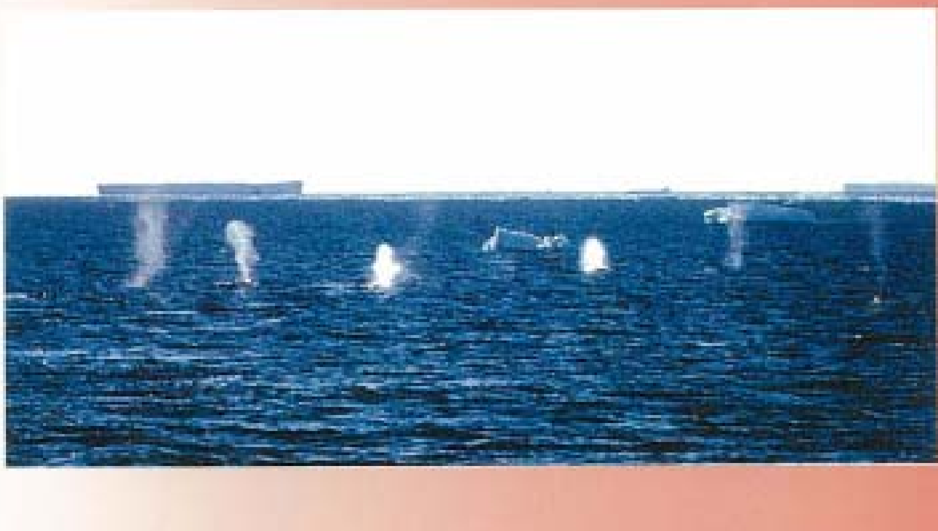
Japan's Whale Research Program under Special Permit in the Antarctic (JARPA)

Second Edition



JARPA

The Institute of Cetacean Research

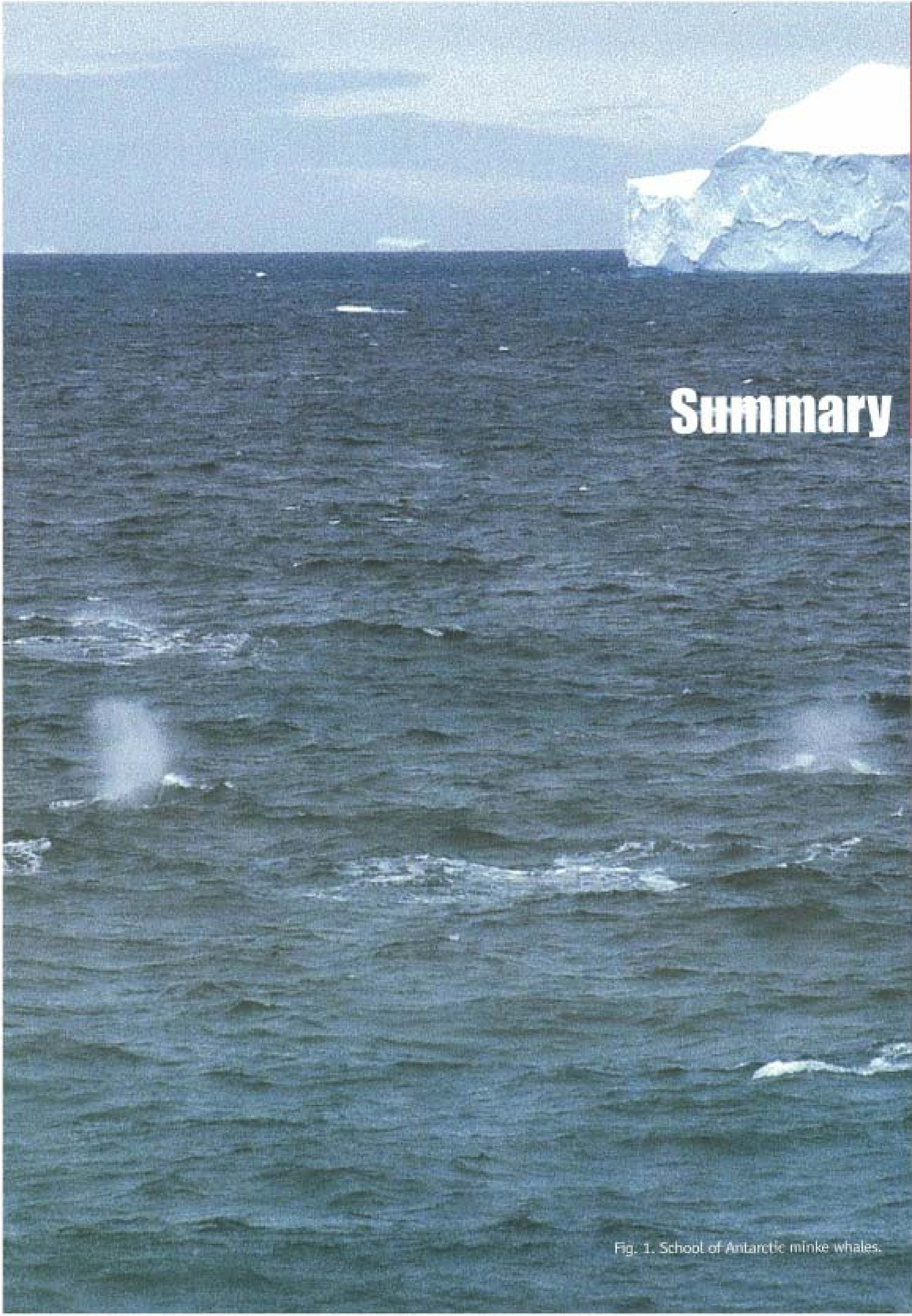
Supervision:

Fisheries Agency, Government of Japan

SUMMARY

MAIN SECTION

QUESTIONS & ANSWERS



Summary

Fig. 1. School of Antarctic minke whales.

Background

CHANGES IN THE ANTARCTIC ECOSYSTEM AND INTENT OF THE JARPA PROGRAM

The Antarctic Ocean 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 to 2005. A large amount of data was collected and many new knowledge was being obtained.

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

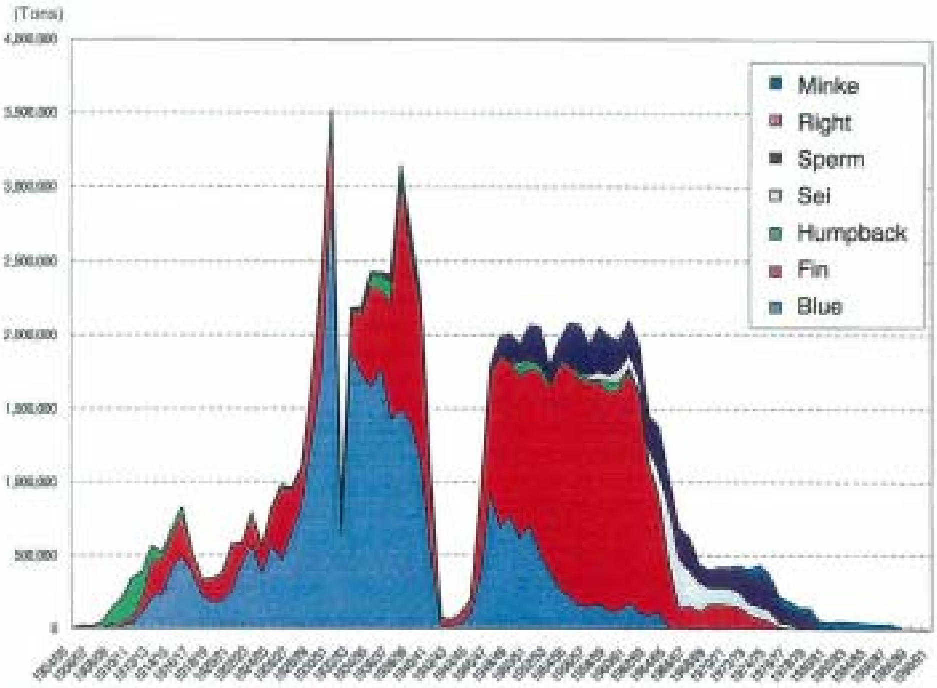


Fig. 2. Change in the whale species composition (number of tons) of commercial whaling catches in the Antarctic.

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 conducted until 2004/05. It was a whale research program spanning sixteen years, and the Institute of Cetacean Research (ICR), authorized and instructed by the Government of Japan, carried out the surveys.

- The JARPA surveys aimed to resolve lack of scientific evidence concerning Antarctic minke whales.
- JARPA promoted 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 the Antarctic minke whale.
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 stock structure of the Antarctic minke whales to improve stock management[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 was 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 blubber 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

The JARPA Review Meeting called by the Government of Japan was held at the Institute of Cetacean Research, Tokyo, on 18-20 January 2005. The purpose of the meeting was to review available data and research results in light of the objectives of the JARPA and to identify future research needs on the basis of this review. A total of 40 scientists from eight countries participated in the meeting.

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.

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.

Fig. 5. Antarctic minke whale.

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 minkes can be recognized at the field by experienced researchers.

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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*).
- 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*.

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

OBJECTIVE 4

The elucidation of the stock structure of Antarctic minke whale

i. In addressing questions of stock structure JARPA has considered results from several techniques, genetic and non-genetic. If similar results are found by different approaches then conclusions can be drawn with greater confidence. This is considered the best strategy to investigate stock structure. In JARPA useful and consistent results were obtained from the analysis of mtDNA, microsatellites, morphometrics, mean body length of physically matured whales and distribution of parasites.

ii. The results from the different techniques were consistent with the hypothesis of two stocks in the JARPA research area, the first, named as Eastern Indian Stock (I-Stock), distributes in Areas III (East), IV and part of Area V. The second, named as Western South Pacific Stock (P-Stock), distributes in Area V (East) and VI (West). These stocks would mix across a soft boundary, which would probably best be placed near 165°E.

iii. Results on stock structure in JARPA provide no support for the IWC's boundaries among Areas III, IV, V and VI.

iv. The information on stock structure obtained under the JARPA suggests that the specification for small areas in the RMP on each 10° longitude sectors does not make sense from the biological point of view. Results suggest the need to revise the IWC's current specifications for management Area boundaries.

> **EASY GUIDE**
>
> ***OBJECTIVE 4 RESULTS***
>
> - The new information on stock structure obtained under JARPA is in conflict with the boundaries of the traditional IWC's management Areas.
> - JARPA results are consistent with the view of two stocks in the research area, Eastern Indian Ocean Stock and Western South Pacific Stock. These stocks would mix across a soft boundary, which would probably best be placed near 165°E.
> - New information does not support the RMP concept of 10°-wide small areas.

OBJECTIVE 1

The estimation of biological parameters to improve stock management of Antarctic minke whale

i. 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.

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

iii. Progress in obtaining unbiased abundance estimation has been made. JARPA sighting surveys provides results on abundance estimation that are comparable with those from IDCR/SOWER surveys.

iv. JARPA results showed a significant recent increase in the age at physical maturity. Consistent with this, the age at sexual maturity shown as the transition phase in earplugs for Area IV suggested a constant or a slight increase after the 1970 cohort following an earlier appreciable decline.

v. Biological parameter values are reported on a biological stock basis, specifically for the I and P stocks, with their boundary set at 165°E. Some parameters showed significant differences between the stocks.

vi. Proportion of pregnancy in sexually matured females is high for both stocks.

vii. JARPA has provided initial estimates of natural mortality coefficient using different methods. By using the Tanaka's method, estimations of this parameter were 0.0486 and 0.0490 for the I and P stocks, respectively. Initial estimates of this parameter based on VPA have been also obtained.

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OBJECTIVE 1 RESULTS

- JARPA has successfully estimated several biological parameters of the Antarctic minke whale, included natural mortality coefficient, on the basis of the identified biological stocks (I and P-Stocks).
- The yearly changes of some biological parameters such as a recent slight increase in the age at physical maturity in Antarctic minke whale stocks may suggest that less food per capita has become available for these whale stocks.

OBJECTIVE 2

The elucidation of the role of whales in the Antarctic ecosystem

i. The latest techniques are used in JARPA to study distribution and abundance of krill using concurrent whale and prey surveys. Krill distribution is associated with the extent and shape of the ice-edge and sea bottom topography.

ii. Antarctic minke whales and krill overlap distribution in the continental shelf slope. Distribution of humpback whales correlated with high krill density zones in both the continental shelf slope and in offshore areas.

iii. Feeding studies conducted during JARPA have confirmed Antarctic krill as the main prey of minke whales, which in turn remain a major predator of krill. Mature Antarctic minke whales consume daily 240-370kg of krill, corresponding to 3.6 to 5.3% of their body weight.

iv. Studies conducted under JARPA have shown that the mean mass of minke whale stomach contents has declined appreciably over recent years, and there has been a coincident decrease in blubber thickness. Results from pollutant studies are also consistent with a recent decline in per capita food consumption by minke whales.

v. Estimates of abundance from JARPA surveys indicate increases in both humpback and fin whale populations.

vi. There is a possible growing competition for krill amongst the baleen whale species in the region covered by the JARPA program.

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OBJECTIVE 2 RESULTS

- Antarctic minke whale remains a major predator of krill.
- JARPA surveys indicated increase in both humpback and fin whale populations.
- Antarctic minke whales and krill overlap distribution in the continental shelf slope. Distribution of humpback whales correlated with high krill density zones in both the continental shelf slope and in offshore areas.
- JARPA results suggest a possible growing competition for krill amongst the baleen whale species in the region covered by the program.

OBJECTIVE 3

The elucidation of the effect of environmental changes on cetaceans

i. Studies on pollutant accumulation in both whale samples and whale's environment conducted under JARPA showed that the Antarctic Ocean is the least contaminated region in the world.

ii. JARPA studies showed that the concentration of Hg and organochlorines such as PCBs and DDT in blubber and muscle tissues of Antarctic minke whales is very low in comparison with concentrations recorded in minke whales harvested in other geographic areas.

iii. JARPA results provided evidence of changes in the Antarctic cetacean habitat (the biological environment), which supplement the growing evidence of density dependent responses in the minke whale population. These observations are possibly related to intra- and inter-specific competition for a single food resource (krill).

JARPA Results – Summary

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OBJECTIVE 3 RESULTS

- JARPA studies on pollutant accumulation in Antarctic minke whale tissues and whale environment have shown that the Antarctic Ocean is the least contaminated region in the world.
- JARPA results provided evidence of changes in the Antarctic biological environment, which supplement the growing evidence of density dependent responses in the Antarctic minke whale population.

III) OTHER RESULTS

Fig. 6. Humpback whale.

1. Photo-id pictures and biopsy samples collected by JARPA on blue, right and humpback whales enabled the studies on movement, distribution, taxonomy and stock structure in these species.
2. Movement of right whales between Australia southern coast and Area IV has been reported using photo-id data partially taken during JARPA surveys.
3. Genetic analysis based on biopsy samples from humpback whales confirmed the geographical segregation of Stocks C (Area III), D (Area IV), E (Area V) and F (Area VI) in the feeding ground. The sector between 110° ad 130°E, which was occupied historically mainly by the E Stock (breeding ground located off eastern Australia), is being occupied recently by the D Stock (breeding ground located off western Australia).

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OTHER RESULTS

- Sighting and other non-lethal surveys in JARPA 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 has provided important information of the stock structure of the humpback whale in the Antarctic feeding grounds.

EXCERPTS FROM THE REPORT OF THE JARPA REVIEW MEETING CALLED BY THE GOVERNMENT OF JAPAN (JANUARY 2005)

1. 'The meeting agreed that JARPA has obtained useful results from a number of genetic and non-genetic analytical methods applied to investigate the stock structure of the Antarctic minke whale'.
2. 'Results on stock structure will also assist in calculating abundance and biological parameter values that relate more closely to biological stocks units'.
3. 'The meeting agreed that JARPA has collected a very large and consistent data base over a 16-year period, which provides a basis for time series analyses relating whales to the Antarctic environment and the beginning of an ecosystem approach to the management of whale resources in the region'.
4. 'The meeting agreed that JARPA has contributed to the elucidation of biological parameters of minke whales, and improved the understanding of the Antarctic marine ecosystem'.
5. 'JARPA has revealed that changes have occurred in the ecosystem since the 1970s, suggesting competition among minke and other large whales'.
6. 'The meeting agreed that data obtained through this monitoring will contribute to the development of ecosystem models, which are necessary for ecosystem-based management of whales'.

