relating body length and living body weight as shown in Table 1. The average body weight is calculated to be 7.065 kg from these data. If the feeding rate is 3.96% of the body weight, the individual food ingested is on average 279 kg per day. Klumov (1963) deduced that whalebone whales require about 30–40 g of food per kg of living body weight per day. From this, the average daily consumption of food for the Southern Hemisphere minke whale would be 213 kg to 283 kg which is quite close to the above result.

WEIGHT OF FULL STOMACH

I weighed the stomach contents of 13 minke whales in the 1971/72 Antarctic season. The stomach contents of those stomachs judged as 'full' by eye when flensing the whale carcass were weighed. The stomach was removed carefully in order not to damage it, and the contents of its first chamber were put into a large plastic basket to leach water. When they were considered fully fresh, the net weight of the contents was obtained.

Table 1 shows the biological data obtained from the 13 minke whales of which the stomach contents were weighed. All food species were identified as *Euphausia superba*. The heaviest contents were 136.4 kg, and the lightest were 50.4 kg. Kawamura (1974) recorded a net weight of 22.4 kg for the stomach contents of an 8.0 m Southern Hemisphere minke whale, which is very small compared with the present results. It is interesting to note that the individual with the heaviest stomach contents was caught at 1420 hours which shows that the minke whale also feeds during the day.

Living body weights were estimated using the formula for the body length – body weight relationship. The percentage ratio of stomach contents to the body weight was calculated individually and ranges widely from 0.59% to 1.95%. It is uncertain whether the lower figures represent a 'full' stomach or not. Some may have been disturbed by a catcher boat during feeding, and for some others food may have been too sparse to satisfy their appetite. The average of the ratios is 0.884%. If the feeding rate is 3.96% in the Southern Hemisphere minke whale, the above ratios are all less than the feeding rate. The minke whale must feed at

Table 1
Weights of 'full' stomach contents of minke whales in the Antarctic in 1971/72

Serial number	Time		Sex	Body length (m)	Body weight (A)[1] (kg)	Sexual condition	Food			Ratio (B/A,%)	Feeding times per day[2]
	Caught	Processed					Species	Size	Weight (B) (kg)		
72J0060	12:00	14:15	F	9.2	9,067	Pregnant	Eu.	L	53.7	0.592	6.7
72J0111	05:00	09:15	M	8.7	7,731	Mature	Eu.	L	59.0	0.763	5.2
72J0112	06:45	09:40	F	8.5	7,234	Pregnant	Eu.	L	83.5	1.154	3.4
72J0113	05:25	10:15	F	9.2	9,067	Pregnant	Eu.	L	80.0	0.882	4.5
72J0116	07:00	11:20	F	9.3	9,351	Pregnant	Eu.	L	68.1	0.728	5.4
72J0422	09:10	10:15	M	8.4	6,994	Mature	Eu.	L	60.0	0.858	4.6
72J0537	07:50	12:15	F	9.3	9,351	Pregnant	Eu.	L	67.9	0.726	5.5
72J0622	09:00	13:25	M	8.5	7,234	Mature	Eu.	M	68.0	0.940	4.2
72J0656	08:10	09:10	F	9.3	9,351	Pregnant	Eu.	M	77.7	0.831	4.8
72J1061	06:20	08:55	F	8.8	7,987	Pregnant	Eu.	M	50.4	0.631	6.3
72J1390	14:20	15:20	F	8.4	6,994	Pregnant	Eu.	L	136.4	1.950	2.0
72J1853	09:50	12:30	M	8.6	7,480	Mature	Eu.	M	66.1	0.884	4.5
72J1980	08:15	08:45	F	7.8	5,661	Immature	Eu.	M	91.0	1.607	2.5

[1]: Calculated from the formula, $W = 0.01610\ L^{2.854}$ and body length.
[2]: Calculated assuming a feeding rate of 3.96%.
Eu.: *Euphausia superba.*
L: Large
M: Medium

least twice a day, and four times a day on average, if the ratios represent the full stomach of each whale. Ivashin (1961) suggested that the humpback whale feeds every 3 to 4 hours in the Antarctic. Sergeant (1969) suggested a twice-daily feeding rate for blue, fin and sei whales. Kawamura (1974) reported that the stomach of the sei whale has to be fully repleted three or four times per day. Best (1977) reported that Bryde's whales must feed three to five times daily.

DAILY CHANGE IN STOMACH CONTENTS

It is known that the daily feeding activity of baleen whales in terms of percentage of food in the stomach, varies in general with a bimodal curve with maxima in the early morning and in the evening (Nemoto, 1957; 1959). Nemoto (1957) suggested that baleen whales often actively feed twice a day, although the pattern of feeding activity varies with the diurnal vertical migration of the food species, the season, the latitudinal position, or sometimes with the topography of the ocean floor.

