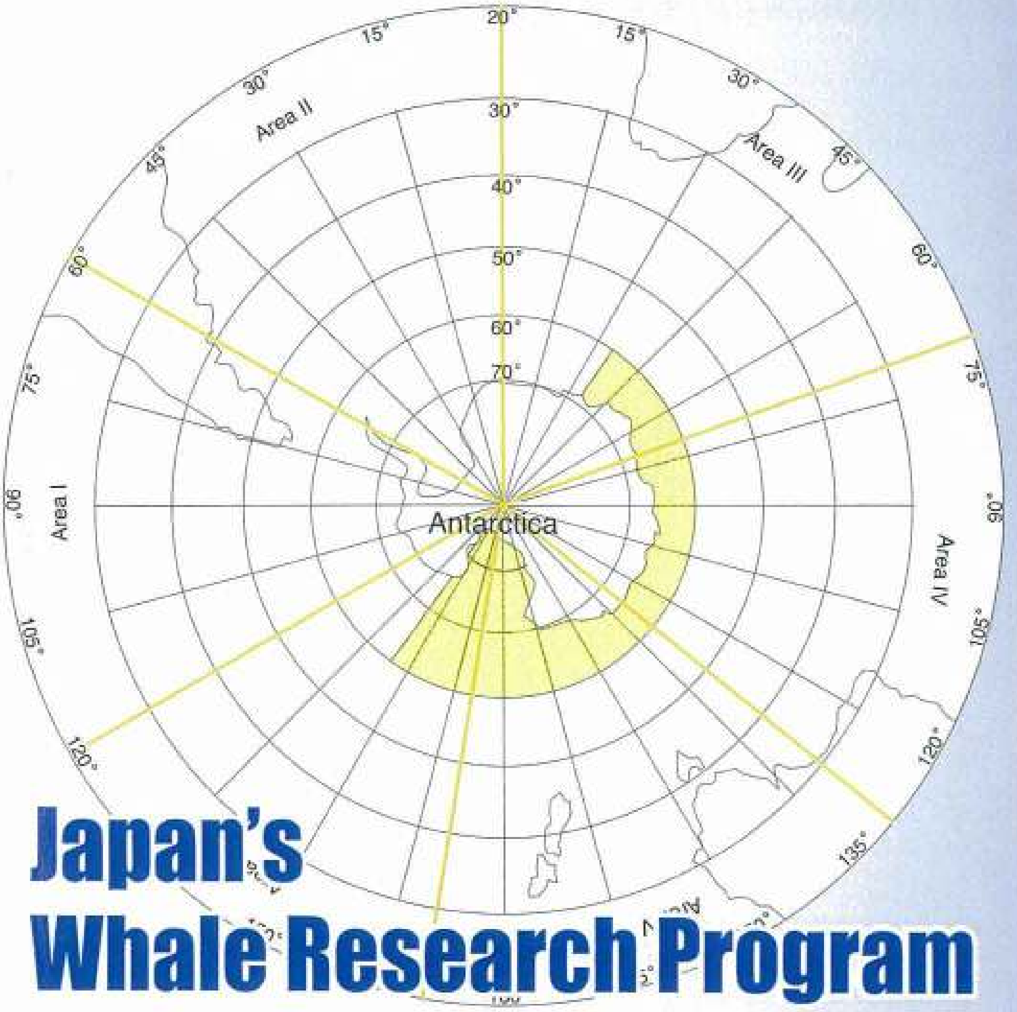


# Japan's Whale Research Program under Special Permit in the Antarctic (JARPA)



The Institute of Cetacean Research

## SUMMARY



## MAIN SECTION



## QUESTIONS & ANSWERS

# Summary

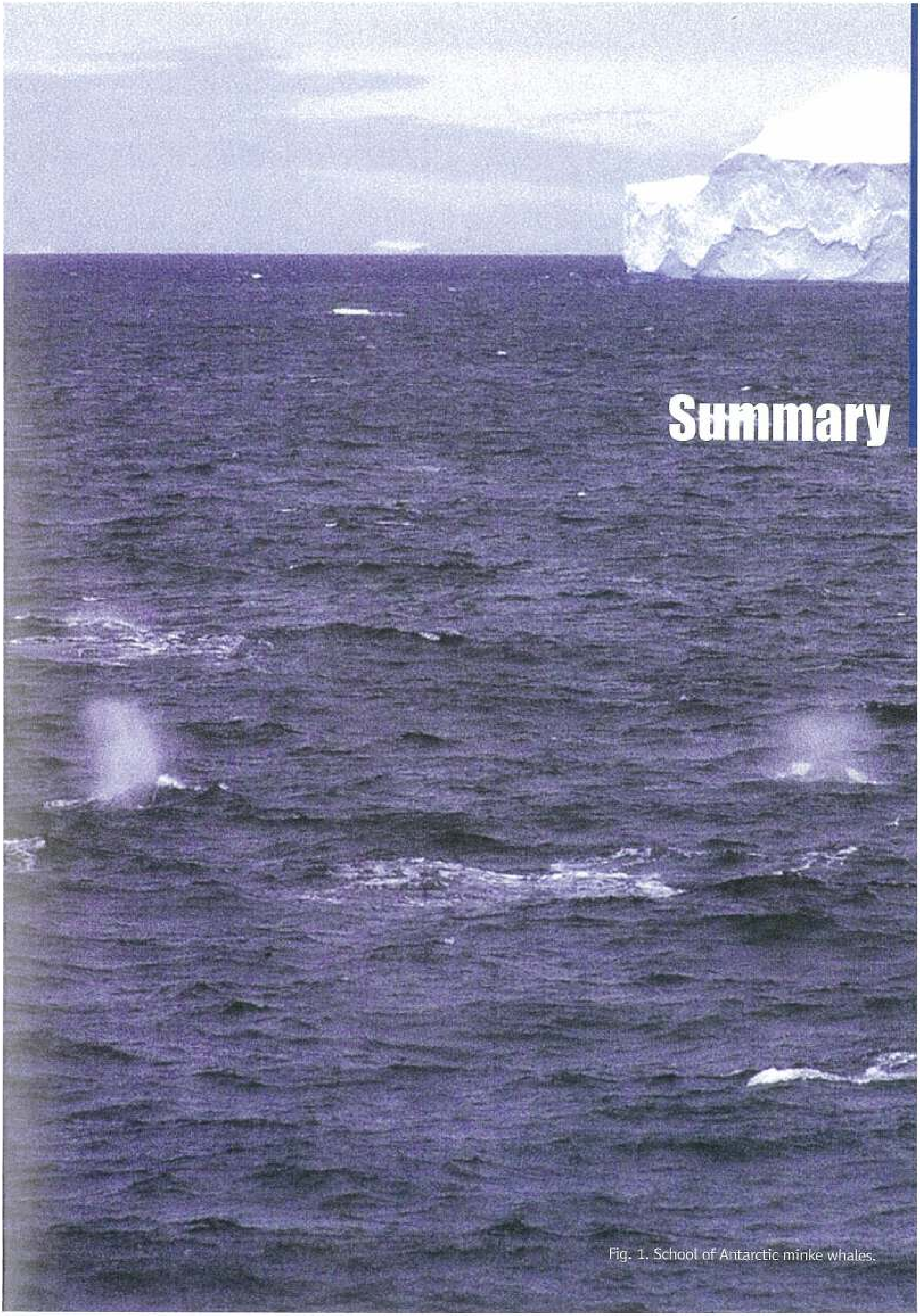

Fig. 1. School of Antarctic minke whales.

# CHANGES IN THE ANTARCTIC ECOSYSTEM AND INTENT OF THE JARPA PROGRAM

The Antarctic Ocean sea is the most productive ocean in the world and Antarctic krill with its resource quantity being enormous, is a key species of this ecosystem. Baleen whales are also one of the main components of this ecosystem as they feed on this abundant resource.

As the Antarctic Ocean enters the spring the ice scrapes-off the ground bringing rich nutrition salts into the water and, when the sunlight enters the sea, the phytoplankton multiplies explosively and in turn, the Antarctic krill, which feeds on those micro algae, does the same. Around the same time, the blue whales and Antarctic minke whales which had become thin after finishing propagation in the warm seas, start to arrive at the vicinity of the pack ice margin where Antarctic krill distributes abundantly, to eat this krill actively and store energy for the next breeding season. Therefore, as they fed on the same prey species, both the blue whale and the minke whale are direct competitors in the same sea area.

When in 1904 land-based modern whaling operations started in the Antarctic Ocean, first the easy-to-target humpback whales became the object of capture but around 1910 the blue whale, the biggest species, which rendered the most oil, became the main target. Since the more efficient mothership whaling was introduced in the mid-1920s the capture quantity increased remarkably (Fig. 2) and with that the blue whale resource decreased rapidly. On the other hand, the Antarctic minke whale had not been exploited by whaling operations till the 1970s, because they are small and their blubber thin. With its competitor species decreasing and the feeding environment becoming good, the population of Antarctic minke whales grew rapidly as their breeding rate increased while their natural mortality rate decreased.

Thus, the Antarctic ecosystem including the baleen whale resources which are one of its main components changed significantly with development of the whaling industry. Since mankind has upset the ecosystem, it should be recovered by us. As the Antarctic minke whale has abnormally increased to levels surpassing its original abundance before the onset of Antarctic whaling, research on this species and its environment as well as the proper understanding of the ecosystem is necessary. On the basis of that, we will be able to advance the rational utilization and management of the Antarctic ecosystem and its living components. With this purpose, Japan has executed continuously the JARPA program from 1987. Though this research has not ended, already many new knowledge is being obtained.

This booklet has been produced to introduce the research methods and some results of the JARPA to improve understanding and gain the support of people in general.

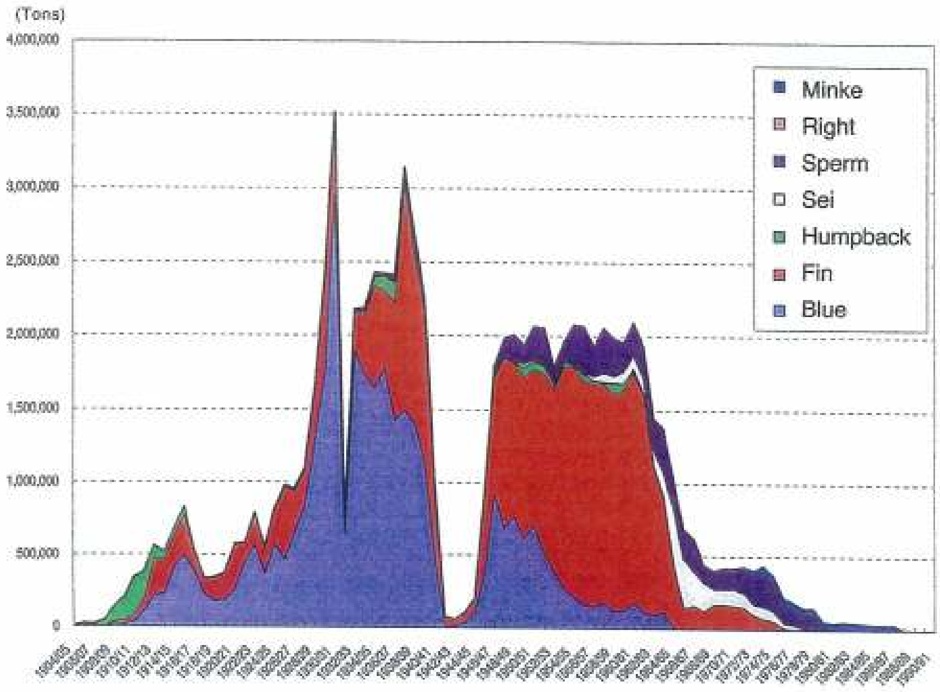


Fig. 2. Change in the whale species composition (number of tons) of commercial whaling catches in the Antarctic.

## EXCERPTS FROM THE REPORT OF THE 1997 INTERNATIONAL WORKING GROUP HELD TO REVIEW THE JARPA DATA AND RESULTS

1. At this halfway point in its programme, JARPA has already made a major contribution to understanding of certain biological parameters (e.g. direct measures of the age at sexual maturity) pertaining to minke whales in Areas IV and V.

2. Under the objective of elucidating the role of minke whales in the Antarctic ecosystem, JARPA has collected data on body condition that, in conjunction with the data on biological parameters as noted above, should result in an improved understanding of the status of Antarctic minke whale resources in these Areas. These data are likely to be useful in testing various hypotheses related to aspects of the "krill surplus" model.

3. Under the objective of "Elucidation of the effect of environmental change on cetaceans", there is considerable uncertainty in how biological parameters of minke whales may vary in relation to environmental change. Therefore, more effort is needed to develop mesoscale studies to integrate physical and biological oceanography and prey distribution with Antarctic minke whale studies.

4. Under the objective of "Elucidation of the stock structure of minke whales to improve stock management", deciding on the amount of genetic data required to meet this objective is difficult because the Scientific Committee has provided only a vague definition as to what constitutes a stock.

5. The results of the JARPA programme, while not required for management under RMP, have the potential to improve the management of Antarctic minke whales in the Southern Hemisphere in the following ways: (1) reductions in the current set of plausible scenarios considered in RMP Implementation Simulation Trials; and (2) identification of new scenarios to which future Implementation Simulation Trials will have to be developed (e.g., the temporal component of stock structure).

6. The results of analyses of JARPA data could be used in this way to increase the allowed catch of Antarctic minke whales, without increasing the depletion risk above the level indicated by the existing Implementation Simulation Trials of RMP for these minke whales.

7. Consensus was reached on the following point regarding the future of JARPA over the next eight years: Future efforts should expand research on the environmental change component of JARPA.

# WHAT IS JARPA[1]?

In 1982, the IWC decided to place a temporary measure (moratorium) on commercial whaling from 1986 on the basis that scientific evidence concerning whale stocks was inconclusive. On the other hand, the IWC agreed that the moratorium would be reconsidered by 1990 based on the "best scientific advice", with resumption of whaling as a premise.

JARPA was launched in 1987/88, starting with a two-year feasibility study, and will be conducted until 2004/05. It is a whale research program spanning sixteen years, and the Institute of Cetacean Research (ICR), authorized and instructed by the Government of Japan, carries out the surveys.

- The JARPA surveys will resolve lack of scientific evidence concerning Antarctic minke whales.
- JARPA will promote adherence to the provisions for reconsidering the moratorium placed by the IWC.

# JARPA HAS FOUR OBJECTIVES

JARPA has the following four objectives to obtain the scientific information necessary for resumption of whaling.

1. The estimation of biological parameters[2] to improve the stock management of whales.
2. The elucidation of the role of whales in the Antarctic marine ecosystem.
3. The elucidation of the effect of environmental changes on cetaceans[3].
4. The elucidation of the range of distribution and boundary of whale stocks[4].

- JARPA will elucidate Antarctic minke whale stock composition by age and sex to achieve safer and sustainable use of resources.
- JARPA will contribute to the well-balanced use of the entire Antarctic marine ecosystem, including whales.
- JARPA will make it possible to manage resources in a safer and sustainable manner by taking a wide range of environmental factors into consideration.
- JARPA will help to apply the safe, strict, and reliable Revised Management Procedure (RMP, see p. 25).

# JARPA IS ABSOLUTELY LEGAL

JARPA is conducted to promote the sustainable use of whale stocks, which is the purpose of the International Convention for the Regulation of Whaling (ICRW), and in exercise of the rights granted by Article VIII of the ICRW. The by-products from the program are sold according to the obligation of the Contracting Government as stipulated therein.

**The International Convention for the Regulation of Whaling, Article VIII**

1. *Notwithstanding anything contained in this Convention, any Contracting Government may grant to any of its nationals a special permit authorizing that national to kill, take, and treat whales for purposes of scientific research (...).*
2. *Any whales taken under these special permits shall so far as practicable be processed and the proceeds shall be dealt with in accordance with the directions issued by the Government by which the permit was granted.*

[1] *Abbreviation of Japanese Whale Research Program under Special Permit in the Antarctic.*
[2] *Natural mortality rate, pregnancy rate, etc.*
[3] *Added from the 9th research expedition.*
[4] *Added from the 8th research expedition.*

# JARPA IS HIGHLY APPRECIATED BY THE IWC SCIENTIFIC COMMITTEE

At the 1997 intersessional review meeting[5], the IWC Scientific Committee acknowledged that the JARPA program has made significant contributions for the better management of whale stocks, although some points to be improved were pointed out. We believe that our research efforts and achievements have been acknowledged by the IWC scientists.

The major points of the review were as follows:

- *The results of the JARPA program have the potential to improve the management of minke whales in the Southern Hemisphere. It will be useful in reducing the current set of plausible scenarios for the RMP, and will contribute to increasing the allowed catch without increasing the depletion risk.*
- *The program has the potential to provide answers to various questions concerning the trend of stock fluctuation of Antarctic minke whales in Areas IV and V. The Japanese surveys have made great contributions to elucidating the biological parameters for Areas IV and V, and the results need to be analyzed by taking into account the new information on stock structure.*
- *The program is useful for elucidating the role of whales in the Antarctic ecosystem*. The collected data should be used to verify hypotheses such as the "krill surplus model."

There are various positive passages in the JARPA review meeting report, such as "The JARPA program has already made significant contribution to understanding certain biological parameters," and "the program is yet to be completed, but knowledge on stock structure has been considerably improved."

Fig. 3. Sampling/sighting vessel Toshi Maru No. 25 sails toward the mothership towing an Antarctic minke whale sampled in Area IV in the Antarctic Ocean (2002).

Fig. 4. Biological survey on the Nisshin Maru deck. One of the research crews (wearing a green helmet) is measuring the fat layer of an Antarctic minke whale. Antarctic Ocean Area IV, 2002.

[5] *The results of the JARPA program have been reported every year at the IWC Scientific Committee, but in addition, the IWC held a five-day review meeting in Tokyo in May 1997. Constructive discussions on the achievement of the proposed objectives and contribution to whale stock research went on in depth, based on the results of the program, including the two-year feasibility studies which started in 1987/88. Forty-four scientists, from about a dozen countries, including US, New Zealand, Australia, and Norway, of the IWC Scientific Committee participated in the review meeting.*

# JARPA RESULTS

JARPA results are summarized here as follows:
I) Contribution to minke whale taxonomy, II) Results related to the main JARPA objectives, and III) Other results (See Fig. 5).

## I) CONTRIBUTION TO THE TAXONOMY OF MINKE WHALES

Until recently minke whales from both hemispheres were considered as a single species, *Balaenoptera acutorostrata*. Genetic analysis based on samples collected by JARPA has contributed to elucidate the taxonomic status of the minke whale.

Two species are actually recognized, the Antarctic minke whale *Balaenoptera bonaerensis* and the common minke whale, *Balaenoptera acutorostrata*. The former is the larger and most abundant species and is restricted to the Southern Hemisphere. The latter species includes minke whales from North Atlantic, North Pacific and the dwarf minke whale, which lives in the Southern Hemisphere.

Genetic studies conducted under the JARPA derived in two main findings a) dwarf minke whale and the Antarctic minke whale are separated at the species level and b) dwarf minke whales are closely related to Northern Hemisphere minke whales, especially to North Atlantic minke whales. Minke whales from the North Pacific and North Atlantic and the dwarf minke whale from the Southern Hemisphere belong to the common minke whale species *B. acutorostrata*.

Studies under JARPA showed that dwarf minke whales feed mainly on fish. Records of the dwarf minke whales made during JARPA surveys showed that they are found much further south than originally thought, with sighting in summer occurring around latitude 60°S.

There are distinct morphological differences between Antarctic minke whale and dwarf minke whale that can be detected at sea e.g. the white patch on the base of flipper. Since it was determined to halt the catches of dwarf minke whales in the Antarctic in 1993/94, effectively no individuals have been taken, showing that both dwarf and Antarctic minke whales can be recognized at the field by experienced researchers.

EASY GUIDE

***TAXONOMY OF MINKE WHALES***

- Genetic analyses conducted under JARPA have contributed to clarify the taxonomy of the minke whale.
- Two species are recognized: the larger and most abundant Antarctic minke whale (*B. bonaerensis*), restricted to the Southern Hemisphere and the common minke whale (*B. acutorostrata*). The latter includes minke whales from North Atlantic, North Pacific, and the dwarf minke whale which lives in the Southern Hemisphere.
- Genetic analyses under JARPA confirmed that dwarf minke whales and Antarctic minke whales are separated at the species level and that dwarf minke whales are closely related to Northern Hemisphere minke whales, especially to North Atlantic minke whales.
- Minke whales from the North Pacific and North Atlantic and the dwarf minke whale from the Southern Hemisphere belong to the common minke whale species *B. acutorostrata*.

# *JARPA RESULTS – Summary*

Fig. 5. The Antarctic minke whale *Balaenoptera bonaerensis*. The white band coloration across each flipper distinctive of other minke whale forms is not present in this species. Compared to other rorquals, the head is extremely pointed. The body coloration is black dorsally and white ventrally. The white round spots of the individual in the photograph are cookie-cutter shark bite scars.

## II) RESULTS RELATED TO THE MAIN JARPA OBJECTIVES ON ANTARCTIC MINKE WHALE *B. bonaerensis*

### OBJECTIVE 1

**The estimation of biological parameters to improve stock management**

1.1 One of the most important data obtained from JARPA is age, which is estimated carefully from each whale sampled. A comparative analysis between JARPA and past commercial whaling samples showed higher age readability in JARPA. For male of body length ranging 7.9-8.8m, age readability for JARPA is 91.3% in comparison to 61.2% for commercial samples. For female of body length ranging 8.2-9.4m, age readability for JARPA is 90.6% in comparison to 63.9% for commercial samples.

1.2 One of the major achievements of JARPA is that the program has made possible the attainment of representative data on age composition of the stock, since minke whales are sampled randomly in the research area. Estimation of biological parameters is based on such representative age distribution data.

1.3 JARPA has been able to conduct concurrent sighting (for abundance estimation) and biological surveys of Antarctic minke whales in the research area. The estimation of biological parameters can be made by taking into consideration the relative abundance of Antarctic minke whales.

1.4 Analysis of sighting data taken under JARPA showed that abundance estimations of Antarctic minke whale in Areas IV and V have been constantly high for the period 1989/90-2000/01.