SUMMARY OF THE JARPA RESULTS

The results from JARPA and other activities for the Antarctic minke whale can be summarized as follows:

Changes found from 1940 to 1970:

- Increase in recruitment
- Acceleration in growth rate
- Decrease in the age at sexual maturity
- Increase in mercury intake

Changes found from 1970 to 1980:

- Decrease in recruitment
- Halt in the decreasing trend in the age at sexual maturity
- Mercury intake stabilizes at fixed level

Changes from 1980 onwards:

- Decreasing growth rate
- Decrease in blubber thickness (from 1980 to present)
- Decrease in stomach contents weight (from latter half of 1980 to present)
- Decrease in mercury intake

AN INTERPRETATION

The results from JARPA are consistent with the behavior to be expected of baleen whale populations competing for a dominant single food resource, krill. The following possible changes are considered to have occurred in the Antarctic minke whale stocks.

Feeding conditions became favorable for the Antarctic minke whales around 1940, at the latest, with the depletion in large baleen whales such as blue and other whales due to overhunting, and the nutritional status of each minke whale individual improved. Thus, growth rate increased for the minke, and they grew to mature body length earlier, reaching sexual maturity younger. Declining age at sexual maturity and increasing pregnancy rates were also observed in fin, humpback and other large baleen whales, suggesting improved feeding conditions for them as well. Overall improvement in feeding conditions is indicated, arising from lower population density due to the decrease in the number of large baleen whales which consumed huge amounts of krill in the Antarctic Ocean (Kato, 1987).

The amount of available prey (krill) per Antarctic minke whale as a consumer became restricted about 1970. Around that time, growth rate and the declining the age at sexual maturity slowed down. By 1980 a halt in the latter trend was observed. It seems that the growth rate of whales in year classes of the 1990s was lower than that of those in year classes of the 1980s. The change in feeding conditions was reflected in blubber thickness. Blubber thickness of Antarctic minke whale has shown a constant decline since 1978/88. Also, the number of humpback and fin whales which are higher in their niches than the number of Antarctic minke whales, migrating to the Antarctic increased from 1990. This suggests the recovery of these stocks, while indicating a further deterioration in feeding conditions for Antarctic minke whales.

Other factors that may have contributed to the changes in feeding conditions include environmental changes such as global warming. Melting of fast ice in the seas around the Antarctic Peninsula has been reported, and a decrease in the number of penguins which incubate on ice has been observed (Croxall *et al.*, 2002). However, Areas IV and V of the Antarctic Ocean, which are the concern of this paper, are on the opposite side of the Antarctic Peninsula and no major melting of fast ice has been reported to date. Analysis of satellite data and oceanographic observations carried out in the JARPA programs have not shown any constant change in the marine environment, although annual fluctuations due to *El Niño* and *La Niña* have been observed (Watanabe *et al.*, 2005).

It is highly possible that nutritional conditions for the Antarctic minke whales have changed due to competition with other whale species such as the humpback whale, and possibly the change in carrying capacity, in the Antarctic marine ecosystem.

What Has Happened to the Antarctic Minke Whale Stocks?

This provides strong qualitative evidence that competition for prey (krill) plays an important role in the dynamics of the Antarctic ecosystem. Modeling studies need to be developed further to ascertain whether such competitive effects alone can fully explain the trends observed, or perhaps there is a need to postulate environmental shifts in addition.

For the appropriate management and sustainable use of Antarctic minke whale stocks, we would need to collect not only data on abundance and biological parameters of major whale species, but also data on their habitat environment and their responses to environmental changes.

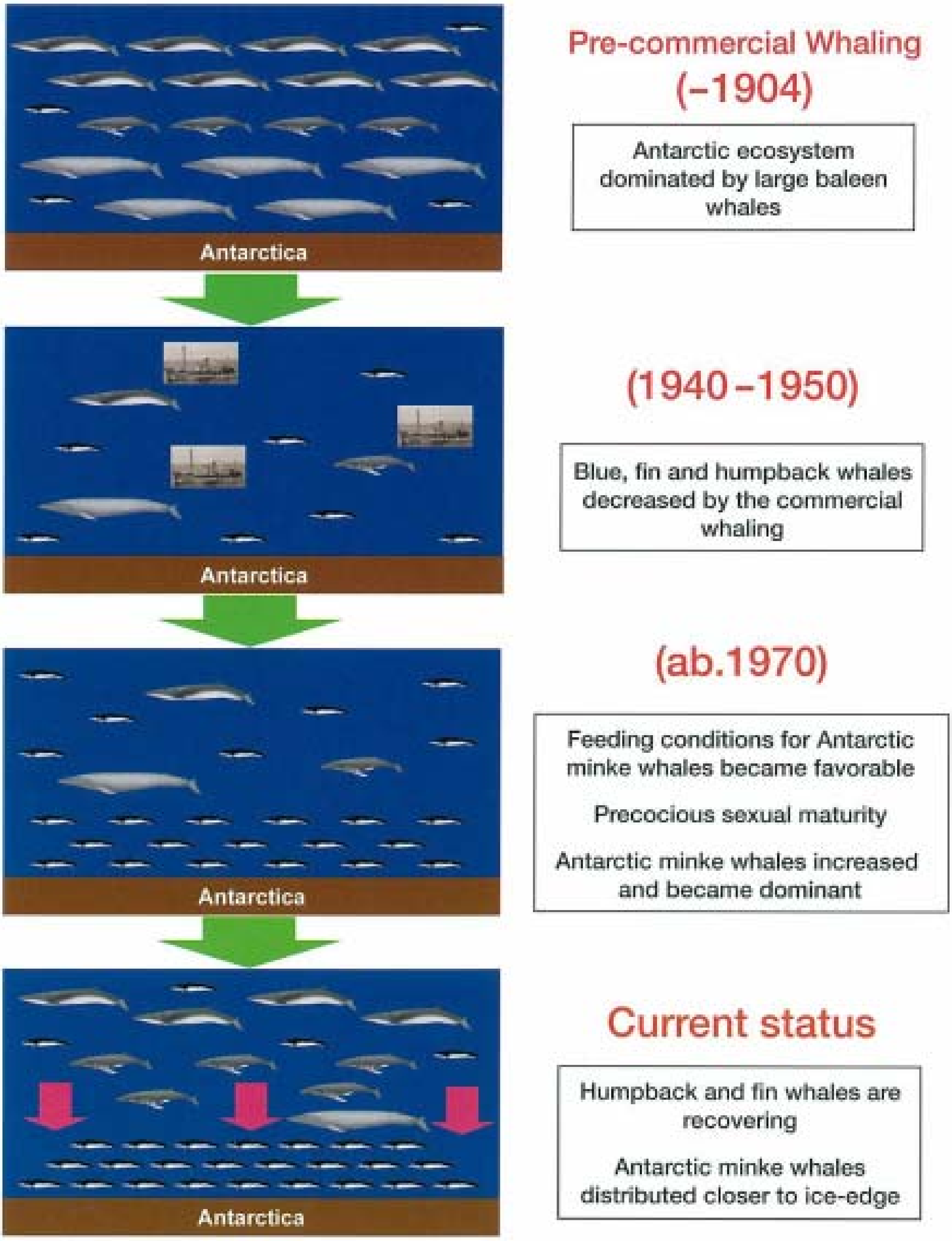

Fig. 7. Antarctic Whale Dynamics.

Main Section

Fig. 8. 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 for JARPA expeditions.

Season	Research Expedition	Research area	Days surveyed	Distance searched (n. miles)	Planned number of samples[a]	Actual number of Antarctic minke whale samples[b]
1987/88	Feasibility s.	Part of area IV	69	8,482	300 (±10%)	273 (1)
1988/89	Feasibility s.	Part of area V	80	9,614	300 (±10%)	241 (5)
1989/90	1st	Area IV	97	17,094	300 (±10%)	330 (3)
1990/91	2nd	Area V	94	14,760	300 (±10%)	327 (4)
1991/92	3rd	Area IV	112	18,205	300 (±10%)	288
1992/93	4th	Area V	113	13,492	300 (±10%)	330 (3)
1993/94	5th	Area IV	107	17,933	300 (±10%)	330
1994/95	6th	Area V	109	14,039	300 (±10%)	330
1995/96	7th	Area III (East) & IV	118	21,456	400 (±10%)	440[c]
1996/97	8th	Area V & VI (West)	103	17,756	400 (±10%)	440
1997/98	9th	Area III (East) & IV	98	16,462	400 (±10%)	438
1998/99[c]	10th	Area V & VI (West)	78	7,494	400 (±10%)	389
1999/2000	11th	Area III (East) & IV	97	16,342	400 (±10%)	439
2000/01	12th	Area V & VI (West)	100	20,484	400 (±10%)	440
2001/02	13th	Area III (East) & IV	101	19,767	400 (±10%)	440
2002/03	14th	Area V & VI (West)	96	18,126	400 (±10%)	440
2003/04	15th	Area III (East) & IV	95	19,287	400 (±10%)	440
2004/05	16th	Area V & VI (West)	92	18,712	400 (±10%)	440

[a] 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.

[b] Includes dwarf minke whales (figures in parentheses) sampled during feasibility surveys and first four research expeditions (16 individuals in total).

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

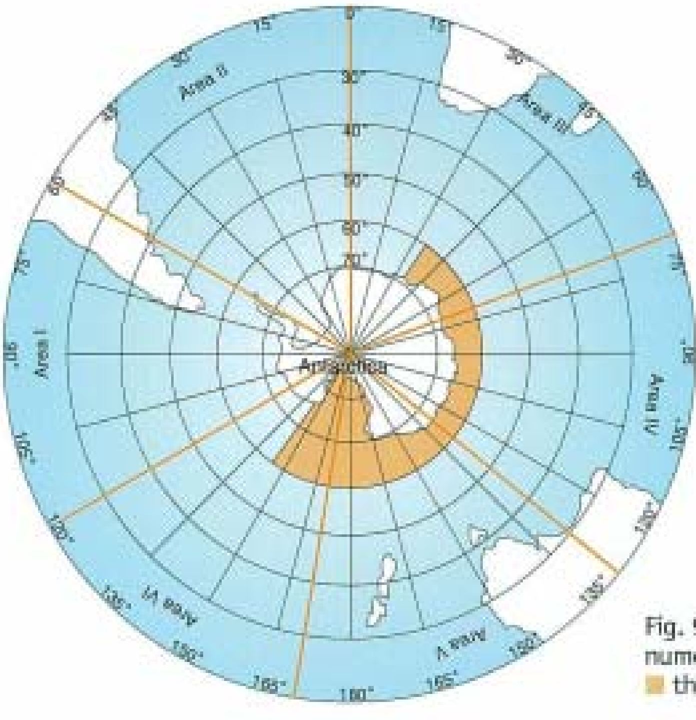

Fig. 9. Map of the Antarctic Ocean. The Roman numerals indicate IWC management areas and the research areas surveyed by JARPA.

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. 17).

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 4).

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. 10. The Institute of Cetacean Research.

Fig. 11. Research vessel leaving Shimonoseki Port.

SURVEY METHODS

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

TRACK LINE

Sighting activities were carried out in the JARPA surveys. The research area was stratified into several small areas. A zigzag track line was 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 was set down randomly every year, using a table of random numbers, so as to avoid going over the same track line (see Fig. 12).

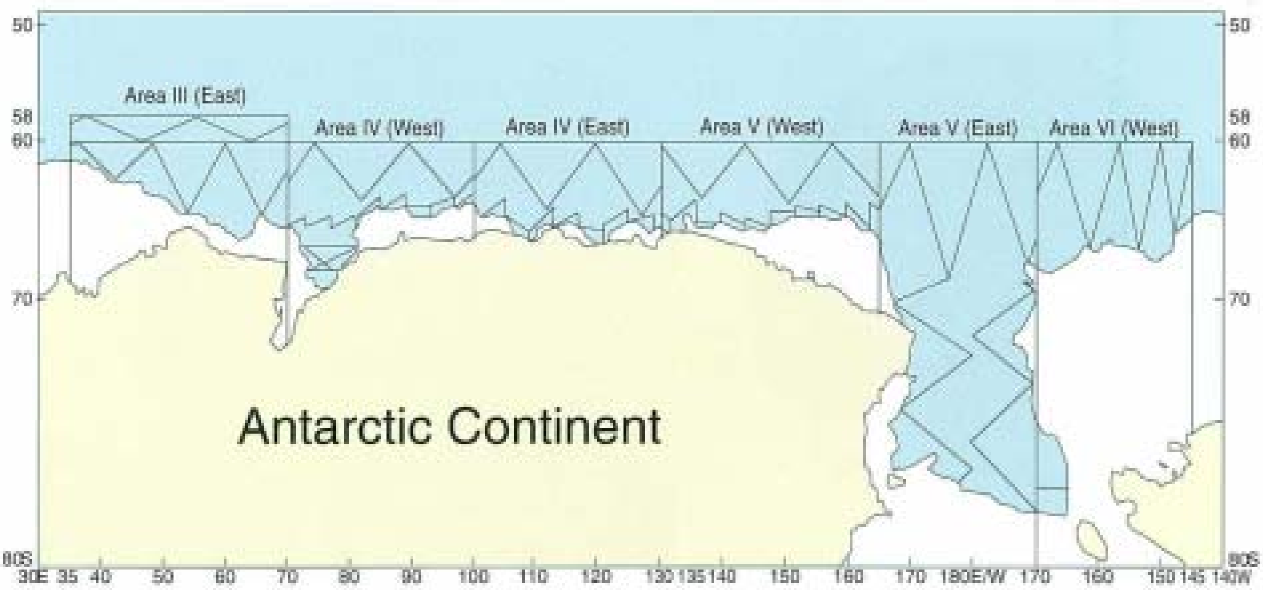

Fig. 12. Track line model diagram in areas III (East), IV, V and VI (West) in the Antarctic Ocean (only shows the main track lines).

RESEARCH FLEET

The research fleet was made up of five vessels: one dedicated sighting vessel, three sampling/sighting vessels, and one research mothership (Figs. 13 to 18 show vessels used for research).

Fig. 13. 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. 14. The sampling/sighting vessel Yushin Maru sailing in close proximity to an iceberg (69.61m, 720 tons).

Fig. 15. The sampling/sighting vessel Kyo Maru No. 1. Since 1987/88 takes part every year in the JARPA program (69.15m, 812 tons).

Fig. 16. 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. 17. 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, 7,659 tons).

Fig. 18. The fishery research vessel Kaiyo Maru (Japan Fisheries Agency) joined 2004/05 JARPA for oceanographic and krill survey.

Role of Research Vessels

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.

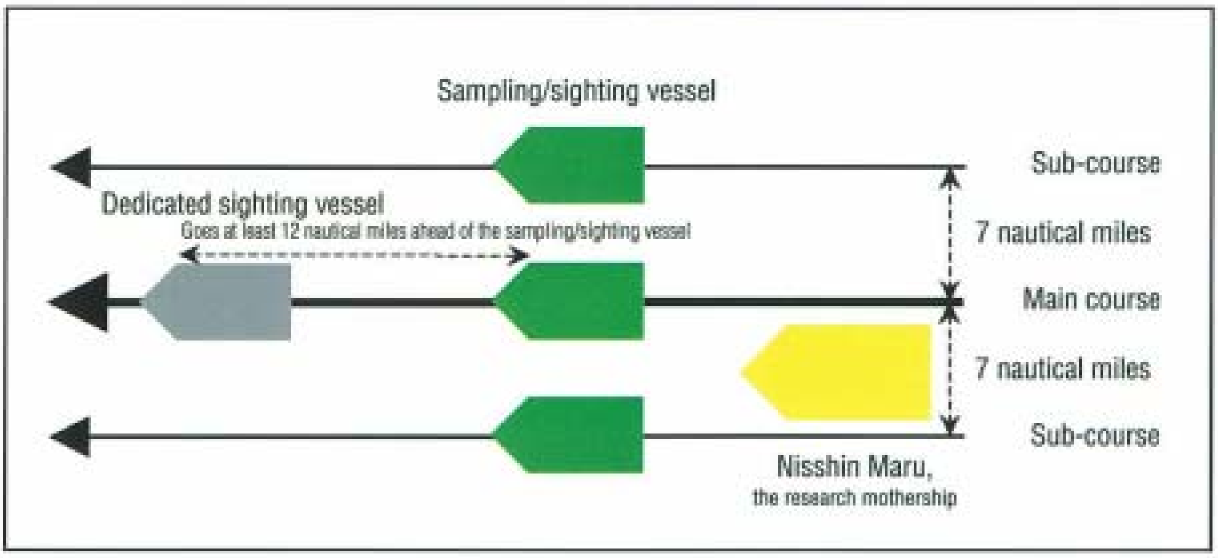

Fig. 19. Configuration of the research vessels. The dedicated sighting vessel goes ahead, followed by the three sighting/sampling vessels, engaging in sampling activities, and the research mothership brings up the rear.