Fig. 2A shows the daily change in quantity of stomach contents of minke whales caught in the Antarctic during late-November to mid-February in the 1971/72 season. The classification of relative quantity is the same as presented by Ohsumi *et al.* (1970), i.e. 0 = empty, r = <25% full, rr = 25%–50% full, rrr = 50%–75% full, R = 75%–100% full. The percentage of animals with empty stomachs increases with time from 0500 hours but decreases somewhat at 2100 hours. Ohsumi *et al.* (1970) drew a similar figure for minke whales caught in the 1967/68 and 1968/69 seasons, and noted that most whales fed actively before dawn with feeding activity decreasing towards midday although recovering gradually in the afternoon and towards the evening. However, such a recovery is not clear in the present results based on the relative quantity ratios of stomach contents. The percentage of rich (rrr) and full (R) stomach contents has a maxima at 0400–0500 hours and then gradually decreases, although it peaks again at 2100 hours as does the empty stomach class. A slight increase in the percentage of rich and full classes can be seen in the early afternoon, but it decreases again after 1400 hours. It therefore appears reasonable to assume that the minke whale does not only feed at particular times.

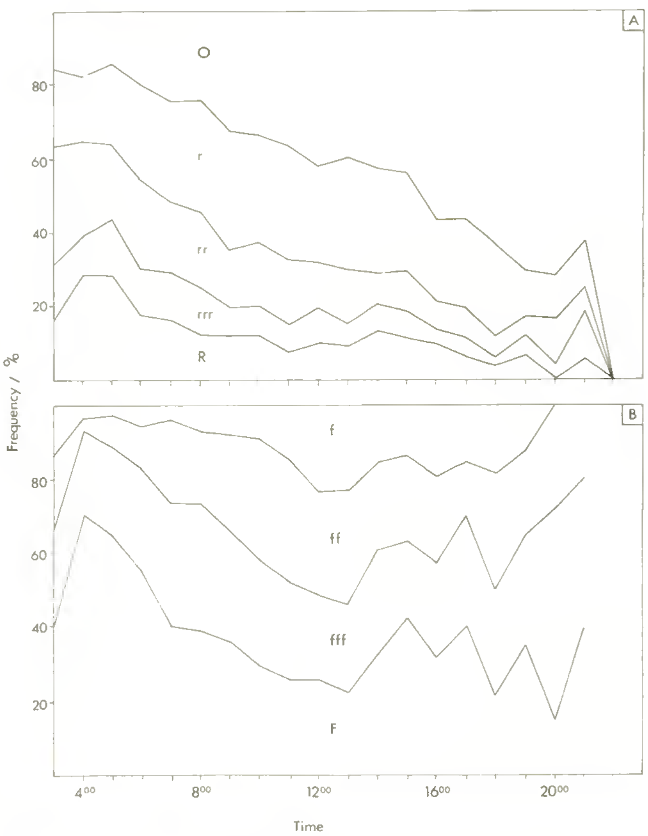

Fig. 2. Change in stomach content of minke whales caught in the Antarctic 1971/72. A: relative quantity, B: relative freshness.

Fig. 2B shows the daily change in freshness of the stomach contents in the minke whale. The 'freshest' class (F) will represent those individuals which were feeding just before death, and gives a better estimate than the food quantity of the time of feeding. There is a peak in this class at 0400 hours after which it gradually decreases until 1300 hours and then increases again in the afternoon. It will also be noticed that the percentage of this class is consistently over

20% (except at 0200 hours). This emphasises that the minke whale feeds during daylight hours. If the minke whale feeds twice a day, and one peak of feeding hour is at dawn, another peak must be in the evening. However, no clear bimodal frequency distributions are observed in either the quantity or freshness of food in the stomach.

SEASONAL CHANGE IN STOMACH CONTENTS

All the stomach contents were identified as euphausiids and although several euphausiid species may be found in the stomach contents of baleen whales from the whaling ground south of the Antarctic Convergence, Nemoto (1959), most were considered to be *Euphausia superba.* (Dr A. Kawamura will soon report on the identification of the stomach contents of the minke whales from the Antarctic.) Ohsumi *et al.* (1970) reported *Euphausia superba, E. spinifera* and *Calanus tonsus* from the minke whales caught in the 1967/68 and 1968/69 Antarctic seasons.

Fig. 3A shows seasonal changes in the relative size frequency of euphausiids from the stomachs of minke whales caught in the 1971/72 season, with respect to 3 size classes:

