The Program for Research on the Southern Hemisphere Minke Whale and for Prelimimaly Research on the Marine Ecosystem in the Antarctic

The Government of Japan

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CONTENTS

	Page
1. Introduction	1
2. Purpose of the Research	3
(1) Estimation of the Biological Parameters Required for the Stock Management of the Southern Hemisphere Minke Whale	3
(2) Elucidation of the Role of Whales in the Antarctic Marine Ecosystem	3
3. Research for the Estimation of the Biological Parameters Required for the Stock Management of the Southern Hemisphere Minke Whale	5
(1) Research Method	5
(2) Research Items	6
i) Age-Specific Natural Mortality Coefficient:	6
ii) Reproductive Parameters:	6
iii) Stock Size:	7
iv) Distribution, Structure and Behavior of Minke Whales in the Low Latitutdes:	7
(3) Research Area	8
(4) Sample Size	9
(5) Outline of the Implementation of the Research Program	12
i) Sighting Surveys:	14
ii) Sampling:	15
4. Research to Elucidate the Role of Whales in the Antarctic Marine Ecosystem	16
(1) Research Method	16
(2) Research Items	16
i) Stomach Contents of the Sperm Whale:	16
ii) Biological Parameter of the Sperm Whale:	16
iii) Stomach Contents and Amount of Fat Reserve of the Whale:	16
iv) Research on the Marine Pollution Using Whale Tissues and Stomach Contents:	17
(3) Research Area	17
i) The Sperm Whale:	17
ii) The Minke Whale:	17
(4) Sample Size	18
i) The Sperm Whale:	18
ii) The Minke Whale:	18

	Page
5. Organization of the Research	19
(1) The Whale Research Coordinating Committee (Provisional Name)	19
(2) Sampling	19
(3) Sighting Surveys	19
(4) Researches Proposed by Other International or Domestic Institutions	20
(5) Opportunities for Participation by Foreign Scientists	20
(6) Conditions for Participation	20
i) Cost:	21
ii) Indemnification and Insurance for Casualty or Personal Injury on Boad the Research Vessels:	21
iii) Cancellation of Participation:	21
(7) Publication of the Information Collected by the Research	22
i) Basic Rules:	22
ii) Procedures for Reporting:	22
iii) Obligation of the Users:	22
6. Expected Effects of the Catches on the Stock	24
(1) The Minke Whale	24
i) Sample Size Compared with RY:	24
ii) Diffusible Effects of Sampling to the Reproduction:	25
iii) Diffusible Effects of Sampling to the Ecosystem:	25
(2) The Sperm Whale	26
i) Sample Size Compared with RY:	26
ii) Diffusible Effects of Sampling to the Reproduction:	28
iii) Diffusible Effects of Sampling to the Ecosystem:	28
Appendix 1 Summary of the Scientific Aspects Regarding the Management of the Southern Hemisphere Minke Whales and its Relation to this Research Program	31
Appendix 2 Summary of the Discussion on the Antarctic Marine Ecosystem	46
Appendix 3 Sampling Scheme	52
Appendix 4 The Relationship between the Sample Size and the Frequency of the Each Age Class when the Sampling Interval is Set at 3 Years or 4 Years	55

1. Introduction

The moratorium decision on all commercial whaling made at the 34th Annual Meeting of the International Whaling Commission (IWC) came into effect in the 1985/86 season for the Antarctic pelagic whaling and the 1986 season for the coastal whaling. It should be noted, however, that the above decision was made without any scientific justification and in the absence of any recommendations by the Scientific Committee of the IWC (IWC/SC).

The member nations of the International Convention for the Regulation of Whaling (ICRW) should, as a matter of their duties, undertake scientific research in order to achieve the objectives of the ICRW which are to "ensure proper conservation and optimum utilization of the great natural and renewable resources represented by the whale stocks". Japan, therefore, has been continuously contributing strenuously in all possible areas to the study and research on whales through sighting surveys and analyses of data obtained from commercial whaling. Japan neither believes that the cessation of the commercial whaling subsequent to the moratorium decision exempts the Contracting Governments from such duties, nor does it believe that it is proper to disrupt the continuous progress beiing made on the study on the whales. In the light of this belief Japan has developed a program for research on the southern hemisphere minke whale and for preliminary research

on the marine ecosystem in the Antarctic based on Article VIII of the ICRW.

This program will be implemented so as to;

(a) estimate various biological parameters including, inter alia, the age-specific natural mortality coefficient which is essential for the assessment of the population productivities of the southern hemisphere minke whale and its management and which the IWC/SC has been discussing as the most important parameter in recent years.

(b) elucidate the role of whales (the sperm whale and the minke whale) as a key species in the Antarctic marine ecosystem.

The program consists of the research take of whales based on Article VIII of the ICRW and the sighting surveys.

Japan firmly believes that the results to be obtained by the implementation of this program will provide scientific basis for resolving problems facing the IWC which have generated confrontation among the member nations due to the divergent views on the moratorium.

[The summary of the scientific aspects regarding the management of the southern hemisphere minke whale and its relation to this research program (Appendix 1) and the summary of the discussion on the Antarctic marine ecosystem (Appendix 2) are attached to this paper as references to provide a basis for a deeper understanding of this program.]

2. Purpose of the Research

(1) Estimation of the Biological Parameters Required for the Stock Management of the Southern Hemisphere Minke Whale

The main subject species of this research program is the southern hemisphere minke whale (Balaenoptera acutorostrata), the exploitable population size of which has been estimated to be at least about 260,000 by the IWC/SC.

The main reason for the failure of the IWC/SC to recommend an agreed catch limit in recent years for the southern hemisphere minke whale stock is that the IWC/SC has not been able to reach agreement on the value of the natural mortality coefficient and its age-specific patterns.

Therefore, the primary purpose of this program is to estimate the age-specific natural mortality coefficient by samples through stochastic samplings which are carried out in combination with systematic sighting surveys. The program is also designed to estimate the stock size and its changes required for stock management, and the reproductive parameters and their changes based on the same samples.

(2) Elucidation of the Role of Whales in the Antarctic Marine Ecosystem

While global scientific interest in the Antarctic

ecosystem has been growing as reflected in the coming into force of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), the most important need is for data on the prey-predator relationship among the krill, fish and squid, and whales.

To meet the purpose of this program, the stomach contents of the sperm whale (Physeter catodon) will be analyzed to identify the krill-squid-sperm whale prey-predator relationship which is considered as one of the major energy-flows in the Antarctic marine ecosystem. A further analysis of the stomach contents and the measurement of blubber thickness, etc., of the minke whales taken, as part of the research based on (1) above, will be undertaken in order to elucidate the krill-minke whale energy-flow.

3. Research for Estimation of the Biological Parameters Required for the Stock Management of the Southern Hemisphere Minke Whale

(1) Research Method

The samples obtained from the commercial whaling in the past could not represent properly the population structure of the minke whales migrating to the Antarctic because of;

(a) the concentrated operations in the high density area near the ice edge zone, and

(b) the catching selectivity with preference for larger whales.

Therefore, the biological parameters estimated using those samples from the commercial whaling are susceptible to some biases.

In order to overcome such shortcomings of the data obtained from the commercial whaling, this program will implement the research take of whales to collect stochastic samples free from possible biases by "nearest neighbors sampling method" (sampling of the animals nearest to the points randomly distributed) based on the density distribution of animals obtained by the expansive sighting survey over the research area, and estimate various biological parameters using the samples thus collected (see Appendix 3 for the details of the sampling method). Therefore, the biological parameters estimated as the result

of this program are expected to be free from biases inherent to the samples from the commercial whaling. For this reason these parameters thus obtained will be useful for the re-evaluation of the parameters already obtained from the commercial whaling in the past. In addition, the natural mortality coefficient, which is the primary purpose of this research program, will be estimated by calculating the decreases of the relative frequency of a given year class between two samples taken in a same area with an appropriate intermission.