1.5 JARPA results showed a marked segregation by sex and age in the research area. Animals younger than 12 years old are less represented in Area V than Area IV. One interpretation of this result is that Areas IV and V are represented by a single stock with the younger animals distributed outside Area V.

1.6 From the age composition of the stock, the annual natural mortality rate has been calculated preliminarily for male and female: 6.9% and 7.2%, respectively, for Areas IV and V combined. Natural mortality rate is a basic parameter in the study of population dynamics using cohort analysis. This parameter is important because for a given natural mortality rate, there is a suitable fishing mortality rate such as to maximize catch for the sake of sustainable use of the resource. Using JARPA data, it has been possible to investigate the number of animals of a given year class in the stock (for example the number of individuals aged 12 years old) and follow the dynamic of this class over the years. The number of animals of that year class dying from natural mortality in a given period of time (for example 28 years) was calculated using the annual natural mortality rate. The number of animals aged 12 at the start of the period is 5,636 and the number of animals that died during that period is 5,208.

1.7 The mortality due to research takes of the JARPA program in the same period is 182 animals; a mere 3.5% of the natural mortality in this period. It can be concluded that the effect of the catches on the stock is much smaller than natural mortality.

1.8 Using the data combined for several years in Areas IV and V, the estimated age at sexual maturity in Antarctic minke whales is approximately 5 years and 8 years for males and females, respectively. The age at sexual maturity of females obtained by JARPA for this period is relatively higher than that obtained using data from commercial whaling. It is necessary to confirm whether or not a temporal trend exists for this parameter. Length at sexual maturity is approximately 7.3m and 8.1m for males and females, respectively. The length at sexual maturity obtained by JARPA for both sexes for this period is similar to that obtained using data from commercial whaling. Age and length at maturity are being examined on a yearly basis to study temporal trends in these parameters.

1.9 Apparent pregnancy rate estimates for Areas IV and V have been constantly high (larger than 80%) in the period 1971/72-1999/00.

1.10 As shown in items 1.4, 1.8 and 1.9 above, abundance and biological parameters can be used as indices of temporal changes in the status of the resource, and by inference, on the possible changes in the Antarctic marine environment.

EASY GUIDE

***OBJECTIVE 1 RESULTS***

- The estimations of changes of abundance and biological parameters obtained during the research period can improve the management of the minke whale.
- The abundance status of the stock can be monitored through the research period.
- Consistently high levels of abundance estimations and pregnancy rates during the research period suggest that the stocks of Antarctic minke whale in Areas IV and V are healthy.

## OBJECTIVE 2

### The elucidation of the role of whales in the Antarctic marine ecosystem

2.1 Detailed oceanographic surveys have permitted the study on distribution and dynamics of krill (*Euphausia superba*), the main prey species of the Antarctic minke whale. Krill distribution is associated with the extent and shape of the ice-edge and sea-bottom topography.

2.2 Concurrent minke whale sighting and krill echo-sounder surveys have been possible under JARPA. Results of the concurrent surveys showed that the distribution of minke whales is closely associated with the occurrence and distribution of krill in the research area near the ice-edge.

2.3 The JARPA program has made possible for the first time the quantitative analysis of the stomach content of Antarctic minke whales. Both the weight of stomach content and the weight of the whole whale body are measured directly. The daily krill consumption of a minke whale has been estimated to be between 200 and 300kg (3-5% of body weight). The consumption of krill in Area IV has been estimated between 1,740,000 and 1,930,000 tons per year (about 30% of estimated krill abundance in Area IV).

2.4 Antarctic minke whales consume more krill than crabeater seals and Adelie penguins in the Ross Sea. The daily consumption of krill by minke whales was estimated at 35,000 tons, while that of Adelie penguins and crabeater seals is 2,100 and 600 tons, respectively.

EASY GUIDE

***OBJECTIVE 2 RESULTS***

- Quantitative analysis of prey consumption by Antarctic minke whales became possible under the JARPA program.
- Minke whales consume about 30% of the available krill in Area IV.
- Antarctic minke whales are the largest predator of krill in the Ross Sea.
- This information should be taken into account in developing an ecosystem-based management scheme.

# *JARPA RESULTS – Summary*

## OBJECTIVE 3

### The elucidation of the effect of environmental changes on cetaceans

3.1 Different kinds of pollutants concentrate in different tissues of the whale (muscle, blubber and internal tissues). The JARPA program made it possible to collect these different tissues for the purpose of pollutant analysis. The level of accumulation of pollutants in minke whales is investigated by taking into consideration age, as accumulation level will be higher in older animals.

3.2 Comparative analyses conducted under the JARPA program show that pollutant accumulation levels in both the minke whale and surrounding Antarctic environment, by far lower than those found in the Northern Hemisphere, are practically inexistent.

3.3 PCB concentration in the blubber of adult Antarctic minke whales has slightly increased, though it seems to be leveling off. The mercury accumulation curve by age also shows some increase over the years, but they seem to reflect the changes in the feeding environment of minke whales.

3.4 The time series oceanographic data obtained by JARPA surveys has allowed for the study of temporal changes in both environmental conditions and in the relation prey-predator. Antarctic minke whales appear to have been affected by considerable inter annual variability in food availability (implying yearly changes in oceanographic conditions) in the ice-edge area, e.g., the most krill-rich area in their feeding grounds.

EASY GUIDE

***OBJECTIVE 3 RESULTS***

- The much lower level of pollutants in both the tissues collected from minke whales and the environment (sea water, air) shows that pollution in the Antarctic marine ecosystem is almost inexistent as compared to the Northern Hemisphere.
- JARPA surveys have detected some yearly variability of krill availability near the ice-edge.
- Time series data obtained during the JARPA program can be used for monitoring changes in the environment, which could affect the status of minke whale resources.

## OBJECTIVE 4

### The elucidation of the range of distribution and boundary of stocks

4.1 In the JARPA program several kinds of data for the study of stock structure have been collected. They include DNA (genetic approach), body proportion measurements (morphometric approach), parasite species and load and level of pollutant (ecological marker approach). Results from a single approach are complemented and interpreted considering those obtained using other approaches.

4.2 The initial view was that independent minke whale stocks migrated to Areas IV and V. The IWC Areas boundaries had been established in the 1930's based on data on concentration and location of catches of blue and fin whales.

4.3 Studies on stock structure under JARPA have shown absolutely no biological support for the IWC boundary between Areas IV and V. The hypothesis derived from the JARPA review meeting is that a core stock distributes in the two Areas and that a different stock could occur in the western part of Area IV in some years. Several lines of evidence (mtDNA, morphometric, contaminant load, etc.) obtained during JARPA support this hypothesis. If this hypothesis is confirmed, biological parameters will be calculated on the basis of the classification of this biological stock.

4.4 The available information on stock structure obtained under JARPA suggests that the implementation of the RMP on each of 10° longitude sectors does not make sense from the biological point of view. In the future, a more realistic stock scenario should be used for the RMP implementation using JARPA results. According to these results, the span of a stock could involve an area similar or larger than that of an IWC management Area, at least 60°-wide area.

EASY GUIDE

***OBJECTIVE 4 RESULTS***

- The new information on stock structure obtained under JARPA is in conflict with the boundaries of the IWC's management Areas.
- Once the geographical and temporal boundaries of the core stock are elucidated, estimation of biological parameters will be based on this biological stock.
- Information on stock structure under JARPA does not support the RMP concept of a 10°-wide small area. The distribution span of a stock in the Antarctic could be similar or larger than the span of actual IWC Areas (at least 60°-wide area).

## III) OTHER RESULTS

1. Results of JARPA surveys suggest an increase in the number of sightings of the blue whale in Areas IV and V (see Table 8).
2. Results from JARPA showed an increasing abundance trend of humpback whales in Areas IV and V. For example, in Area IV the average annual rate of increase is estimated at 13.4% for the period 1989/90-1999/00.
3. Movement of right whales between Australia southern coast and Area IV has been reported using photo-ID data partially taken during JARPA surveys.
4. Genetic analysis based on biopsy samples taken from humpback whales during JARPA has increased the knowledge of stock structure of this species in the feeding grounds. Results have confirmed that two stocks distribute in Areas IV and V, respectively, and that geographical overlap occurs between these stocks. Whales from the stock in Area V seem to move into the eastern part of Area IV.
5. Sighting data obtained during JARPA have been analyzed to investigate abundance of the fin whale. Abundance of this species in Area V was estimated as 6,362 (CV=0.50) in 2000/01 season.

EASY GUIDE

***OTHER RESULTS***

- Sightings and other non-lethal surveys used in the JARPA program have allowed the study of abundance, stock structure, distribution and movement of large whale species such as blue, humpback, right and fin whales in the Antarctic.
- JARPA surveys have revealed an increasing abundance trend of fin and humpback whales.

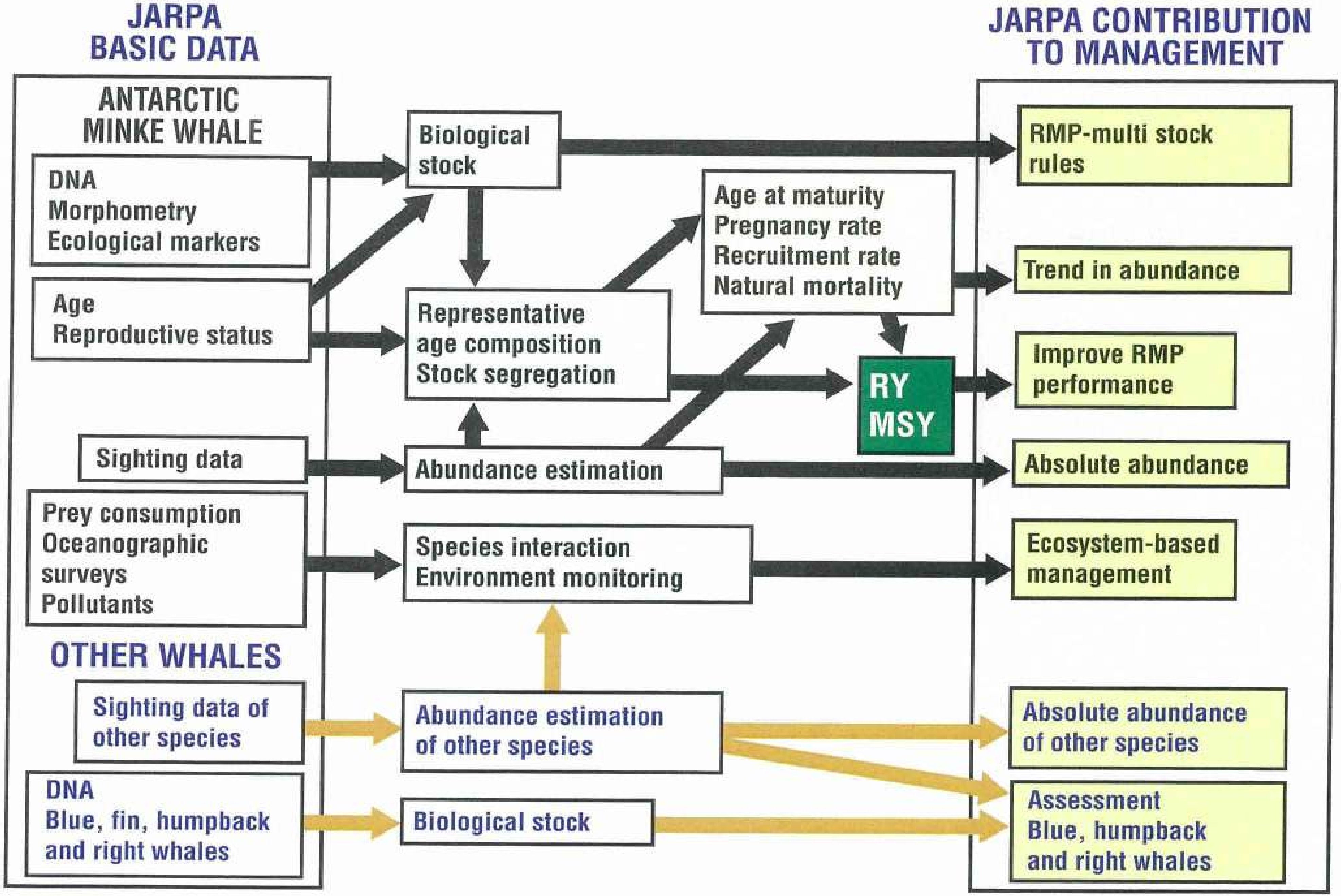


Fig. 6. JARPA summary. Data obtained and their contribution to management.

# Main Section

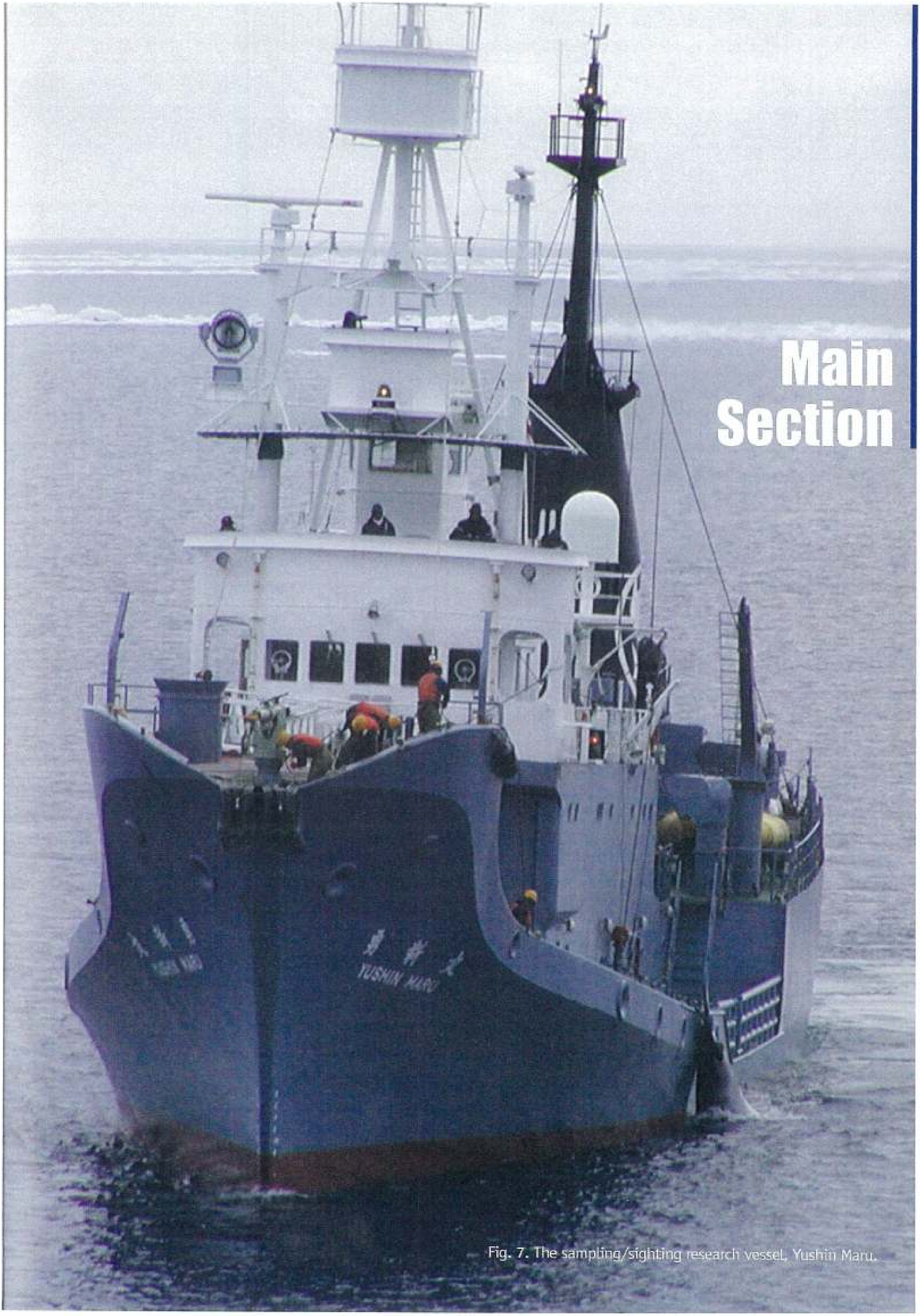


Fig. 7. The sampling/sighting research vessel, Yushin Maru.

# CURRENT JARPA OUTLINE (1987/88 - 2004/05)

## RESEARCH AREA AND SAMPLE SIZE

Table 1. Research area, effort and number of samples[a] for JARPA expeditions.

| Season | Research Expedition | Crew | Research area | Days surveyed | Distance searched (n. miles) | Planned number of samples[a] | Actual number of Antarctic minke whale samples | Actual number of dwarf minke whale samples |
|---|---|---|---|---|---|---|---|---|
| 1987/88 | Feasibility s. | 158 | Part of area IV | 69 | 8,482 | 300 (±10%) | 273[b] | (1) |
| 1988/89 | Feasibility s. | 180 | Part of area V | 80 | 9,614 | 300 (±10%) | 241[b] | (5) |
| 1989/90 | 1st | 186 | Area IV | 97 | 17,094 | 300 (±10%) | 330[b] | (3) |
| 1990/91 | 2nd | 188 | Area V | 94 | 14,760 | 300 (±10%) | 327[b] | (4) |
| 1991/92 | 3rd | 158 | Area IV | 112 | 18,205 | 300 (±10%) | 288[b] | |
| 1992/93 | 4th | 162 | Area V | 113 | 13,492 | 300 (±10%) | 330[b] | (3) |
| 1993/94 | 5th | 162 | Area IV | 107 | 17,933 | 300 (±10%) | 330 | |
| 1994/95 | 6th | 163 | Area V | 109 | 14,039 | 300 (±10%) | 330 | |
| 1995/96 | 7th | 198 | Area III (east) & IV | 118 | 21,456 | 400 (±10%) | 440[c] | |
| 1996/97 | 8th | 200 | Area V & VI (west) | 103 | 17,756 | 400 (±10%) | 440 | |
| 1997/98 | 9th | 204 | Area III (east) & IV | 98 | 16,462 | 400 (±10%) | 438 | |
| 1998/99[d] | 10th | 202 | Area V & VI (west) | 78 | 7,494 | 400 (±10%) | 389 | |
| 1999/2000 | 11th | 194 | Area III (east) & IV | 97 | 16,342 | 400 (±10%) | 439 | |
| 2000/01 | 12th | 195 | Area V & VI (west) | 100 | 20,484 | 400 (±10%) | 440 | |
| 2001/02 | 13th | 193 | Area III (east) & IV | 101 | 19,767 | 400 (±10%) | 440 | |
| 2002/03 | 14th | 198 | Area V & VI (west) | 96 | 18,126.2 | 400 (±10%) | 440 | |
| 2003/04 | 15th | 200 | Area III (east) & IV | 95 | 19,287.4 | 400 (±10%) | 440 | |
| 2004/05 | 16th | Plan. | Area V & VI (west) | | Plan. | 400 (±10%) | | |

[a] Abundance of Antarctic minke whales: 761,000 (Rep. Int. Whal. Commn 41 (1991), p.117). The present planned number of samples corresponds to 0.05% of the whale resource.

[b] Includes dwarf minke whales (figures in parentheses) sampled during feasibility surveys and first four research expeditions (16 individuals in total). The presence of the dwarf minke whale form in these waters was thus confirmed for the first time.

[c] The annual sampling size was set down as 300 whales (±10%) based on stock hypotheses from the commercial whaling days. With the progress of JARPA research it became apparent that the results did not tally with the hypotheses. It became necessary to expand the research area in two directions (east and west), and take an additional 100 whales (±10%) per year from the extended regions in order to delve into the question of stock structure.

[d] Actual number of samples, miles and days surveyed decreased due to a fire incident aboard the research mothership.

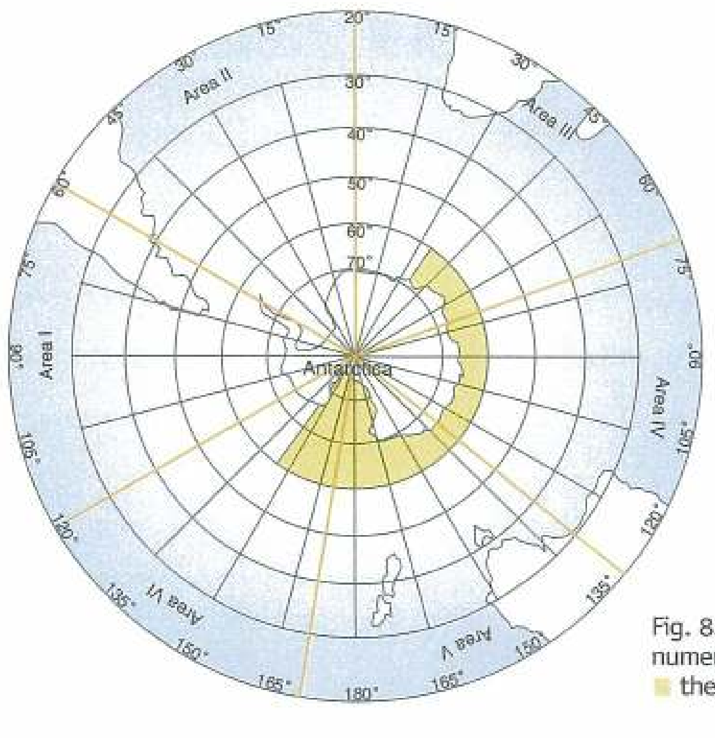


Fig. 8. Map of the Antarctic Ocean. The Roman numerals indicate IWC management areas and ■ the research areas surveyed by JARPA.

## RESEARCH PERIOD

The austral summer season, from the end of November or beginning of December to the middle of March the next year. Sighting surveys for cetaceans are also carried out in the low to middle latitudes of the southern hemisphere on the way to the research area and back.

## RESEARCH FLEET

One research mothership, three sampling/sighting vessels (with the exception of the 1st feasibility survey, which used two), and one dedicated sighting vessel (since the 7th expedition).

## MAIN RESEARCH ORGANIZATIONS

The Institute of Cetacean Research implements the program authorized by the Government of Japan, in association with other organizations, employing vessels owned by Kyodo Senpaku Co.

