A Review of the Studies on Estimation of Biological Parameters Conducted under the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA)

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ABSTRACT

The estimation of biological parameters is one of the main objectives of the JARPA. Background information and interim results on the estimation of biological parameters under the JARPA are reviewed and discussed.

1. INTRODUCTION

Japan started the research take program of minke whales (*Balaenoptera acutorostrata*) in the Antarctic in the 1987/88 season, under the special permit for purpose of scientific research based on the Article VIII of the International Convention for the Regulation of Whaling. This program is abbreviated as JARPA, and it is planned as a long term research project for about 16 years.

The estimation of biological parameters in the minke whale, especially the natural mortality coefficient, is one of the main objective of the JARPA. The research program is designed to collect biological data and materials by random sampling of minke whales from the populations which are distributed in the Antarctic Management Areas IV and V.

From 1987/88 to 1995/96 a total of nine JARPA surveys have been conducted so far. The research procedures have been improved on the basis of constructive comments by the members of the Scientific Committee (SC) every year. Thus, a large amount of biological data and materials has been accumulated during this period. Based on these biological data and materials, many papers have been produced related to the estimation of biological parameters as shown in the references and Appendix of this paper.

Among various kinds of biological parameters of the minke whale such as natural mortality rate, body length and age at sexual maturity, ovulation and pregnancy rates, sex ratio of foetuses, litter size, body length at birth, etc., the natural mortality rate and age at sexual maturity will be mainly reviewed in this document. These two kinds of parameters have been the subject of many discussion at the SC meetings.

The background and future works of the JARPA survey will be also discussed in relation to the estimation of biological parameters.

2. BACKGROUND OF THE JARPA

2.1. Arguments about biological parameters in the SC

The full-scale commercial pelagic whaling operation to take minke whales in the Antarctic started by Japan in the austral 1971/72 season. The Soviet Union joined the minke whale exploitation in the next season. Based on this situation, the first discussion on the population assessment of the Antarctic minke whale in the SC was held in 1973. Since then, discussions on assessment have been carried out in the SC every year.

A special meeting of the SC on the Antarctic minke whale was held in 1978 (IWC, 1979) after increasing concern on management problems of this stock and whaling moratorium. Since then various arguments about biological parameters, especially age-specific natural mortality coefficient were expressed at SC meetings but no agreement was reached. Then, there was a need to solve this problem through stochastic sampling of materials.

2.2. Moratorium of commercial whaling

The IWC decided the moratorium on commercial whaling in its 1982 annual meeting (IWC, 1983a) argumenting uncertainty in the biological knowledge on the whale resources. Subsequently, the Soviet Union and Japan stopped the Antarctic whaling in 1987. Then, Japan initiated a research in order to solve the uncertainty of biological knowledge and then to remove the moratorium decision of the IWC.

2.3. Need of monitoring of population

Biological parameters should be monitored systematically in order to investigate yearly variation and trend. This monitoring should be carried out even under the moratorium and the JARPA surveys are conducted for that purpose.

2.4. Need of lethal methods for the study of biological parameters

Ohsumi (1995) compares the advantages of lethal methods with regard the non-lethal methods in the biological studies of whales (see Table 1). He concluded that lethal methods are largely more advantageous in the studies of all kinds of biological parameters than non-lethal methods.

For example, information on the age of whales is essential to estimate many biological parameters such as the age at sexual maturity and mortality rate. Lethal methods are essential for the collection of age characters such as earplugs and baleen plates.

2.5. Advantage of research take of whales compared with research under the commercial whaling

Table 2 identified several advantages of the research take of whales in comparison with the research conducted under the commercial whaling (after Ohsumi ,1997). Therefore, the research take should be recognised as ideal for ecological research on whales.

2.6. Comprehensive assessment of the Antarctic minke whale

A meeting on the comprehensive assessment of the Antarctic minke whale populations was held in 1990 (IWC, 1991). Biological parameters such as age at recruitment, age at maturity, sex ratio, pregnancy rates and natural mortality rates, were examined thoroughly at that meeting.

2.7. Completion of the Revised Management Procedure (RMP)

The Scientific Committee completed the RMP in 1992 (IWC, 1993). Although it is pointed out that biological parameters are not absolutely necessary for the application of the RMP, knowledge on biological parameters related to the MSYR is useful for the implementation trial of the RMP on each whale stock and practical application of the RMP to reduce the range of biological parameters which should be used for calculation of the catch limit.

3. COLLECTION OF BIOLOGICAL DATA AND MATERIALS

3.1. Establishment of research area and season

The IWC Antarctic Management Areas IV and V were chosen to be surveyed in alternate years. In addition to the fact that these Areas are closer to Japan, large amount of data related to the estimation of biological parameters had been accumulated in these Areas by Japan during the commercial whaling years until 1986/87. These data could be useful for the JARPA survey.

The research area in each year is shown by Nishiwaki *et al.* (1997) from 1987/88 to 1995/96.

The research season is the austral summer from December to March. In January and February most of the minke whales are expected to gather the research area.

3.2. Methodology of random collection of data and materials

For the purpose to collect unbiased biological samples, the track line was designed to cover the whole area uniformly. The line transect sampling procedures were applied to collect samples proportionally to the density of whales encountered. All the schools sighted were collected and animal (s) in a school was randomly sampled.

Detailed sampling methods, which have been employed, are described in the cruise reports in each year (Fujise *et al.*, 1990b; 1993a; 1993b; Kasamatsu *et al.*, 1993, Kato *et al.*, 1989; 1990a, Nishiwaki *et al.*, 1994; 1995; 1996).