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. 19). 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. 20. 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 and Experiments

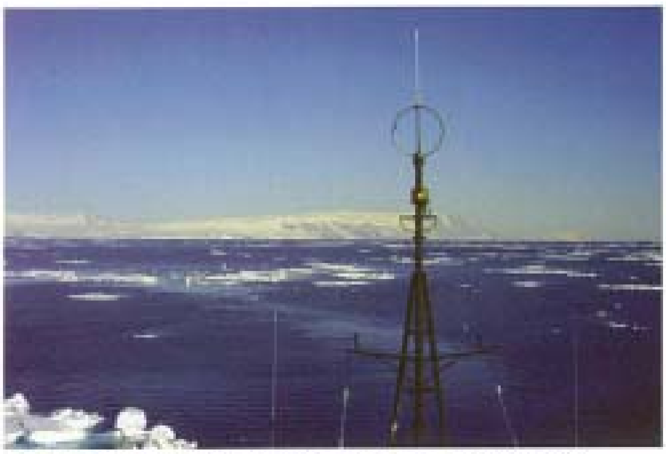

Fig. 21. Looking back towards the stern from the top barrel.

Fig. 22. 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.

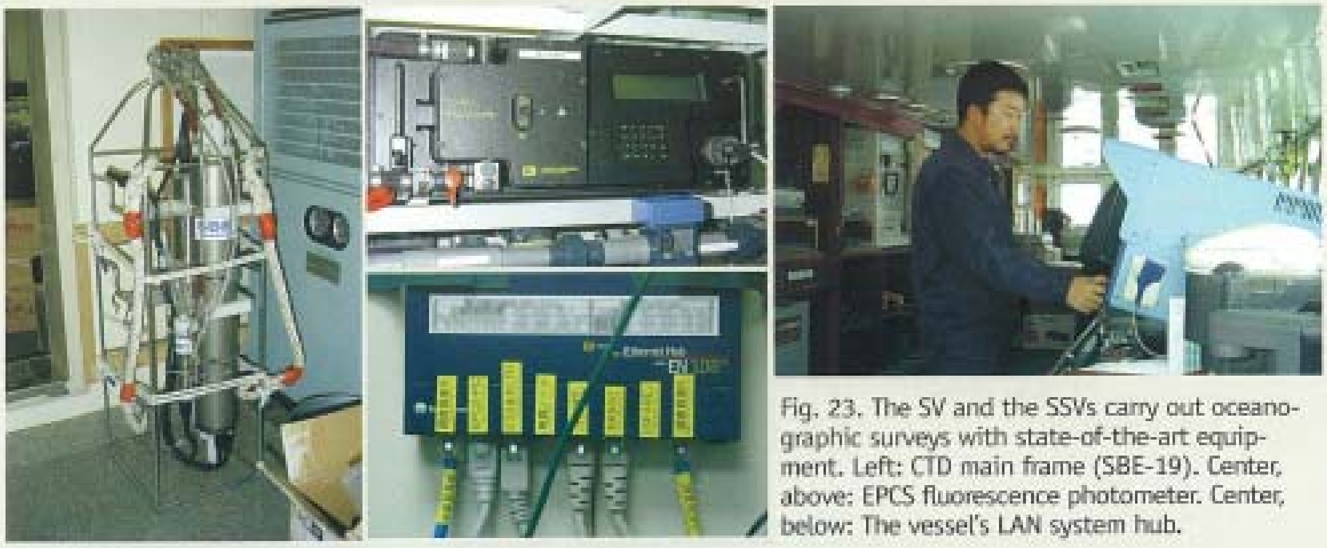

Fig. 23. The SV and the SSVs carry out oceanographic surveys with state-of-the-art equipment. Left: CTD main frame (SBE-19). Center, above: EPCS fluorescence photometer. Center, below: The vessel's LAN system hub.

Cetacean Sightings

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. 24. Antarctic minke whale surfacing. The pointed head is characteristic.

Fig. 25. Sperm whale and its characteristic blow.

Fig. 26. 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 by species observed in the JARPA cruises in each Area between 1987/88 and 2004/05.

	Research area	Eastern Area III		Whole Area IV		Whole Area V		Western Area VI		Total	
Surveyed distance (Miles)		33,010		127,154		111,869		23,178		295,210	
Whale species		Schools	Ind.	Schools	Ind.	Schools	Ind.	Schools	Ind.	Schools	Ind.
Baleen whales	Antarctic minke whale*	**1,608**	**4,707**	**9,587**	**28,099**	**11,756**	**33,239**	**1,211**	**2,502**	**24,162**	**68,547**
	Dwarf minke whale	0	0	17	18	66	66	1	1	84	85
	Humpback whale	849	1,617	4,720	8,916	923	1,665	280	477	6,772	12,675
	Fin whale	285	1,244	245	1,349	409	1,393	83	188	1,022	4,174
	Blue whale	82	162	65	108	77	124	15	21	239	415
	Southern right whale	2	2	123	147	12	13	0	0	137	162
	Sei whale	0	0	4	5	19	34	2	2	25	41
	Large baleen whales	330	711	405	796	514	1,017	155	265	1,404	2,789
Toothed whales	Killer whale	131	673	719	10,049	515	7,906	34	369	1,399	18,997
	Long-finned pilot whale	0	0	68	3,421	23	805	0	0	91	4,226
	Sperm whale	499	513	2,012	2,092	1,049	1,109	135	138	3,695	3,852
	Southern bottlenose whale	261	483	789	1,430	332	608	102	183	1,484	2,704
	Arnoux's beaked whale	6	57	15	138	28	230	0	0	49	425
	Gray's beaked whale	9	46	1	5	10	34	4	11	24	96
	Strap-toothed whale	2	7	0	0	3	6	0	0	5	13
	Hourglass dolphin	22	146	99	634	196	1,249	1	5	318	2,034
	Southern right whale dolphin	0	0	1	15	1	15	0	0	2	30
	Spectacled porpoise	0	0	0	0	2	2	0	0	2	2
	Beaked whales	348	561	1,491	2,643	1,064	1,894	173	273	3,076	5,371
	Pilot whales	1	5	43	2,070	24	617	0	0	68	2,692
	Mesoplodon sp.	13	22	10	23	21	68	5	7	49	120

* Including "like-minke".

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. 27. Measuring of body proportion.

Fig. 28. 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

Taxonomy of Minke Whales

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 species and is restricted to the Southern Hemisphere. The latter includes minke whales from the North Atlantic, North Pacific and Southern Hemisphere dwarf minke whales. Genetic studies conducted under JARPA found that dwarf minke whales were separated from the Antarctic minke whales at the species level and were more closely related to the Northern Hemisphere minke whales, especially to the North Atlantic minke whales (Fig. 29).

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

Distinct morphological differences exist between Antarctic and dwarf minke whales that detectable at sea e.g. the white patch on the base of the flipper. Since the catches of dwarf minke whales in the Antarctic was determined halt in 1993/94, effectively no individuals have been taken, showing that dwarf and Antarctic minke whales can be correctly identified at the field by experienced researchers.

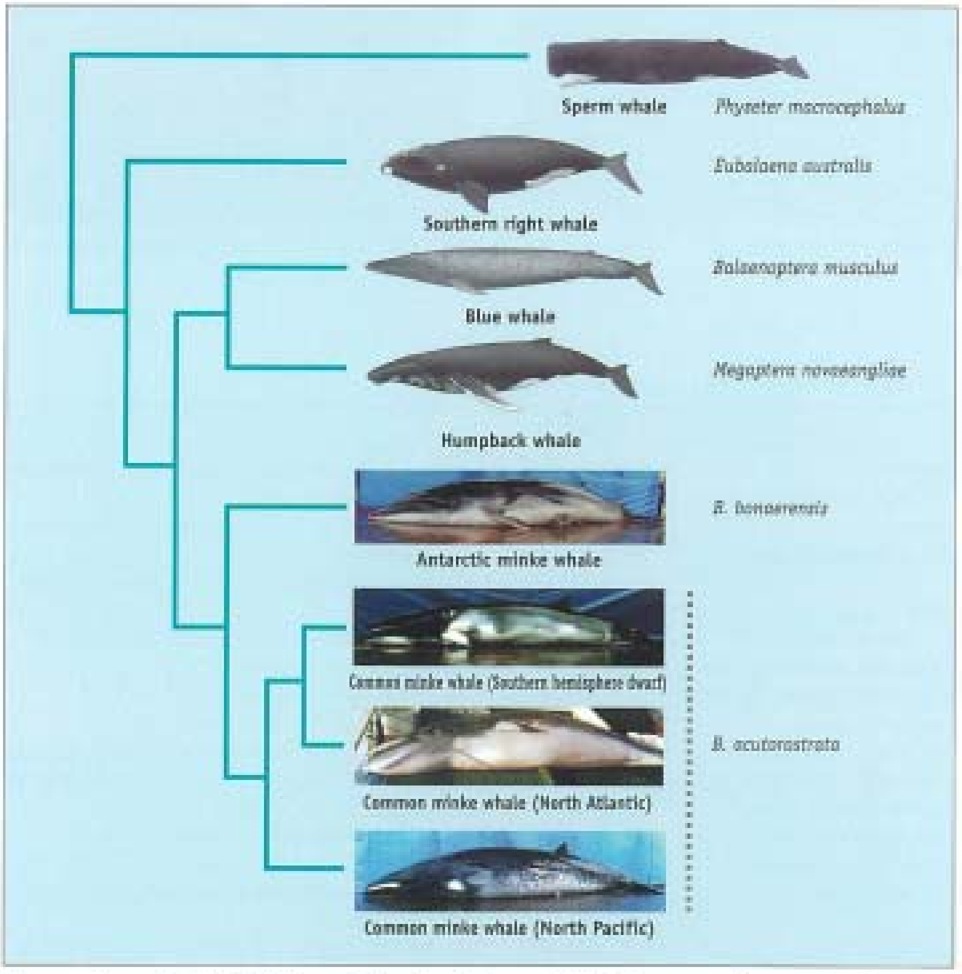

Fig. 29. Phylogenetic analysis of minke whales based on mtDNA. For comparison, other large whale species examined under JARPA, such as humpback, blue, and Southern right whales are included.

Antarctic minke whales are a distinct species.

STOCK STRUCTURE HYPOTHESIS

One of the main objectives of JARPA is to elucidate the stock structure of the Antarctic minke whales to improve stock management. Description and identification of stock structure is important for the estimation of biological parameters and the application of RMP to effectively manage this resource.

Minke whales are believed to undertake seasonal migrations between feeding grounds in the Antarctic waters in summer and breeding grounds in the tropical or temperate waters in winter. The JARPA surveys in Areas IIIE, IV, V, and VIW cover the Antarctic regions adjacent to the eastern Indian Ocean and western South Pacific Ocean where breeding grounds for the minke whales are suggested to be located. The hypothesis to be tested is whether or not minke whales from genetically different stocks occupy the JARPA research area. It could be either only minke whales from the same stock (single stock scenario) or those from the different stocks migrate into the area (two-stock scenario).

In order to test the above hypothesis, genetics (stock differentiation in mtDNA and microsatellite genetic variation) and non-genetics (stock differentiation in mean body length of physically matured whales, morphometrics, and infection rate of *Anisakis simplex*) analyses were conducted using the Antarctic minke whale samples collected during the JARPA surveys from 1987/88 to 2003/04 seasons. The best strategy in identifying stocks is to use the multi-approaches as acknowledged by many other studies.

The different kinds of analyses showed the similar pattern of the stock structure.

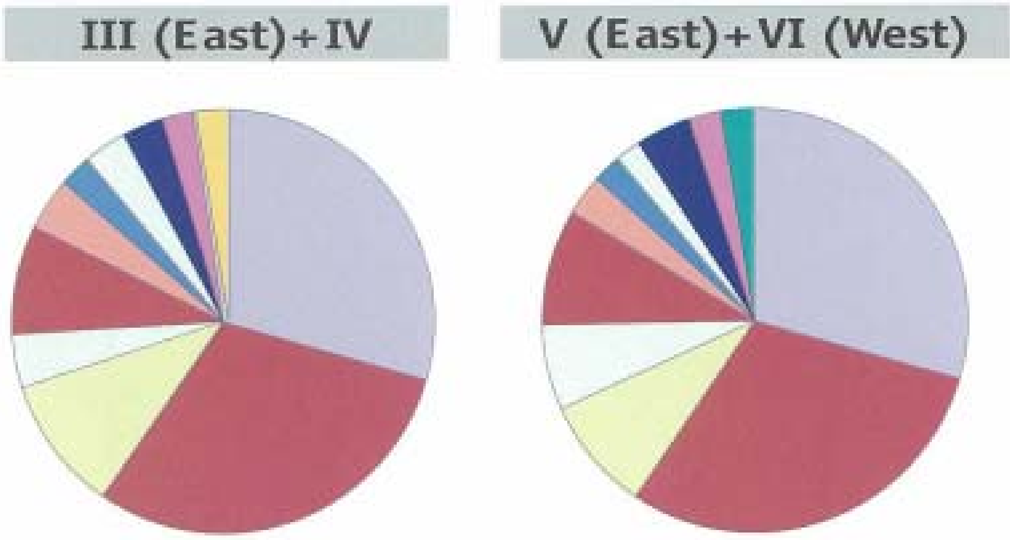

Fig. 30. Haplotype frequencies of mtDNA in the minke whales from the Areas III (East) + IV and V (East) + VI (West).

For instance, mtDNA analysis found substantial genetic heterogeneity between the whales from III (East) and IV and those from V (East) and VI (West), suggesting these whales came from genetically different stocks (Fig. 30). Mean body length at physical maturity significantly differed between the whales from III (East), IV, and V (West) and those from V (East) and VI (West) (Fig. 31). Furthermore, infection by the parasite *Anisakis simplex* was observed mainly in the whales from Areas V and VI (West) (Fig. 32).

Two different stocks of Antarctic minke whales in the research area, i.e., I and P-Stocks.

Stock Structure

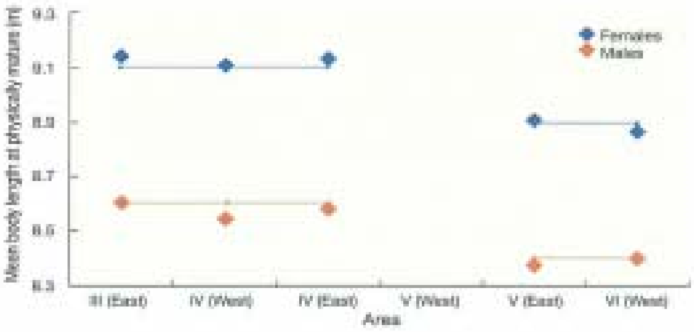

Fig. 31. Mean body length at physically mature minke whales from Areas III (East), IV (West), IV (East), V (West), V (East), and VI (West). Horizontal lines indicate the average length.

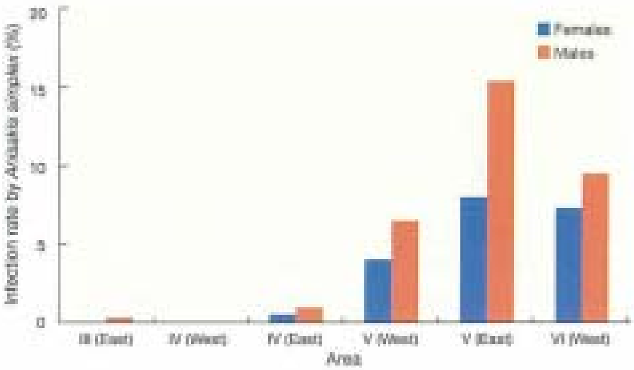

Fig. 32. Infection rate by *Anisakis simplex* in minke whales from Areas III (East), IV (West), IV (East), V (West), V (East), and VI (West).

The multi-analysis approach supported the two-stock scenario in the JARPA research area. Fine scale mtDNA analysis suggested that these stocks could mix around the soft boundary placed at approximately 165˚E. The results also provided no support for the IWC-defined stock boundaries in the Areas III, IV, V, and VI. The mixing rate between the two stocks in the mixing region may vary temporally and spatially due to biotic and abiotic conditions, and the extent of the changes should be investigated in the future years.

The above results were consistent with the past mark-recapture studies conducted in these areas, underneath geography, and oceanographic conditions. Given that the JARPA research area is adjacent to the two suspected breeding areas, it is likely that whales might come from the breeding grounds in eastern Indian Ocean and western South Pacific. These stocks were therefore named as 'Eastern Indian Ocean Stock (I-stock)' and 'Western South Pacific Stock' (Fig. 33).