## RESEARCH ITEMS

### 1. Sighting surveys

The dedicated sighting vessel and the sampling/sighting vessels record schools and number of animals in the research area by whale species in accordance with the line transect method (see Survey Methods, p. 23).

### 2. Biological surveys

On the mothership, collection of various samples (tissues for DNA analysis, ear plugs, etc.) and research is conducted on more than one hundred items (see Survey Methods, Table 3).

### 3. Other surveys

Other surveys not directly related to the JARPA main objectives include: recording natural markings, satellite tagging, taking biopsy samples, conducting acoustic surveys and oceanographic observations, etc.

## OVERSEAS COLLABORATION

Joint research work with scientists and research institutions from overseas and within Japan making use of the data obtained through JARPA surveys is being carried forward in almost every research field presented in this booklet.

Fig. 9. The Institute of Cetacean Research.

Fig. 10. Research vessel leaving Shimonoseki Port.

# SURVEY METHODS

Both sighting and biological surveys (data measurement and capture of samples) are carried out concurrently in the JARPA program.

## TRACK LINE

Sighting activities are carried out in the JARPA surveys. The research area is stratified into several small areas. A zigzag track line will be set across every 4 degrees in longitude in the southern waters (excluding the Ross Sea), and in the northern portion, according to the distance calculated by days of surveying. The starting point is set down randomly every year, using a table of random numbers, so as to avoid going over the same track line (see Fig. 11).

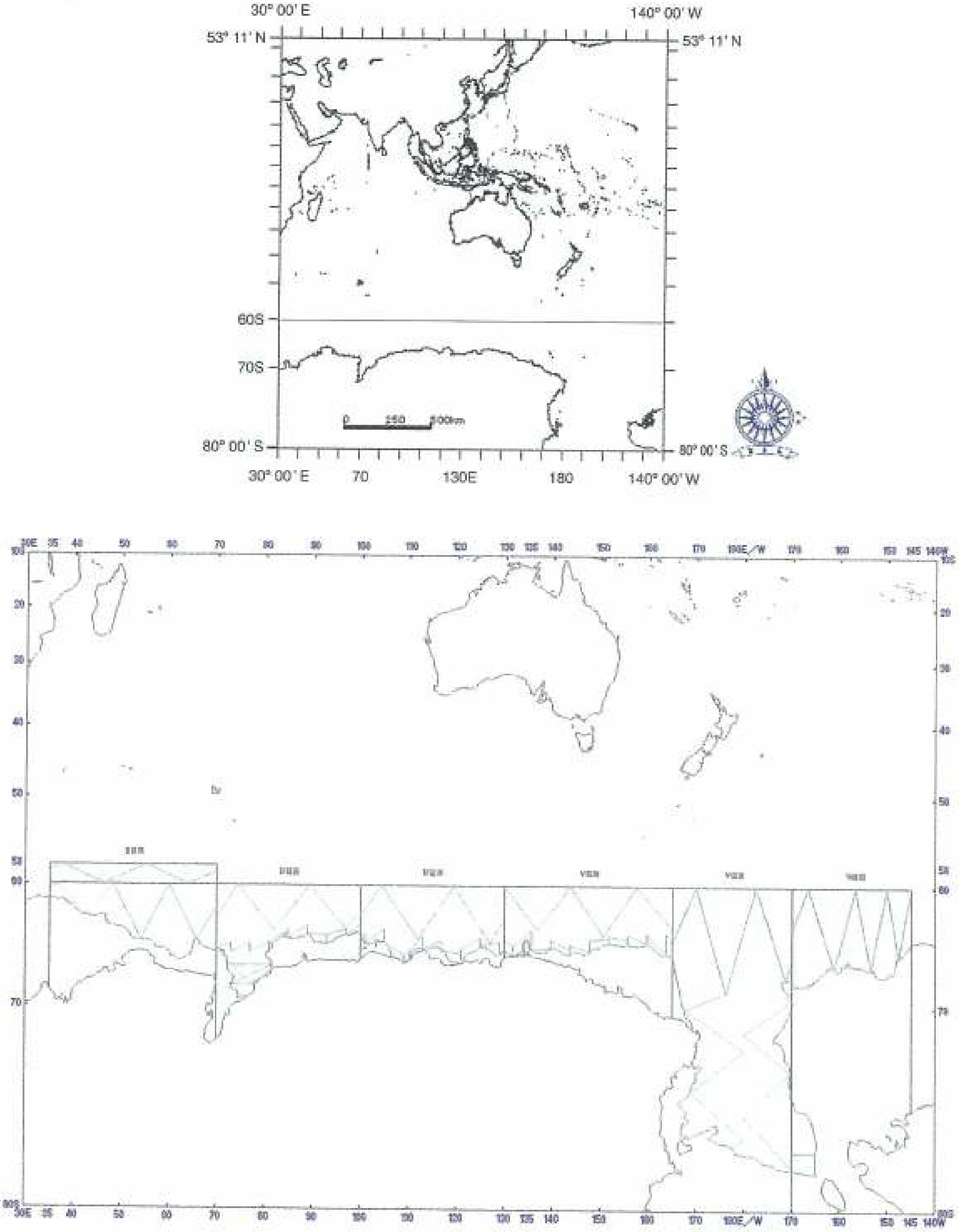


Fig. 11. Track line model diagram in areas III (east), IV, V and VI (west) in the Antarctic Ocean (only shows the main track lines).

# Research Fleet

## RESEARCH FLEET

The research fleet is made up of five vessels: one dedicated sighting vessel, three sampling/sighting vessels, and one research mothership (Figs. 12 to 17 show vessels used for research).

Fig. 12. The dedicated sighting vessel Kyoshin Maru No. 2 navigating ice floes in the Antarctic Ocean. Conducts echo-sound research on krill resources and oceanographic surveys besides sighting surveys (68.18 m, 372 tons).

Fig. 13. The sampling/ sighting vessel Yushin Maru sailing in close proximity to an iceberg (69.61m, 720 tons).

Fig. 14. The sampling/sighting vessel Kyo Maru No. 1. Since 1987/88 takes part every year in the JARPA program (69.15m, 812 tons).

Fig. 15. The sampling/sighting vessel Yushin Maru No. 2. Joined the research fleet from 2002/03. Fitted with oceanographic research equipment, besides its capacity to perform sighting/sampling surveys (69.61m, 747 tons).

Fig.16. The research mothership Nisshin Maru. From here instructions are given to the sighting/sampling vessels. Biological surveys and processing of by-products are performed here (129.58m, 7,638 tons).

Fig. 17. Three sampling/sighting vessels sailing towards the research area in the Antarctic. Once the survey starts, a constant distance of 7 nautical miles is maintained between each of them.

## ROLE OF RESEARCH VESSELS

The dedicated sighting vessel leads the fleet and carries out research activities, taking care not to bother or affect the whales, and tries to estimate the exact number of whales in the research area. The dedicated sighting vessel, besides carrying out sighting activities, surveys krill abundance using echo-sounding equipment, and conducts oceanographic observations using the XCTD and CTD (expendable and fixed instruments for measuring vertical distribution of salinity and water temperature), EPCS (Electronic Particle Counting and Sizing System: a surface biotic environment monitoring system which automatically measures sea water temperature, salinity, dissolved oxygen, chlorophyll), and other research items as shown in Table 2.

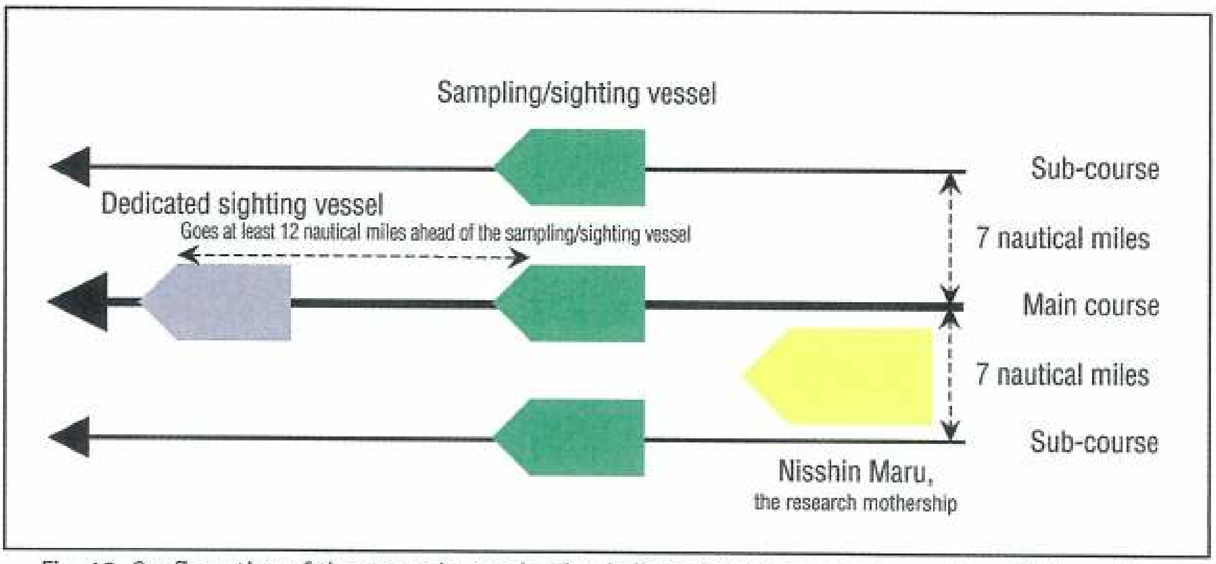


Fig. 18. Configuration of the research vessels. The dedicated sighting vessel goes ahead, followed by the three sighting/sampling vessels, engaging in sampling activities, and the research mothership brings up the rear.

The three sampling/sighting vessels follow the dedicated sighting vessel, along courses set down parallel to that of the dedicated sighting vessel in the center (Fig. 18). The three pick out animals for sampling from schools of Antarctic minke whales they spot. The selection is done in strict accordance to the rules, choosing the animal using a table of random numbers so as to impartially pick out a sample representing the whales distributing in the whole research area. The research mothership brings up the rear, taking care not to disturb the activities of the other vessels.

Apart from acting as the commander of the entire research program, she takes aboard the samples caught by the sampling/sighting vessels and carries out various biological research as well as by-product processing.

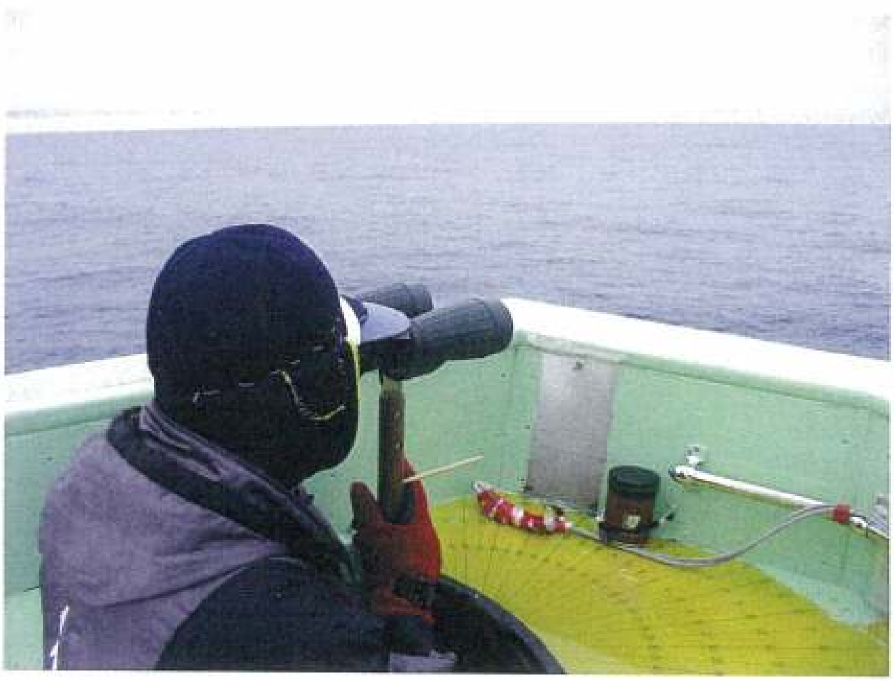

Fig. 19. Survey crew engaged in sighting activity in the top barrel. In the top barrel, there are always 3 observers constantly engaged in whale searching along the survey course, using binoculars fitted with a special graduation scale. The top barrel is about 20m from the sea surface, and distance to the horizon is about 9 nautical miles (17km). In front is the angle estimation board. Sighting survey is performed each day from 7:00 to 19:00.

# Sighting Surveys

Fig. 20. Looking back towards the stem from the top barrel.

Fig. 21. XCTD data monitor. Oceanographic survey data are processed on board.

Table 2. Major items covered in the JARPA sighting survey research.

| Items | SV [a] Kyoshin Maru No. 2 | SSV [b] Kyo Maru No. 1 | SSV [b] Yushin Maru | SSV [b] Yushin Maru No. 2 | Mothership Nisshin Maru |
|---|---|---|---|---|---|
| Cetacean sighting record | ● | ● | ● | ● | |
| Sighting effort record | ● | ● | ● | ● | |
| Weather observation record | ● | ● | ● | ● | |
| Sighting distance and angle experiment | ● | ● | ● | ● | |
| Natural marks (photo-ID) | ● | ● | ● | ● | |
| Biopsy sampling | ● | ● | ● | ● | |
| Whale acoustic monitoring | ● | | | | |
| Marine debris survey | ● | | | | |
| XCTD [c] survey | ● | | | | |
| CTD [d] survey | ● | | | | |
| EPCS [e] survey | ● | | | ● | |
| Satellite tagging experiment | | | ● | ● | |
| Scientific echosounder survey | ● | | | | |
| Ice-edge record | ● | | | | ● |

[a] Dedicated sighting vessel; [b] Sighting/sampling vessel; [c, d] Device to determine salinity, temperature and depth; [e] Surface Biotic Environment Monitoring System: Device for automatic measurement of surface sea water temperature, salinity, dissolved oxygen and chlorophyll.

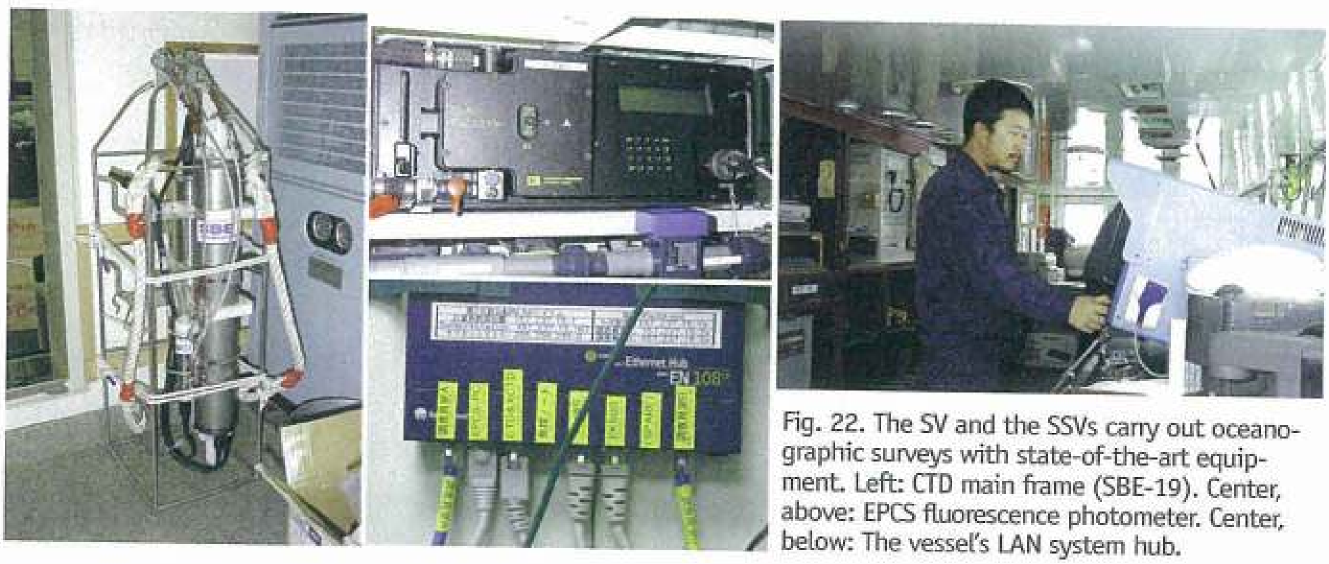

Fig. 22. The SV and the SSVs carry out oceanographic surveys with state-of-the-art equipment. Left: CTD main frame (SBE-19). Center, above: EPCS fluorescence photometer. Center, below: The vessel's LAN system hub.

## CETACEAN SIGHTINGS

What kind of whales inhabit the Antarctic Ocean? Table 3 shows the whale species and the number of schools and animals sighted in the JARPA surveys. The largest number sighted in all research areas are Antarctic minke whales. They are followed by humpback whales, with frequent sightings in Area IV. Fin whales have also been frequently spotted in recent years. As for toothed whales, the most often sighted is the killer whale. Many sperm whales have also been sighted.

Fig. 23. Antarctic minke whale surfacing. The pointed head is characteristic.

Fig. 24.Sperm whale and its characteristic blow.

Fig. 25. Blue whale in the Antarctic Ocean. The blow is tall, reaching 9m or more in height. Body bluish grey in color, the head is broad and U-shaped, and the dorsal fin relatively small.

Table 3. Number of sightings for species observed in the JARPA cruises in each Area between 1987/88 and 2001/02.

| | Research area | Eastern Area III | | Whole Area IV | | Whole Area V | | Western Area VI | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surveyed distance (Miles) | | 27,115 | | 113,762 | | 85,099 | | 13,110 | | 239,086 | |
| Whale species | | Schools | Ind. | Schools | Ind. | Schools | Ind. | Schools | Ind. | Schools | Ind. |
| Baleen whales | Antarctic minke whale | **1,243** | **3,003** | **8,479** | **24,951** | **7,903** | **22,245** | **840** | **1,959** | **18,465** | **52,158**[a] |
| | Dwarf minke whale | 0 | 0 | 14 | 15 | 60 | 60 | 1 | 1 | 75 | 76 |
| | Humpback whale | 564 | 1,098 | 3,191 | 6,054 | 629 | 1,138 | 161 | 297 | 4,545 | 8,587 |
| | Fin whale | 175 | 747 | 219 | 1,268 | 332 | 1,101 | 50 | 122 | 776 | 3,238 |
| | Blue whale | 55 | 107 | 55 | 96 | 60 | 99 | 9 | 13 | 179 | 315 |
| | Southern right whale | 2 | 2 | 122 | 145 | 6 | 7 | 0 | 0 | 130 | 154 |
| | Sei whale | 0 | 0 | 4 | 5 | 11 | 22 | 1 | 1 | 16 | 28 |
| | Large baleen whales | 243 | 484 | 352 | 644 | 368 | 719 | 110 | 185 | 1,073 | 2,032 |
| Toothed whales | Killer whale | 56 | 601 | 669 | 8,784 | 384 | 5,549 | 20 | 228 | 1,129 | 15,162 |
| | Long-finned pilot whale | 0 | 0 | 62 | 3,111 | 22 | 1,115 | 1 | 100 | 85 | 4,326 |
| | Sperm whale | 367 | 379 | 1,884 | 1,964 | 816 | 865 | 80 | 83 | 3,147 | 3,291 |
| | Southern bottlenose whale | 217 | 407 | 711 | 1,297 | 239 | 451 | 53 | 85 | 1,220 | 2,240 |
| | Arnoux's beaked whale | 6 | 57 | 13 | 127 | 22 | 166 | 0 | 0 | 41 | 350 |
| | Gray's beaked whale | 1 | 5 | 0 | 0 | 10 | 34 | 1 | 2 | 12 | 41 |
| | Strap-toothed whale | 2 | 7 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 8 |
| | Hourglass dolphin | 22 | 146 | 99 | 628 | 211 | 1,561 | 1 | 5 | 333 | 2,340 |
| | Southern right whale dolphin | 0 | 0 | 1 | 15 | 1 | 15 | 0 | 0 | 2 | 30 |
| | Spectacled porpoise | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 2 | 3 |
| | Beaked whales | 260 | 415 | 1,294 | 2,300 | 939 | 1,670 | 91 | 143 | 2,584 | 4,528 |
| | Pilot whales | 2 | 7 | 41 | 2,012 | 22 | 616 | 0 | 0 | 65 | 2,635 |
| | Mesoplodon sp. | 11 | 19 | 9 | 21 | 17 | 60 | 2 | 5 | 39 | 105 |

[a] Including "like-minke".

# Biological Surveys

## BIOLOGICAL SURVEYS ON BOARD THE RESEARCH MOTHERSHIP

Antarctic minke whales taken by the sampling/sighting vessels undergo detailed examination aboard the research mothership. It is outfitted with a huge scale that can weigh the whole whale, and the laboratory is equipped with an ultralow temperature freezer, biological microscopes, blood analyzer, and other instruments necessary for research purposes. The biological research covers more than one hundred items, from observation of the body to taking photographs and measurements and various biological samples, and is undertaken by experienced research crew. Table 4 shows a list of research items taken in the biological surveys, but different kinds are collected for other research and collaborations with various research institutions. After returning to Japan, the collected data and samples are handed over to scientists of specialized fields for analyses. Once all the examinations are completed, the whale carcass is processed on board as by-products of research in accordance with the International Convention for the Regulation of Whaling.

Fig. 26. Observing the whole whale.

Figure 27. Detailed examination of the skull.