(2) Research Items

i) Age-Specific Natural Mortality Coefficient:

Up to 1983, a fixed value had been used for the natural mortality coefficient regardless of age, but if the age-specific natural mortality coefficient could be obtained, then estimate of replacement yield (RY) will be remarkably improved. This parameter is also necessary as an input parameter for the cohort analysis. By using the age-specific natural mortality coefficient, a more accurate estimate of the recent change of RY can be made, and thereby the increasing rate of the stock can be obtained.

ii) Reproductive Parameters:

The estimates of neo-natal sex ratio, litter size, pregnancy rate, age at sexual maturity and others and their changes have to be obtained in order to identify the

reproductive parameters in the stock. Under this research program, biological observation and collection of specimens are to be undertaken with respect to these parameters.

iii) Stock Size:

The stock size of the southern hemisphere minke whale has been estimated by using the data collected by the sighting survey conducted under the International Decade of Cetacean Research Program of the IWC (IWC/IDCR).

Under the present program, systematic sighting surveys based on the line-transect theory (an IDCR type) will be continued to estimate the stock size. By coinciding the Area for the whale sightings with that for the research take of whales, both the stock size and biological parameters such as age-specific natural mortality coefficient can be obtained for the same Area and same year. Hence the stock assessment of the southern hemisphere minke whale stock will be made far more accurate than before, and the repetitive sighting surveys within the same Area will enhance the accuracy of the population estimates.

In addition, various experiments in relation to the sighting parameters will be conducted with the sighting surveys in the program.

iv) Distribution, Structure and Behavior of Minke Whales in the Low Latitudes:

Dispite that the biological information of the southern hemisphere minke whales in the breeding area (outside of the Antarctic) is extremely important in order to identify the

stock size, reproductive parameters and migration and other characteristics, these information are very scarce. Therefore, the first several years of this program will include the sighting surveys in the low latitudinal waters to collect information on the pattern of distribution and density, structure and behavior especially that of cow-calf pairs in order to provide the basis for the future researches.

(3) Research Area

Area IV (70°-130°E) and Area V (130°E-170°W) will be surveyed under this research program. The following are the reasons for this selection.

The cumulative numbers of the minke whales taken in the Antarctic by Japanese fleet from 1978/79 through 1985/86 seasons were 455 (Area I), 172 (Area II), 3,772 (Area III), 8,621 (Area IV), 7,913 (Area V), and 3,271 (Area VI). During this period, the biological investigation were conducted on all whales caught. The information from the past researches, therefore, was concentrated in Area IV and Area V, while very little information was obtained for Area I and Area II. For this reason, a lot of information of the stocks migrating into the high latitudes of Area IV and Area V are now available together with the operational knowledge for catching such as the sea and ice condition there. Those information makes the research more efficient.

It should be noted that the researches will be conducted for the two consecutive years in a particular Area, alternating Area IV and Area V in every two years.

(4) Sample Size

Since the primary purpose of this research program is to estimate the age-specific natural mortality coefficient, the sample size must be at least the minimum number required for the estimation of this coefficient.

0.086 (95% confidence limit; 0.060, 0.12) was the value for the natural mortality coefficient (M) of the southern hemisphere minke whale adopted by the IWC/SC in the most recent year. Under this research program, sample size is calculated so as to make detection possible of the decrease between two sets of samples taken in different years in the relative frequency of a cohort to estimate the age-specific natural mortality coefficient, using M=0.086 as well as its lower limit of 0.060.

The probability of successfully detecting the change of relative frequencies of the same cohort over the two consecutive years assuming M=0.086 (or M=0.060) would be extremely low, unless a very large sample size is made availalbe. However, if a certain period of interval could be allowed between two sets of samples, the cumulative number of animals dead due to natural mortality during such period would grow large and thus detection of decrease can

be made possible with a smaller sample size. If the interval between the two samplings is set longer, the natural mortality coefficient can be estimated with a sufficiently high precision with a small sample size, while there could be a demerit from a prolonged sampling interval such as a possible noise that might occur in the age composition due to continuous increase of recruitment. Under this research program, the sampling interval of four years is adopted in consideration of the effect of the catch to the reproductivity of the stock and the practical reasons of the logistics such as the steaming capacity of the research vessels. However, actual sampling will be made in the two consecutive years in a particular Area. Samples thus collected from two consecutive years are pooled together to make one set of age composition for comparison with similar set of age composition collected after four years from the same Area. Assuming no change in the stock size, with M=0.086, during two samplings, the relative frequency to the total samples of a given year class in the second sampling (P_2) must decrese to 70.9% of that in the first sampling (P_1) after four years ($P_2=P_1e^{-0.086x4}$). This research program is designed to obtain the sample size necessary for the detection of such decrease in the relative frequency of one certain year class in a statistically significant manner.

According to the data collected from the commercial whaling, the sample size must be considerably large for

estimating the natural mortality coefficient of individual cohort. In the case of a limited sample size below a certain level, some handling strategy such as grouping of the cohort will be necessary.

According to the crude age composition of the Antarctic Area IV and Area V obtained from the commercial whaling (Fig. 1), the age at which the calculation of the natural mortality coefficient is possible from the catch curve is approximately the age of 20 or above, and the relative frequency of animals above this age is 30% to 20%. If these age groups were combined to 5 - 6 groups, then the average relative frequency of each group amounts to 6 - 5%. If the decrease in the age compositions of the same cohort is detected at 5% significance level (at $p=0.05$) with the research cycle of four years, the sample size is calculated to be 1,479 to 1,794, the average of which is approximately 1,650 (from Appendix 4). Adopting the average 1,650 as the sample size and dividing this number into the two year sampling period, 825 samples are required in each sampling year.

In the case where the estimate of the natural mortality coefficient obtained turns out to be smaller than expected, $M=0.060$ for example, the estimate with sufficient precision cannot be achieved with the sample size of about 1,650 and therefore, an increase of the sample size or re-grouping of the cohort will become necessary. In this case, the estimate of the natural mortality coefficient could be

obtained with the same precision as the case in which M=0.086 is adopted, by grouping the cohort into two or so groups.

Such inefficiency in the estimation was resulted from the lack of the data of the younger age whales. In the case of the well designed sampling of whales covering evenly all the waters of distribution, such inefficiency would be eliminated. Moreover, the estimation efficiency and its reliability would be enhanced if the relationship between the natural mortality coefficient and age is established.

(5) Outline of the Implementation of the Research Program

The first stage of the program will be for four years from 1987/88 to 1990/91. The second stage will be for another four years from 1991/1992, and the third stage will be from 1995/96. The first stage will be implemented with the research in the two Areas, Area IV and Area V, with a rotation of research Areas by every two years as one cycle. The research in this stage will include the sighting survey for the third round in Area IV and Area V where the sighting surveys have already been conducted by the IWC/IDCR, together with the assessement of the population structure such as age composition and other biological aspects based on the whales taken under the stochastic sampling.

The research in the second stage will be sampling of the whales to derive, inter alia, the age-specific natural

mortality coefficient by the comparison of the age composition with the samples taken during the course of the first stage of the program. This will be carried out again in combination with the sighting surveys in the Area IV and Area V. The research in the third stage will be the follow-up of the research conducted in the first and second stages, the detail of which will be worked out later in the light of progress made in those stages.

Although the importance of the collection of the biological data from the low latitudinal waters (breeding grounds) has been recognized, only a very limited information on the distribution, structure and behavior of the minke whales have been available to date. Therefore, the survey of the time-space distribution pattern, density and structure by sighting will be initiated in the early part of the research program so as to consider the implementation of the research involving take of whales in the low latitudinal waters (breeding grounds) to ascertain the stock identity, reproductive cycle and jeuvenile natural mortality coefficient.

The outline of the annual plans for the sighting surveys and the sampling of whales is shown in the following Table 1.

Table 1

Plan for Implementation of the Research Program

Season	Stage	Area for Sighting	Area for Sampling
1987/88	1st Stage	IV	IV
1988/89	"	IV	IV
1989/90	"	V	V
1990/91	"	V	V
1991/92	2nd Stage	IV	IV
1992/93	"	IV	IV
1993/94	"	V	V
1994/95	"	V	V
1995/96	3rd Stage	-	-
1996/97	"	-	-
-	-	-	-
-	-	-	-

i) Sighting Surveys: -

Number of Vessels; Two vessels each year

Area; The same Area in which sampling is conducted

Relation with the IWC/IDCR; The period and duration, steaming distance and research items under sighting survey of

this programm will be adjusted with the IWC/IDCR type survey to the extent possible.

ii) Sampling:

Time; December to March

Number of Vessels; One factory ship (research base) each year, and two sampling vessels each year

Area and Sample Size; The following total number in each Area will be sampled over the period of fours years in the first stage.