Small	< 40 mm long
Medium	40–50 mm long
Large	> 50 mm long

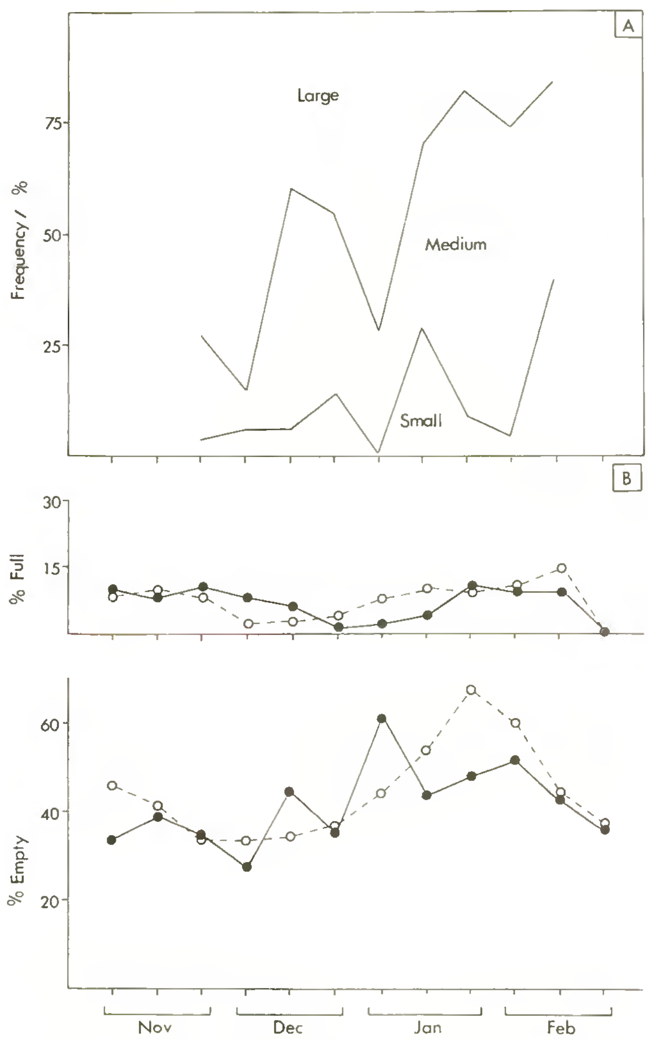

Fig. 3. Seasonal changes in the stomach contents of minke whales taken in the Antarctic.
A: size of euphausiids (1971/72 season).
B: % empty and full stomachs (seasons 1971/72–1976/77). Closed circles: males. Open circles: females

The large class was dominant at the beginning of the whaling season, but gradually decreased, while the small class was low at the beginning of the season, and then gradually increased. This suggests that in the Antarctic the minke whale does not select for size of euphausiid.

Fig. 3B shows the seasonal changes in the relative quantity of stomach contents. No difference in quantity of food is observed between sexes. The percentage of empty stomachs decreases gradually from the first decade of November to the first decade of December, and then increases to a maximum by the last decade of January after which it decreases again. No large seasonal change in the relative frequency of full stomachs is observed. The total frequency of empty stomachs was 38.0% and 41.6% in males and females respectively, during the seasons 1971/72–1976/77. Nemoto (1959) showed differences in frequency of empty stomachs by whale species, and noted that the humpback whale had the lowest frequency and the fin and sei whales had the highest.

AREA CHANGE IN STOMACH CONTENTS

Fig. 4 shows the relative frequency from each class of stomach contents in each statistical Area for the minke whales caught during the seasons 1971/72–1976/77. The ratio of empty stomachs is high in Areas II and III, but low in Areas I and VI. Nemoto (1959) examined the same matter for fin whales for seasons 1956/57 and 1957/58, and noted that a comparatively large number of fin whales took their food in Area VI, and that over 60% of the stomachs were empty in Areas IV and V. The pattern is somewhat different from the present result.

It is difficult to examine possible reasons for this difference, because there are no data on the fin whales caught in the waters adjacent to the pack ice regions of the Antarctic during recent seasons which would be comparable to the present result. One reason may be the change in abundance of euphausiids in each Area, and another the differences in the feeding habits of the different whale species.

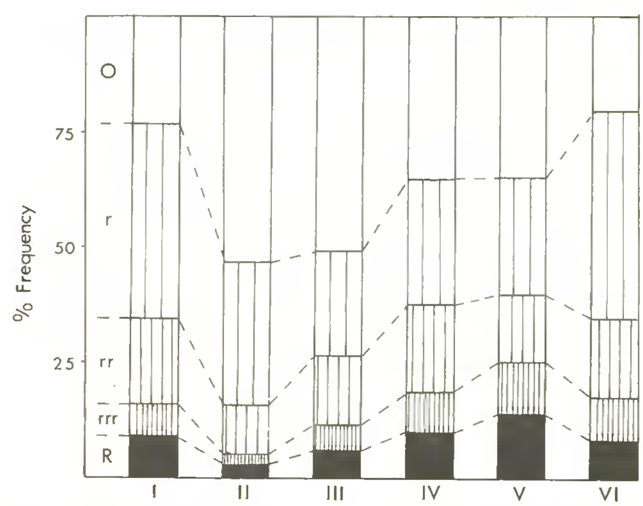

Fig. 4. Change in the quantity of stomach contents of minke whales taken during seasons 1971/72–1976/77 by Area.