Table 4. Major items covered in the JARPA biological research.

| Items | Done on: | Items | Done on: |
|---|---|---|---|
| Morphological observation | All ind. | Sampling of skin, blubber, muscle, liver, kidney and heart tissues for genetic study | All ind. |
| Photographic record of external characters (3 parts) | All ind. | | |
| Measurement of body length | All ind. | Sampling of muscle, liver and kidney tissues for heavy metal analysis | All ind. |
| Measurement of external proportions (20 parts) | All ind. | | |
| Body weight | All ind. | Blubber and liver tissues for organochlorine analysis | All ind. |
| Body weight by total weight of parts | 1 ind. / day | | |
| Skull measurement (length and breadth) | All ind. | Muscle, blubber and liver tissues for lipid analysis | 1 ind. / day |
| Standard measurement of blubber thickness (5 points) | All ind. | Weight of testis and epididymis | All males |
| Detailed measurement of blubber thickness (14 points) | 1 ind. / day | Histological sample of testis | All males |
| Diatom film record and sampling | All ind. | Histological sample of epididymis | All males |
| Weight of stomach content in each compartment | All ind. | Testis and epididymis stamp smear for sperm detection | All males |
| Evaluation of digestion stage and fullness of stomach content | All ind. | Measurement of mammary gland (max. length and breadth) | All females |
| Stomach contents for food and feeding study | Feeding ind. | Breadth measurement of uterine horn | All females |
| Stomach contents for heavy metal analysis | Some ind. | Observation and sampling of ovaries | All females |
| Stomach contents for organochlorine analysis | Some ind. | Sampling of endometrium tissue | All females |
| Stomach contents for fatty acid analysis | Some ind. | Observation and sampling of mammary gland tissue | All females |
| Number of ribs | All ind. | Fetus collection | Very small ones |
| Serum sample for physiological study | All ind. | Skin, blubber, muscle, liver, kidney and heart tissues of fetus for genetic study | All fetuses |
| Earplug for age determination | All ind. | | |
| Tympanic bone for age determination | All ind. | Photographic record of fetus | All fetuses |
| Largest baleen plate for age determination | All ind. | Fetus weight and body length | All fetuses |
| Largest baleen plate for morphological and chemical analysis | All ind. | Measurement of fetus body proportions (parts) | All fetuses |
| Vertebral epiphyses sample | All ind. | Milk sample for chemical analysis | Lactating females |
| Observation and collection of external parasites | All ind. | | |
| Observation and collection of internal parasites | All ind. | Checking Discovery marks | Marked whales |
| Preparation of skull specimen and detailed measurements | Two whales | Collecting skeletons | As appropriate |

## ESTIMATION OF BIOLOGICAL PARAMETERS

Biological parameters such as natural mortality rate, age of sexual maturity, age composition (cetacean version of the population pyramid so to speak), pregnancy rate[6] (ratio of pregnant females to mature females taken), and growth curve, are very useful data to improve management of whale stocks, and the JARPA surveys have made major contributions in this respect.

## BASIC DATA FOR BIOLOGICAL PARAMETER ESTIMATION

Basic data on age and reproduction are required for the estimation of biological parameters, and earplugs, testicles, and ovaries are collected and analyzed in the JARPA surveys for this purpose. Cerumen accumulates in the external auditory canal of baleen whales and thus formed earplugs show striped patterns in the center like tree rings. Counting of these stripes (growth layers) helps to estimate the age of the whale. Sexual maturity and reproductive status can be gathered from examining reproductive organs.

Fig. 28. Earplugs are collected from Antarctic minke whales through dissection.

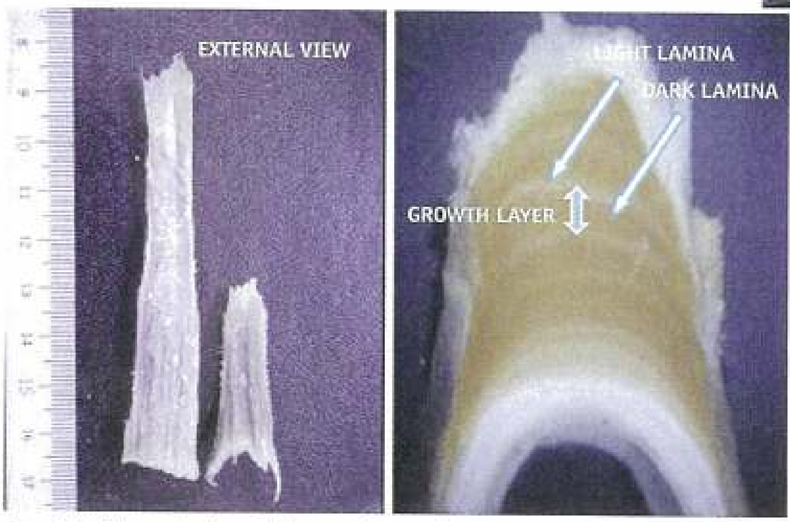


Fig. 29. External view of the earplugs of an Antarctic minke whale (left). The picture in the right is a transversal section of an earplug showing the growth layers.

Fig. 30. Antarctic minke whale age is determined through earplug observation under the microscope.

## ELUCIDATION OF BIOLOGICAL PARAMETERS CONTRIBUTES TO RMP[7]

The RMP, the whale management procedure to be implemented, is considered to work safely based on two data only (the present estimated abundance and data on past takes). However, elucidation of biological parameters is very important to make the RMP even safer, and for the optimal use of resources. This is because the RMP is basically designed with MSY (maximum sustainable yield) as a concept; although direct input of the above two values is sufficient, elucidating biological parameters will help to estimate MSY more accurately. As the RMP is applied on a stock basis it is necessary to know the classification and distribution range of each single stock. Obtaining these data as a result of JARPA research will increase the catch quota without depleting whale stocks and contribute to a more effective way of utilizing resources.

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[6] *Pregnancy rate: the ratio of pregnant Antarctic minke whale females to mature females taken in the research Area.*

[7] *Revised Management Procedure (RMP)*

*In the RMP, moderate catch quotas are calculated for small "sub-areas" that have been set down, corresponding to each whale stock, in consideration of various risks to the resources. The only two values required as input for the catch limit algorithm, the basis on which the RMP works, are the present abundance estimation and the data on historical catches. The effective application of the RMP rests on "sub-areas" that correspond to the actual range of whale stocks. Further elucidation of stock structure and distribution is one of the objectives of JARPA and, therefore, the program should contribute to improving the implementation of the RMP for the Antarctic minke whale if the surveys achieve the proposed objectives. It will also contribute to better management and sustainable use of whales.*

# Natural Mortality and Recruitment

## NATURAL MORTALITY AND RECRUITMENT OF ANTARCTIC MINKE WHALES

### Whale population dynamics model and biological parameters

In simplified terms, if there is little change in resource size before and after a certain take, it means that a take of that scale is sustainable. Besides anthropogenic takes, mortality (predation by natural enemies, diseases, starvation, strandings, etc.) in the natural life cycle of whales and the appearance of younger generations (recruitment) are major factors that affect cetacean population dynamics. Studying these factors is very important for the safe management of whale stocks. Together with pregnancy rate, natural mortality coefficient[8] (*M*) and recruitment rate (*r*) are biological parameters, and it is one of the major objectives of the JARPA surveys to study them.

### Estimation of Natural Mortality

There are several ways to estimate natural mortality. In order to estimate natural mortality more reliably, age data for each individual and abundance estimates are used. This approach differs from those used in the case of fisheries research.

Tanaka and Fujise (1997) estimated the natural mortality by age (every five years) for both areas IV and V. The estimated natural mortality ranged between 0.0166 and 0.154.

Another estimate was made using the number of catch and age data from Areas IV and V, including the data up to 1999/2000 and assuming annual recruitment as constant to simplify calculation[9]. Estimation of natural mortality for males ranged from 0.064 to 0.081 and for females from 0.068 to 0.076[10]. These estimates were within the range of the previous ones.

### Natural Mortality Coefficient M and Annual Mortality Rate D

The natural mortality coefficient M is the ratio of individuals which die in a unit of time (a short period of time where the population can be considered as invariable), and the natural mortality rate is the ratio for the population (average mortality rate) of the number of individuals that die in a fixed period of time (for example, a year). If we compare this as an example to a vehicle's speed, the mortality coefficient would be the speed indicated by the speedometer, while the natural mortality rate would be the distance (average velocity) advanced during a fixed period of time (for example one hour). With the population dynamics model, we assume that a fixed ratio of the present population (=M) is the natural mortality number. But, if that M is applied on the population of the beginning the year, the mortality becomes larger than the actual number of deaths of that year. That is because the number of individuals decreases moment by moment due to mortality. Because of that, the annual mortality rate D is expressed by the formula $D= 1-e^{-M}$. A calculation example is shown below in order to show concretely the difference of both M and D.

| Month | Resource | Deaths |
|---|---|---|
| 0 | 10,000 | 100 |
| 1 | 9,900 | 98 |
| 2 | 9,802 | 98 |
| 3 | 9,704 | 96 |
| 4 | 9,608 | 96 |
| 5 | 9,512 | 94 |
| 6 | 9,418 | 94 |
| 7 | 9,324 | 93 |
| 8 | 9,231 | 92 |
| 9 | 9,139 | 91 |
| 10 | 9,048 | 90 |
| 11 | 8,958 | 89 |
| 12 | 8,869 | - |

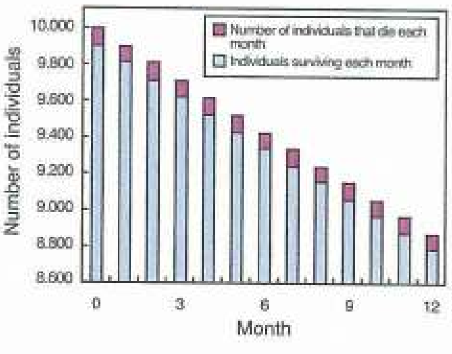



Fig. 31. Example calculation of individual number by month in the case a population of 10,000 individuals and M =0.12.

### Reasons to Estimate Natural Mortality Coefficient M

In order to grasp resource trend, information concerning birth rate and mortality rate is important. Data collected from JARPA are used to estimate natural mortality rate. Furthermore, if natural mortality rate separated by age is determined, a finer resource management becomes possible. In addition, the larger the natural mortality coefficient M is, the more robust the resource against the fluctuation of capture pressure. So, the natural mortality rate becomes important information in order to know the catch level that can be applied to maximize sustainable utilization of the resource.

[8] *Strictly speaking, it will differ from natural mortality, but estimation of M can be converted to natural mortality.*

[9] *Data for animals aged less than 12 in Area V are excluded in this calculation.*

[10] *These estimates were derived from crude data. But the data should be weighted by the relative abundance of Antarctic minke whales in each stratum to estimate M. The estimate might be revised by weighting the data.*

Table. 5. Relation between M and D. When M is 0.1 or less, M and D are considered almost equal.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Natural Mortality Coefficient | 0 | 0.050 | 0.100 | 0.200 | 0.300 | 0.400 | 0.500 | 1.000 |
| Natural Mortality Rate *D* | 0 | 0.049 | 0.095 | 0.181 | 0.259 | 0.330 | 0.393 | 0.632 |

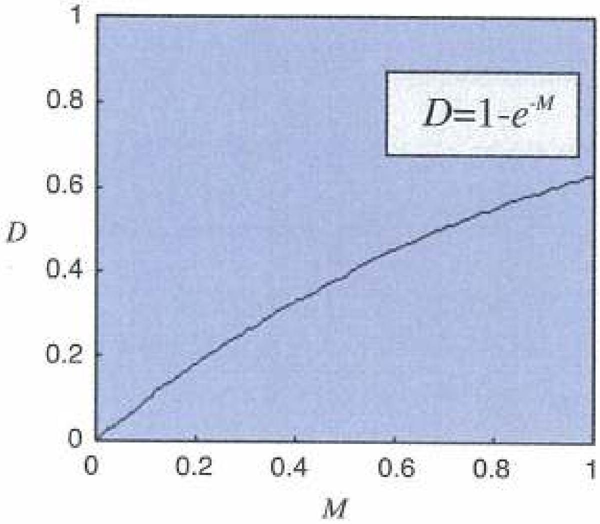



Fig. 32. Relation between natural mortality coefficient M and natural mortality rate D.

As Fig. 33 shows, the level of precision in the estimates improves when more samples are used. Our expectation is that the final estimations of natural mortality at the end of the JARPA program will be even more accurate.

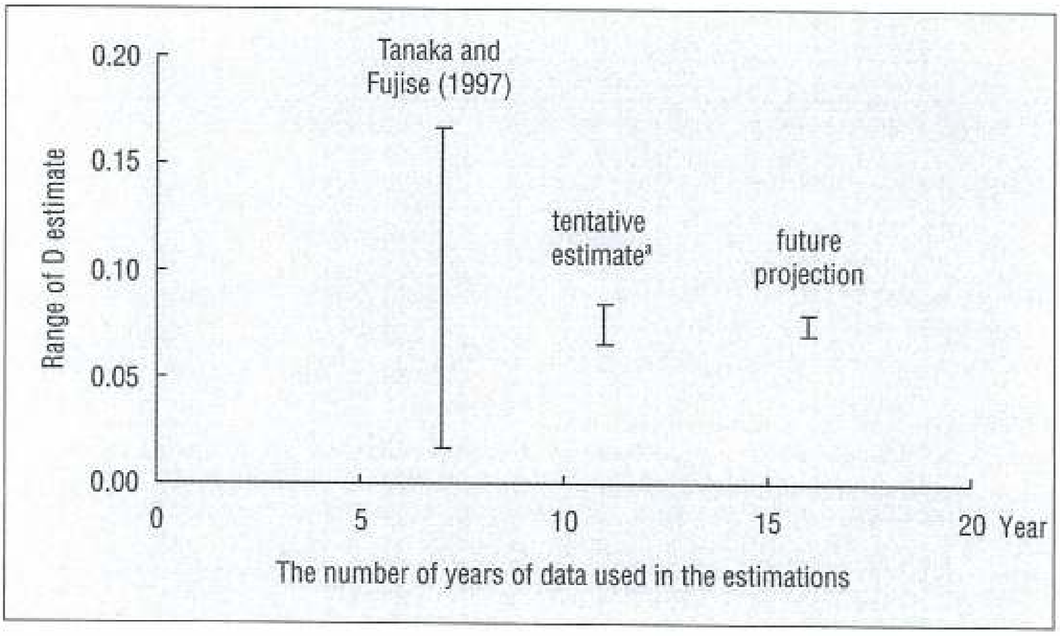



Fig. 33. Estimates of *M* in JARPA and changes in precision level. This figure shows that if more samples are used in the estimation, a higher level of precision is obtained. a: Estimate of *M*, independent of age.

# Age Composition

## Age Composition and Stock Structure

Data from commercial whaling show a bias, since larger (mature and older) whales were taken from highly concentrated areas in pursuit of production efficiency. Random sampling is practiced in the JARPA surveys to obtain unbiased data on distribution of Antarctic minke whale resources, and as a result, we have made quite a few discoveries. For one, it has now become clear that a high proportion of young whales (which were too small to be taken in commercial whaling) migrate to the Antarctic Ocean to feed. It is especially obvious when you compare the age composition in area IV (using age data estimated by the earplugs and baleen plates collected in the JARPA surveys) with age composition, using age data obtained during commercial whaling. We also found that compared with Area IV, there were fewer young animals in Area V and that it showed a different age composition. It is quite unnatural in view of the conventional hypothesis that separate whale stocks exist in areas IV and V. A more plausible scenario would be that Antarctic minke whales of the same stock are occupying different areas according to their reproductive status.

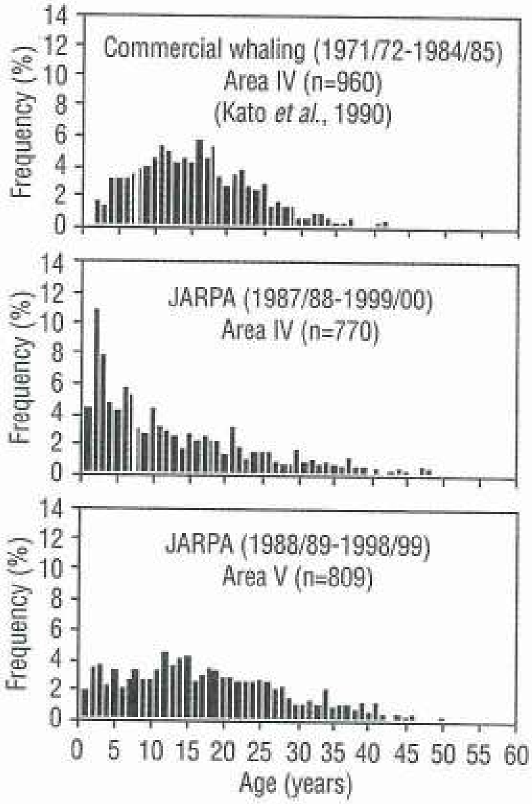



Fig. 34. Age composition of Antarctic minke whales (female) taken in the JARPA surveys and commercial whaling (unpublished JARPA data, Zenitani).

## Age Estimation Ratio

Among the whales taken, the ratio of individuals whose age could be estimated from the earplugs (the age estimation ratio) increases with body length. In Fig. 35 we have compared the age estimation ratio (classified by length) of data from the days of commercial whaling, when larger animals were selected for capture, and from JARPA, where random sampling methods result in the sampling of larger numbers of smaller individuals. In the case of JARPA, age estimation for individuals smaller than 6.0 m is performed not only from earplugs but from baleen plates as well, allowing for a higher age estimation ratio. JARPA's age estimation rate for large individuals (males: 7.9 - 8.8m; females: 8.2 - 9.4m) is higher (91.3% for males and 90.6% for females) than that obtained during commercial whaling (61.2% for males and 63.9% for females). This is because in addition to the basic earplug-collection technique established during the commercial whaling days, we take enough time and painstaking care in the dissection process to avoid inflicting any damage to the earplugs since they are the source of extremely important data. It is also the result of our careful efforts during preparation of earplug section specimens for reading and age estimation.

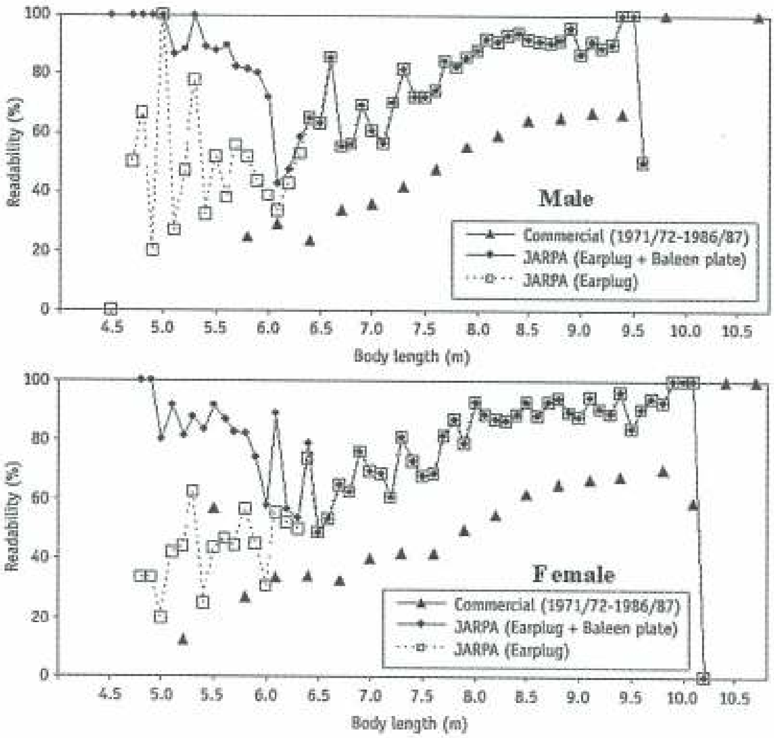



Fig. 35. Comparison of age estimation ratio by body length (Commercial whaling: 1971/72 - 1986/87; JARPA: 1987/88 - 2001/02).

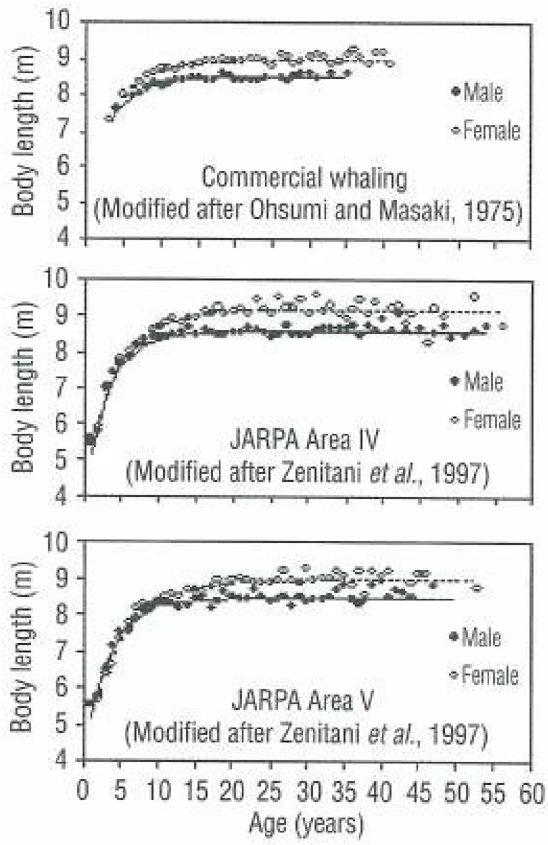



Fig. 37. Growth curve of the Antarctic minke whale estimated from data obtained in the JARPA surveys and commercial whaling.

Fig. 36. School of Antarctic minke whales in the Antarctic Ocean.

## Growth Curve

The growth curve line which shows the growth process of the Antarctic minke whale on the basis of length and age data has been estimated also from length and age data obtained during the commercial whaling days. However, as smaller individuals were not captured then, the data for age 5 years or less are scarce and thus the growth curve itself was not representative enough. With the supplementing data from the JARPA surveys on age and body length of younger whales (including small size individuals of age 1-2 years), we were able to come up with a more accurate growth curve covering most age groups of the Antarctic minke whale, from juveniles to old whales.

## SEGREGATION

Catch quotas in the management of whaling under the RMP will be calculated for an entire whale stock, in disregard of age and sex. The RMP has a built-in mechanism for retroactive adjustment in order to avoid adversely affecting the stock when more females are taken, but needless to say, it will be better to avoid such risks beforehand if possible. The JARPA surveys have made it clear that the Antarctic minke whales occupy different areas according to sex and maturity.