1987/88	Area IV	825	1,650
1988/89	Area IV	825	
1989/90	Area V	825	1,650
1990/91	Area V	825	

4. Research to Elucidate the Role of Whales in the Antarctic Marine Ecosystem

(1) Research Method

Examination of the stomach contents and measurement of nutritious characteristics of the sampled sperm whales and minke whales (see chapter 3) will be implemented.

(2) Research Items

i) Stomach Contents of the Sperm Whale:

Identification of the food species and measurement, as far as possible, of the weight of the stomach contents as well as examination of other characteristics such as the nutritious condition of the whale.

ii) Biological Parameter of the Sperm Whale:

In addition to the research on the stomach contents described above, various biological examinations will be carried out with all sampled whales in relation to the reproductive and growth parameters.

iii) Stomach Contents and Amount of Fat Reserve of the Whale:

The food species from the stomach contents of all sampled minke whales will be identified, and as far as possible the weight of the contents will be measured. Some indecies of amount of the fat reserve such as thickness of

blubber will be also measured.

In addition, biological measurement of length, weight, and sex, as far as possible, of the food species such as krills which retain their original form, and collection of krills with fresh condition or other organisms among the stomach contents will be made.

iv) Research on the Marine Pollution Using Whale Tissues and Stomach Contents:

Concerns have been expressed regarding the marine pollution in a global scale today, and it is feared that the pollution is reaching the Antarctic. Although it may be outside of the principal purposes of this research program, examination of heavy metals and other substances in the tissue of various organs and debris in the stomach of the sampled whales will be conducted.

(3) Research Area

i) The Sperm Whale:

The research involving take of sperm whales will be implemented in the four Divisions, Div. 4 - 7.

ii) The Minke Whale:

The samples collected according to the research described in chapter 3 will be used. Therefore, the research area will be the same area as described in chapter 3-(3).

(4) Sample Size

i) The Sperm Whale:

The research will be implemented for duration of the first and sercond stages of the research under chapter 3, with two years of sampling in each Division (Div. 4 - 7).

The maximum sample size in each year is 50 males.

ii) The Minke Whale:

The samples collected according to the research described in chapter 3 will be used.

5. Organization of the Research

(1) The Whale Research Coordinating Committee (Provisional Name)

A standing committee will be organized which coordinates various phases of this research program and will be tentatively called "Whale Research Coordinating Committee". The committee will consist of the Whale Research Institute, the Far Seas Fisheries Research Laboratory, the Fisheries Agency and other relevant institutions.

The secretariat of this committee will be located in the Whale Research Institute, who will be also in charge of the liaison and communication with other organizations and individuals outside of the Committee.

(2) Sampling

The Whale Research Institute will implement the sampling research. Therefore, the special permit by the Government of Japan provided for by Article VIII of the ICRW will be issued to the Whale Research Institute.

(3) Sighting Surveys

The Government of Japan is prepared to offer two

research vessels for the IWC/IDCR sighting research cruise, provided that the sighting survey Area coincides with the sampling research Area and it would not interfere with the implementation of this research program by Japan.

(4) Researches Proposed by Other International or Domestic Institutions

The Whale Research Coordinating Committee will consider proposals for researches by other international or domestic institutions, following the procedure described below, provided that such proposals are made on timely basis and without hindrance to the implementation of this program.

(a) Submission(s) for research item(s) proposed by scientific research organization(s), or scientist(s), either international or domestic.

(b) Consideration on practicability of a proposal such as;
- instrument required for the proposed research
- restrictions by time available
- restrictions by manpower available

(c) Adjustment of the allocation of the research costs

(5) Opportunities for Participation by Foreign Scientists

Opportunities for participation in the research cruises under this program will be given to any scientist to the extent allowed by accomodation and other logistic

consideration, provided that such participation does not cause inconveniences in the implementation of the program. The selection of the participants, however, will be finalized by the Whale Research Coordinating Commitee who will consider the various conditions such as accommodation and others for determination.

(6) Conditions for Participation

i) Costs:

Costs for participation, travel expenses to and from the port of boarding the research vessel, meals on board the research vessel, and any special instruments required by the participant will be borne by the participant.

ii) Indemnification and insurance for casualty or personal injury on board the research vessels:

The Whale Research Institute and the crew of the research vessel or research team will not be held responsible for any casualty or personal injury to the participants resulting from the participant's negligence or force majore.

iii) Cancellation of participation:

Any participants who are found to have intentionally sabotaged in the course of implementation of the researches and thereby impaired the execution of such researches shall be cancelled of his/her participation in this program.

(7) Publication of the Information Collected by the Research

i) Basic rules:

All the data specified in Schedule 27, 28, and 29 to the ICRW, collected under this program, will be reported to the IWC according to the guideline set forth separately. Such data and materials will be placed under the supervision of the IWC allowing free access to the scientific activities by the IWC. In addition, the biological materials collected by this program will be kept in the custody of the Whale Research Institute and may be offered to researchers for scientific studies. However, this principle dose not necessarily apply to some of the information pertaining to the researches on the Antarctic ecosystem.

ii) Procedures for reporting:

The format of the report containing information to be given to the IWC will be determined separately. The deadline for such reporting to the IWC will be set in accordance with the activities of the IWC/SC.

iii) Obligation of the users:

Persons who have utilized information or data collected by this program for their scientific thesis or other publications shall be required to so state and describe the data source including at least the title of this program and workers' name(s) who compiled the original data in such thesis or publications, and shall be obliged to send a copy

of such thesis or publications to the Whale Research Institute.

6. Expected Effects of the Catches on the Stock

(1) The Minke Whale

i) Sample Size Compared with RY:

The IWC/SC has recommended to the IWC every year since 1979 the catch limits of the stocks of this species based on the RY estimates with correction for the sex ratio in the catch. In the recent years, however, the IWC/SC has not been able to reach agreement on the estimates of the RY values. The 37th Annual Meeting of the IWC/SC in 1985 lost the basis for the need of recommendation of the catch limits because of the moratorium for the commercial whaling. Although an agreement was reached on the stock size, there were four different proposals on RY at that IWC/SC Meeting (Table 2).

Table 2: The proposals on RY of the southern hemisphere minke whale at 37th IWC/SC

	Area IV	Area V
View 1	885	921
View 2	1,328	1,381
View 3	1,328-1,771	1,381-1,842
View 4	1,498	1,119

The planned sample size for the first stage of the research is 1,650 animals in the Areas IV and V, respectively (825 whales per year). Since the sampling in each Area will be conducted for two years out of four year period, the mean annual sample size during four years will be 413. It should be noted also that the number of samples of 825 is less than the smallest RY (View 1) recommended for Area IV or V (Table 2) and is between 45% and 74% of RYs of other views.

As already known, the stock size of the minke whale migrating into the Antarctic whaling ground estimated by the sighting survey is considerably smaller than that of the total population, so that a real RY for total population should be greater than the values expressed in all of the views above (Table 2); hence the upward correction of RY would be necessary.

ii) Diffusible Effects of Sampling to the Reproduction:

The present sampling plan does not exceed the minimum estimation of RY in any of the single year, and the mean annual sample size in each stage of the research is far below RY. Therefore, on the premises that there is no environmental changes, the stock size of the southern hemisphere minke whale is expected to continue to increase under this research program.

iii) Diffusible Effects of Sampling to the Ecosystem:

The IWC/SC has no established technique with regard to the assessment of the effects to the ecosystem. In the case

where 825 whales are taken in one stage (mean annual sample size of 413 whales) out of the estimated population of about 50,000 whales at least, the detection of the effects of such catches to the ecosystem within the short term of the research will be likely to become impossible due to their absorption into the various noises. Therefore, the detection of the effects needs to be made in relation to other factors in the ecosystem over a long term.

(2) The Sperm Whale

i) Sample Size Compared with RY:

The stock assessment of the Antarctic sperm whale was made at the Annual Meeting of the IWC/SC in 1979 for the last time; no systematic assessment with regard to the stock has been made since then. It should be noted that there have been no catches from these stocks since 1981/82 season.