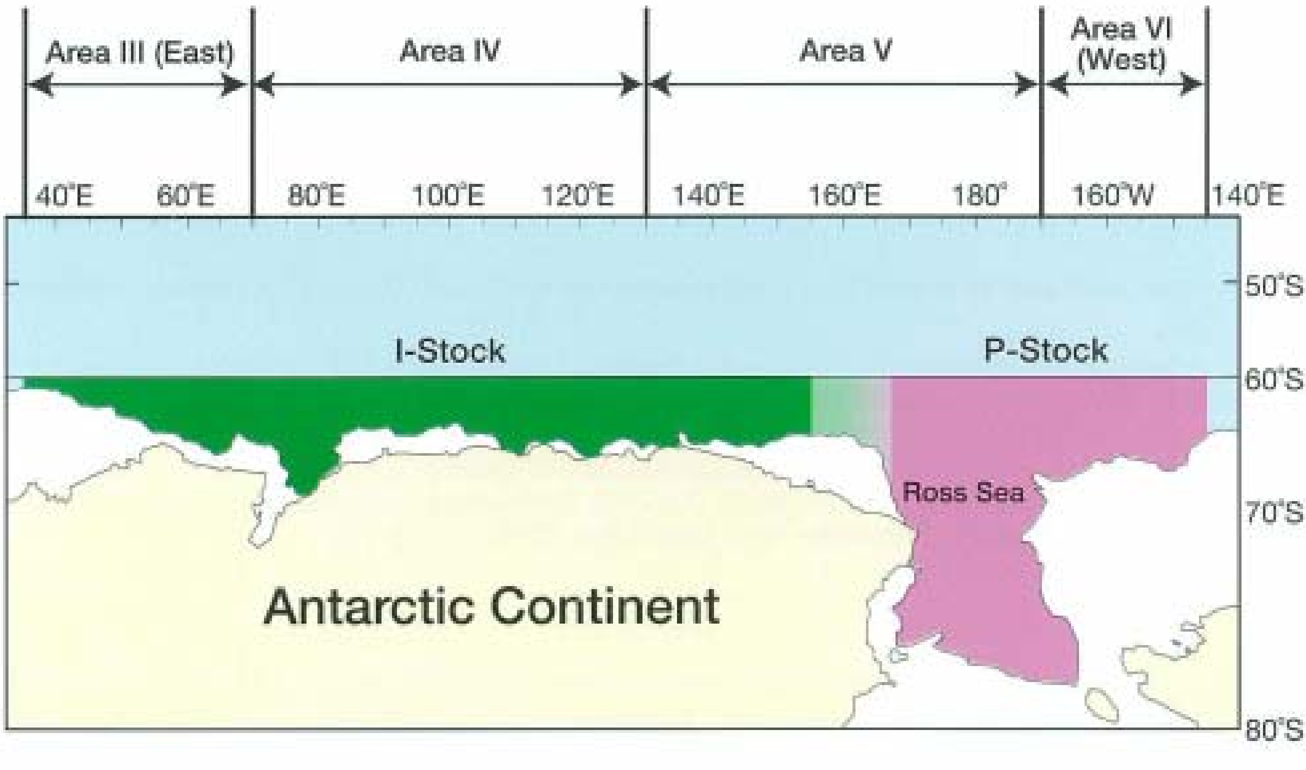

Fig. 33. Stock structure hypothesis based on the multi-analysis approach.

ELUCIDATION OF THE STOCK STRUCTURE OF ANTARCTIC MINKE WHALES

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)[6].

Stock structure under JARPA is investigated using different approaches: genetic analyses based on mitochondrial DNA 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.

INFERRING STOCK STRUCTURE USING GENETIC METHODS

In most animal species, genetic information is passed from generation to generation as a gene. 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 simply 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 family, genus, or 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. 34, 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. 34, 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.

[6] *Revised Management Procedure (RMP)*
In the RMP, catch quotas are calculated for small "small-areas" that have been occupied by whales from one 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 "small-areas" based on the information on stock structure. The 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.

Stock Structure

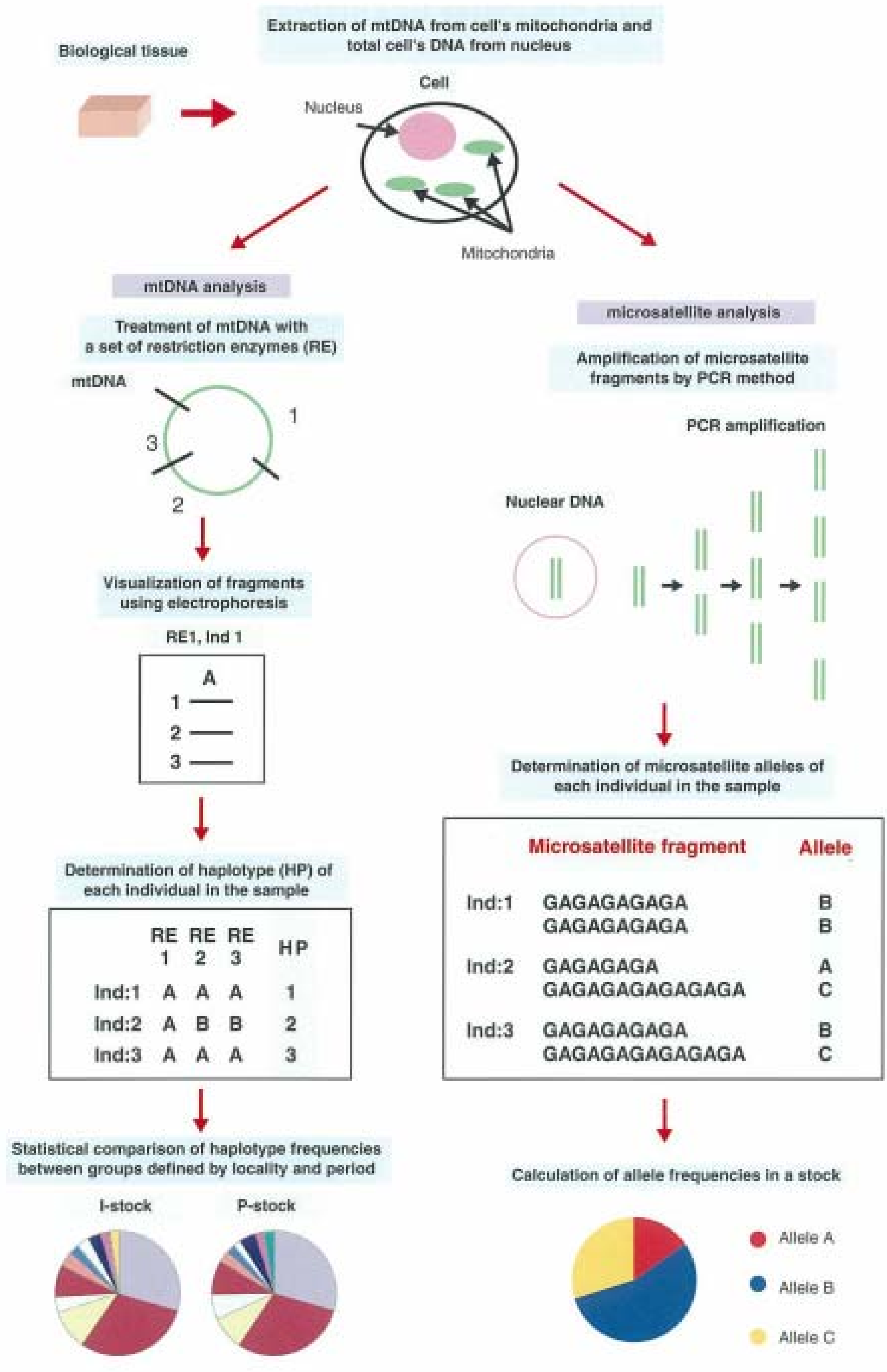

Fig. 34. Scheme of mtDNA and microsatellite analysis.

ESTIMATION OF BIOLOGICAL PARAMETERS

Biological parameters such as natural mortality rate, recruitment rate, age at sexual maturity and age at physical maturity are useful to improve management of whale stocks, and the JARPA surveys have made major contributions in this respect.

BASIC DATA FOR BIOLOGICAL PARAMETER ESTIMATION

Estimation of biological parameters require for basic understanding of age, reproduction and growth. In order to obtain these basic data, earplugs, testes and ovaries are collected and analyzed in the JARPA surveys. Earplug is formed in the external auditory meatus of baleen whales and the core of earplugs shows striped patterns (growth layers: a pair of light and dark laminae) like tree rings. Individual age is obtained by counting growth layers in earplug (Fig. 35). Sexual maturity and reproductive status can be determined by observation of testes and ovaries. The growth continues even after attainment of sexual maturity. Physical maturity is attained when growth has ceased. Physical maturity status can be investigated by examining cartilage between centrum and epiphysis (condition of ossification) in 6th dorsal vertebrae (Fig. 36).

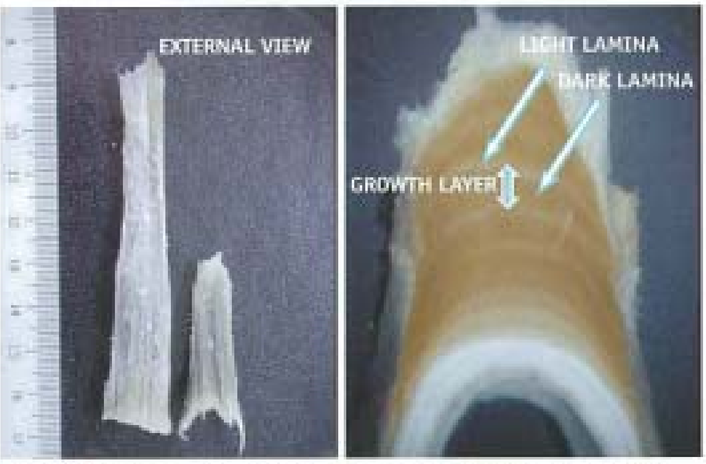

Fig. 35. External view of the earplugs of an Antarctic minke whale (left). The picture in the right is a transversal section of an earplug showing the growth layers.

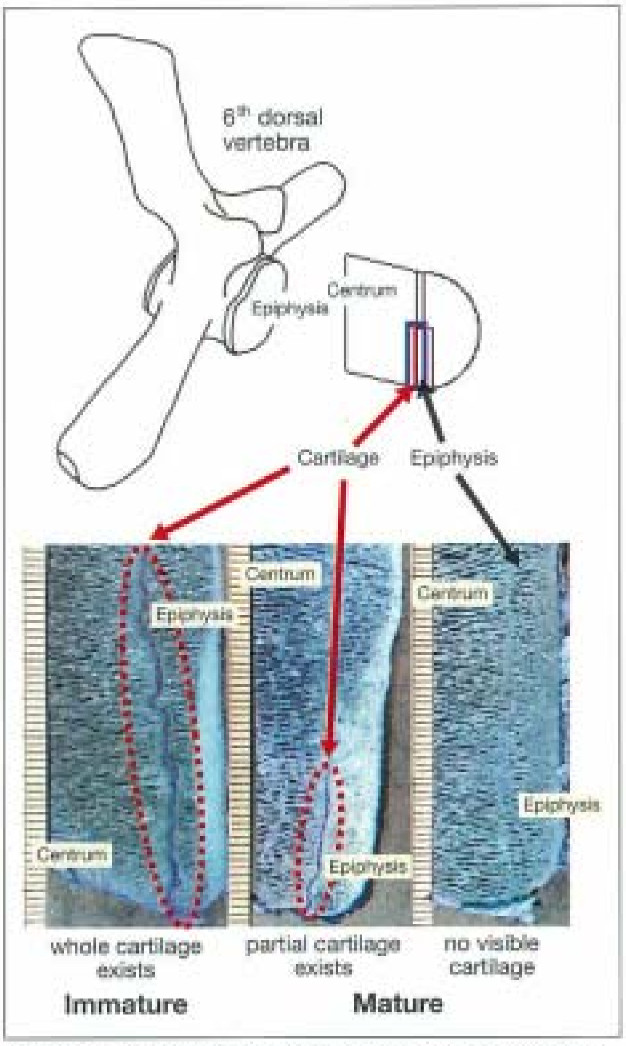

Fig. 36. Criterion of physical maturity. Stained section of 6th dorsal vertebra of three Antarctic minke whales.

ELUCIDATION OF BIOLOGICAL PARAMETERS CONTRIBUTES TO RMP

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

Age at Sexual Maturity

LONG-TERM TREND OF AGE AT SEXUAL MATURITY

It is generally known that the transition phase of growth layers in earplug is an indicator of the age at sexual maturity. Without using this characteristic, it is impossible to estimate the age at sexual maturity of an mature animal and to calculate its cohort by back-calculation from its age at capture. We are able to know long-term trend in age at sexual maturity of Antarctic minke whales by using age and transition phase data.

The analysis of commercial whaling (1971/72-1986/87) and JARPA (1987/88-2003/04) data in Area IV revealed again that the age at sexual maturity declined from 12-13 years in 1945 cohort to around 7 years in late of 1960s cohort (Fig. 37). By incorporating new data set by JARPA, it was newly found that the decline of age at sexual maturity until 1970 cohort which was identified by previous studies had no longer continued and the mean age at sexual maturity had remained constant at 7-8 years or slightly increased from the early 1970s to the late 1980s cohorts; so that these results may suggest less food availability for Antarctic minke whales.

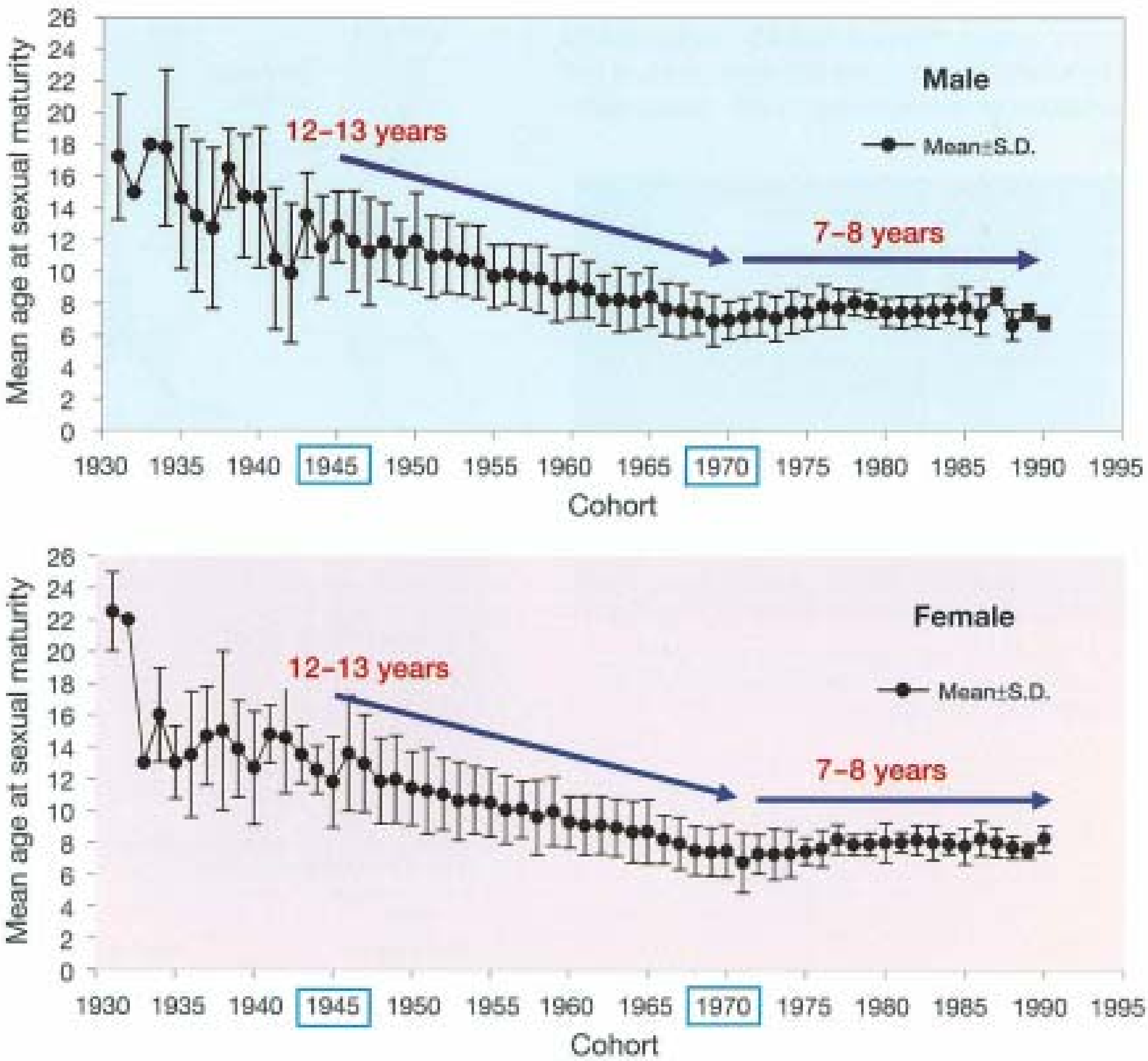

Fig. 37. Yearly change in mean age at sexual maturity derived from transition phase in earplug by cohort for each sex in Area IV. Closed circle shows mean age and solid line shows range of standard deviation.