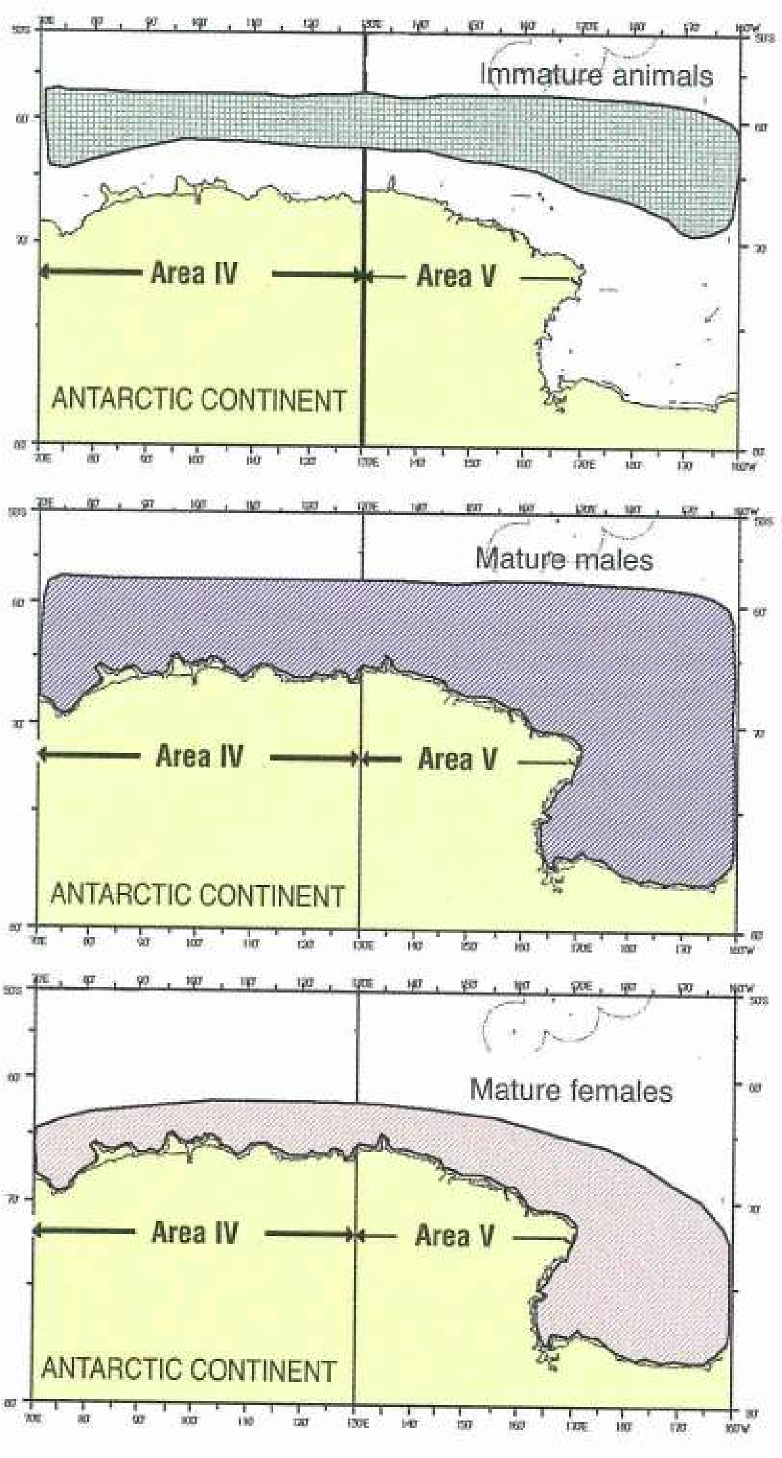
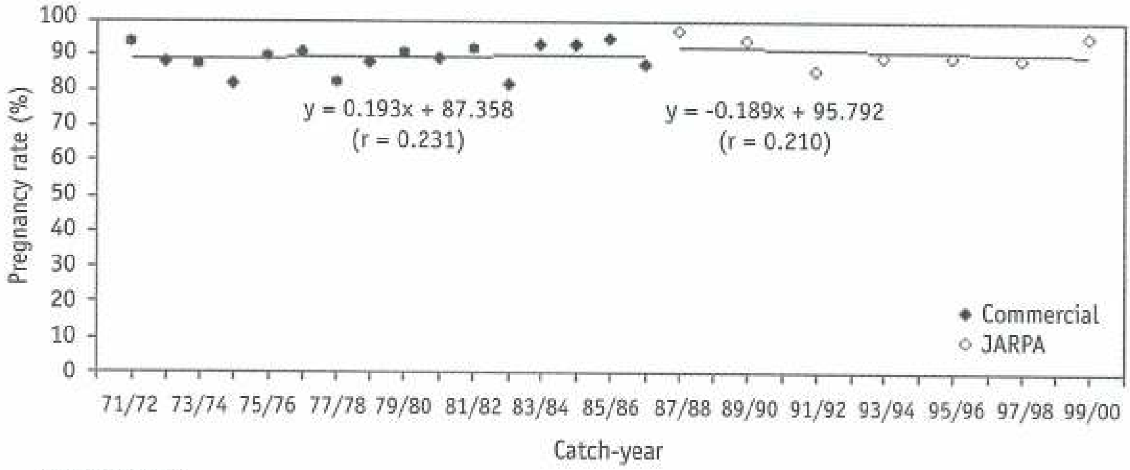



Fig. 38. Antarctic minke whale segregated distribution by sex and age.

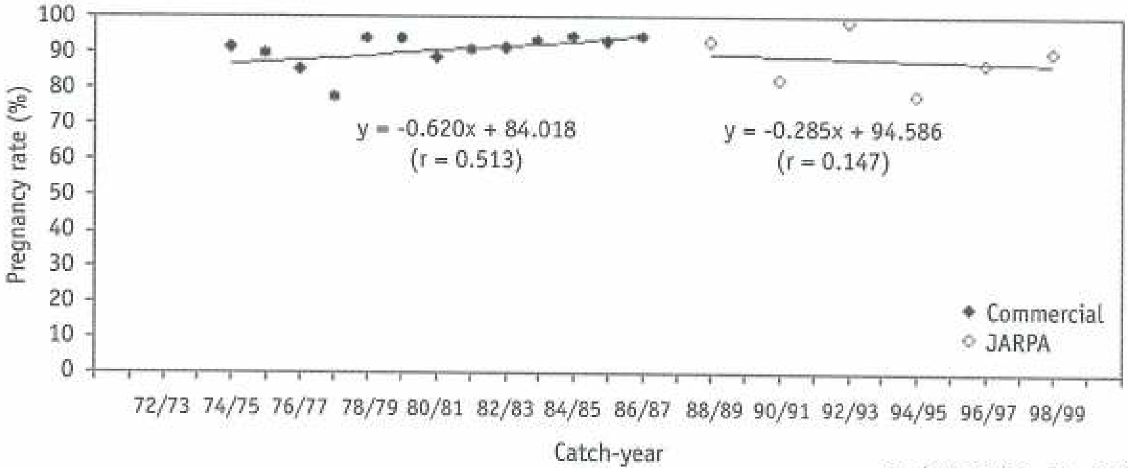
## PREGNANCY RATE

Almost all the mature females migrating to the Antarctic Ocean are pregnant. The high pregnancy rate (80% or more) has been maintained since the days of commercial whaling. The Antarctic minke whale usually bears one offspring every year, and is considered to show a high breeding rate.

### AREA IV




### AREA V




87/88-88/89 : feasibility study

Fig. 39. Yearly variation of Antarctic minke whale pregnancy rate by Area.

## BIOLOGICAL PARAMETERS AND THE OCEANIC ENVIRONMENT

Body length at which 50% of animals attain sexual maturity (body length at sexual maturity) in Antarctic minke whales was estimated approximately as 7.3m and 8.1m for males and females, respectively, using data from 1987/88 to 2001/02 (Areas IV and V combined). The body length at sexual maturity obtained by JARPA for both sexes is similar to that obtained using data from past commercial whaling. Age at which 50% of animals attain sexual maturity (age at sexual maturity) in minke whales was estimated approximately as 5 years and 8 years for males and females, respectively. The age at sexual maturity of females obtained by JARPA is relatively higher than that obtained using data from commercial whaling.

It can be seen from the commercial whaling data that the growth rate of the Antarctic minke whale has increased and that sexual maturity is attained at a younger age. This is probably due to improvement in their feeding environment, since many large whales such as the blue whale were removed in commercial whaling operations in the prewar. Such changes in habitat conditions are reflected in biological parameters. Biological parameters including body length and age at sexual maturity are estimated on a yearly base in JARPA. These parameters are useful for monitoring changes in the status of the population over time. Also they can be used as indicators of changes in the marine environment.

# Researching the Antarctic Ecosystem

## RESEARCHING THE ANTARCTIC ECOSYSTEM

Krill is the major prey for baleen whales, pinnipeds, birds, and fish in the Antarctic Ocean ecosystem. It is no overstatement to say that all the animals living in the Antarctic Ocean are competing over krill.
Vessels equipped with the latest research equipment are employed in the JARPA surveys, and concurrent surveys on the distribution and abundance of krill are implemented along with surveys on those of whales. Oceanographic observations are also carried out. As a result, we found that Antarctic minke whales were distributed near the ice-edge and that their range overlapped with the area in the continental shelf slope where krill is densely distributed (see Fig. 40).

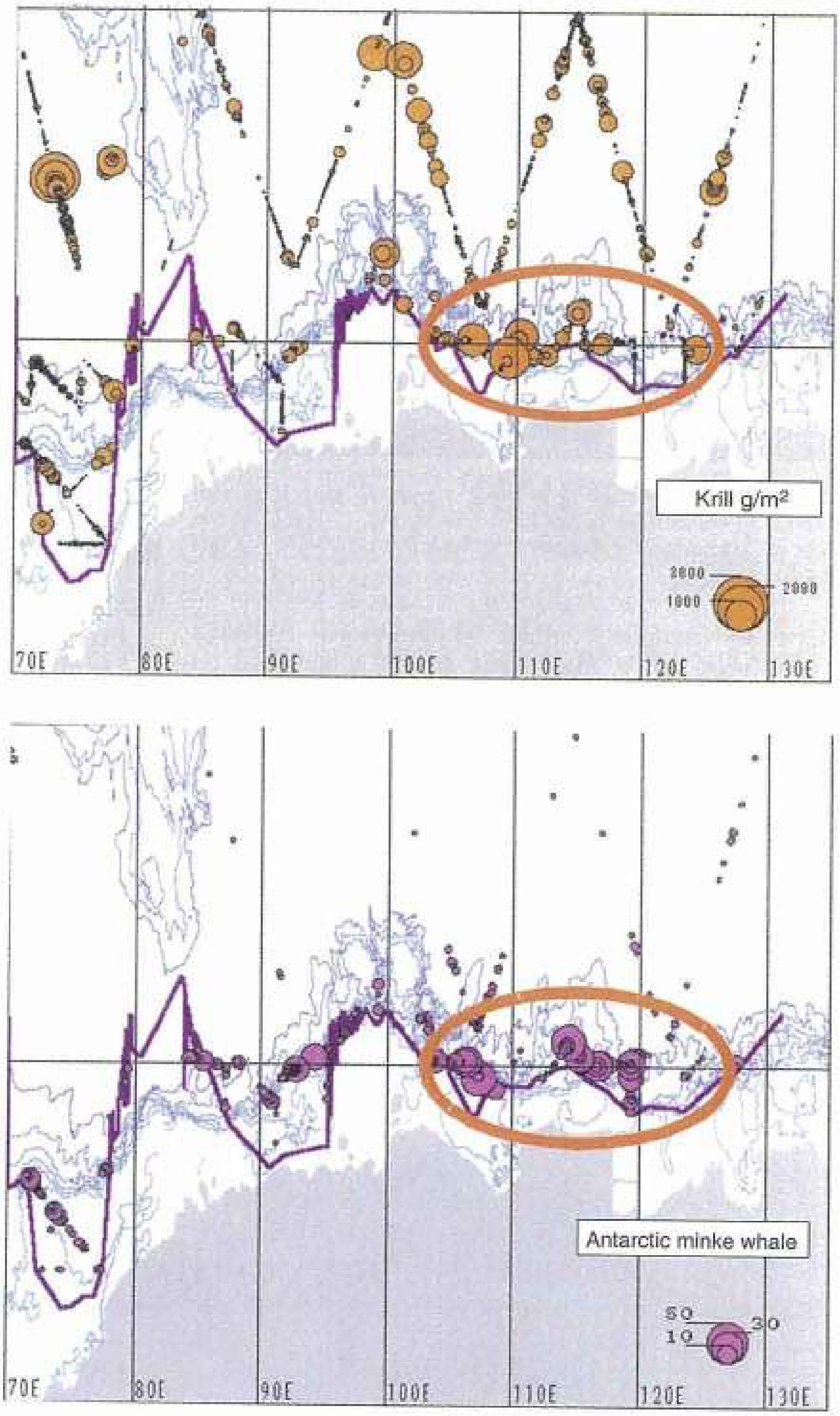



Fig. 40. Range of krill (above) and Antarctic minke whales (bottom) in the 1999/2000 JARPA surveys. Narrow lines show isobaths, and the thick line represents ice-edge (Murase *et al.*, revised).

# BLUE WHALE vs. ANTARCTIC MINKE WHALE

Blue whale

Antarctic minke whale

## ABUNDANCE

The present abundance of blue whales has decreased to **0.6%** of its past level. On the other hand, the abundance of Antarctic minke whales is now **9.5 times** that of the past.

| | Blue whale (individuals) | Antarctic minke whale (individuals) |
|---|---|---|
| Past | **200,000** (Gambell, 1976) | **80,000** |
| Present | **1,260** (IWC) | **760,000** (IWC) |

## BIOMASS

We can estimate the whale average body weight by using the Trites and Pauly (1998) formula.
Body weight : Blue whale, **103 t**; Antarctic minke whale, **6.6 t**.
The biomass of blue whales has decreased to **0.6%** of its past level. On the other hand, the biomass of Antarctic minke whale is now **9.5 times** that of the past.

| | Blue whale (tons) | Antarctic minke whale (tons) |
|---|---|---|
| Past | **20,600,000** | **530,000** |
| Present | **130,000** | **5,000,000** |

## ANNUAL FOOD CONSUMPTION

We can calculate the daily food consumption of whales by the following equation:

$$D = 206.25 \times M^{0.783} / 1110$$ (Sigurjonsson and Vikingsson, 1998)

$D$ : Daily food consumption (kg); $M$ : Body weight (kg); 1110: Caloric value of krill (Kcal/day)

Annual consumption was estimated from abundance, biomass and daily food consumption. Both blue and minke whales fed mainly on *Euphausia superba* (krill) near the ice-edge where there exists direct competition for food among blue whales, minke whales, crabeater seals and penguins.

| | Blue whale (tons) | Antarctic minke whale (tons) |
|---|---|---|
| Past | **114,000,000** | **5,300,000** |
| Present | **720,000** | **50,000,000** |

**An increase of 680,000 minke whales amounts to taking away the food for 80,000 blue whales.**

Fig. 41. Changes in the Antarctic ecosystem.

# Contamination Monitoring

## MONITORING CONTAMINATION OF THE ANTARCTIC OCEAN

Pollutant concentration in whales provides an indication of marine contamination in the seas they inhabit. The JARPA surveys help to monitor oceanic pollution.

The JARPA program is designed to repeatedly survey the same area during the same season and with the same methods, and is most appropriate for following the year to year changes in the environment and picking up long term trends. Figures 42 and 43 show the yearly contamination rate obtained through the JARPA surveys.

The Antarctic Ocean can be said to be one of the least affected seas in the world by organochlorines. The PCB concentration in the blubber of adult Antarctic minke males seems to be leveling off, as shown in Fig. 42. DDT and HCB levels show a decreasing trend since 1993/94. The accumulation curve by age of mercury (Hg) in the liver also show changes over the years (see Fig. 43). We believe that they reflect the changes in the feeding environment of Antarctic minke whales.

These changes detected by the concentration of PCBs and Hg are still going on, and we need to continue to monitor the environment and discuss appropriate measures to take in the future. The whale research programs play a major role in the monitoring activities[11], and are expected to provide valuable information.

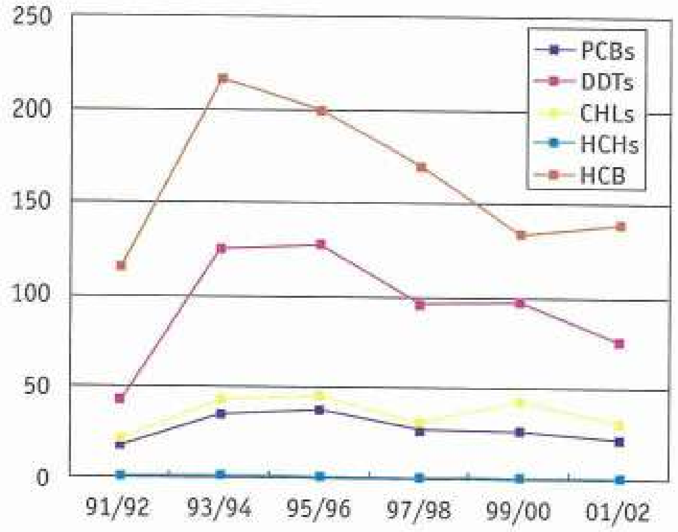



Fig. 42. Annual changes in organochlorine concentrations in mature male Antarctic minke whale blubber (Aono *et al.*, 1997, Niimi, 2002 and Tanabe, unpublished data). The PCB concentration shows significant increase from 1984/85 to 1994/95, but from 1996/97 started to level off.

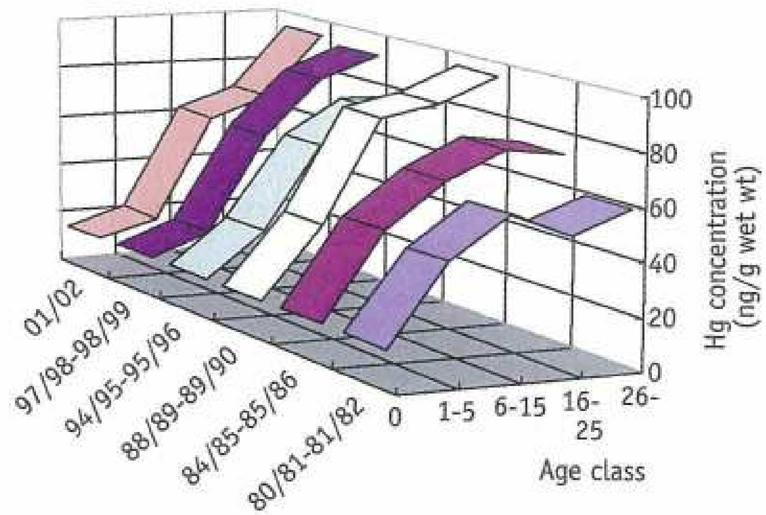



Fig. 43. Annual changes in Hg accumulation curve by age in Antarctic minke whale liver (Aoki *et al.*, 2002). It is generally known that Hg concentration in the liver increases with age, but samples from 1980/81 to 1981/82 do not show this tendency. Yet age-dependent accumulation is detected in recent years (1988/89), showing a different pattern in the accumulation curve by age depending on the year. The mercury accumulation level for the 1-5 years age class shows a decreasing trend. It is believed that these patterns reflect the changes in the feeding environment of Antarctic minke whales.

[11] *The Ministry of Health and Labor has set down 0.4 ppm as the standard in the total mercury concentration for fishery products, and for those that exceed the provisional restriction to undergo a further test for methyl mercury, designating those that exceed 0.3 ppm as mercury contaminated fishery products. The provisional restriction standard for PCBs in fishery products is 3 ppm for those in inland waters and 0.5 ppm for offshore fishery products. Cetaceans are categorized in the later (0.5 ppm). See also Table "Concentration of PCBs in blubber and total mercury in muscle of the Antarctic minke whale sampled by the Japanese Whale Research Program in the Antarctic (JARPA)" in the Questions and Answers section of this booklet.*

## ESTIMATION OF KRILL CONSUMPTION OF ANTARCTIC MINKE WHALES

One of the major objectives of JARPA is to elucidate the role whales play in the Antarctic Ocean ecosystem. The weight of Antarctic minke whales (Fig. 44), and the weight of stomach contents were measured directly to estimate the daily amount consumed (see Fig. 46). We found that they consumed an average of 200 to 300 kg of prey, corresponding to 3 to 5% of their body weight.

Fig. 44. Antarctic minke whale weight measurement.

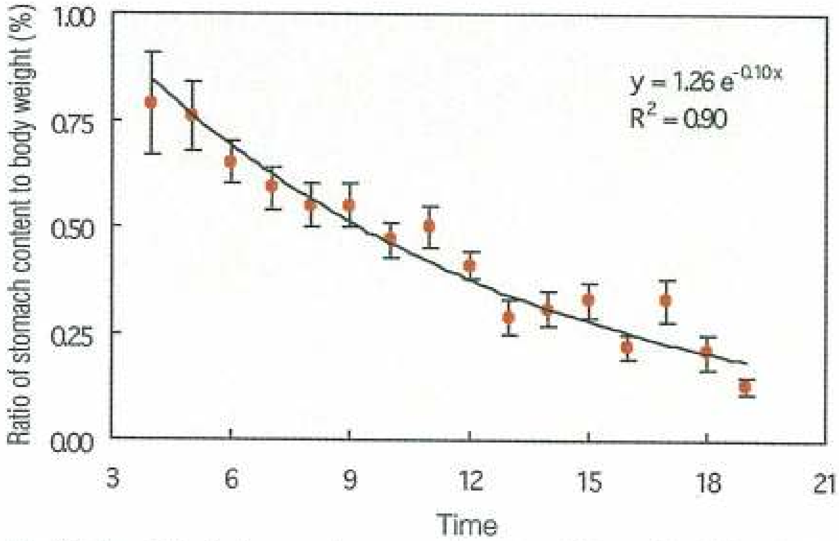



Fig. 46. Transition in temporal consumption rate of Antarctic minke whales.

Fig. 45. Antarctic krill. Stomach content of Antarctic minke whale.