At the Sperm Whale Sub-Committee in 1979, (a) CPUE analysis based on the La Jolla model, (b) analysis by division using the population estimated by sighting (of which, an analysis of mark and mark recapture data for Division 3, and estimation technique of catch/fishing mortality for Division 3, and estimation technique of catch/fishing mortality for Division 9 were utilized) were made. The estimates made by using the technique (b) were not adopted for recommendation to the IWC after all.

The estimates by the above technique (a) for Divisions

2, 4, 5, and 9 were adopted, but were considered to give underestimates, while it was pointed out that some factors exist in the technique that might give over-estimates. In addition, due to the doubts concerning the compatibility between the observed value of pregnancy rate and the estimated value from the La Jolla model, it was impossible to estimate the MSY and the level of MSY against the Initial Manamgment Population. It was possible, however, to estimate the population of Division 3 utilizing the mark and mark recapture analysis.

The stock size and RY for Divisions 1 to 8 as of 1979 were calculated as shown in the Table 3 below. The stock assessment for Division 9 was made at the IWC/SC Meeting in 1980.

Table 3: The Stock size and RY of the sperm whale for Div.'s 1 to 8

	Division							
	1	2	3	4	5	6	7	8
Male Population	-	10,610	6,580	7,560	4,160			
RY	-	765	-	743	741	-	-	-
Female Population	-	41,140	42,900	32,260	30,840			
RY	-	-	-	-	-	-	-	-

In the Sub-Committee, some members believed that the

IWC/SC should recommend the estimates to the IWC. Other members believed that it should not make recommendation because they believed that there was a serious doubt in the estimates.

In 1980, the Annual Meeting of the IWC/SC conducted the stock assessment of Division 9, and estimated that the population of the males of over age 10 in 1981 is 66,500 and the females over age 9 in 1981 is 124,600. Although the estimated value of RY was not shown, it was recommended that the MSY of the females was 405.

ii) Diffusible Effects of Sampling to Reproduction:

No assessment technique is available at the present time to accurately evaluate the effects of the catch which represents approximately 7% of RY to the reproduction of each stock. Furthermore, the effects of such number of the catch would be impossible to measure because it would be overshadowed by the dynamics of the population caused by the natural factors; its effects are considered to be only negligible for either short or long term.

iii) Diffusible Effects of Sampling on the Ecosystem:

As in the case of the diffusible effects to reproduction, it would be almost impossible to quantify the effects to the ecosystem. Such effects are considered to be virtually negligible.

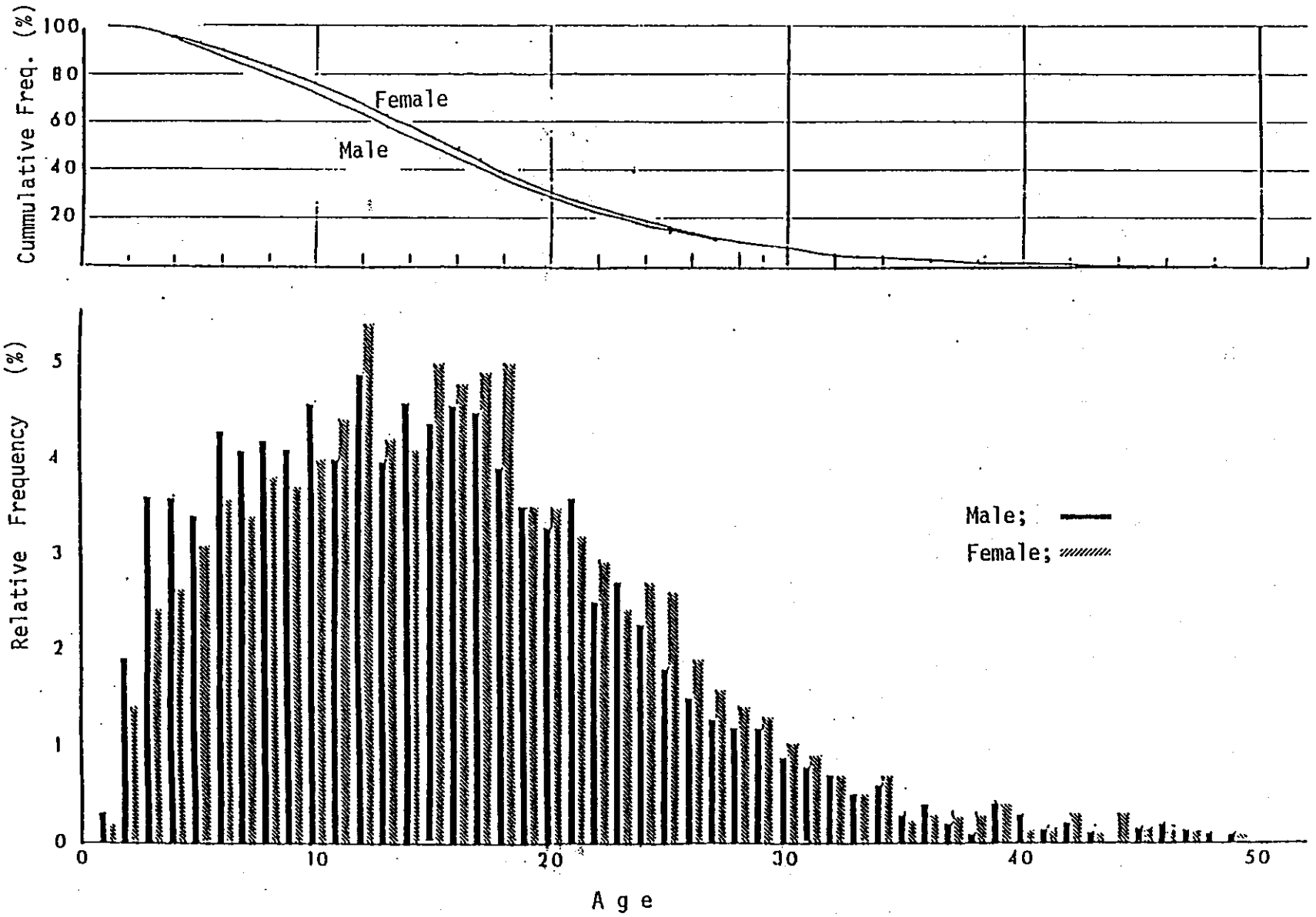
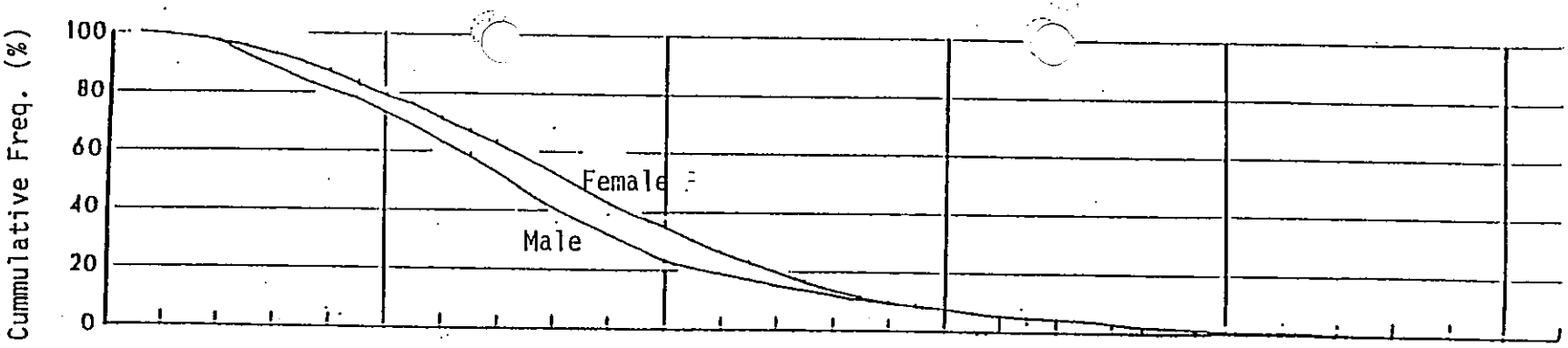


Fig. 1 Age compositions (bottom) and cumulative frequency (relative) starting from oldest age class (top) by sex based on the catches by the Japanese Antarctic whaling expeditions from 1978/79 to 1983/84 seasons. Area IV.