Changing biological parameters of Antarctic minke whale

ESTIMATION OF BIOLOGICAL PARAMETERS BY STOCK

Analysis of JARPA data revealed that two stocks of Antarctic minke whale ('Eastern Indian Ocean Stock': I-stock and 'Western South Pacific Stock': P-stock) are distributed in the research area. Various biological parameters were estimated for each stock by using JARPA data obtained from 1987/88-2003/04 surveys.

Sexual Maturity

Body length at which 50% of males attained sexual maturity (male body length at sexual maturity) was estimated as 7.3m for I-stock and 7.1m for P-stock, respectively. Age at 50% sexual maturity for male was estimated as 5.3 years for both stocks.

Female body length at sexual maturity was estimated as 8.2m for I-stock and 8.0m for P-stock. Age at 50% sexual maturity of female was estimated as 7.6 years for I-stock and 8.2 years for P-stock, respectively (Fig. 38).

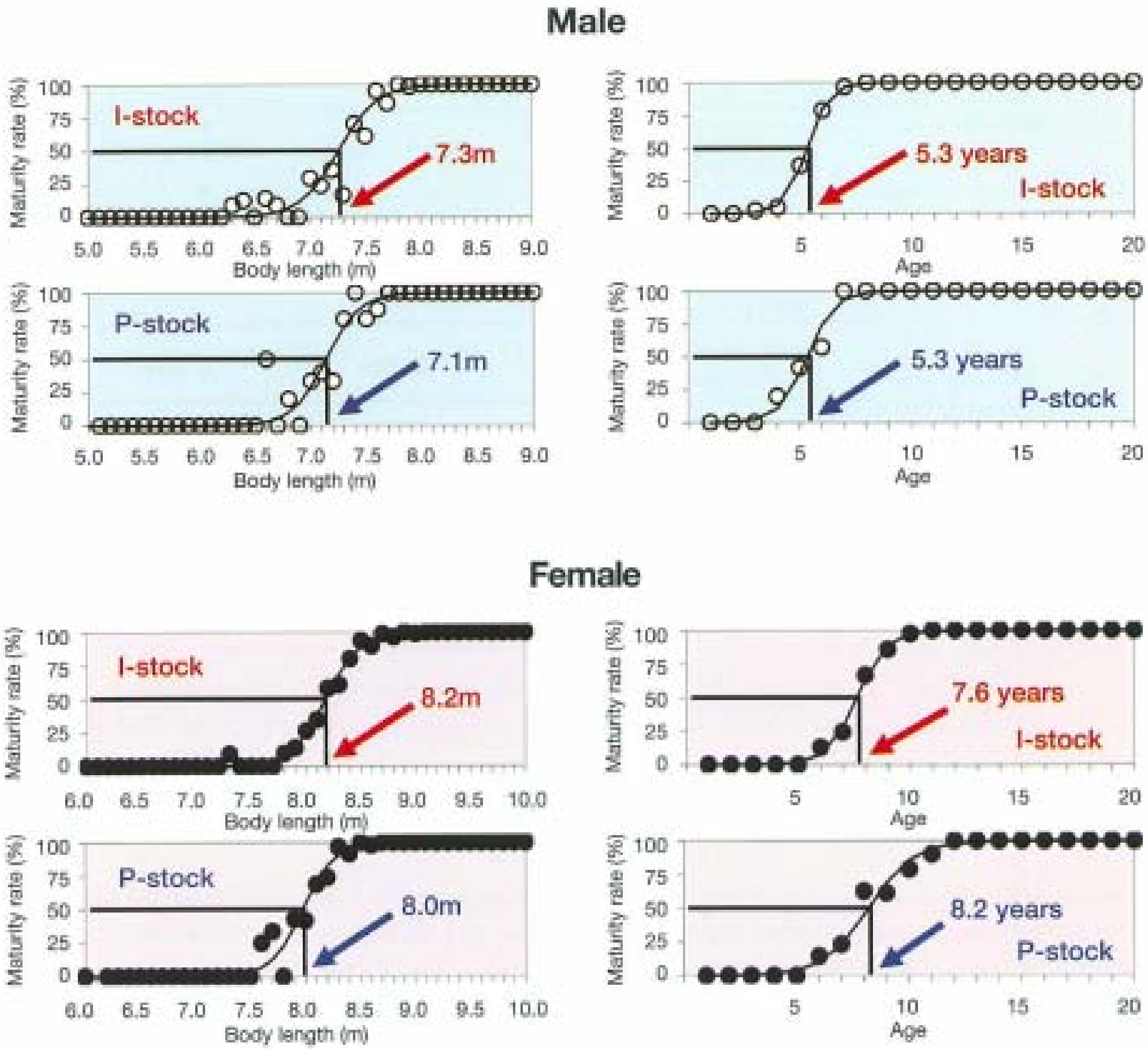

Fig. 38. Estimated body length (left) and age (right) at 50% sexual maturity of Antarctic minke whales in each sex and biological stock.

Estimation of Biological Parameters

In addition to the method of 50% sexual maturity, age and body length at sexual maturity of females were estimated by calculating mean age and body length of the whales at first ovulation. Body length at sexual maturity was estimated as 8.4m for I-stock and 8.3m for P-stock, respectively. Age at sexual maturity was estimated as 7.9 years for I-stock and 8.6 years for P-stock, respectively.

Table 5. Biological parameters of Antarctic minke whales estimated by biological stock. Bold values show significant difference between two stocks.

Male		I-stock	P-stock
Sexual maturity	Body length at 50% maturity	7.3m	7.1m
	Age at 50% maturity	5.3 years	5.3 years
Physical maturity	Body length at 50% maturity	**8.3m**	**8.2m**
	Age at 50% maturity	16.6 years	16.7 years
Female		**I-stock**	**P-stock**
Sexual maturity	Body length at first ovulation	8.4m	8.3m
	Body length at 50% maturity	**8.2m**	**8.0m**
	Age at first ovulation	7.9 years	8.6 years
	Age at 50% maturity	**7.6years**	**8.2years**
Physical maturity	Body length at 50% maturity	**9.0m**	**8.7m**
	Age at 50% maturity	20.6years	19.8years

Physical Maturity

Body length at 50% physical maturity of male was estimated as 8.3m for I-stock and 8.2m for P-stock. Age at 50% physical maturity was estimated as 16.6 years for I-stock and 16.7 years for P-stock, respectively. In the female, body length at 50% physical maturity was estimated as 9.0m for I-stock and 8.7m for P-stock. Age at 50% physical maturity was estimated as 20.6 years for I-stock and 19.8 years for P-stock, respectively. Body length at sexual and physical maturity showed higher value in I-stock than P-stock and age at sexual maturity showed lower value in I-stock than P-stock.

Other Parameters

Proportion of pregnant whales in sexually matured females is high for both stocks (92.5% for I-stock and 87.4% for P-stock, respectively). Almost all pregnant whales had only one fetus and multiple fetus is very rare (occurrence of multiple: 0.006 for I-stock and 0.016 for P-stock, respectively). Male ratio of fetus is 51.8% for I-stock and 46.7% for P-stock, respectively.

YEARLY CHANGE OF AGE AT PHYSICAL MATURITY

Increasing trend was detected on age at physical maturity for both sexes and stocks (Fig. 39). This means that more time is needed to attain physical maturity in recent years. Decreasing trend in age at sexual maturity ceased for Antarctic minke whale and the cause was thought as the result of decrease in food availability. The increasing trend detected in age at physical maturity is also showing the possibility that nutritional condition of Antarctic minke whale is deteriorating. Further monitoring of biological parameters is needed.

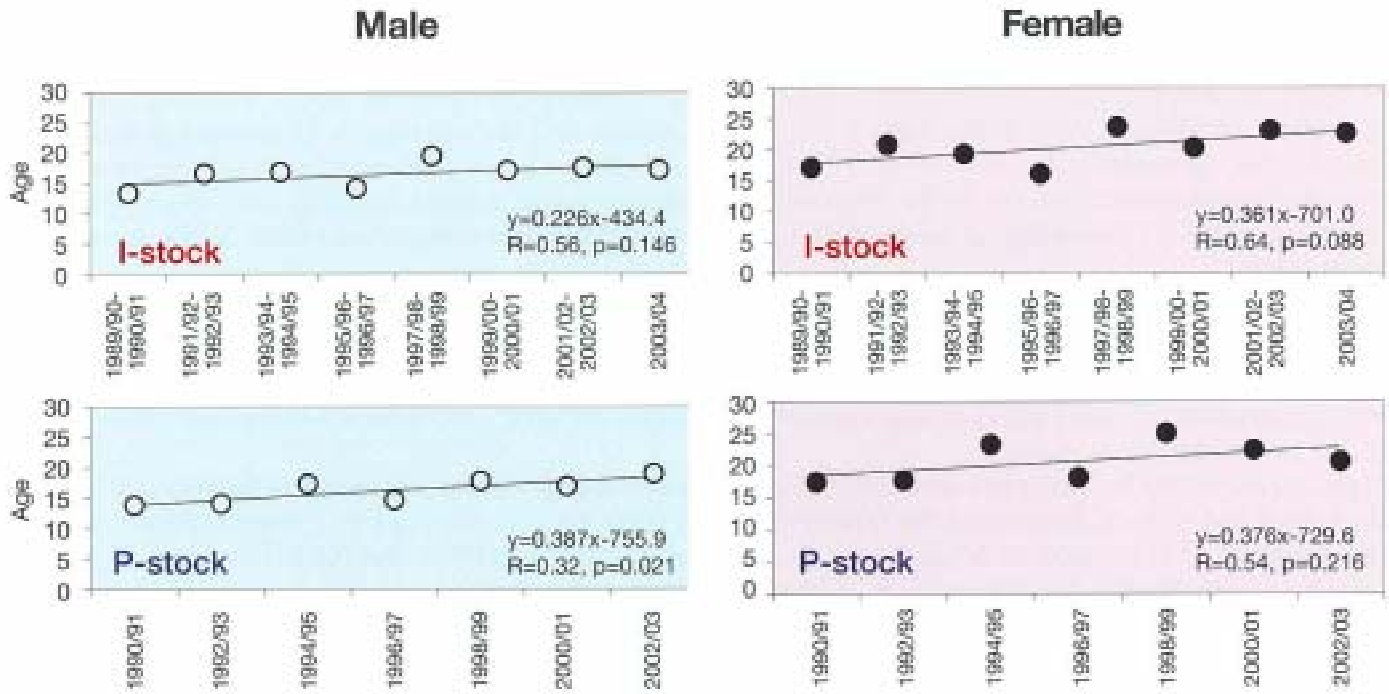

Fig. 39. Yearly change in age at physical maturity for each sex and biological stock.

WHAT IS SUGGESTED BY YEARLY TREND OF BIOLOGICAL PARAMETERS?

It was suggested that the yearly changes of biological parameters estimated using commercial data in the Antarctic minke whale such as decline of age at sexual maturity and increase of the growth rate were caused by depletion of other large baleen whales such as blue, fin and humpback whales which had a strong competitive relation to Antarctic minke whales, and this phenomenon led to greater availability of food for minke whales.

Through the JARPA data analysis it was found that the decline of age at sexual maturity was no longer continued, and it remained constant or has been increasing slightly. The increasing trend of age at physical maturity is also observed. It is considered that the present results may suggest less amount of food availability for Antarctic minke whales, which is reflected by a constant or increasing trend of age at sexual maturity and increase of age at physical maturity.

The biological parameters changing in accordance with not only changes in their own population but also change of ecological competition and change of environmental circumstances will be useful indicator for understanding of change in the marine ecosystem.

Therefore, it is important to provide information for rational management of the Antarctic whales through long-term monitoring of biological parameters of some baleen whale species.

Natural Mortality and Recruitment

NATURAL MORTALITY AND RECRUITMENT OF ANTARCTIC MINKE WHALES

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 were used to estimate natural mortality coefficient *M*. 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.

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 demographics. Studying these factors is very important for the safe management of whale stocks. Together with pregnancy rate, natural mortality coefficient[7] (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 Coefficient *M* and Recruitment trend

There are several ways to estimate natural mortality Coefficient. 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.

M was estimated by Tanaka's method and VPA analysis (see next page). *M* was estimated as 0.0486 and 0.0490 for I-stock and P-stock, respectively by Tanaka's method. There are two estimates by applying VPA separately. One estimate of *M* is 0.068 in Areas IV and V combined. Another is 0.0788 and 0.0497 in Areas IV and V, respectively. In future, further analyses by both methods should be conducted to estimate M and their precision for I-stock and P-stock, respectively.

Estimation of Recruitment trend

Recruitment trend was estimated by using VPA. Their estimate of recruitment trend is shown in Fig. 40. Recruitment has a peak in 1960s and it had decreased from 1960s to 1980s. From 1990, there was observed no significant trend in Recruitment.

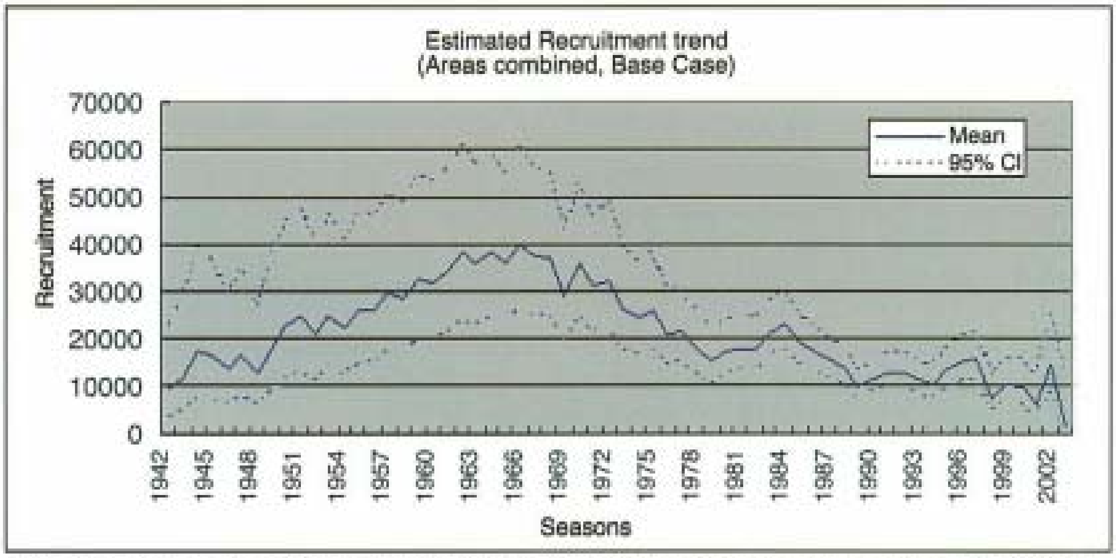

Fig. 40. Estimated recruitment trend in Areas IV and V combined (Mori and Butterworth, 2005).

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

ESTIMATION OF MSYR (MAXIMUM SUSTAINABLE YIELD RATE)

MSYR is defined as MSY (maximum sustainable yield) divided by MSYL (i.e. population level that attains maximum sustainable yield). MSYR is an index of increasing rate of the population. MSYR cannot be estimated from VPA directly because population dynamics model used in VPA don't include reproductive terms (i.e. don't have parameters related to MSYR), as explained above. Estimation of MSYR was initially attempted by fitting a recruitment model of the Pella-Tomlinson form to recruitment series and mature female abundance estimates from VPA. The estimated MSYR(1+) is 4.0%.

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 $D = 1\text{-}e^{-M}$.