YEARLY CHANGE IN STOMACH CONTENTS

As the relative frequency of the quantity of stomach contents differs by Area, and as minke whales have not been caught in each Area in every season, I have selected Area IV, where minke whales have been caught in every season from

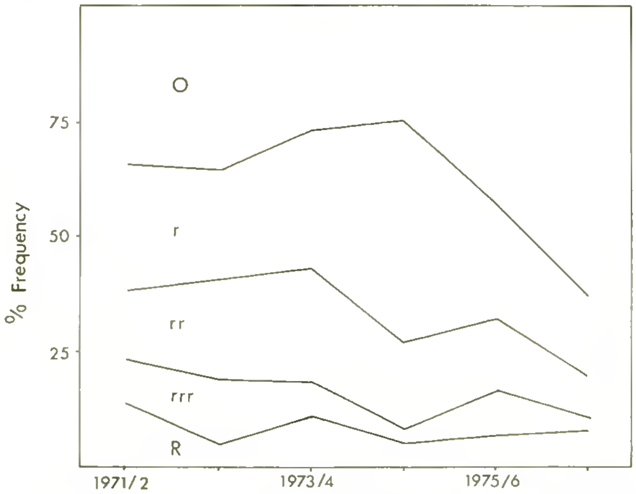

Fig. 5. Change in the quantity of stomach contents of minke whales in Area IV, by year.

1971/72 to 1976/77, to examine the yearly change in stomach contents.