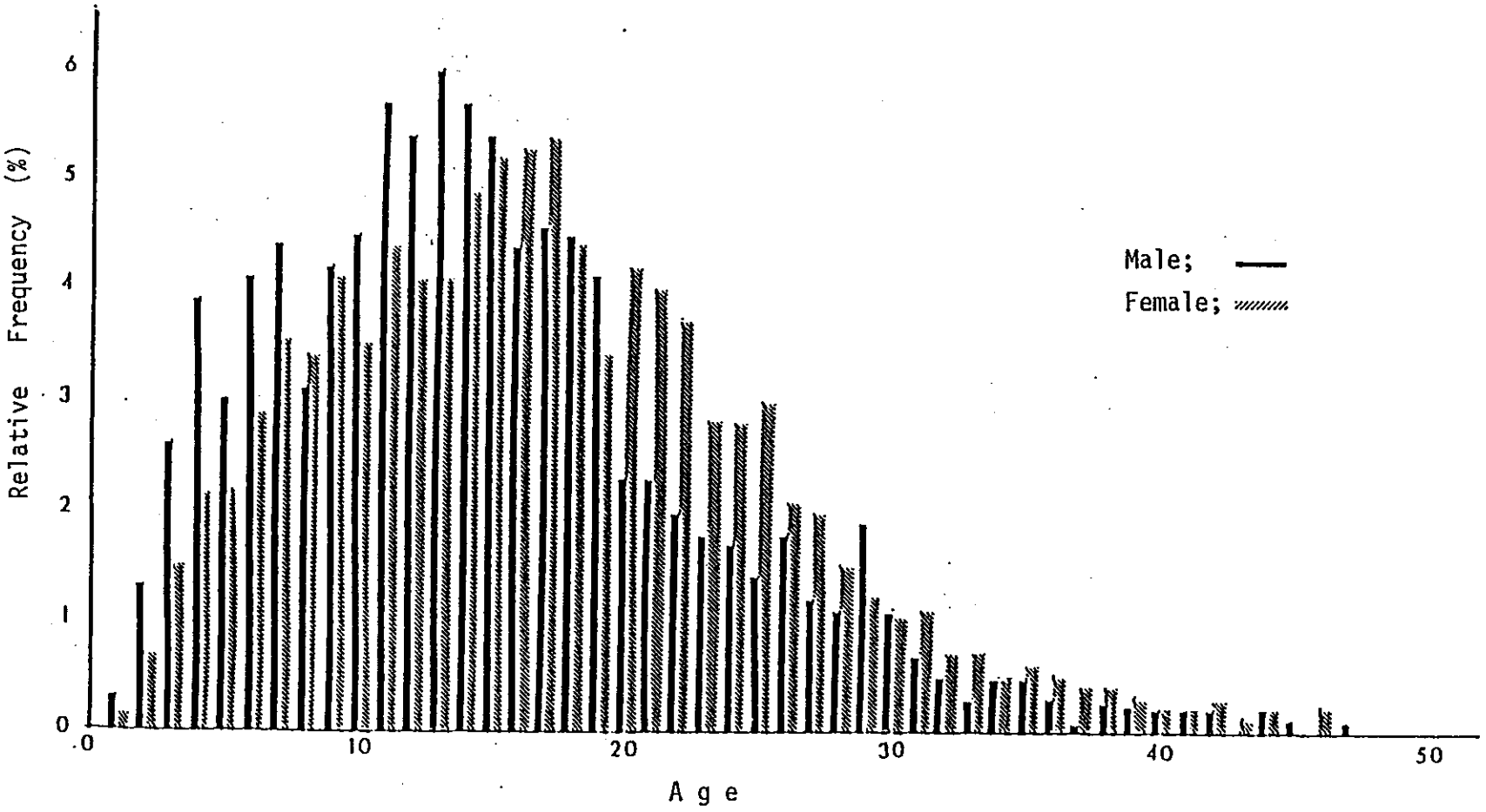


Fig. 1 (cont.) Area V

Appendix 1

Summary of the Scientific Aspects Regarding the Management of the Southern Hemisphere Minke Whales and its Relation to this Research Program

1. Whale Sightings

(1) Sighting Theory and Parameters

Table 1-1 shows the outline and the result of the IWC/IDCR cruises conducted in the past seven years.

The earlier cruises aimed mainly at the estimation of the stock size, and were thus planned, and implemented. During the recent cruises efforts have been more directed to the examination of the various parameter values of sighting theory as well as to the whale sighting survey itself.

The IWC/SC Workshop held at Cambridge in 1985 noted the following items as the major experiments;

(a) Experiment to establish the value of 1-g(0), which is the rate of the whales missed on the trackline which may be inherent to the individual survey vessel (or an observer).

(b) Depending on the result of the further simulation study to be conducted by Hiby (SC/J85/S1), measurement and estimation of the cue counting and blow-rate, if necessary.

(c) To establish and to specify the interaction between

research vessel and whales, if it exists.

(d) To monitor the distribution of the sighting effort by individual observer.

(e) Parallel ship experiment with inter-ship distance of 1.0 nautical mile, if such experiment proves to offer useful information.

In addition to the above, the following projects would be regarded as important tasks.

(f) Estimation of school size.

(g) Studies and validation of the statistical stratification.

These items have been responded by appropriate experiments. For example, (a) has been accomplished by placing a secondary independent observer on the same vessels in addition to the primary observer.

Furthermore, at the 38th IWC/SC Meeting, there was a recommendation to obtain an appropriate function for the right angle distance distribution of the sightings to analyze the effects generated by the estimated values of f(0), g(0) and g(0)/f(0).

(2) Population Estimates

Sightings have been considered to be superior to other methods for population estimate such as mark and mark recapture because of the less number of assumptions inherent in the procedure. In the case of southern hemisphere minke whale, however, certain problems have been left unresolved

for the sightings, i.e., the low precision of the estimate and the exclusion of the whales in the unsurveyed areas. The precision of the past population estimate using sightings was higher if $g(0) \cdot \bar{y}=0.5$ was assumed rather than the assumption of eh=1.0. The coefficients of variation of the estimates for six Antarctic Areas were the smallest (0.127) for Area IV and the largest (0.268) for Area V. For improvement of the precision of estimates, the following points have to be investigated.

(a) optimum distribution of the sighting efforts (the trackline distance of survey) and the revision of the statistical stratification,

(b) extension of the trackline and/or its centralization, and

(c) reiteration of the surveys

Of the above points of consideration, the reitration of the surveys would be an effective approach for the improvement of whale sightings theory under the condition where research effort can not be increased and the small annual fluctuation of the population size exists.

The IWC/SC considers that the values shown in the Table 1-1 is generally an underestimate because it does not include the individuals distributed in the unsurveyed areas such as inside the pack ice or the low latitudes.

The survey of the population inhabiting in the low latitude would involve little difficulty for implementation. However, if the research effort is set uniform, the

distribution of the effort allocated to the low latitudinal waters where the density is considered low might lead to a lower precision of the over-all estimates. Some sporadic observations have been made reporting the high density inside the pack ice, but no full-scale research has been conducted regarding this subject. A prompt implementation of the preliminary experiments using aircrafts, etc. are desired.

2. Stock Identification, Distribution and Migration

Several attempt have been made to determine stock boundaries using the morphological and biochemical techniques, catch distribution, mark and mark recapture and the sighting analyses, while the six Areas are used for the management of the stock. The assessment of the stocks in itself determines the basic framework of the stock management, but in the past, it can be pointed out that the efforts for the assessment of the ecological interpretation behind the information obtained for stock assessment have been insufficient. It is assumed that biological stock boundaries of whales migrating in Areas IV and V are in conformity with the boundaries for management, while in the case of Areas II and III the migration of the whales over the boundary from the Area II into Area III have been observed, hence a doubt exists whether the stock is discrete.

If there were more data, whole movement indicated by recaptured marked whales would provide direct information on the stock boundary of minke whales. However, the recaptures of only 38 whales out of 2,881 marked whales in 1975/76 to 1981/82 seasons leave much to be desired (IWC/34/4 Annex E).

The IWC/SC has not yet obtained scientific information pertaining to the changes of the existing boundary for the management. If a great number of marked whales are to be liberated with prospects of recapture, the information that are useful for such changes would be made available. At the 38th IWC/SC Meeting the need of simulation studies to elucidate the problems in stock management generated by the discrepancy between the management boundaries and the biological stock boundaries and the usefulness of the genetic biochemical method for stock separations were discussed.