VPA (Virtual Population Analysis)

How can we estimate recruitment trend by VPA? It is a method to estimate abundance by age using catch-at-age data and natural mortality coefficient estimate. For example, assuming we know abundance of an animal aged 10 and the number of death for this animal by year and age, we can calculate abundance of animals aged 9 last year by adding the numbers of death of animals aged 9 last year to abundance of animals aged 10 present year. By repeating a procedure like this more 9 times, we can obtain the number of animals aged 0 (i.e. the number of births) ten years ago. Similarly, we can obtain the number of births 11 years ago from information of the number of animals aged 11. In this way, we can estimate the number of births in previous years. A merit of VPA is that we can estimate the birth by year without strong assumption as for birth rate or increasing rate, which are difficult to estimate (As explained in this example, we can estimate the number of births without information about birth rate.).

Natural mortality coefficient for Antarctic minke whales was estimated from JARPA data.

Researching the Antarctic Ecosystem

RESEARCHING THE ANTARCTIC ECOSYSTEM

Krill is the major prey for baleen whales, pinnipeds, birds, and fish in the Antarctic ecosystem. It is not an overstatement to say that all the animals living in the Antarctic are competing with each other over krill. Some of the latest research techniques are used in the JARPA surveys, to study the distribution and abundance of krill using concurrent whale and prey surveys. 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, whereas distributions of humpback whales correlated with high krill density zones not only in the continental shelf slope but also in offshore area (see Fig. 41).

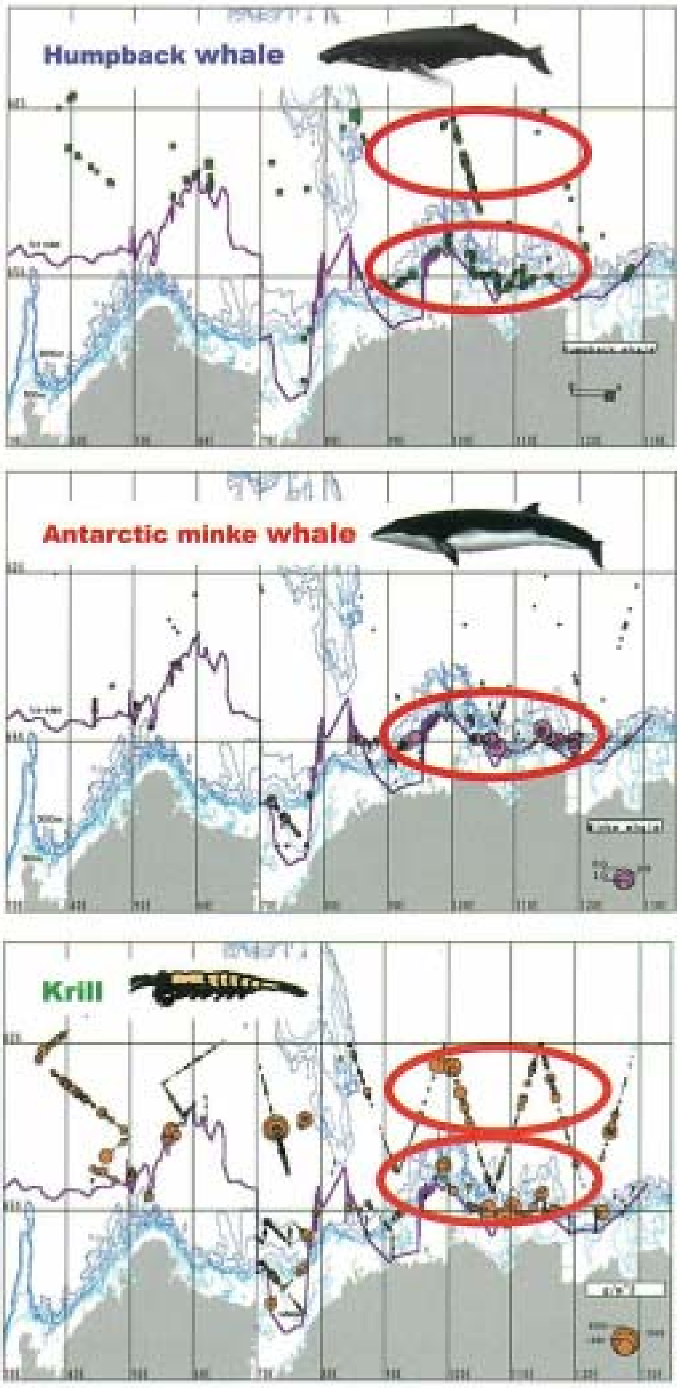

Fig. 41. Distributions of humpback (top) and Antarctic minke whales (middle) and krill (bottom) in the 1999/2000 JARPA surveys. Blue lines show isobaths, and the thick purple line represents ice-edge (Murase *et al.* (2002), revised).

Krill Consumption Estimation and Blubber Thickness

ESTIMATION OF KRILL CONSUMPTION OF ANTARCTIC MINKE WHALES

One of the major objectives of JARPA is to elucidate the role of whales in the Antarctic Ocean ecosystem. The body weight of Antarctic minke whales (Fig. 42), and the weight of stomach contents were measured directly to estimate the daily amount of prey consumed (Fig. 44). We found that they consumed an average of 240 to 370 kg (mature animals) of prey, corresponding to 3.6 to 5.3% of their body weight.

Fig. 42. Antarctic minke whale weight measurement.

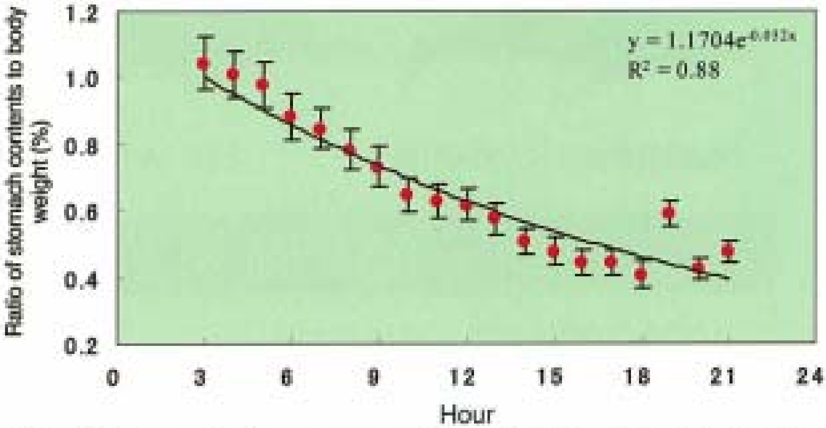

Fig. 44. Changes in diurnal consumption rate of Antarctic minke whales.

Fig. 43. Antarctic krill.
Stomach contents of Antarctic minke whale.

TREND OF BLUBBER THICKNESS

Blubber thickness is an indicator of energy storage for whales. This graph (Fig. 46) shows the yearly trend of blubber thickness of the Antarctic minke whales in the late period of feeding season (February). It has decreased in both males and females in Area IV. This result confirms the deterioration of food availability for minke whale in this area. The shortage of food availability could cause many negative impacts to the minke whale population. Although many factors affect on the food abundance in the Antarctic Ocean, the competition among other large baleen whales and crabeater seals should be considered.

Fig. 45. Crabeater seals.

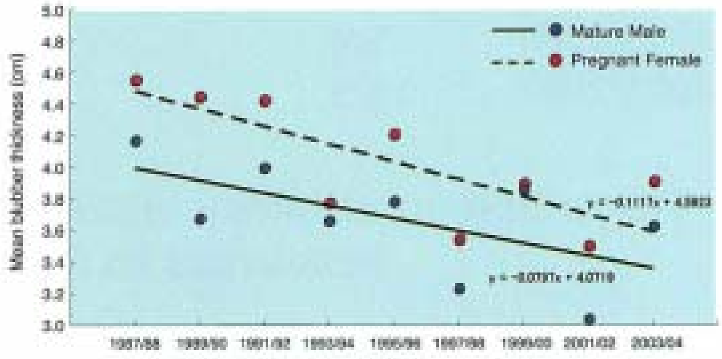

Fig. 46. Yearly change in blubber thickness of Antarctic minke whales.

Has been food availability decreased?

Hypothesis on the Competition among Baleen Whales

HUMPBACK WHALE vs. FIN WHALE vs. ANTARCTIC MINKE WHALE (Area IV: 70E – 130E)

	Humpback whale	Fin whale	Antarctic minke whale
ABUNDANCE (individuals)			
1999/2000	16,211	1,162	44,572
2001/2002	33,010	7,642	61,463
KRILL CONSUMPTION (tons)			
1999/2000	2,157,000	283,000	1,347,000
2001/2002	4,392,000	1,860,000	1,850,000

KRILL BIOMASS (tons)

1999/2000	36,420,000
2001/2002	38,120,000

CONSUMPTION RATES IN KRILL BIOMASS (%)

	Humpback whale	Fin whale	Antarctic minke whale
1999/2000	5.9	0.8	3.7
2001/2002	11.5	4.9	4.9

Three baleen whales consumed 10-21 % of krill resources in Area IV.

Fig. 47. Competition among baleen whales in the Antarctic ecosystem.

There might be competition among these baleen whales in the Antarctic!

MONITORING CONTAMINATION OF THE ANTARCTIC OCEAN

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 far below the provisional restriction standard set down by the Ministry of Health, Labor and Welfare by a very wide margin (Fig. 48).

Pollutant concentration in whales provides an indication of marine contamination in the seas they inhabit. The JARPA surveys help to monitor oceanic pollution in the Antarctic. Pollutant levels in whales can be influenced by contamination levels in the atmosphere and the seawater, their food items and the age, however our results suggest that those in the Antarctic Ocean are the lowest in the world. These levels suggest that environment of Antarctic minke whales is clean and that these have not negative effects on the health of whale species.

The JARPA program is designed to repeat surveys in the same area during the same season and with the same methods, and is the most appropriate sign for examining the yearly changes in the environment and picking up long term trends. HCHs and HCB levels in blubber of Antarctic minke whales significantly decreased during 1988/89 and 2002/03 seasons on JARPA surveys, while yearly changes of PCBs and DDTs are unclear.

Annual changes detected in concentration of pollutants 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 pollutant monitoring activities, and are expected to provide valuable information.

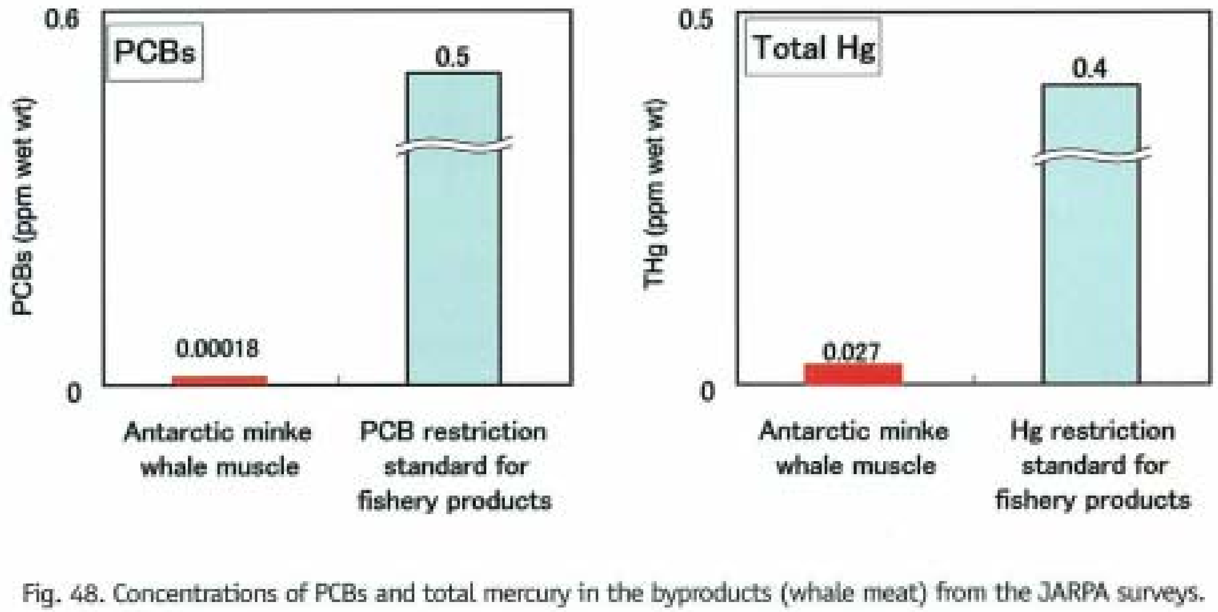

Fig. 48. Concentrations of PCBs and total mercury in the byproducts (whale meat) from the JARPA surveys.

The pollutant levels of Antarctic minke whales in the Antarctic Ocean are the lowest in the world

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 temporal variations. According to the data obtained in the research cruises from 1989/90 to 2003/04, it was revealed that the stock abundance in the research areas (Areas IV and V) shows no significant increase or decrease in yearly trend (Fig. 49 and 50).

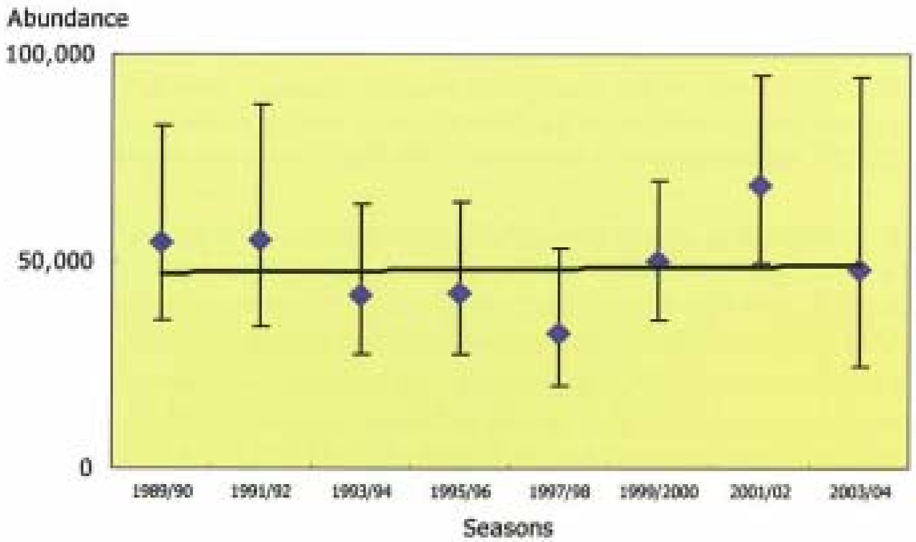

Fig. 49. The regression curve above shows the abundance trend of Antarctic minke whales from 1989/90 to 2003/2004 for Area IV. The vertical lines indicate the 95% confidence interval[8] for the estimate.

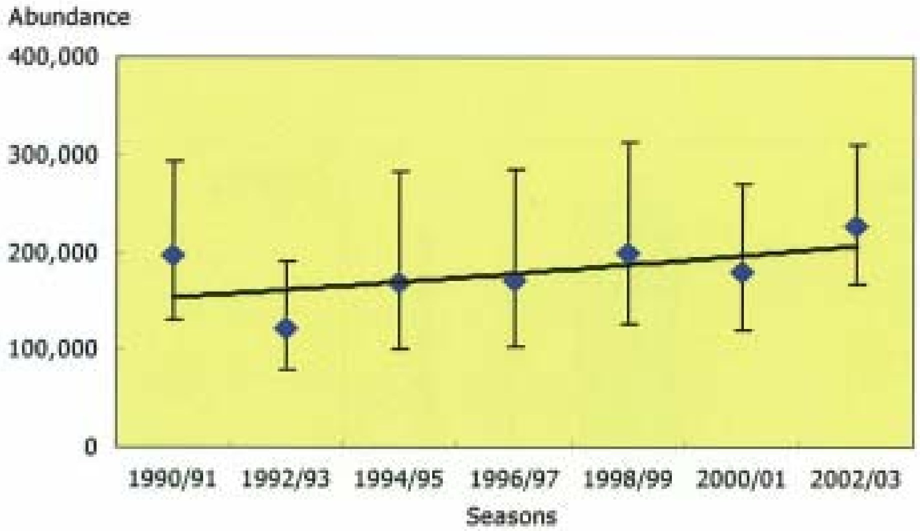

Fig. 50. The regression curve above shows the abundance trend of Antarctic minke whales from 1990/91 to 2002/2003 for Area V. The vertical lines indicate the 95% confidence interval[8] for the estimate.

Antarctic minke whale abundance is consistently high.