Fig. 5 shows the result. The percentage of empty stomachs was almost constant in the three early seasons, but has been increasing in the two later seasons. It looks as if the availability of food for minke whales has been decreasing in recent years, although the ratio of full stomachs has been almost constant. Further study will be needed to confirm the trend of food availability.

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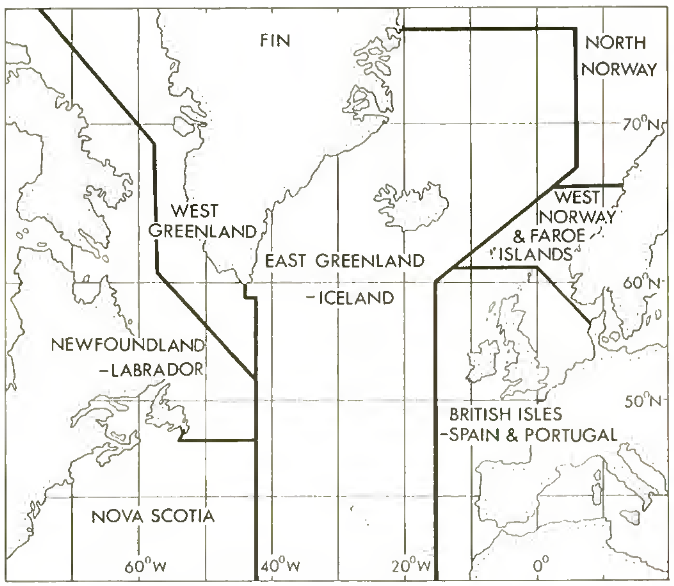
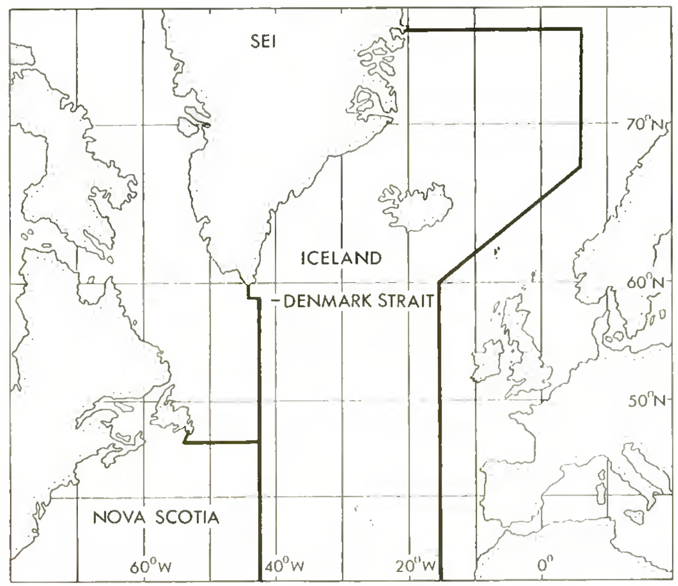
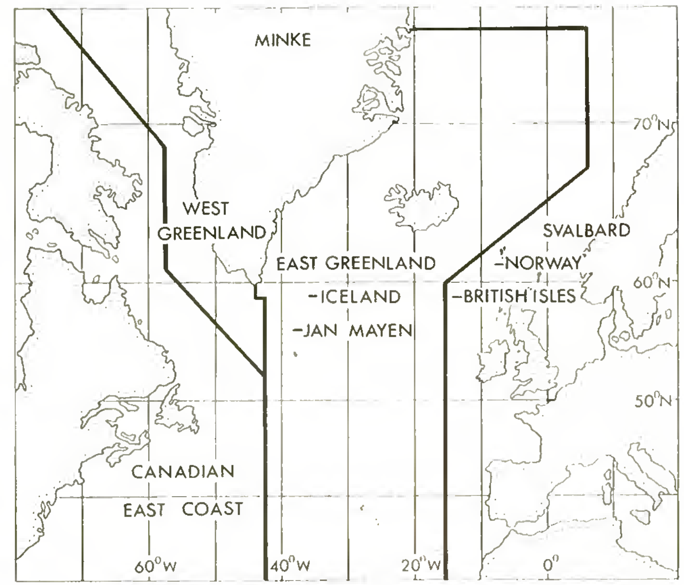
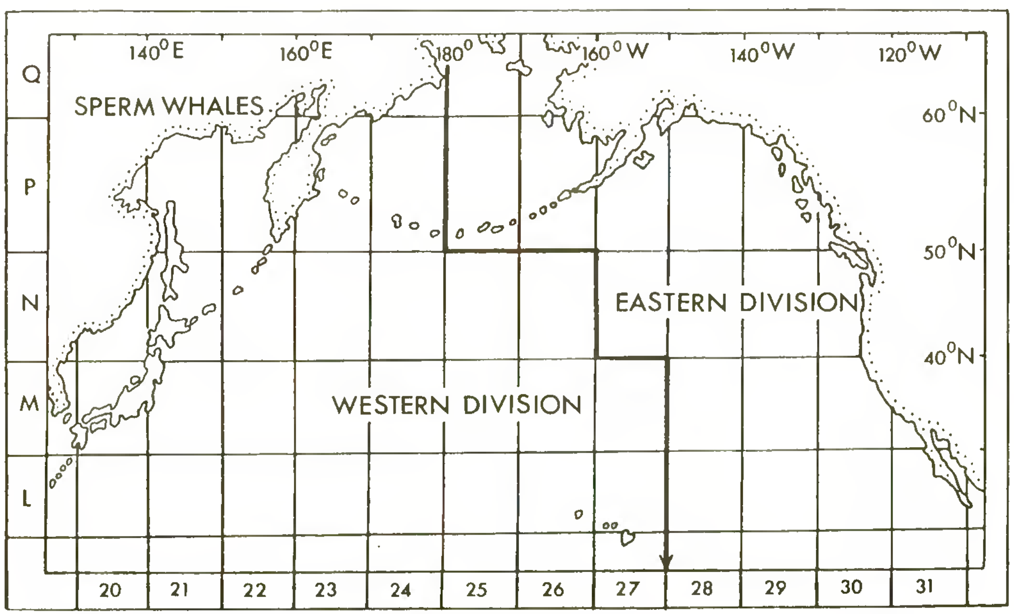
North Atlantic Stock Divisions