All of the southern hemisphere minke whales do migrate to the low latitudinal waters for breeding in the winter of the southern hemisphere, and to the Antarctic for feeding in its summer. The IWC/SC has maintained an opinion that the younger animals and the females with calves do not migrate to the Antarctic, as shown in the diagram in Fig. 1-1. Contrary to the inactive nature of the discussion concerning this matter up to date at the IWC/SC, such information is extremely important in the future for planning the sampling in order to enable the accurate assignment of the biological parameters of the population without biases. Due to the

possibilities that the biological parameters such as pregnancy rate, age at sexual maturity and age composition based on the data collected up to date do not fully reflect those of the population (one of its reasons is attributable to the catching selectivity in the commercial whaling, another is attributable to the characteristics of the distribution and the migration), the discussion concerning these parameter values has been complex and difficult. In consideration of these existing problems, the need of the stochastic sampling is recognized as immensely important.

The problems stated in the foregoing can only be resolved by the research involving take of whales which can be systemized and implemented on the basis of a scientifically justifiable program.

3. Reproductive Parameters

(1) Pregnancy Rate

The apparent pregnancy rate (pregnant females/sexually mature females in samples) estimated from the commercial operations in the feeding areas has remained constant around 0.90 for fifteen years (1971/72 to 1985/86). The IWC/SC has agreed to adopt the value 0.78 as a true pregnancy rate based on the material collected in the breeding area off Durban. The Sub-Committee for the Southern Hemisphere Minke Whale at the 35th IWC/SC Meeting recommended the collection of the ovaries, mammary glands, length and sex of the

feotuses, uterine muscosa from both horns of the uterus from the minke whales in the waters off Brazil(breeding ground) in winter. The research take of whales should incorporate in its planning comprehensive research items described above in the low latitudes in order to estimate the true pregnancy rate.

(2) Age at Sexual Maturity and its Yearly Changes

The age at sexual maturity for the females is considered particularly important and the criteria to determine it is clear while the criteria for that of the males is not. Due to the short catch history, the age related function of the proportion of sexually mature individuals is available only for limited number of year classes. However, the transition phase technique makes it possible to estimate age at sexual maturity and to examine the changes in longer time-series. Whether or not there were any yearly changes in this parameter can be a useful circumstancial evidence for the expanding population before the begining of the exploitation of the stock. For a number of years, the Japanese scientists have been analyzing the various data such as the transition phase in the earplugs, ovulation rate, relationship between the age and the number of the corpora, and have estimated that the age at sexual maturity for the females of the year class of 1945 was 12 to 13 and it has declined to 7 for the year class of the late 1960's, and it has remained at 7 since then. There were

some other scientists, however, who did not agree to this and believed that this apparent declining trend can be explained by mathematical biases (such as truncated sampling problem), aging error and catching selectivity, thereby they asserted that the method for analyses has certain problems which required further examination.

If the samples of a longer time series of the year class each containing the younger animals through to the old ones can made available, such problems can be resolved by continuous collection and analyses of the samples.

The catching selectivity can be ascertained by;

(a) the analyses of the materials collected by the research take of whales by the stochastic sampling, and

(b) the confirmation of its nature of selectivity by the cohort analyses with the correct number of the population by age in the recent years added to the historical catch data, and finally

(c) clarification of the bias in the selectivity that might have occurred in the whales caught at the start of the exploitation.

In summary, the controversy over the yearly trends of the age at sexual maturity is a major problem of the stock management of the southern hemisphere minke whales. It is concluded, therefore, that the continuation of the collection and analyses of the materials are needed more than anything else.

4. Survival

(1) Age at Recruitment

The age at recruitment into commercial catches has been required for the population assessment. The IWC/SC has considered the age 7 as the age at recruitment for both male and female. This parameter is not an important item under the sampling research. However, the ascertainment of the age at which the whales migrate into the Antarctic would be necessary for the understanding of the overall picture of the population in the Antarctic (See Fig. 1-1).

(2) Natural Mortality Coefficient (M)

Accurate estimate of the natural mortality coefficient (M) is an extremely important parameter for the effective stock management. Most of the problems involved in the stock assessment can be resolved by obtaining its accurate parameter value.

The materials for natural mortality of the southern hemisphere minke whale are:

(a) Estimation using the age composition of the whales in the catch, and

(b) Analogical estimation using relationship between M and maximum body length of some whale species whose M and the maximum length are known.

0.086 was the value adopted by the 32nd through the 35th IWC/SC Meetings, but no agreement has been made on a value

at any of the meetings since then. The ascertainment of the age-specific natural mortality coefficient is necessary for the analyses of various other biological parameters as well as of itself and for the population assessment.

The problems inherent to the materials collected for age composition from the commercial whaling are that bias exists in the catch for the age composition by which the population is not fully represented, and the insufficient number of samples, and the problems of the estimation technique adopted. The bias of the sampling and the insufficient number of the samples would be overcome by the research take of whales under scientific program. Since the controversy over the analysis methods is due to the variable nature of the sampled materials, it is indispensable that the materials used should be of a clear origin.

An analogical estimation on M is an adaptation of the biological empiricism, and its basic effectiveness has not been lost. However, such problems as the limitation of the number of species compared, and ambiguity in the materials have been pointed out. Since abundant materials and information can be made available from the southern hemisphere minke whales, it is desirable that the parameters should be obtained by accumulation of information of its own rather than borrowing them from other species, while the increase of the knowledge of this stock could provide analogical information for other species.

When the age composition is used as a basic data for

estimation of M, it can be adequately estimated by eliminating the defects in the materials accumulated to date as described above. The following are the conditions necessary for such estimation: (a) using samples representing the population, (b) securing the adequate precision, and (c) the implementation of the researches and the development of analyses that facilitate the estimation of the age-specific natural mortality. In addition, the tasks described in the following (3) would be undoubtedly required for the accuracy and the objectivity of the age determination. Therefore, the research take of whales which assures the above three conditions should form a nucleus of this program.

(3) Age Determination

At the workshop on the age determination of the IWC/SC in April 1983, the aging method and a number of problems involved in the analyses of other biological parameters using age information were discussed. The workshop noted the points for the future studies of this subject.

This research program, as its main task, will conduct age reading according to the method and the criteria, which have so far been established, in order to offer the results thus obtained to the scientists. An effort would be made to consider the technicality of the age reading for its objectivity, provided there was time and funds available. It is expected that a systematic aging will be made by

utilizing an instrument with applied image processing system.

5. Age Composition in the Population

Up until the present time, there is no practical measurements which fully represent the age composition in the population. The recently developed cohort analysis uses the age composition in the catch to estimate, as one of its final products, the age composition in the population. The accuracy of this, however, would have to be verified in comparison with other observational information. Also, the result to be obtained by the cohort analysis can be made more easily objective, if the animals in a population by age classes in one season can be made available.

The natural mortality coefficient is one of products of the analysis using the same data, and the real status of the dynamics of the population can be ascertained by the cohort analysis. The collection of the information of this kind, therefore, is indispensable and a rigorous research for such collection should be strongly supported.

6. Mark and Mark Recapture

In spite of the fact that, in theory, mark and mark recapture method is widely effective in many studies such as population analyses, stock identification, analyses of the

migration, movements and growth, variety of analyses utilizing the data collected from this method tend to show slow progress. This is due to the difficulties involved in the confirmation of effectively marked individuals as well as the very limited number of expected recaptures.

Another reason for precluding this method from practical use has been that, in the past, the mark and mark recapture were both conducted within the feeding ground in the Antarctic. If mark and mark recapture could be available both in the low latitude (breeding ground) and the high latitude (feeding ground), this method would certainly produce information with the highest accuracy ever obtained by any other methods ever adopted in the past for ascertainment of stock movements, migration and identification.

Table 1-1: The Outline of the IWC/IDCR Sighting Survey of the Antarctic Minke Whale Stocks in the Past Years.