[8] *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 assume that the true value is included in this range.*

Antarctic Minke Whale Abundance

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 estimated to be about 80,000, it can be said that Antarctic minke whale abundance is stable at a consistently high level, recently.

Fig. 51. School of Antarctic minke whales.

JARPA AND IDCR/SOWER

In the JARPA program, we survey Areas IV and V every other year. The two areas have been surveyed eight times each in the sixteen years from 1989/90 to 2004/05. 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 temporal changes in Antarctic minke whale abundance.

Fig. 52. 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 Shonan Maru, 2001).

Trend in Other Baleen Whales

INCREASE IN ABUNDANCE OF LARGE WHALES

In the Antarctic Ocean, catch of southern right, humpback, blue, fin and sei whales was prohibited in 1932, 1963, 1964, 1976 and 1978, respectively. Seventy years have passed already since southern right whale has been protected, and more than 40 years have passed since humpback whale and blue whale have been protected. In coastal waters of South America, South Africa and east and west coast of Australia, significant recovery of southern right and humpback whales are reported recently in these breeding areas (Table 7). On the other hand, the information on the present status of pelagic species, such as blue, fin, sei and minke whales was limited from surveys in the coastal waters. JARPA has been monitoring baleen whale populations by the large-scale and long-term line transect survey for over 16 years in Areas IV and V.

Humpback whale

Abundance of humpback whales in Area IV has increased and recent abundance estimate (by the dedicated sighting vessel) is 31,750 whales (Matsuoka *et al.*, 2005). The sighting results show that the humpback whale stocks in the Antarctic Ocean are rapidly recovering.

Fig. 53. 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.

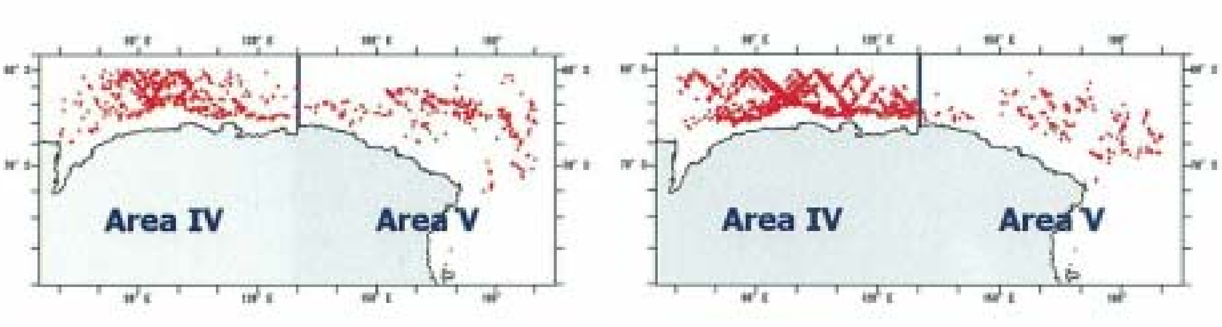

Fig. 54. The sighting positions of humpback whales in the first half (Left; from 1989/90 to 1996/97) and in the later half (Right; from 1997/98 to 2003/04) by three sighting and sampling vessels. The number of sightings increased in the second half.

Rapid increase of humpback whales

Trend in Other Baleen Whales

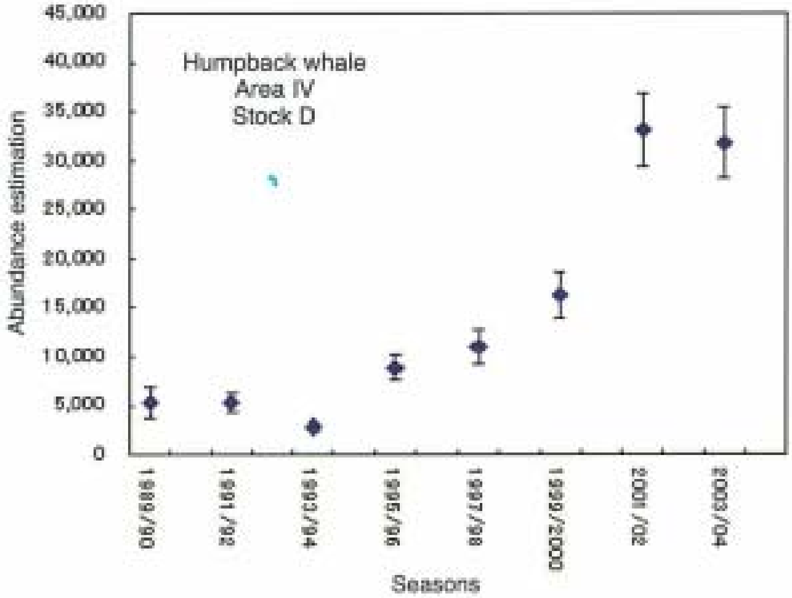

Fig. 55. Yearly trend in abundance estimates of humpback whale in Area IV (south of 60°S) between 1989/90 and 2003/2004 seasons. Vertical lines show standard errors.

Fin whale

Recent estimates of fin whales in the whole area south of 60°S based on the IWC/IDCR and SOWER data were 2,100 (1978/79-1983/84, CV=0.36), 2,100 (1985/86-1990/91, CV=0.45) and 5,500 (1991/92-1997/98: not completed, CV=0.53) in the first, second and third circumpolar series, respectively (Branch and Butterworth, 2001). Present JARPA estimate of 15,000 (CV=0.20) in the half of Antarctic Areas (south of 60°S, 35°E -145°W) indicates significant increases of fin whales in these Areas.

Fig. 56. A school of two fin whales in the Antarctic Ocean. The fin whale's jaw is black on the left side and white on the right side.

Trend in Other Baleen Whales

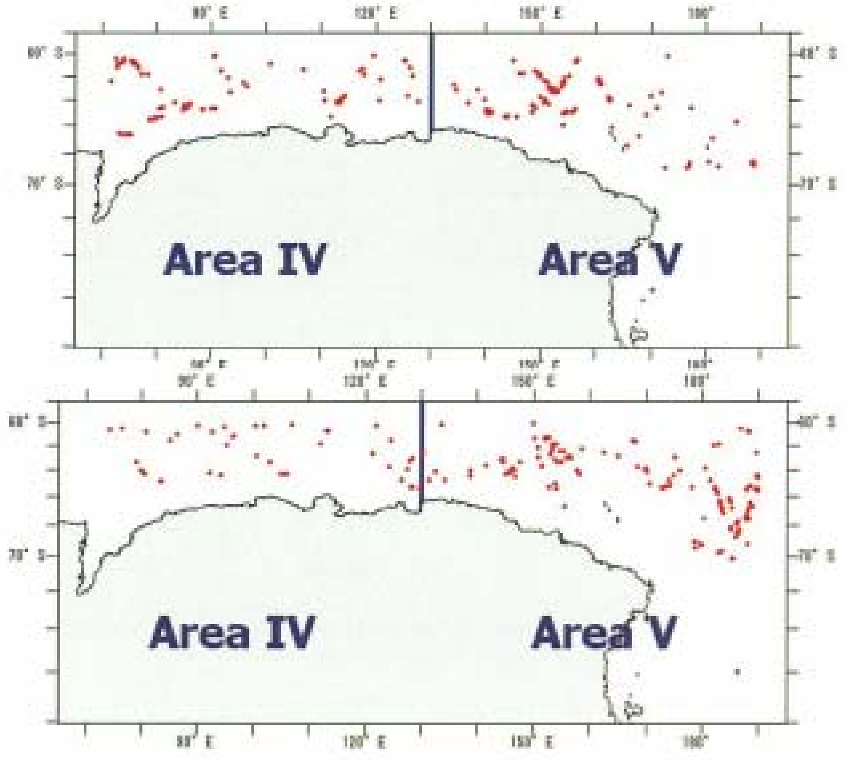

Fig. 57. The sighting positions of fin whales in the first half (Left; from 1989/90 to 1996/97) and in the later half (Right; from 1997/98 to 2003/04) by three sighting and sampling vessels.

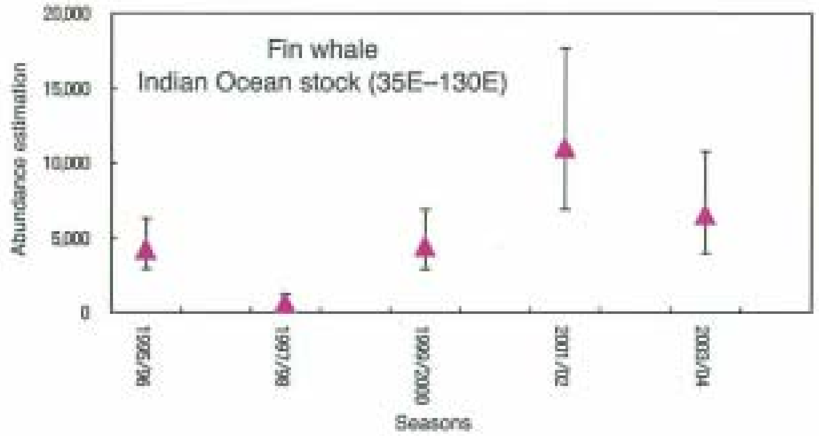

Fig. 58. Yearly trend in abundance estimates of fin whale for the Indian Ocean stock (south of 60°S, 35°E-130°E) surveyed between 1989/90 and 2003/2004 seasons. Vertical lines show standard errors.

In the Southern Hemisphere, the southern right whale also shows a rapid recovery with a high increase rate (Table 7). 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. 59. Southern right whale.

Fig. 60. Blue whale.

Blue whale

Initially, there were as many as 200,000 blue whales in the whole Antarctic as calculated by a logistic model, but their number was greatly reduced by over-hunting, and their take was banned in 1964. After forty years, however, they are still small in number less than 2,000 (Branch *et al*, 2004). In the JARPA research area, blue whales were rarely encountered by the surveys though they were widely distributed in the research area. Abundance of this species (south of 60°S, 35°E-145°W) was 900 (CI: 500-1,600) in 1999/2000 + 2000/01 seasons and 500 whales (CI: 300-1,000) in 2001/02 + 2002/03 seasons. They are still less than 1,000 in number (biomass: less than 8,000 tons) in the JARPA research area and so far from recovering.

Blue whale? still small in number

Trend in Other Baleen Whales

SHIFT IN BALEEN WHALE DOMINANCE IN AREA IV

A "shift in baleen whale dominance" from Antarctic minke to humpback whales, was observed in Area IV since 1997/98 season. In 1989/90 season, biomass of Antarctic minke was higher (382,000 tons) than humpback whales (128,000 tons), and after 15 years, the biomass of humpback whales (841,000 tons) increased twice than that of Antarctic minke whales (335,000 tons). Habitat expansion of humpback and fin whales were also observed in Area IV from the first half (1989/90-1996/97) to the later half of surveys (1997/98 -2002/04). During this period, abundance of Antarctic minke whales is stable in Area IV, however, increases of abundance and habitat expansion of humpback and fin whales, may cause competition with Antarctic minke whales. Yearly change in some biological features also suggest this "Event". Further monitoring survey of the Antarctic ecosystem is necessary to follow the change in the ecosystem and such information is essential for the baleen whale management in the Antarctic Ocean.

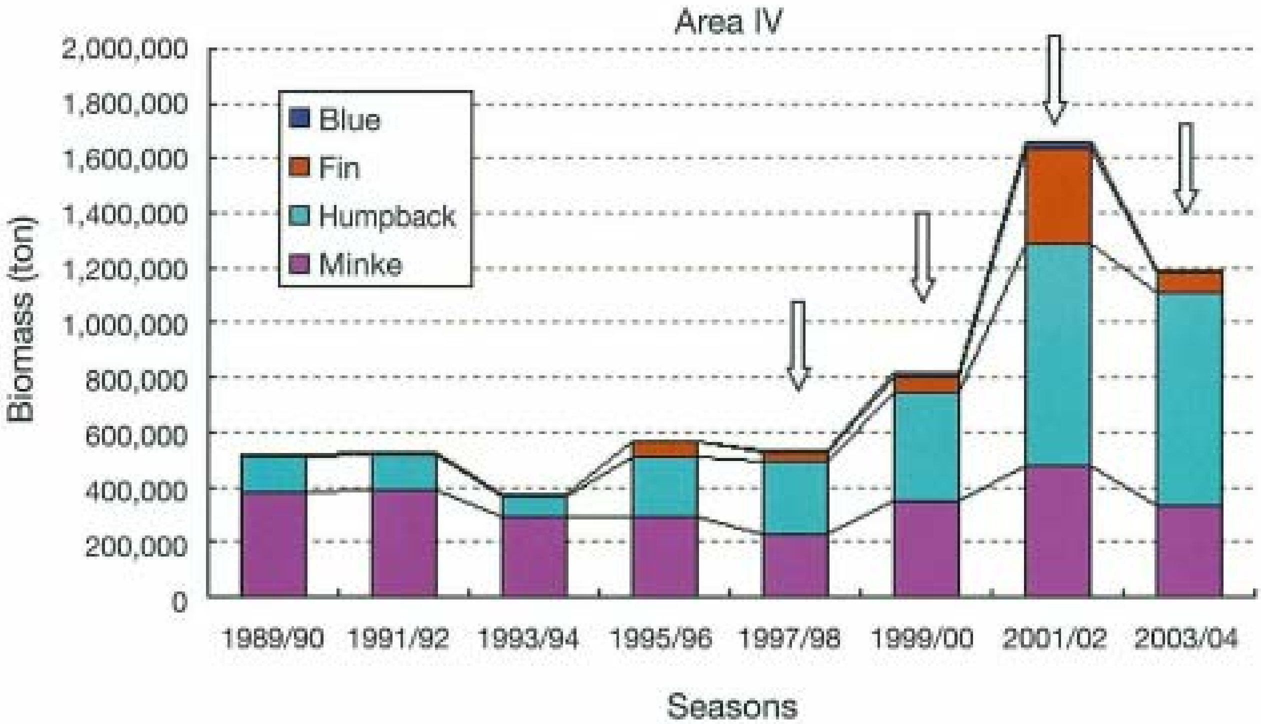

Fig. 61. Yearly trend in biomass of Antarctic minke, humpback, fin and blue whales in Area IV (south of 60°S) between 1989/90 and 2003/2004 seasons. A "shift in baleen whale dominance" from Antarctic minke to humpback whales was observed since 1997/98 season (arrows).

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 were obtained originally using an air gun designed at ICR. Most recently a crossbow is being used. A total of 303 biopsy samples from humpback whales, 35 from right whales, 22 from blue whales and 16 from fin whales have been obtained in the JARPA surveys up till 2003/04. 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. 62. Biopsy air gun.

Fig. 63. Aiming the biopsy air gun.

Fig. 64. Shooting to collect a biopsy sample.

Fig. 65. Picking up the sample.

Fig. 66. 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 491 photographs of humpback whales, 150 blue whales, and 238 of southern right whales have been taken and selected up till the 2003/04 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. 67. Southern right whale. The head callosities pattern is useful for individual identification in this species.

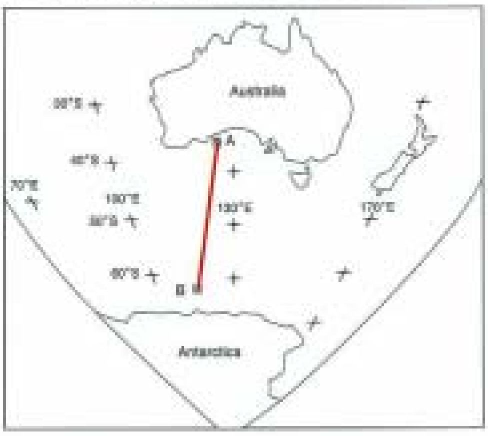

Fig. 68. A study revealed that a whale photographed in the JARPA survey in Area IV in 1996, was the same animal observed in the seas off Western Australia (Bannister *et al.*, 1999).

Biopsy Sampling and Photo ID

STOCK STRUCTURE STUDY IN THE ANTARCTIC HUMPBACK WHALE

A total of 287 biopsy samples taken from humpback whales during JARPA surveys conducted between 1993/94 and 2003/04 were used in genetic analyses based on mitochondrial DNA and microsatellites. The genetic study was focused to test the number and distribution of stocks in the feeding grounds covered by JARPA surveys, as proposed by the IWC/SC comprehensive assessment of the species. Analysis of mtDNA discriminated clearly among Stocks C (Area III), D (Area IV, breeding stock off Western Australia), E (Area V, breeding stock off Eastern Australia) and F in the feeding ground (see Fig. 69). Analysis of mtDNA suggests that the historical sector of mixing between Stock D and E at 110-130°E is being occupied in recent years by the Stock D. Analysis based on six microsatellite loci, while exhibiting some degree of genetic heterogeneity, was unable to discriminate among these stocks. Different degree of fidelity to feeding and breeding areas between females and males are suggested to explain such result.