It was also estimated that Antarctic minke whales consumed about 35,000 tons of krill per day in the Ross Sea, compared with 2,100 tons for Adelie penguins and 600 tons eaten by crabeater seals in the same area, suggesting that the Antarctic minke whale was the largest predator of krill in the Ross Sea (see Fig. 49). The CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) has estimated krill abundance in Area IV to be 6,670,000 tons, of which nearly 30% (1,740,000 to 1,930,000 tons per year) is probably consumed by Antarctic minke whales in the area. As can be seen, whales, including the Antarctic minke, play a major role as one of the top predators in the Antarctic ecosystem, and may greatly affect krill resources.

Fig. 47. Adelie penguins.

Fig. 48. Crabeater seals.

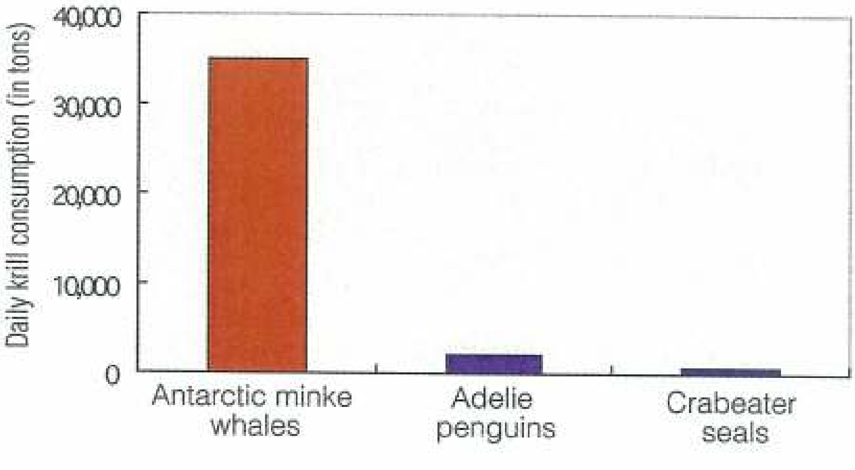



Fig. 49. Diurnal krill consumption in the Ross Sea.

# Stock Structure

## ELUCIDATION OF THE STOCK STRUCTURE OF ANTARCTIC MINKE WHALES

The understanding of the stock structure (identification of the number of stocks and their geographical and temporal boundaries) is important for the sustainable use of the Antarctic minke whale. Biological parameters are believed to differ among stocks; therefore the estimation of such parameters should be ideally conducted on the basis of individual stocks. Information on stock structure in this species is also useful for the safer and more effective implementation of the Revised Management Procedure (RMP).

Stock structure under JARPA is investigated using different approaches: genetic analyses based on mitochondrial DNA (see Fig. 50) and nuclear DNA (microsatellites), as well as morphological analyses, including measurements and comparison of the body proportions. Ecological markers such as pollutant burden and parasites load are also used for this purpose.

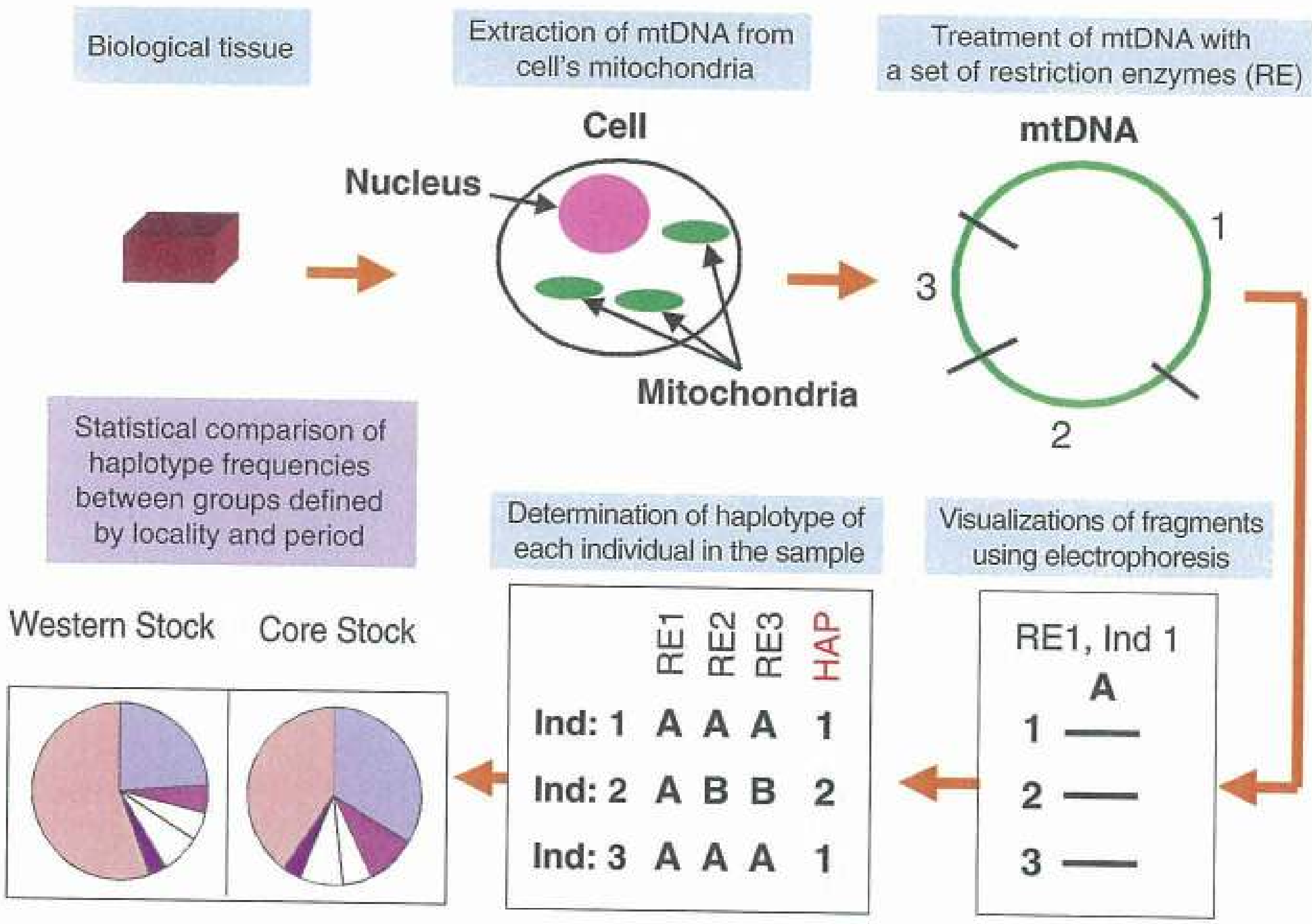



Fig. 50. Scheme of mtDNA analysis.

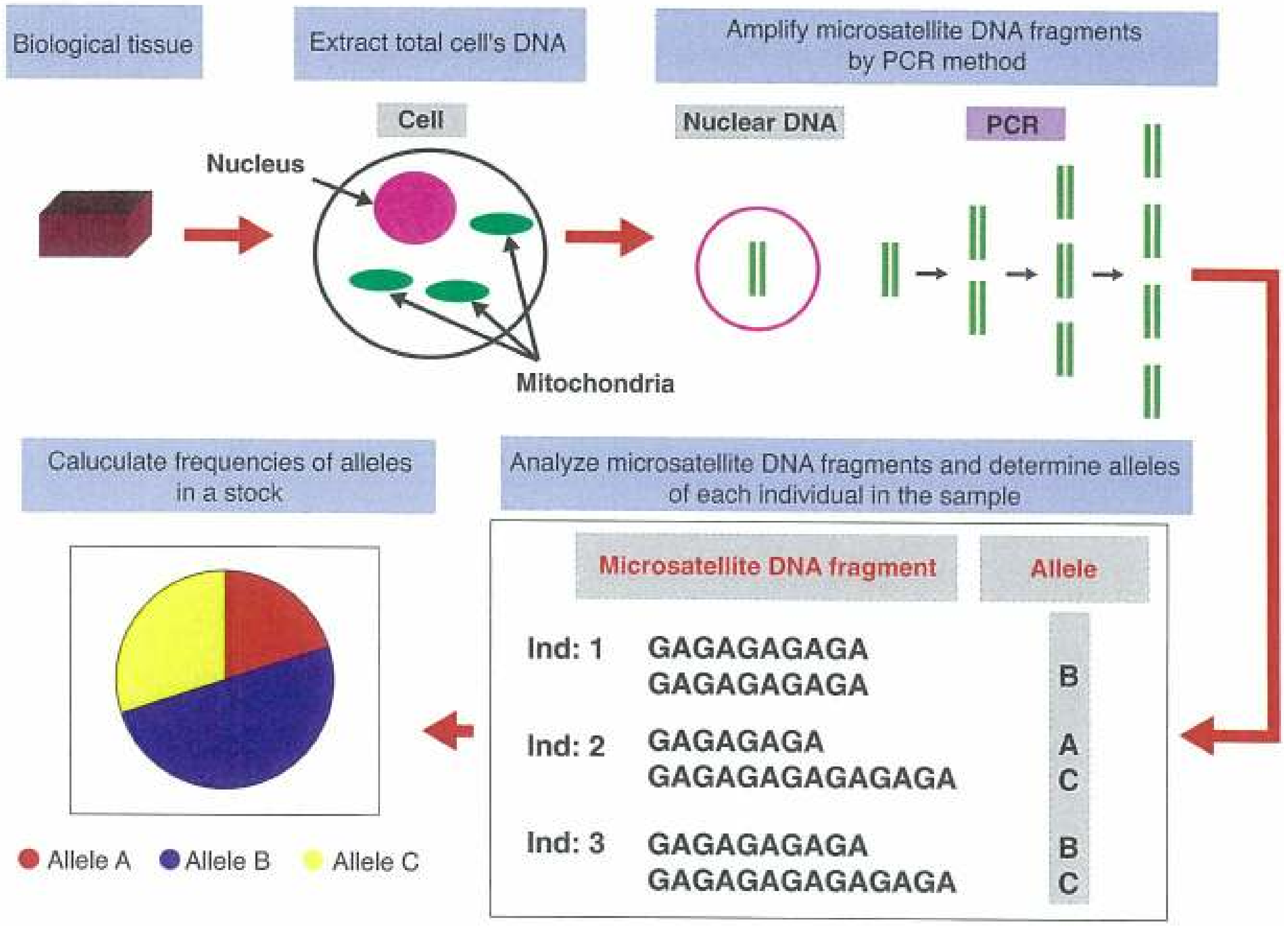



Fig. 51. Scheme of mtDNA allele determination analysis.

## *Inferring stock structure*

In most animal species, genetic information is passed from generation to generation as a gene. The molecular basis of the gene is a substance called DNA. In a cell, two different kinds of DNA exist: biparentally-inherited nuclear DNA in the nucleus and maternally-inherited mitochondrial DNA (mtDNA) in the mitochondria. Genetic information is encoded in DNA in the sequence of four bases, adenine (A), guanine (G), thymine (T), and cytosine (C). Although gene orders (blocks of DNA sequences) are in general the same within a species, DNA sequences may differ between individuals within any of these groups (this is called genetic variation). Different sequences in mtDNA are called "haplotypes" and each of them can be designated by a numeral or character as shown in Fig. 50, so that haplotypes frequencies within samples are calculated. Microsatellite nuclear DNA consists of alleles that are arrays of different numbers of base repeats (GAGA... GA) as shown in Fig. 51, so that allele frequencies within samples are calculated. Heterogeneity in the haplotype or allele frequencies among the samples can be then statistically tested in order to see if there is any evidence of genetic differences existing between the samples. If genetic differences exist, then this could indicate that the samples came from genetically different stocks, suggesting existence of multiple stocks in the sampled area.

# Stock Structure

## STOCK STRUCTURE HYPOTHESIS

The JARPA surveys cover the Antarctic regions corresponding to eastern Indian Ocean (Area IV) and the western South Pacific (Area V). At the beginning of JARPA, the view was that independent biological stocks (separate breeding groups) migrated to Areas IV and V, but as the research progressed, it was revealed that a large stock (Core Stock) occurs across the two Areas, and that a different stock (Western Stock) migrates to the western part of Area IV, depending on the year and season. The research area has been expanded to include the eastern part of Area III and the western part of Area VI, in an effort to elucidate the range of distribution of Antarctic minke whale stocks distributed in Areas IV and V.

Once the geographical and temporal boundaries of the Core Stock are elucidated, estimation of biological parameters will be conducted on the basis of this biological stock.

Information on stock structure under JARPA does not support the RMP concept of a 10°-wide small area. The distribution span of a stock in the Antarctic could be similar or larger than the span of actual IWC Areas (at least 60°-wide area).

Detailed genetic analyses are being conducted in Area III East and VI West to elucidate stock structure in these Areas.

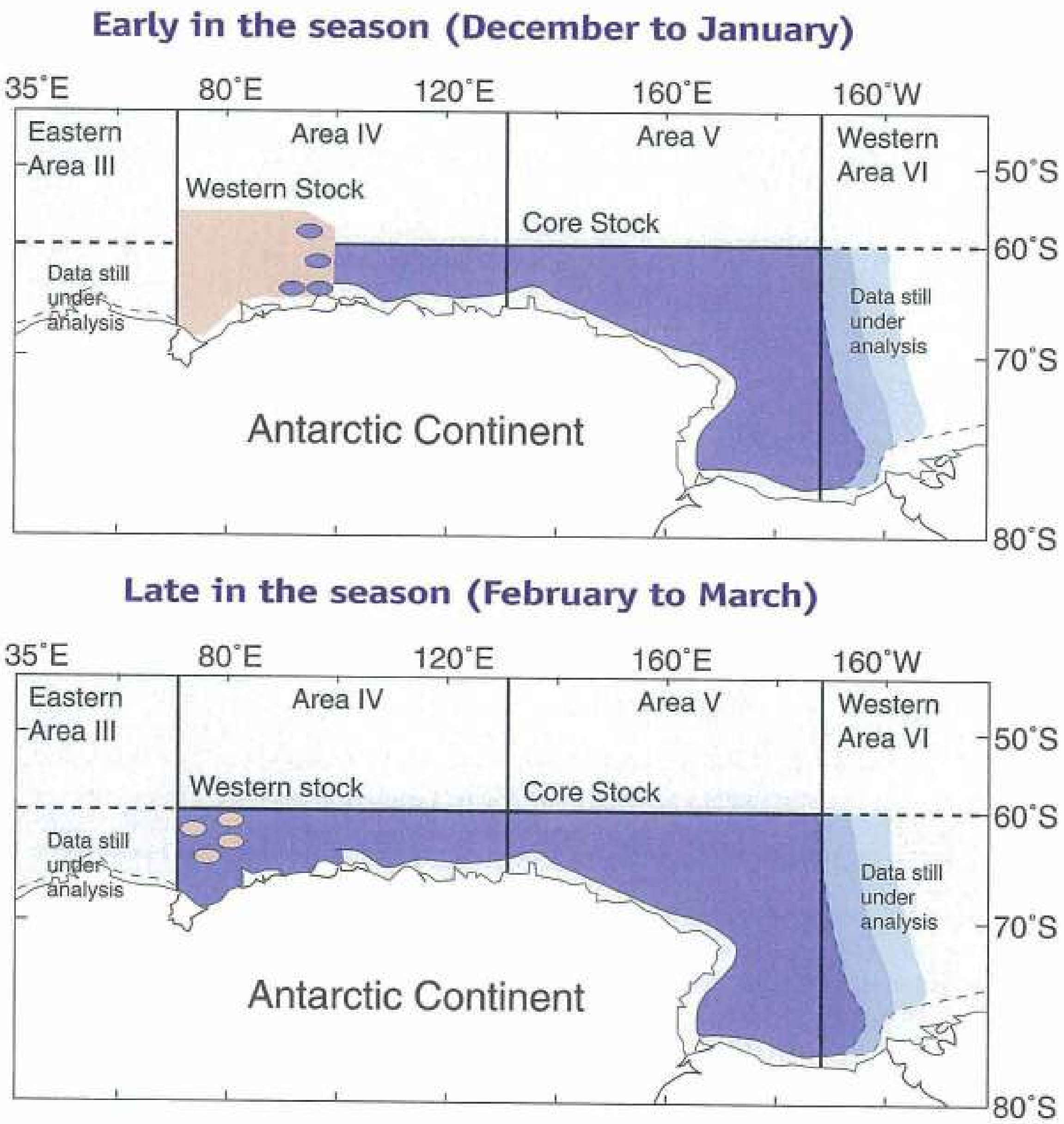



Fig. 52. A hypothesis on stock structure based on mtDNA analysis.

## TAXONOMY OF MINKE WHALES

Until recently minke whales from both hemispheres were considered as a single species, *Balaenoptera acutorostrata*. Genetic analyses conducted using JARPA samples contributed to elucidate the taxonomic status of the minke whales. For example these analyses confirmed the previous view based on morphological analyses that two species of minke whales exist: the Antarctic minke whale, *Balaenoptera bonaerensis* and the common minke whale, *B. acutorostrata*.

The former species is the larger and most abundant and is restricted to the Southern Hemisphere. The latter includes minke whales from the North Atlantic, North Pacific and the dwarf minke whale, which lives in the Southern Hemisphere.

Genetic studies conducted under JARPA derived in the findings that dwarf minke whale and the Antarctic minke whale are separated at the species level and that dwarf minke whales are closely related to Northern Hemisphere minke whales, especially to North Atlantic minke whales (see Fig. 53).

Studies under JARPA showed that dwarf minke whales feed mainly on fish. Records of the dwarf minke whales made during JARPA surveys showed that they are found much further south than originally thought, with sighting in summer occurring around latitude 60°S.

There are distinct morphological differences between Antarctic minke whale that can be detected at sea e.g. the white patch on the base of the flipper. Since it was determined to halt the sampling of dwarf minke whales in 1993/94, effectively no individuals have been taken by JARPA, showing that both dwarf minke whale and Antarctic minke whale can be recognized at the field by experienced researchers.

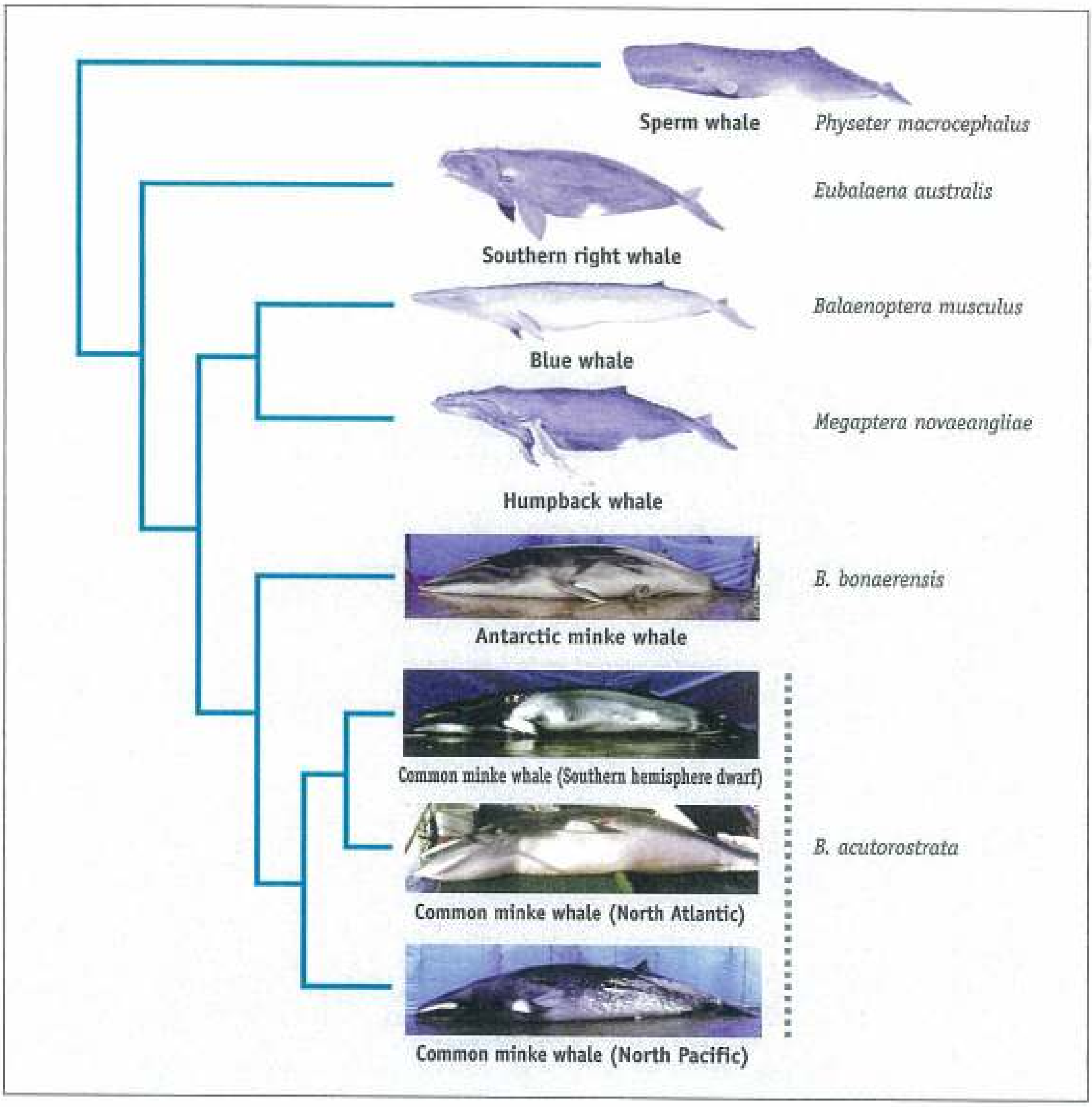



Fig. 53. Phylogenetic analysis of minke whales based on mtDNA. For comparison, other large whale species examined under JARPA non-lethal research, such as humpback, blue, and right whales are included.

# Antarctic Minke Whale Abundance

## ANTARCTIC MINKE WHALE ABUNDANCE

The JARPA surveys have found that Antarctic minke whale abundance has stabilized at a high level.

Sighting activities are carried out in the JARPA program to study abundance and possible variations. According to data obtained in the research cruises from 1989/90 to 2000/01, it was revealed that the stock abundance in the research areas (Area IV and V) has remained stable.