Year	Vessels	Aggregate number of days	Period	Area*	Steaming distance	No. of schools sighted	No. of schools per 1000 n.mile	Estimated number in population
1978/79	T16, T18	82	Dec.29	IV-N	4,414	164	37.2	23,773
			-Feb.7	S	3,511	400	113.9	14,153
				To.	7,925	564	71.2	37,926
1979/80	K27, T11	118	Dec.28	III-N	4,693	123	26.2	16,523
			-Feb.14	S	2,512	328	130.6	33,592
				To.	7,205	451	62.6	50,115
1980/81	K27, T11	135	Dec.23	V-N	3,435	214	62.3	-
	V34		-Feb.5	S	3,735	451	120.7	-
				To.	7,170	665	92.8	71,617
1981/82	SM1, SM2	126	Dec.27	II-N	4,012	186	46.4	-
	V34		-Feb.6	S	2,966	343	115.7	-
				To.	6,977	529	75.8	25,163
1982/83	SM1, SM2	105	Dec.30	I-N	2,480	164	66.1	26,335
	V34		-Feb.12	S	2,376	469	197.4	9,729
				To.	4,856	633	130.4	36,064
1983/84	SM1, SM2	184	Jan.4	VI-N	1,865	74	39.7	21,677
	K27, V34		-Feb.18	M	2,120	87	41.0	11,788
				S	560	25	44.6	2,545
				To.	4,545	186	40.9	36,010
1984/85	SM1, SM2	228	Jan.23	IV-N	1,756	60	34.2	10,762
	K27, V34		-Feb.19	M	1,940	70	36.1	3,703
	(Western half only)		***	S	1,777	159	89.5	8,873
				Prydz	759	24	31.6	285
				To.	6,232	313	50.2	23,622**

Remarks; * N. for the area stands for the northern stratum of the Area. S. for the southern stratum, M. for middle stratum.

** The estimated value when $g(0)\cdot\bar{y}=0.5$

*** The first half period was for the experiments, and the last half period was for the population research.

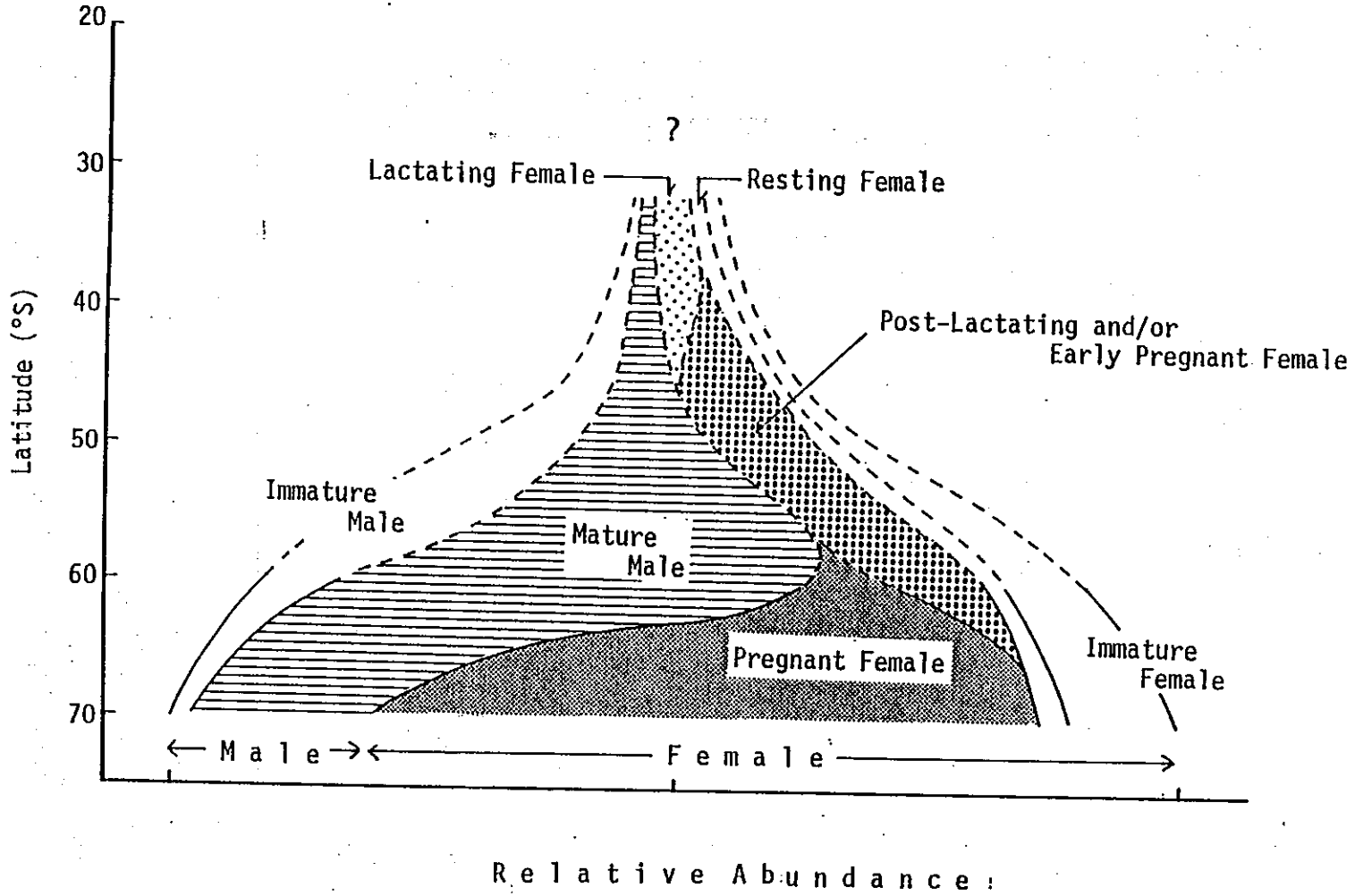


Fig. 1 - 1 Schematic illustration of hypothesized latitudinal changes in sex ratio, sexual status and relative abundance of the southern minke whale population in austral summer (Jan.-Feb.; Area IV). After Kato (unpublished)

Appendix 2

Summary of the Disscussion on the Antarctic Marine Ecosystem

The Antarctic Treaty signed in 1959 provides for obligation of the signatorty nations to preserve and conserve the living resources in the Antarctic. In relation to this Treaty, the three separate conventions, namely the Convention for the Conservation of Antarctic Seals (adopted in 1972), the Convention for the Conservation of Antarctic Marine Living Resources (signed in 1980) and the International Convention for the Regulation of Whaling (signed in 1946) almost exhaustively cover all of the marine living resources in the Antarctic.

Of these three conventions, the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) provides for the principles to be adhered to for the harvest of the marine living resources applied by the CCAMLR. These principles are: (a) to maintain the ecological relationship between the harvested, dependent and related populations of marine living resources, (b) to minimize the risk of changes in the marine ecosystem which are not potentianlly reversible over two or three decades.

In the Antarctic marine ecosystem, the food-web is structured with the krill as a principal species at the

secondary trophic level (primary consumer), and the baleen whale, the crabeater seal, the penguin, the squid and the fishes which are at the thirtiary trophic level (secondary consumer) feeding on the krill, and finally the killer whale, the leopard seal and the sperm whale forming the fourth trophic level (thirtiary consumer). In addition, the order of food-web for the sperm whale is unique as it is the krill - squid - sperm whale.

According to the recent studies (Bengston, 1984; Laws, 1985), the consumption of the krill is 400 to 470 million tons per year of which 127 to 130 million tons are consumed by the crabeater seal, 115 to 130 million tons are consumed by penguins and other birds, 100 million tons by the squid, 34 to 40 million tons by the baleen whales and 70 million tons by the fishes.

The assignment for the studies of the various marine living resources in the Antarctic as described in the foregoing has been given to a number of intergovernmental organizations: Sub-Committee on Birds Biology of the SCAR on birds, Group of Specialists of Seals of the SCAR on seals, and the IWC on whales. No organization, however, has yet been established for the studies on the interspecific relations.

Under these social and scientific circumstances, many attempts for variety of mathematical modelling of the Antarctic marine ecosystem have been made, out of which the need of verification to prove the validity of the models for

the management of the population and the ecosystem by controlled experiments has been recognized. In short, there are views advocated recently that the present environment, if continued, would lead to the utopia for the penguins and crabeater seals and would incapacitate the maintenance of the ecological balance, which is the principle of the resources utilization defined by the CCAMLR.