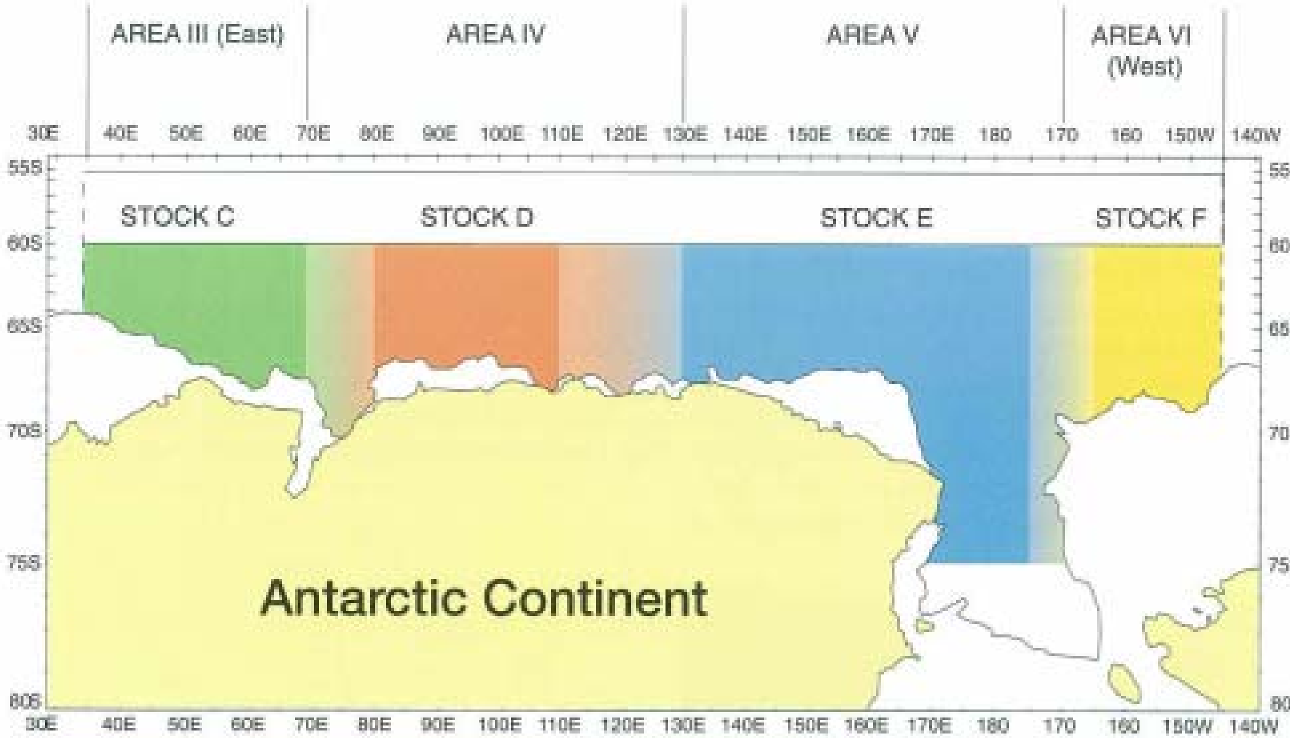

Fig. 69. Stocks of the humpback whale in the Antarctic feeding grounds surveyed by JARPA (Areas III (East), IV, V and VI (West)). Sector comprised between 70°E and 80°E is occupied by both C and D stocks. Sector 110°E-130°E, where traditionally Stocks D and E mix, is occupied mainly by the D Stock in recent years.

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. These data provide to investigate the Antarctic marine ecosystem including the relation between environmental condition of the sea and distribution of whales.

Fig. 76. CTD observations. The CTD is thrown into the sea to collect data on the vertical profile of water Conductivity (salinity), Temperature, and water pressure (Depth).

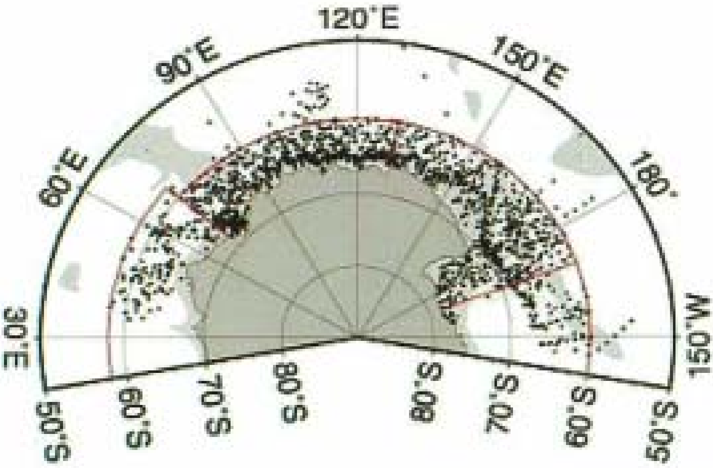

Fig. 77. Oceanographic observation in the JARPA. This map shows all oceanographic observation stations (CTD, XCTD and XBT) in the JARPA.

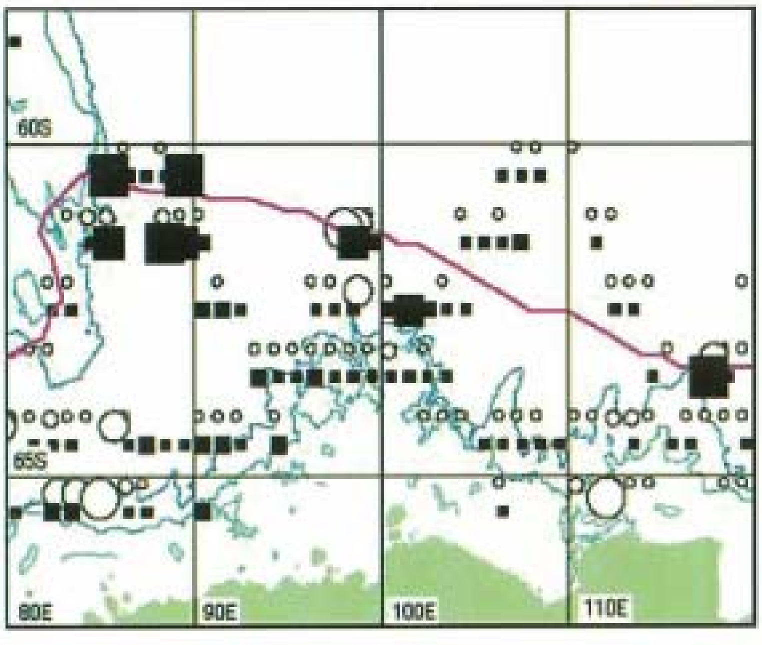

Fig. 78. The frontal system of the Antarctic Circumpolar Current (ACC) is important for the marine ecology of the Southern Ocean. The Southern Boundary (SB) of ACC is a southernmost front of ACC and is recognized as an important oceanographic feature for large whales in the JARPA area. For example, the humpback whale (black square symbols) prefers the area around SB of ACC (red colored line).

Satellite Tagging and Acoustic Monitoring

SATELLITE TAGGING

Satellite tagging (Fig. 79) 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.

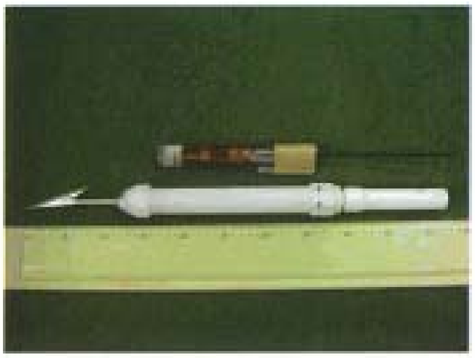

Fig. 79. Satellite tag used in whale tagging experiments.

Fig. 80. Attached satellite tag used in whale tagging experiments. Left: humpback whale. Right Antarctic minke whale.

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. Preparing the sono-buoy for deployment, aboard the sighting vessel Kyoshin Maru No. 2 developed by the ICR.

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

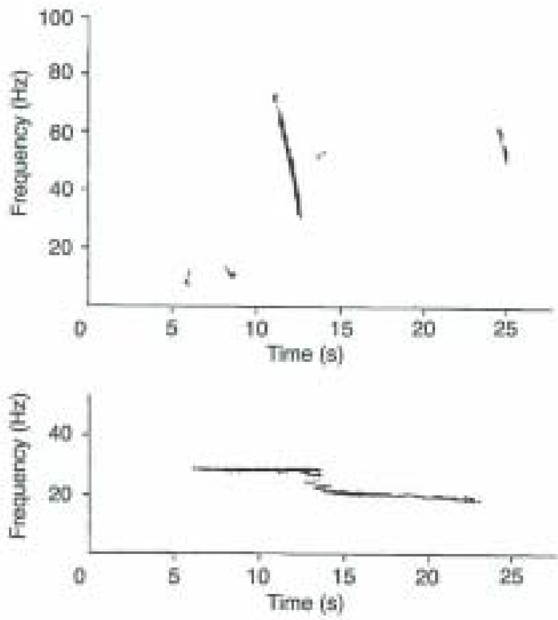

Fig. 83. Whale calls as recorded during JARPA cruises. Upper graph shows the spectrogram of a typical fin whale call; bottom, the spectrogram of a typical blue whale call. Both recorded in Area V on 21 January 1999.

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. 85), and open to the general public. We collect samples for scientific research, and cooperate in collecting specimens for exhibition purposes on request.

Fig. 84. Antarctic minke whale skull prepared for osteological studies.

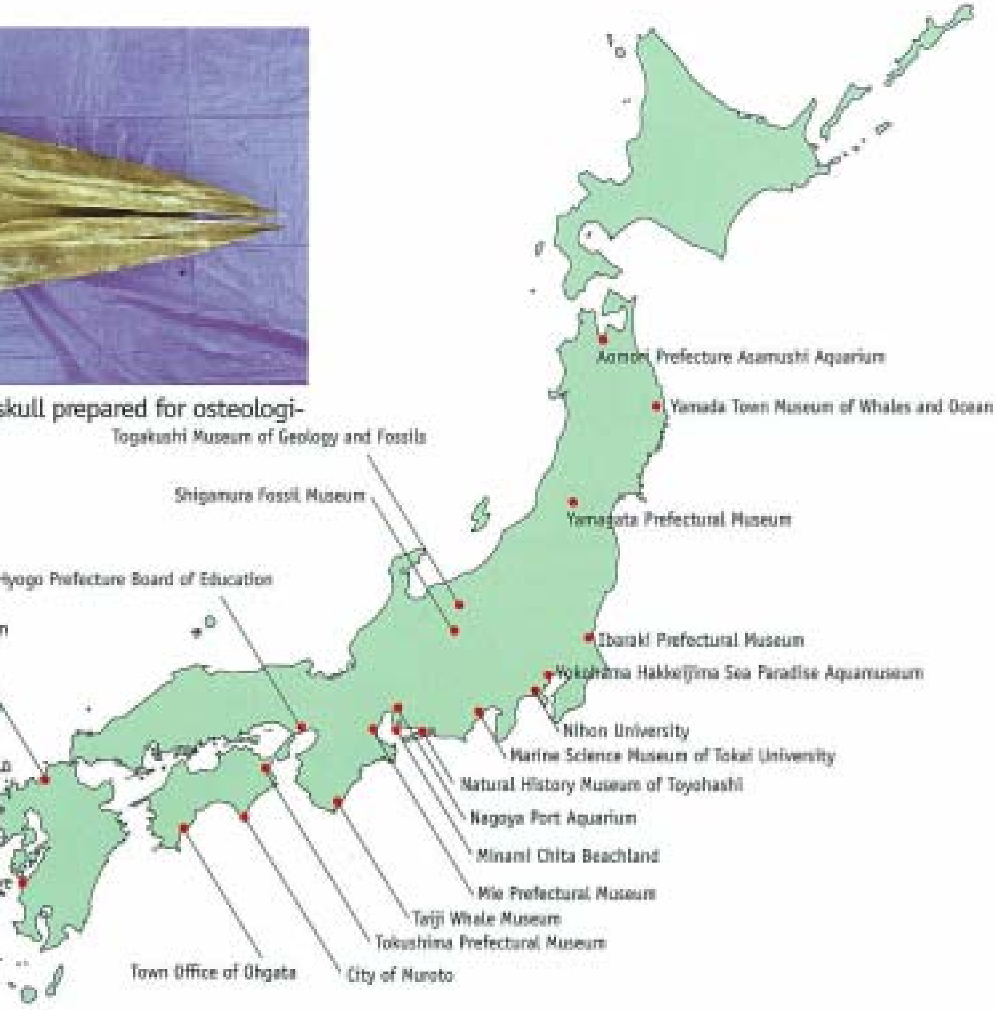

Fig. 85. Museums and other institutions throughout Japan where skeletal preparations of Antarctic minke whale were supplied.

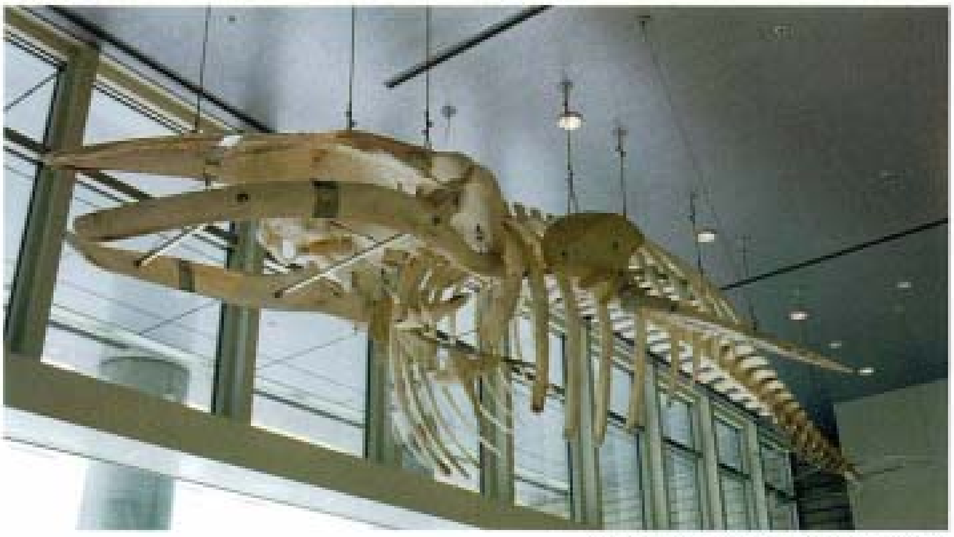

Fig. 86. Antarctic minke whale skeleton on display at Tokushima Prefectural Museum.

Photo credit: Tokushima Prefectural Museum

Number of Papers and Documents

Table 8. Number of papers and documents based on JARPA data.

Year	Number of papers published in scientific and general journals and books	Number of documents submitted to the IWC/SC meeting and other related meetings
1987		2
1988	1	1
1989	3	3
1990	8	7
1991	12	5
1992	4	5
1993	7	7
1994	5	11
1995	6	12
1996	9	8
1997	12	25
1998	15	5
1999	7	13
2000	8	15
2001	12	7
2002	23	9
2003	7	13
2004	10	3
2005	2	23
Total	149	174

Questions & Answers

Need for Lethal Research

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

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)
Pollution	Possible to take tissue samples for pollutant and biomarkers analysis	Can only determine high level organochlorine compounds in the blubber
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. Possible to collect milk sample of mother.	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, fatty acid from biopsy sample)
Tracking	Possible to use internal body markers/tags	Individual recognition, use of radio tags and satellite 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.

Need for Lethal Research

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 on maturity, 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.

JARPA provided a wide variety of information on biological parameters of the Antarctic minke whales and revealed that some of the biological parameters showed yearly trend corresponding to the change in food availability. The review meeting conducted in January 2005 agreed that results from JARPA are consistent with the competition among whale species for a single food species, krill. The effect of worldwide climate changes, including global warming, is becoming apparent in the Antarctic Ocean. JARPA results suggest strongly that the Antarctic ecosystem undergoes a major shift at present. Therefore, there is a need to monitor changes of Antarctic ecosystem in order to understand how cetaceans adopt the shift in the ecosystem structure, so as to provide scientific basis for the comprehensive management of whale resources.

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