The IWC Scientific Committee has agreed in 1990 that the abundance estimate of Antarctic minke whales distributed in the entire Antarctic Ocean (south of lat. 60°S.) is 761,000. Since initial abundance was about 80,000, it can be said that Antarctic minke whale abundance is stable at a consistently high level.

**Antarctic minke whale abundance is consistently high.**

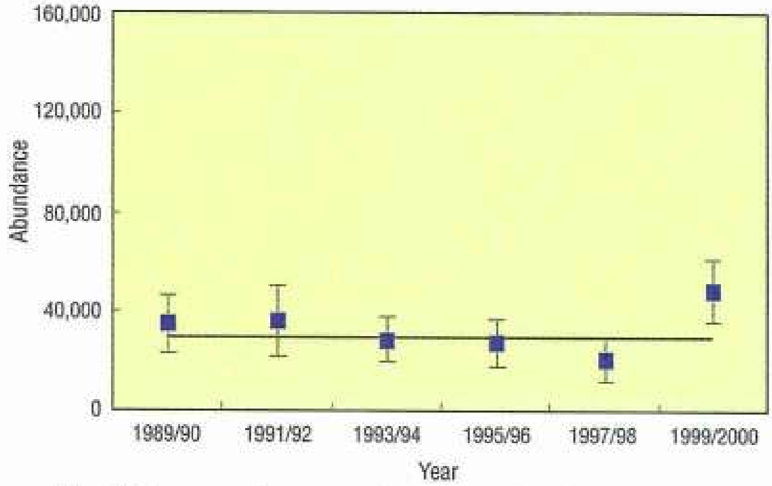



Fig. 54. The regression curve above shows the abundance trend of Antarctic minke whales from 1989/90 to 1999/2000 for Area IV. The vertical lines indicate the 95% confidence interval[12] for the estimate.

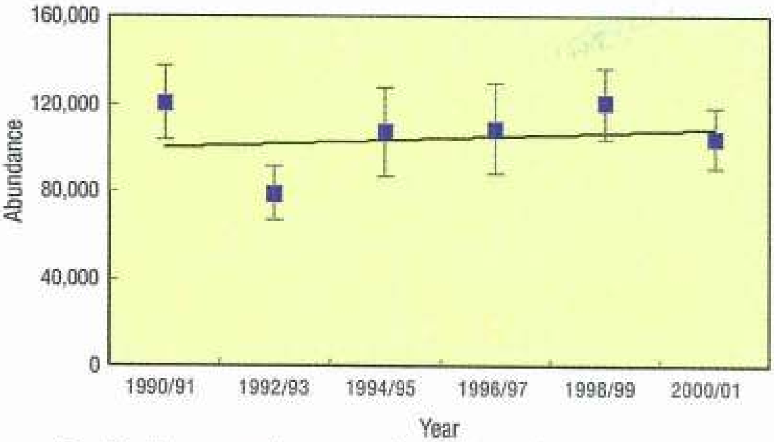



Fig. 55. The regression curve above shows the abundance trend of Antarctic minke whales from 1990/91 to 2000/2001 for Area V. The vertical lines indicate the 95% confidence interval[12] for the estimate. The regression curves are almost flat for both Area IV (Fig. 54) and V, indicating that Antarctic minke whale abundance has remained stable.

Fig. 56. School of Antarctic minke whales.

[12] *95% confidence limit for the estimate: There is always a margin of error in making estimations of any kind, and the estimated amount is not necessarily the true value. The 95% confidence limit is a statistic range that includes the true value by a probability of 95%, and we can more or less assume that the true value is included.*

## ANTARCTIC MINKE WHALE ABUNDANCE ESTIMATION BY THE IWC SCIENTIFIC COMMITTEE

The IWC Scientific Committee reviewed the sighting results from the first and second IDCR (International Decade for Cetacean Research) circumpolar cruises and agreed on an abundance estimate of 761,000 for Antarctic minke whales in 1990. With the first SOWER (Southern Ocean Whale and Ecosystem Research) circumpolar cruise (the third, including the two IDCR cruises) about to be completed, the Committee is now working for a new abundance estimate in 2006.

Table 6. Abundance estimate for Antarctic minke whales south of 60°S.

| | Abundance Estimate | Reference |
|---|---|---|
| CPII (1982/83-1988/89) | 761,000 | IWC (1991) |
| CPIII (research incomplete) | 644,818[a] | Butterworth *et al.* (2001) |

[a]: Estimate from only passing mode data.

As mentioned above, the JARPA surveys have found that Antarctic minke whale abundance has stabilized at a high level for the past twelve years, and we expect that the review in 2006 will result in the same level of abundance as 1990.

Taking in consideration that these studies are yet to be completed, Dr. Douglas Butterworth (South Africa) and other scientists have arrived at an abundance estimate of 640,000. In view of the IWC Scientific Committee abundance estimate of 761,000 Antarctic minke whales, the JARPA surveys data show that, at least in Areas IV and V, abundance remains consistently stabilized at high and similar levels.

## JARPA AND IDCR/SOWER

In the JARPA program, we survey Areas IV and V every other year. The two areas have been surveyed six times each in the twelve years from 1989/90 to 2000/01. The IWC Scientific Committee has carried out the International Decade for Cetacean Research (IDCR) and the Southern Ocean Whale and Ecosystem Research (SOWER), which grew out of IDCR, using research vessels provided by the Government of Japan. Sighting surveys in the entire Antarctic Ocean (south of lat. 60°S.) are conducted in these cruises, and the Scientific Committee estimates Antarctic minke whale abundance based on the data obtained. However, to date, the IDCR/SOWER cruises have only gone over the same research area three times at the most, and the surveys are conducted at a much wider span, with an interval of several years. In this respect, the JARPA surveys are more suitably designed to accurately monitor any changes in Antarctic minke whale abundance.

Fig. 57. Biopsy sampling during IDCR/SOWER whale research. Experiment to collect biopsies from a school of three blue whales. The scene shows scientists preparing to retrieve the dart that has hit one of the animals (Antarctic Ocean Area VI on board the R/V Shonan Maru, 2001).

# Increase of Humpback Whale Abundance

## INCREASE OF HUMPBACK WHALES IN THE ANTARCTIC OCEAN

Abundance of humpback whales in Area IV has increased at an average annual rate of 13.4% from 1989/90 to 1999/2000, according to the JARPA sighting surveys. The abundance estimate (by the dedicated sighting vessel) is 12,664 whales (Matsuoka et al., 2000). The increase of humpback whales in Eastern and Western Australia, which are almost due north of Area IV, have also been confirmed (see Table 7). The sighting results show that the humpback whale stock in the Antarctic Ocean is rapidly recovering.

Fig. 58. A school of humpback whales swimming close to the research vessel in the Antarctic Ocean (Area IV, 2002).

Fig. 59. A school of three humpback whales in the Antarctic Ocean Area IV in 1999. The whale on the left is raising its head out of the water in a display of spy-hopping behaviour.

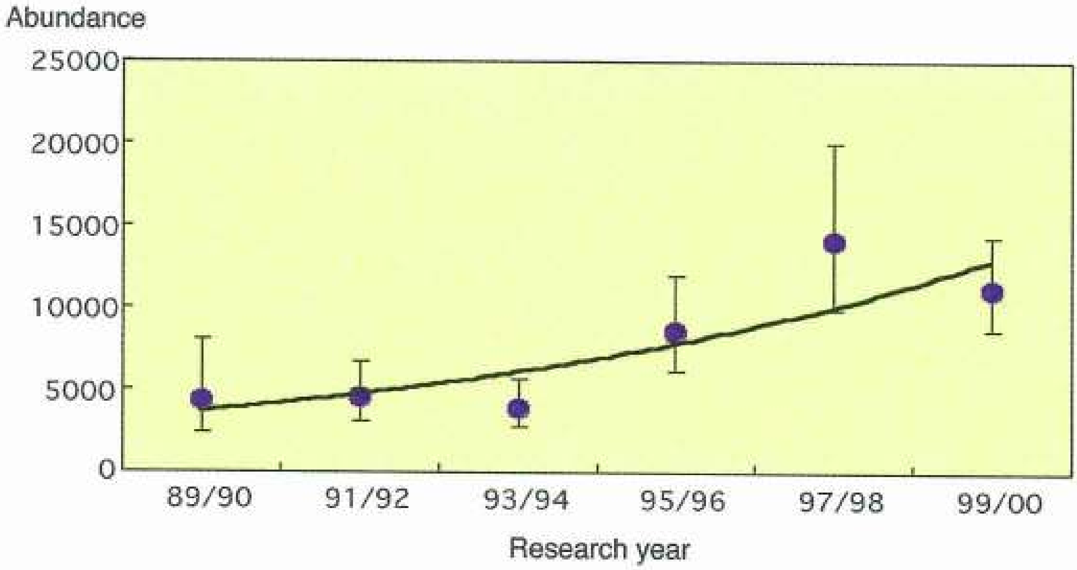



Fig. 60. Abundance estimate of humpback whales in Area IV from 1989/90 to 1999/2000. It is clear that abundance shows an increasing trend. The vertical lines indicate the 95% confidence limit[12] for the yearly abundance estimate.

# *Increase of Other Large Whales Abundance*

The increase in humpback whales observed in the JARPA program (Matsuoka *et al.*, 2000) is not an exceptional case, and there have been many reports of significant recovery of whale stocks. As can be seen in the table below, in the southern hemisphere, the southern right whale also shows a rapid recovery with a high increase rate. In the northern hemisphere, humpback whales in the western North Atlantic have increased at an annual rate of 3.1% from 1979 to 1993 (Stevick *et al.*, 2001), and gray whales in the eastern North Pacific at an yearly 3.2% from 1967/68 to 1987/88 (Buckland, 1990). Many whale stocks are known to be increasing and recovering.

Table 7. Average annual rate of increase for whales in the southern hemisphere.

| Whale stocks | | Annual increase rate | Period |
|---|---|---|---|
| Southern right whale | (Australia) [a] | 8.3% | 1983-1997 |
| Southern right whale | (South Africa) [a] | 7.2% | 1969-1996 |
| Southern right whale | (Argentina) [a] | 7.1% | 1971-1996 |
| Humpback whale | (East Australia) [b] | 12.3% | 1981-1996 |
| Humpback whale | (West Australia) [c] | 10.9% | 1977-1991 |

[a]: *Best, P.B., et al.*, 2001. [b]: *Brown, M.R., et al.,1997 (SC/49/SH35).* [c]: *Bannister, J.L., 1994.*

Fig. 61. Southern right whale.

Fig. 62. Blue whale.

Table 8. Blue whales sighted in Areas IV and V in the JARPA program. Numbers sighted show an increasing trend for both areas.

**Area IV**

| Research year | Surveyed distance (Miles) | Number of schools | Number of whales |
|---|---|---|---|
| 1989/90 | 17,094 | 5 | 9 |
| 1991/92 | 18,205 | 3 | 3 |
| 1993/94 | 17,933 | 5 | 9 |
| 1995/96 | 21,456 | 1 | 1 |
| 1997/98 | 21,598 | 5 | 6 |
| 1999/00 | 16,342 | 14 | 30 |
| 2001/02 | 19,767 | 11 | 18 |

**Area V**

| Research year | Surveyed distance (Miles) | Number of schools | Number of whales |
|---|---|---|---|
| 1990/91 | 14,760 | 4 | 6 |
| 1992/93 | 13,492 | 7 | 9 |
| 1994/95 | 14,039 | 13 | 20 |
| 1996/97 | 17,756 | 1 | 1 |
| 1998/99 | 8,064 | 7 | 16 |
| 2000/01 | 20,484 | 15 | 25 |

# Biopsy Sampling and Photo ID

## BIOPSY SAMPLING AND PHOTO IDENTIFICATION

Apart from lethal research, the JARPA program also has a non-lethal research component involving skin biopsy sampling (begun in the 1993/94 research expedition) for genetic studies, and taking photographs of natural marks for individual identification (started in 1989/90). The main target species are humpback, blue, and southern right whales. These studies have made major contributions in elucidating their range of distribution, movements, stock identification, and taxonomy.

## BIOPSY SAMPLING

Biopsy skin samples are obtained using an air gun designed at ICR. A total of 290 biopsy samples from humpback whales, 29 from right whales, 17 from blue whales and 16 from fin whales have been obtained in the JARPA surveys up till 2001/02. Genetic analyses based on PCR technology have been conducted to investigate taxonomy in right and blue whales, and distribution, movement and stock structure in the case of the humpback whales. The sex of each individual is routinely determined using molecular techniques. The research is conducted in collaboration with other laboratories both in Japan and abroad.

Fig. 63. Biopsy air gun.

Fig. 64. Aiming the biopsy air gun.

Fig. 65. Shooting to collect a biopsy sample.

Fig. 66. Picking up the sample.

Fig. 67. Rinsing the biopsy sample before storage for analysis.

## PHOTO IDENTIFICATION (PHOTO ID)

Photographs of natural marks, such as lateral markings and pigmentation patterns of ventral flukes, are useful to identify individuals in the humpback whale; head callosities pattern is useful in the case of the right whale and the mottled pigmentation pattern is used to identify individuals in the case of the blue whale. A total of 447 photographs of humpback whales, 130 blue whales, and 189 of southern right whales have been taken and selected up till the 2000/01 research expedition. They have been compiled into the ICR Photo ID Catalog and the data are being processed and filed. Individual ID is used to study mainly the movement of individual whales.

Fig. 68. Right whale. The head callosities pattern is useful for individual identification in this species.

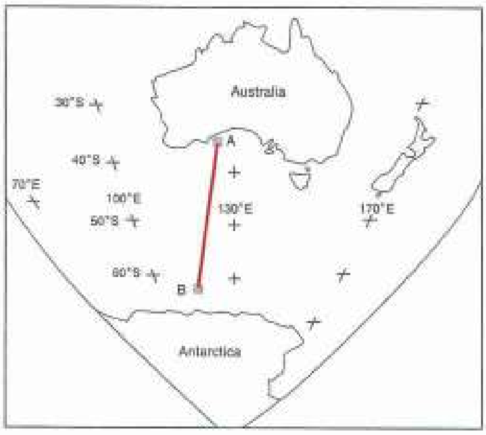



Fig. 69. A study revealed that a whale photographed in the JARPA survey in Area IV in 1996, was the same animal observed in the seas off Western Australia (Bannister *et al.*, 1999).

## *IN-VITRO* FERTILIZATION

We are collaborating with Obihiro University of Agriculture and Veterinary Medicine on the breeding physiology of baleen whales. We froze and preserved the spermatozoa of the Antarctic minke whale, attempted *in-vitro* cultivation of immature oocytes, and successfully produced embryos with *in-vitro* fertilization for the first time in the world, which is one of our major achievements. The samples and data from the JARPA surveys have been put to use to obtain much basic knowledge, with the preservation of species in view, including artificial breeding.

Fig. 70. Observation of Antarctic minke whale sperm.


Fig. 71. Testis and epididymis of the Antarctic minke whale.

Fig. 72. Incubator containing *in-vitro* cultivation vials of Antarctic minke whale immature oocytes.

Fig. 73. Data collection of *in-vitro* Antarctic minke whale immature oocyte culture.

Fig. 74. Examination under the microscope of Antarctic minke whale fertilized egg condition.

Photo credit: Prof. Yutaka Fukui, Obihiro University of Agriculture and Veterinary Medicine

Fig. 75. *In-vitro* fertilized Antarctic minke whale embryo in the cell division stage.

# Oceanographic Observations

## OCEANOGRAPHIC OBSERVATIONS

The distribution of the prey species of whales is known to be closely related with the marine environment, and the study of oceanographic structure is essential in elucidating the distribution and ecology of whales in the research area. The JARPA program has the advantage of being able to collect sighting and biological data at the same time as the oceanographic observations using various instruments and devices aboard the dedicated sighting vessel. The setup helps to obtain more accurate information on the concurrent oceanic conditions and the distribution of whales.

Fig. 76. CTD observations. The CTD is thrown into the sea to collect data on the vertical distribution of water temperature and salinity.

Fig. 77. The laboratory of the dedicated sighting vessel. Data obtained with the various instruments are collected here.

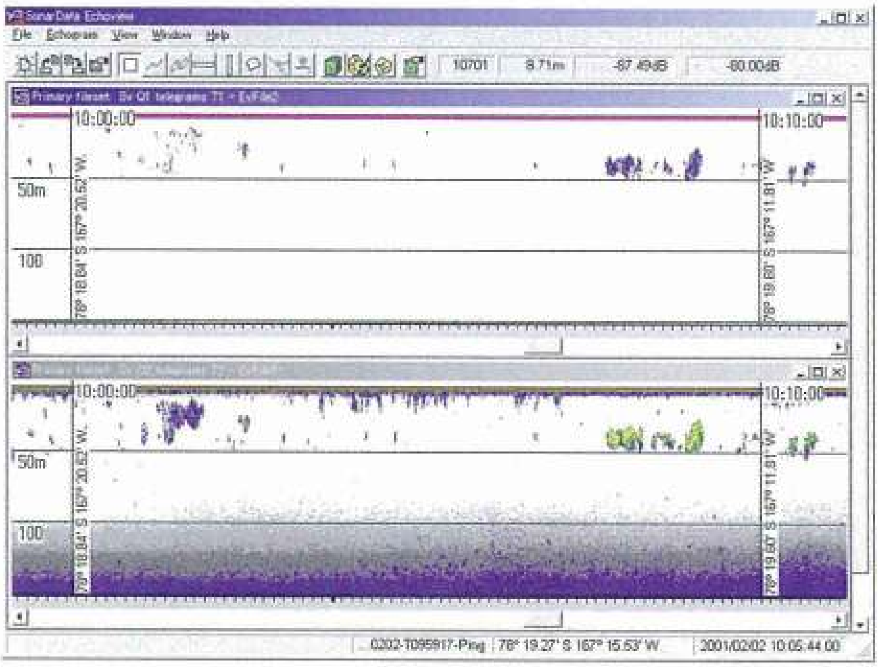



Fig. 78. Schools of krill captured on the echo-sounder. It calculates the density of the school using sound waves to find out the biomass of prey.

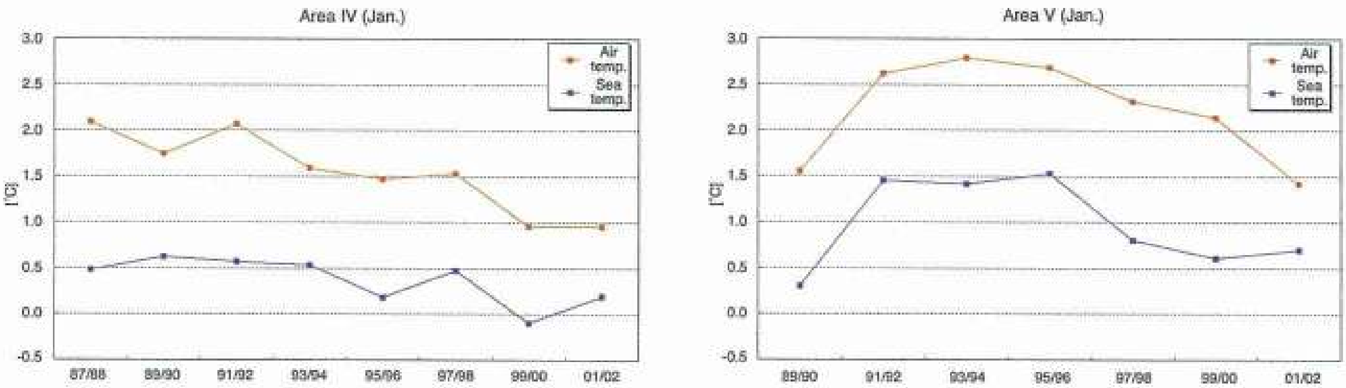



Fig. 79. Yearly variation of air temperature and sea water temperature in the Antarctic Ocean research Areas IV (left) and V (right). The data from our research do not show any strong evidence of rising temperatures in the Antarctic Ocean.

# Satellite Tagging and Acoustic Monitoring

## SATELLITE TAGGING

Satellite tagging (Fig. 80) makes it possible to follow the whales' migrating routes and find out when they migrate. It provides valuable information on the ecology of whales, and in the JARPA program, we are actively engaged in tagging experiments and trying to develop better tagging devices and methods.

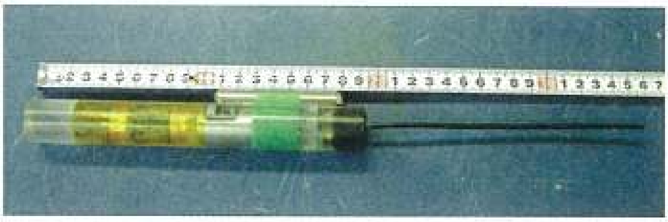


Fig. 80. Satellite tag used in whale tagging experiments.

## RECORDING WHALE CALLS

In water, sound waves not only travel about 4.5 times as faster than through air but also reach farther. Whales are believed to call out to each other in communication and to let out sounds to detect objects. Research is going on using a device to record the sounds (sono-buoy, shown in photo) in an effort to study their ecology and to locate whales.

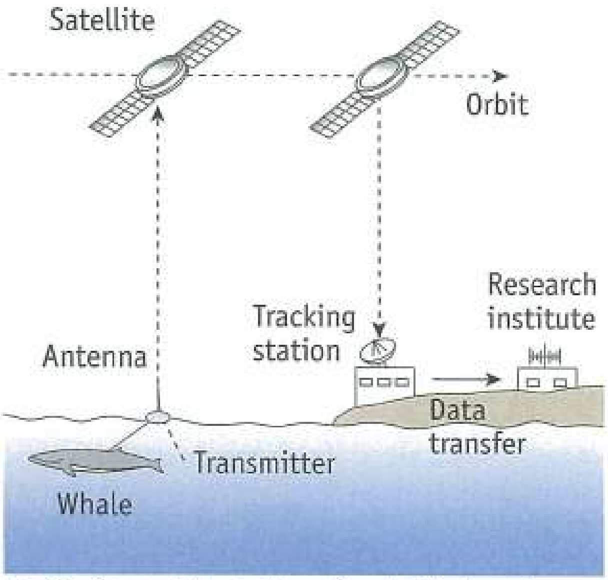


Fig. 81. Concept illustration of a satellite-based whale tracking system.