At the Ecosystem Monitoring Workshop Meeting of the CCAMLR held in Seattle in May, 1985, the direction of the scientific activities was set for (a) detection and recording of the important changes occurring in the major species, (b) monitoring of the behavior and the parameter values of the indicator and harvested species. Three sea areas were suggested as candidates for the research areas at that meeting; they were Prydz Bay (Area III), Brunsfied Strait, and around the South Georgia Island. Further studies and re-examination of this project was undertaken at the Workshop Meeting held in Hamburg in July, 1986.

Many areas of the biological knowledge related to the prey-predator relation between the sperm whale and the squid are still left unresolved, in spite of the fact that it holds the special importance within the Antarctic marine ecosystem.

The BIOMASS Project from its early stages recognized the importance of the studies on the squid; in Japan, the Oceanic Research Institute of the University of Tokyo and the Japan Marine Fishery Research Center have participated

in the researches, from which the importance of the assessment of the food-web concerning the krill, the squid and the sperm whale has been pointed out. Subsequently, the BIOMASS Workshop Meeting held in September, 1983, recommended the need of development of the researches on the squid based on the stomach contents and the feeding habits of the larger predatory species for the progress of ecological studies on the squid.

There are as many as six species centering around the small and medium size squids collected by the test operation of the krill fishery. Of these species, especially important from the biological point of view are Kondakovia longimana and Moroteuthis knipovitchi, the length of the head and body of these two species had been believed to be approximately 40 cm at the most. In the past, the body length of many of the K. longimana eaten by the sperm whale occurred to be large with their length longer than 40 cm. Since the sperm whales feed in the deeper water, this squid species has been assumed to make vertical segregation by sizes for their habitat. It is also noted that K. longimana harvested by the krill fishery feed only on the Antarctic krill, but M. knipovitchi feed on other fishes as well as the krill. From these, it is suggested that the feeding characteristics of the squid differ by species.

For the shallow water collection of the samples of K. longimana, the priority species is the Antarctic krill, while there is no analyses made on the samples collected in

the deep water, leaving no knowledge available regarding the variety and the feeding pattern of these species. The absence of knowledge in this area is causing a great obstacle for the assessment of the dynamics of the Antarctic marine ecosystem.

In the meantime, the sperm whale fishery in the Antarctic, following the moratorium for pelagic whaling of the sperm whale, was only conducted in the coastal waters of Chile and Peru since 1979/80 season. These coastal whaling, however, has been prohibited since 1981/82 season, and no information concerning the Antarctic sperm whale has been collected since then.

The Sub-Committee on the Sperm Whale of the IWC/SC in 1979 pointed out eight items for the future studies to be undertaken on the population of these stocks, and in relation to the biological characteristics, a need of analyses on age data was pointed out in addition to the sighting, CPUE and the stock identification. It was suggested that without solving problems associated to these eight items, an effective development of any new population assessment cannot be expected.

Therefore, in addition to these principal objectives, the research by the collection of the sperm whale for the assessment of the food-web (krills-squids-sperm whales) needs to be further developed for the studies on the biological characteristics peculiar to this species in line with the items pointed out by the Sub-Committee of the

IWC/SC described above.

Appendix 3

Sampling Scheme

In general, the minke whales in the southern hemisphere migrate to the south into the Antarctic in early summer and leave the Antarctic to the north with the end of summer, thus making north-south movement. Such migratin may form ageal and sexual differences in terms of time and place. In addition, the distribution of minke whales in summer is affected by the advance and retreat of the pack ice line. The IDCR/IWC sighting surveys have revealed that the density of the minke whale in the feeding area is high along the pack ice line and becomes lower with the distance away from the pack ice line.

Furthermore, it is unlikely that the individual animals maintain uniformal or random spatial distribution, and therefore it is more realistic to suppose that it has a factor of patchy distribution. In order to make stochastic sampling of the minke whales, the sampling design for this program should take into account of these characteristics.

1. Stratification

(1) Time-Space Stratification

As mentioned in Chapter 3-(5) of the main document, in

the first stage of the program, Area IV is to be covered in consecutive 2 years. The area to be covered in one year, therefore, is one half of Area IV, namely the eastern (or the western) half of the Area IV, which constitutes a 30° longitudinal strip of the sea. This 30° strip is further divided into six narrower longitudinal strips. Then, the number of days available during the season is equally divided into 18 time-units (assuming total number of days as 90, 1 time-unit is 5 days). These time-units are allocated evenly to 6 longitudinal strips to make 18 time-space strata, in other words, each longitudinal strip is to be covered by sampling survey 3 times during the season with appropriate intermissions.

(2) Sub-Stratification

Each time-space stratum is further stratified into 2 sub-strata, divided into southern half and northern half areas, to take into account of the densities of whales and the positions of the pack ice. This is done on the basis of the observation of the position of the pack ice to be carried out through sighting survey of the period immediately precedent to the actual sampling in each stratum.

2. Allocation of Number of Samples:

Total number of whales to be sampled (825) is allocated

equally to each time-space stratum. Thus the number of whales to be sampled from each stratum is 45 or 46. Then the number is further allocated to each of the substratum in proportion to the density of whales observed during the sighting cruise in the preceding period.

3. Actual Sampling of Whales

The substrata are further divided into smaller squares all of which have equal sizes each, the number of which should be more than twice the number of the samples to be collected in that stratum. From these small squares thus formed, the equal number of small squares to the number of the samples assigned to that stratum are randomly selected. The center points of these small squares thus selected are plotted on the chart. Searching of the whales is started from each point thus located along a given direction (say, east or west) in which the first whale observed is sampled. A limit of time is determined, as a give-up time in advance, for the research program, and if no whale is observed during that time limit, then the sampling for this point is given up and a newly selected starting point will be added as substitute.

Appendix 4

The Relationship between the Sample Size and the Frequency of the Each Age Class when the Sampling Interval is Set at 3 Years or 4 Years

The following design was adopted for the sample size capable of detection of the decrease of the frequency of a cohort between two samplings:

Z: Critical Ratio=2, which gives nearly 95% confidence limit

P_1: Relative frequency in certain age (a) and year (i)

P_2: Relative frequency in age (a + x) and year (i + x), then $P_2 = P_1 e^{-MX}$

n_1: Sample size at year (i)

n_2: Sample size at year (i + x)

$\bar{P}$: Mean value of expected frequency (weighted by sample size)

From

$$Z = \frac{P_1 - P_2}{\sqrt{\frac{\bar{P}(1-\bar{P})}{n_1} + \frac{\bar{P}(1-\bar{P})}{n_2}}}$$

where, $n_1 = n_2$ and expressed as n and $\overline{P} = P_1$

then

$$n = \frac{C\,(1-\overline{P})}{\overline{P}}$$

is obtained. Here $C = \dfrac{8}{(1-e^{-MX})^2}$

At M=0.086, when X is set at 3, C is 154.7. When x is set at 4, C is 94.43, and at M=0.06, C is 294.8 and 175.72, respectively.

The Tables 4-1, 4-2 below show the relationship between $\overline{P}$ and n, and interval year x.

Table 4-1: Sample Size (n) at M=0.086

x \ $\overline{P}$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
3	15,315	7,580	5,002	3,713	2,939	2,424	2,055	1,799	1,564	1,392
4	9,348	4,627	3,053	2,266	1,794	1,479	1,252	1,086	955	850

Table 4-2: Sample Size (n) at M=0.060

x \ $\overline{P}$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
3	29,185	14,445	9,532	7,075	5,601	4,619	3,917	3,390	2,981	2,653
4	17,396	8,610	5,682	4,217	3,339	2,753	2,335	2,021	1,777	1,581

Based on the figures listed in the above Table 4-1 with M=0.086 and interval of 3 years in order to estimate natural mortality coefficient of the year class with the relative frequency around 5%, 2,900 individuals will be required as samples, and for the year class with the relative frequency around 10%, 1,400 individuals will be required. When the interval is 4 years, however, the sample size will be decreased, to about a half of the above two figures, to 1,800 individuals and 850 individuals respectively. From the reasons mentioned in Chapter 3-(4) in the main document, average of the combined frequencies of year classes ($\overline{P}$) of 5 to 6% and sampling interval of 4 years are chosen for this program. The sample size required, assuming M = 0.086, is 1,479 to 1,794, according to Table 4-1, the mean of which is 1,650.