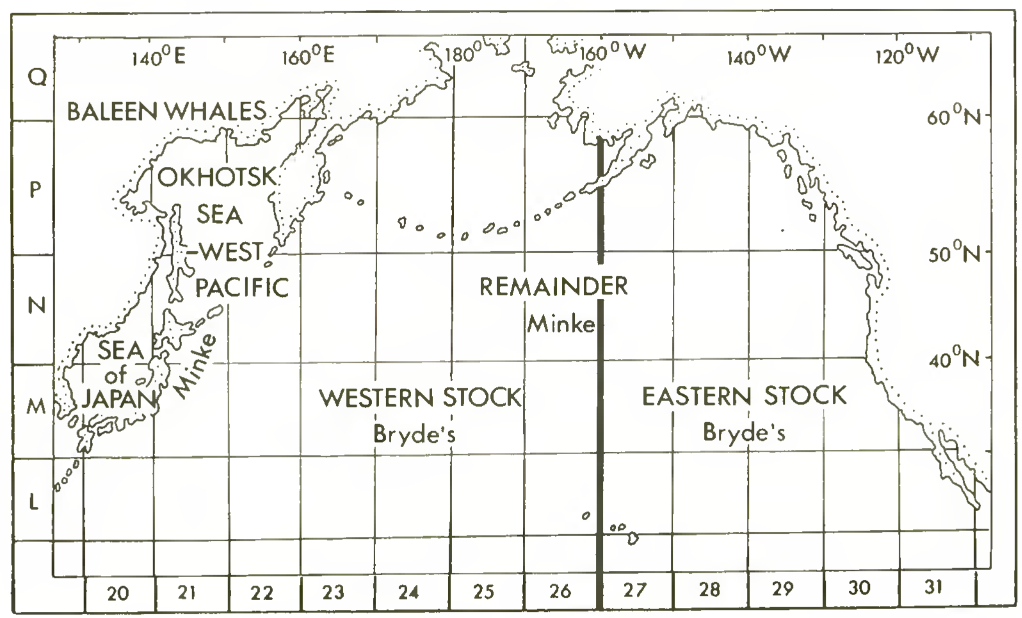




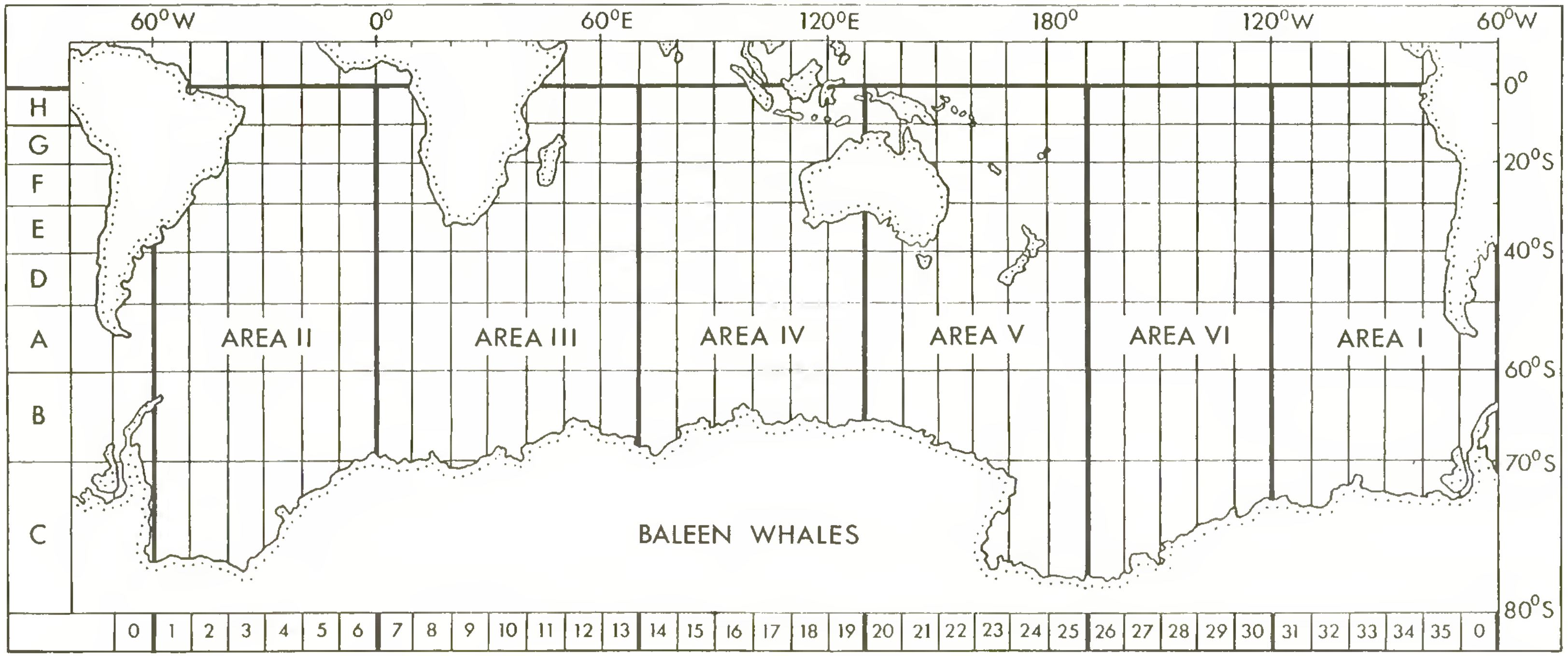


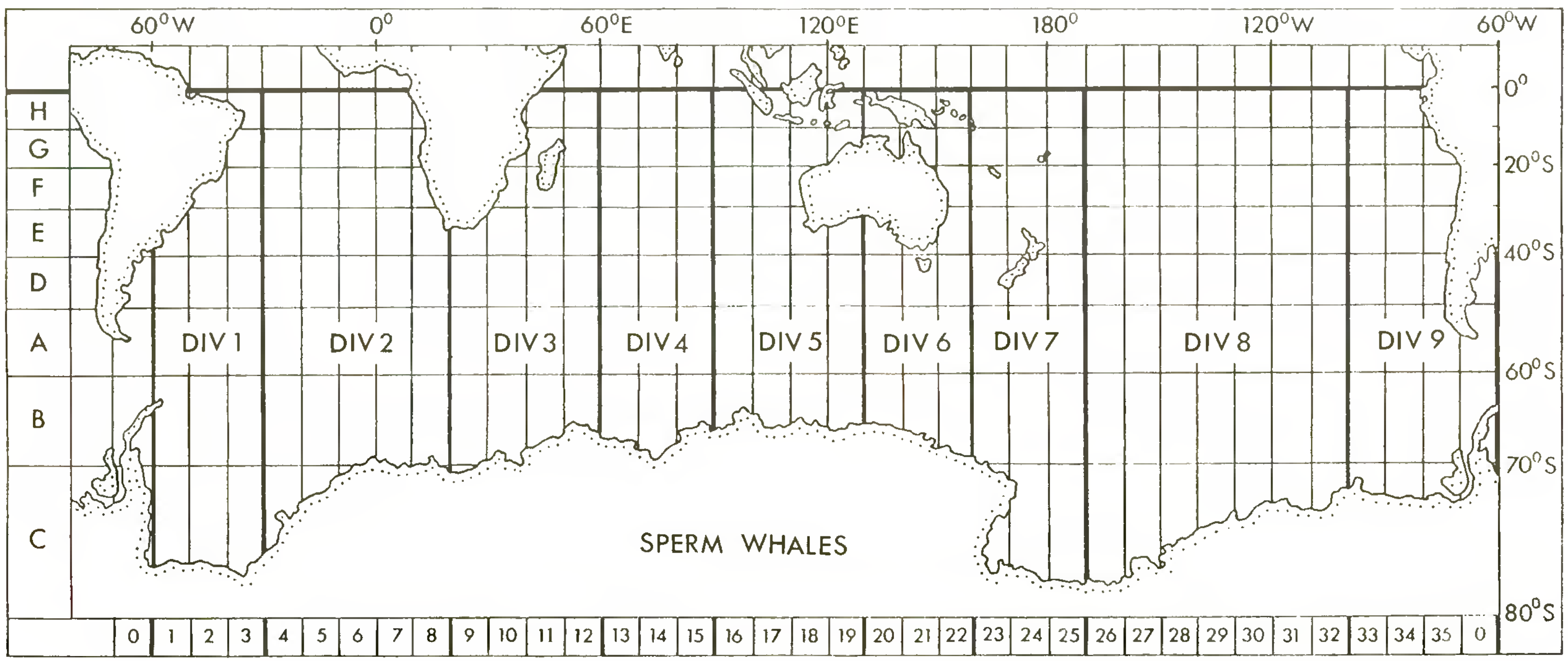
North Pacific Stock Divisions



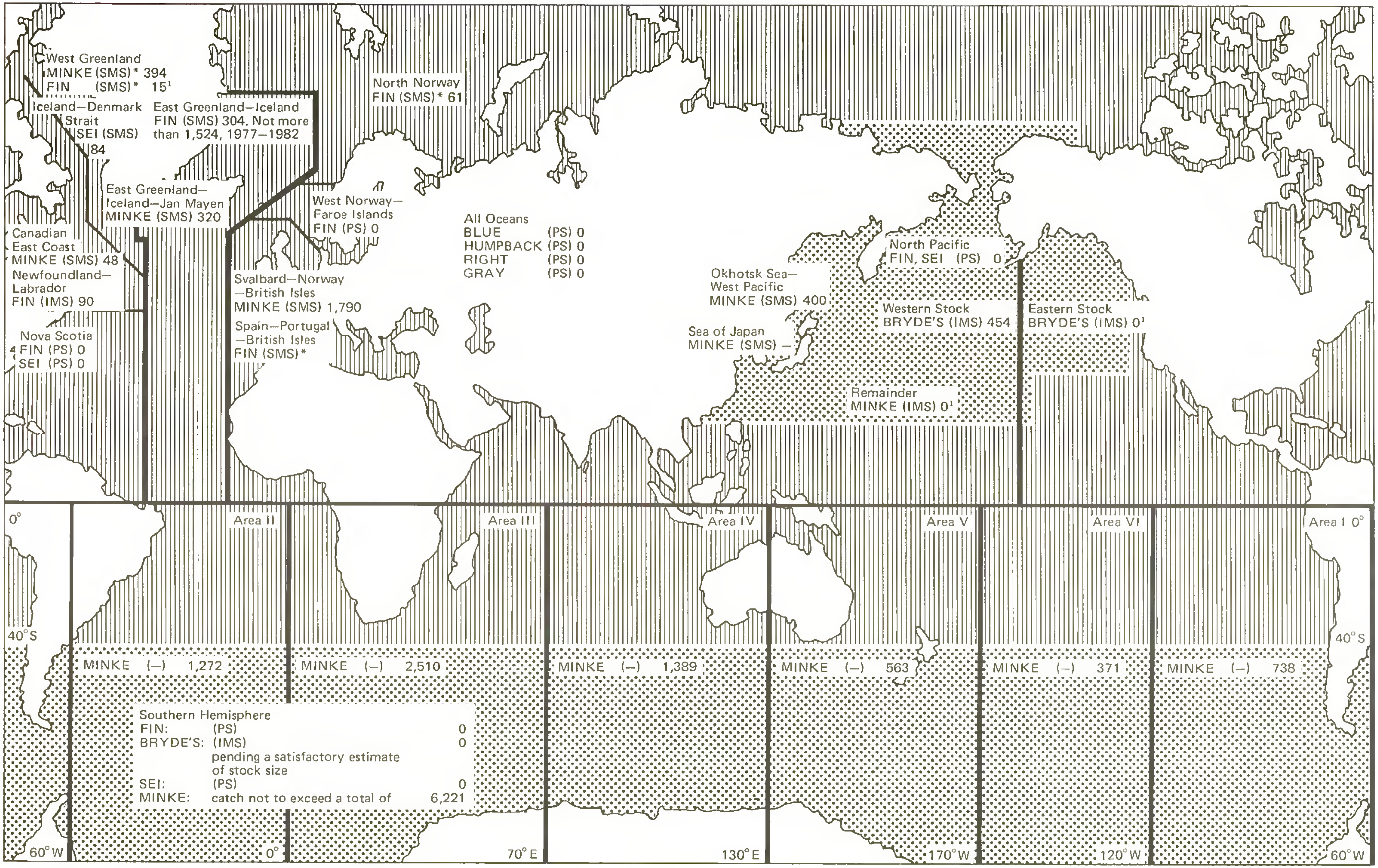


Southern Hemisphere Stock Divisions





Baleen Whale Stocks, Classification and Quotas, 1978/79 and 1979 Seasons