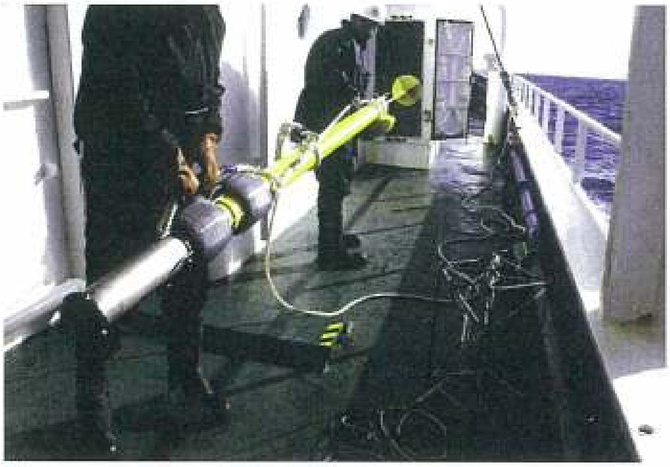


Fig. 82. Preparing the sono-buoy for deployment, aboard the sighting vessel Kyoshin Maru No. 2.

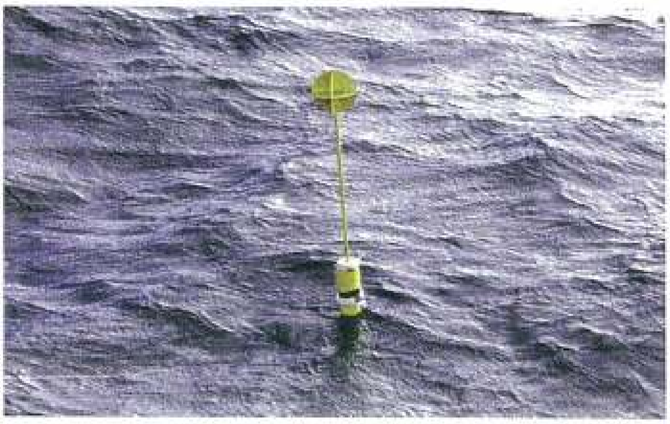


Fig. 83. The sono-buoy afloat in the sea.

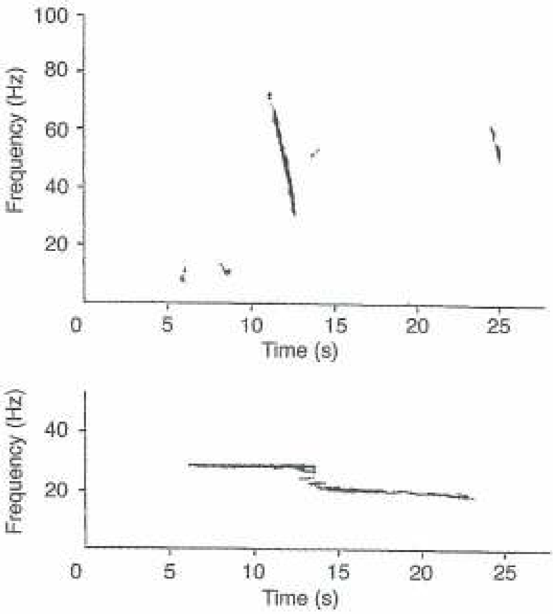


Fig. 84. Whale calls as recorded during JARPA cruises. Upper graph shows the spectrogram of a typical fin whale call; bottom, the spectrogram of a typical blue whale call. Both recorded in Area V on 21 January 1999.


Fig. 85. Analyzing the data collected with the sono-buoy.

# Cooperation with Museums

## COOPERATION WITH MUSEUMS

The specimens of the Antarctic minke whale skeletons collected in the JARPA surveys are exhibited in museums and aquariums throughout Japan (Fig. 87), and open to the general public. We collect samples for scientific research, and cooperate in collecting specimens for exhibition purposes on request.

Fig. 86. Antarctic minke whale skull prepared for osteological studies.

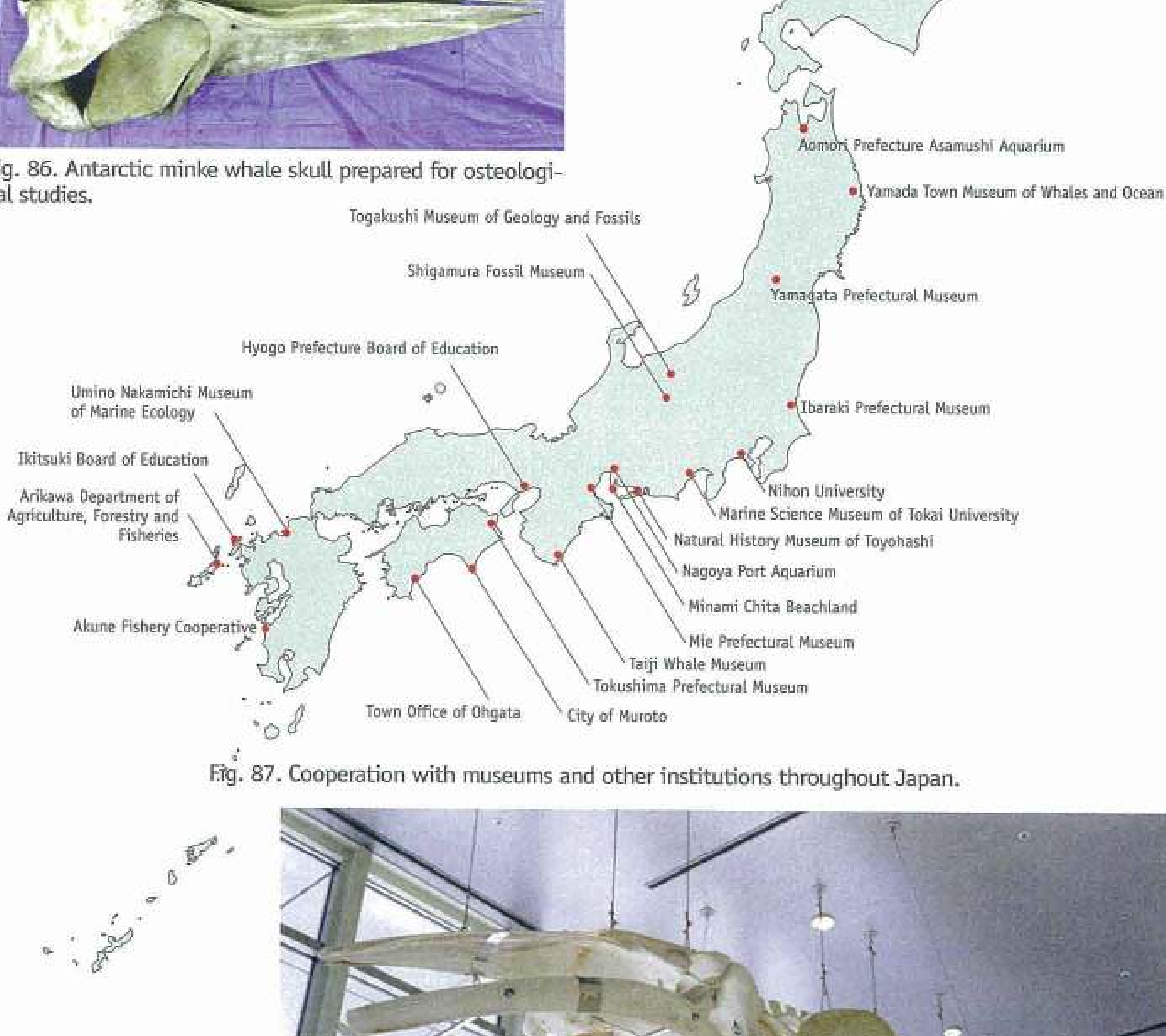



Fig. 87. Cooperation with museums and other institutions throughout Japan.

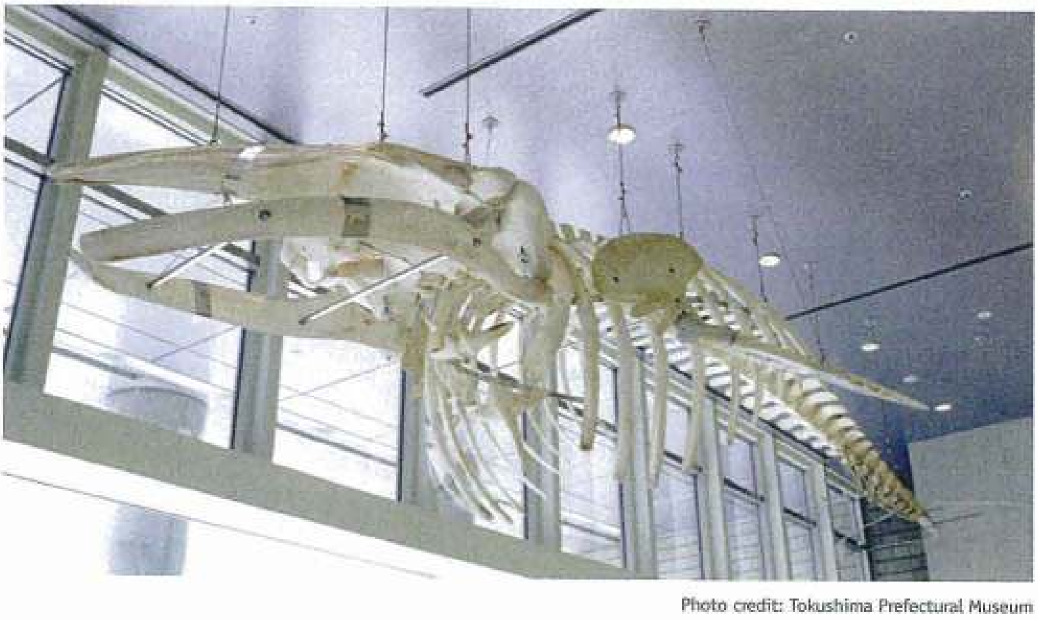


Fig. 88. Antarctic minke whale skeleton on display at Tokushima Prefectural Museum.

Photo credit: Tokushima Prefectural Museum

# Questions & Answers

# QUESTIONS AND ANSWERS

**Q** **Isn't it possible to obtain information needed for the management of whales without killing them?**

**A** **Lethal research is essential.**

As shown in the tables below, there are survey methods that involve the killing of whales (lethal methods) and those that do not (non-lethal). They both have advantages and disadvantages, so we combine the two in actual survey activities, depending on the purpose. For instance, one of the objectives of JARPA requires the "census" of whales. If we can learn whale stock composition by age and reproductive status, it will make resource management much safer. (Incidentally, the lack of this type of information was one of the reasons for the moratorium on commercial whaling.) We need to sample earplugs (to find out age) and gonads (to study reproductive status and pregnancy rate) to obtain information, but they are located deep inside the whale and cannot be obtained without killing them. We also need to examine the concentration of pollutants in internal organs to study the effects of the marine environment on whales. We have to look at the stomach contents for the qualitative (prey species) and quantitative study (amount consumed) of preys that whales feed on. Lethal methods are a must for the effective implementation of research. Certainly, some data can be obtained from non-lethal research such as biopsy sampling, but their inefficient and impractical aspects have been acknowledged at the IWC Scientific Committee.

Table 9. Comparison of lethal and non-lethal research methods.

| ITEM | LETHAL METHODS | NON-LETHAL METHODS |
|---|---|---|
| Target animal | Killing required | Killing not required |
| Population size | Unsuitable for scarce resources | Suitable for scarce resources |
| Species behavior | Sampling possible irrespective of swimming speed | Limited to slow-swimming species |
| Sample material | Large amounts can be obtained quickly | Only a small amount can be obtained |
| Specimens | Can be obtained from whole whale | Can be obtained only from part of body surface |
| Survey location | Possible even under poor conditions | Only possible under favorable conditions |
| Survey time | Can spend as much time as needed | Must be done in a short time |
| Survey term | Results can be obtained in a short time span | Requires long-term research |
| Continuity | Can only study one stage of the animal | Single individuals can be observed repeatedly |
| Length of body and parts | Can take actual measurements directly | Only photographing and deducing size from photos |
| Weight of body and parts | Can make direct measurements (weigh by dissecting) | Cannot be done (impossible to capture animal alive) |
| Biochemical composition | Can take tissue samples for analysis. | Impossible |
| Research costs | Cost recovery possible | Cost recovery not possible |
| Utilization of sampled resource | Possible | Not possible |
| Sampling | Partial recovery of research costs means better research funding available, providing better sampling opportunities | Inconvenient (expensive research costs restrict number and quality of samples) |
| Legal basis | The right to conduct lethal research is explicitly authorized by Article VIII of the ICRW | Non-lethal research does not preclude the necessity and justifiability of lethal research |

# Need for Lethal Research

Table 10. Comparison of lethal and non-lethal methods in relation to research objectives.

| ITEM | LETHAL METHODS | NON-LETHAL METHODS |
|---|---|---|
| Total and proportional body length | Adequate and precise (take actual measurements) | Only photographing and taking measurements from photos |
| Total and partial body weight | Direct measurement (weigh after dissecting) | Not possible (impossible capture animal alive) |
| Biochemical composition | Possible to take tissue samples for biochemical analysis | Impossible |
| Age | Possible to collect phenotypic features showing age (teeth, earplugs, baleen plates, etc.) | Can only observe external morphological features |
| Growth | Possible to measure body length, and determine age of individual | Only long-term observations of identified individuals |
| Maturation | Possible to examine directly reproductive glands | Only external genital observation is possible |
| Fertilization | Possible to examine directly reproductive glands and organs | Can only observe mating behavior |
| Breeding season | Possible to deduce from fetus size | Only observation of whales when they come to breeding grounds |
| Pregnancy | Direct verification of fetus presence | Inadequate (take blood samples for sex hormone analysis) |
| Lactation | Can directly examine mammary gland of mother, stomach content of calf | Can only observe behavior of mother and calf pairs |
| Breeding cycle | Possible to determine from pregnancy rate and other data | Only isolated long-term observations of identified individuals |
| Diet | Possible to study through direct examination of stomach content | Inadequate (only observation of feeding behavior, feces collection) |
| Tracking | Possible to use internal body markers/tags | Individual recognition, use of radio tags |
| Stock structure | Possible to take samples of organs, tissues and phenotypic features showing age | Only biopsy collection, satellite tagging, individual recognition |

**Q** **Whale meat taken in the research programs is sold in Japanese markets. Isn't research a pretext to sell whale meat? Isn't that the real purpose?**

**A** **Of course not. We are obliged to utilize the by-products of the research to the major extent possible under the Convention (ICRW).**

It is clearly stipulated in the ICRW (Article VIII, Paragraph 2) that Contracting Governments must process the leftover parts from the research as far as practicable and sell them as food and other purposes. The whale research programs are implemented according to meticulous plans and cost a lot of money. Proceeds from the by-product sales are used to partly fund the research. Also, it would be a waste of valuable resources not to use the whales as much as possible. It is the proper thing to do, and it should be noted that we have a long tradition of using the whole whale in Japan. The JARPA program, by the way, amasses scientific knowledge and maintains a high standard as a research project, as is described in this booklet.

**Q** **You may need to kill whales, but aren't you taking more than you need?**

**A** **The sample size is the minimum required to obtain results.**

The number of whales killed is the minimum necessary to obtain statistically significant results. The annual sampling size was determined as 300 whales (±10%) at the initial stage in 1987/88, but since the 1995/96 research expedition up till the present, it has been increased to 400 (±10%). This is because the initial sampling size was determined based on stock hypotheses from the commercial whaling days (see "Elucidation of the stock structure of Antarctic minke whales"), but with the progress in research, we found that the results did not tally with the hypotheses. It became necessary to expand the research area in two directions (east and west) and take 100 whales (±10%) per year from the extended regions in order to delve into the question of stock structure. The present sampling size, by the way, corresponds to a mere 0.05% of Antarctic minke whales. It is smaller than the net recruitment rate, and therefore has no adverse effect on the whale stock.

**Q** **Conversely, what if the present sampling size was too small to achieve the purposes of the research program?**

**A** **The present number of Antarctic minke whales captured makes possible to obtain statistically meaningful scientific data without producing a negative effect on the resource.**

However, a substantial increase in the scale of the sampling size would improve the precision of the research and would make possible to obtain results much more quickly.

**Q** **Is there any need to take whales for eighteen long years including the feasibility studies?**

**A** **The project period was a logical result of implementing the necessary surveys without taking too many Antarctic minke whales in a short time span that would be detrimental to the stock.**

The required sampling size to achieve the research objectives has been calculated for the entire project, carried out across the years. It is also necessary to disperse the take of whales to avoid any adverse effect on the stock. The sixteen years of the full-scale JARPA surveys have been designed as a result of taking the statistically required number of whale samples per year into consideration. In addition, the programme has proved to be useful for the monitoring (observations related to stock structure, data collection, etc.) of whales and their environment, which is also necessary.

**Q** **Aren't the JARPA surveys illegal in view of the moratorium on commercial whaling and the Southern Ocean Sanctuary?**

**A** **JARPA is a strictly legal project. Neither ban on whaling is applicable for the take of whales for scientific research purposes.**

JARPA and all the other Japanese whale research programs are perfectly lawful. Article VIII of the ICRW states that any Contracting Government may take whales for purposes of scientific research subject to conditions the Government thinks fit, "Notwithstanding anything contained in this Convention." In other words, the ICRW allows any member country of the IWC to conduct whale research programs, and no restriction under the moratorium on commercial whaling and the Southern Ocean Sanctuary applies to them.
By the way, not only the moratorium is no longer necessary; the Southern Ocean Sanctuary itself violates the Convention because it is maintained "irrespective of the conservation status of whale stocks."

**Q** **Will be necessary in future to continue carrying out research programs similar to JARPA in the Antarctic?**

**A** **Yes, indeed.**

To be able to put for the use of mankind the splendid and abundant Antarctic Ocean resources in future, deepening our understanding of the marine ecosystem including whale stocks, the materialization of continual monitoring, rational resource conservation and management are indispensable. The present JARPA research program is playing an important role that in future must be further developed.
Furthermore, JARPA research becomes necessary in any circumstance, not only for the development of population dynamics theory, ecosystem structure, relation with the environment, etc. Commercial whaling alone makes difficult to obtain ample scientific data, so in future it will be necessary to continue monitoring environment change, the movements of Antarctic minke whales and gather other necessary information through research in order to be able to determine the best methods to sustainably utilize whale resources.

# One of the Cleanest Foods

**Q** **It is said that oceanic contamination is getting worse and that whales have a high concentration of pollutants. Isn't the meat of Antarctic minke whales taken in the JARPA surveys contaminated?**

**A** **The meat and blubber of Antarctic minke whales are one of the least contaminated food.**

The Antarctic Ocean is the least contaminated region on earth in terms of human-induced chemical pollution. Monitoring activities have been kept up in the JARPA surveys, and so far, only a very small amount of mercury and organochlorines such as PCBs and DDT have been accumulated in the blubber and muscles of Antarctic minke whales. The amount is less than a tenth of that in whales in the northern hemisphere, and clears the provisional restriction standard set down by the Ministry of Health and Labor by a very wide margin. The Antarctic minke whale is one of the cleanest foods. The details of the JARPA research results are available on the web site of the Institute of Cetacean Research (www.icrwhale.org/index.htm).

Table 11. Concentration of PCB in blubber and total mercury in muscle of the Antarctic minke whale sampled by the Japanese Whale Research Program in the Antarctic (JARPA).

| Species | | PCB in blubber (μg/g) | Total Mercury in muscle (μg/g) |
|---|---|---|---|
| Antarctic minke whale ('89 - '03) | Average | 0.031 | 0.027 |
| | (lowest - highest) | (0.00031 - 0.11) | (0.003 - 0.07) |
| | Number of samples | 26 | 232 |

**Mercury:** The Antarctic minke whale muscle showed the lowest mercury concentration, being in average one tenth lower than the provisional restriction standard. Research indicates that mercury shows relatively high concentration in the internal organs (especially liver) and muscle (red meat) of whales, but the Antarctic minke whale showed low contamination of these parts.

**PCB:** PCB are fat-soluble and according to research, show higher concentration in the blubber and other fatty tissues of whales. PCB concentration in the muscle of Antarctic minke whale is very low and clears the provisional restriction standard by a large margin. The concentration of PCB in the blubber also clears the provisional restriction standard being one decimal place lower. These data show that Antarctic minke whale by-products contamination is extremely low.

**Note:** The Ministry of Health, Labor and Welfare has set down 0.4 ppm as the standard in total mercury concentration for fishery products, and for those that exceed the provisional restriction to undergo a further test for methyl mercury, designating those that exceed 0.3 ppm as mercury contaminated fishery products. The provisional restriction standard for PCB in fishery products is 3 ppm for those in inland waters and 0.5 ppm for offshore fishery products. Cetaceans are categorized in the latter (0.5 ppm).

**Q** **How much by-products have been produced so far?**

**A** **The production volume from 1987/88 to 2002/03 was 25,367 tons.**

In JARPA, following the ICRW Article VIII Paragraph 2 stipulation below, the leftover parts from the whale body are processed into by-products and sold according to instructions from the Government, and the proceeds are used to fund part of JARPA research in the following year. All by-products are used for food.

**International Convention for the Regulation of Whaling, Article VIII**

1. Notwithstanding anything contained in this Convention, any Contracting Government may grant to any of its nationals a special permit authorizing that national to kill, take, and treat whales for purposes of scientific research subject to such restrictions as to number and subject to such other conditions as the Contracting Government thinks fit, and the provisions of this Article shall be exempt from the operation of this Convention. Each Contracting Government shall report at once to the Commission all such authorizations which it has granted. Each Contracting Government may at any time revoke any such special permit which it has granted.
2. Any whales taken under these special permits shall so far as practicable be processed and the proceeds shall be dealt with in accordance with the directions issued by the Government by which the permit was granted.

Table 12. By-product type and amount during 1987/88 - 2002/03 JARPA seasons.

| By-product | Amount (tons) |
|---|---|
| Meat | 17,010 |
| Blubber | 6,503 |
| Others | 1,854 |
| Total | 25,367 |

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