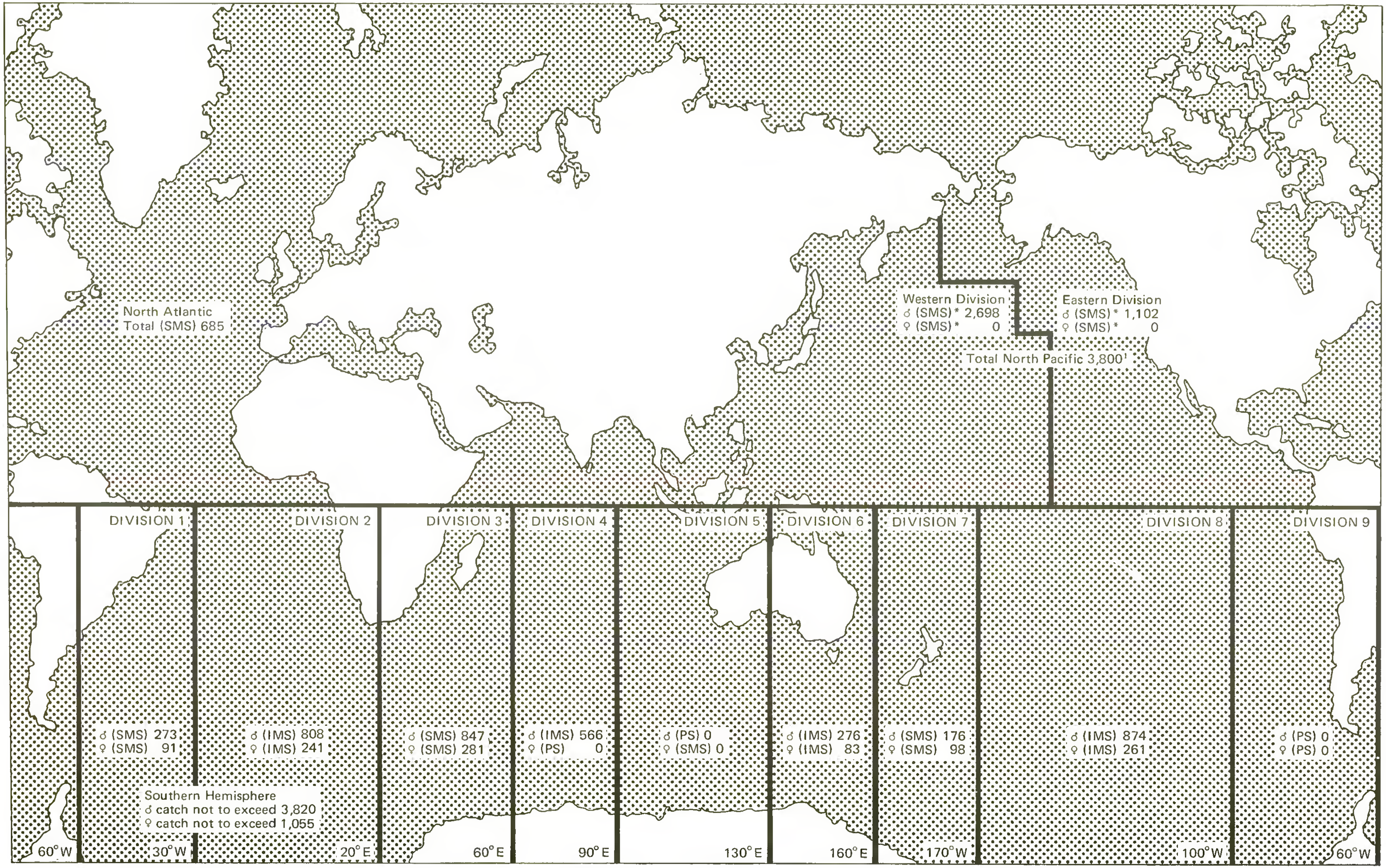


Regions closed to factory ships for taking and treating baleen whales

(PS) Protection Stock
(SMS) Sustained Management Stock
(IMS) Initial Management Stock

*Provisional
[1] Pending a satisfactory estimate of stock size

Sperm Whale Stocks, Classification and Quotas 1978/79 and 1979 Seasons



(PS) Protection Stock
(SMS) Sustained Management Stock
(IMS) Initial Management Stock

*Provisional
¹ Included within this figure there may be a by-catch of females not to exceed 11.5% and all whaling operations are to cease when this by-catch has been reached.