Two whales sampling method was applied in the early years of JARPA (1987/88-1991/92), and from 1992/93 one whale sampling has been used. Fujise *et al.* (in prep) examines rightness of the random sampling.

3.3. Data and materials collected for the objective to estimate biological parameters

The lists of data and materials including items, years, categories and numbers of data and samples are shown in documents and as materials for this meeting. Many items of these data and materials have been used for the studies of estimation of biological parameters.

4. NATURAL MORTALITY RATE

4.1. Previous works

Ohsumi *et al.* (1970) estimated the total mortality coefficient (Z) of the Antarctic minke whale for the first time by use of slope of age and corpora albicantia distributions and ovulation rate. The estimation of Z was 0.104. Ohsumi and Masaki (1975) further examined the Z values using the same methods but a larger amount of data and they estimated Z to be 0.127. Ohsumi (1979a) estimated the natural mortality coefficient (M) of the Antarctic minke whale from the interspecific relationships to be 0.094. Kato (1982) further estimated Z values of both sexes in Areas III, IV and V using the two kinds of approaches.

Ohsumi (1979b) recognized that Z = M + I, where M is the natural mortality coefficient and I is the population growth coefficient. Since then, in the SC the estimation of M value has been based on the interspecific relationships instead of Z value from age distribution.

Tillman and Chapman (1981) pointed out that a direct estimate of the coefficient of M is not available and the currently used value of M, 0.095, was derived by an interspecific relationship. They also stated that an accurate, unbiased estimates of M is critical since this parameter plays a very sensitive role, when stock sizes or replacement yield are estimated.

Chapman (1983) revised Ohsumi's estimate and get the M value of 0.086 (with 95% confidence interval of 0.059, 0.116). In 1984, however, the SC agreed that mortality rates estimated from an interspecific relationship would not be used, because various problems related to the indication of increasing recruitment prior to exploitation, were presented on this technique and the SC could not reach a consensus (IWC, 1985a). In the same year views were divided in the SC on the recruitment rate, and two sets of catch limit were proposed for the Antarctic minke whales (IWC, 1985b).

4.2. Method for estimation of age-specific natural mortality by JARPA

Tanaka (1988; 1990) presented a method to estimate M value from catch-at-age data and sighting data obtained by JARPA. Denoting the number of whales of age a in year t in the stock by Nat and in the catch by Cat, M of age a whales is given by

$$Ma = 1/k \ln [(Nat - Cat)/Na+k, t+k]$$

Here, Nat is calculated from stock abundance information obtained by whale sightings, and age composition from the research takes. Following this principle, estimates of Heinke's mean M and age-specific Ma are calculated.

Tanaka *et al.* (1992) evaluated likely precision from JARPA and IDCR data. The precision of the mean M is dependent more on the variability in the estimated stock abundance by whale sightings than that in the age composition of the research take. Annual sample size of 200-400 whales is expected to provide estimates with highest precision, if the total available ship-day is limited to the present level. Estimation of age-specific Ma is more difficult than that of mean M, but there is a good possibility of detecting age dependency, when the dependency is fairly strong.

4.3. Estimation of age distribution in the JARPA survey

4.3.1. Age characters

The earplugs and baleen plates have been collected as the age characters. The earplug is used primarily for age determination, and for a younger individual of which ear plug is difficult to read age, the baleen plate is used alternatively (Fujise *et al.*, 1994).

4.3.2. Correction of age distribution

A crude age distribution thus obtained in each stratum should be corrected to estimate an age distribution of total population by considering aging error and abundance. Kishino *et al.* (1991a) and Fujise *et al.* (1994) examined on this problem.

4.4. Interim results of estimation of M

Tanaka and Nakamura (1995) tried to estimate Heinke's mean M using JARPA data from 1989/90 to 1992/93, two years for each of Areas IV and V, and assuming constant stock abundance during the period.

The estimated values of M varied depending on Areas and on the youngest age group used for the estimation. When age 11 and older groups are used, the M value is 0.016 for Area IV and 0.098 for Area V. CV values of these estimates are large, but it is expected that the CV would be improved quickly as the number of years is increased.

Tanaka (in prep.) conducted the same calculation again using 7 year data up to 1995/96. Under the assumption that the population growth rate is the same between Areas IV and V, mean M for age groups 11 and older is obtained 0.05 for Area IV and 0.12 for Area V. When the 16 year program is completed, S.E. of M is expected to be 0.2-0.3.

Butterworth *et al.* (1996) applied ADAPT VPA technique to catch-at-age data both from JARPA and past commercial whaling in Area IV. When M is high at 0.14, estimated recruitment decreases monotonously from 1944, while moderate M of 0.05 gives increasing trends before 1965 and after 1980 and a decrease between these years. It is possible to estimate M value by fitting the calculated population trends to the observed abundance data by the IDCR.

4.5. Discussion and future works

In 1992 the IWC/SC completed its work for development of the RMP. This procedure uses a kind of Bayesian approach and does not need explicitly the value of M. The RMP has been tested thoroughly for its performance under various conditions and proved to be practical as robust and safe management procedure.

It may be said that M value lost its importance by abolition of the NMP. Nevertheless, information on M value could contribute to improve the efficiency of the RMP. In the RMP, a possible range of μ, which roughly corresponds to MSYR, is postulated to be 0.00-0.05. When μ = 0, catch limit is necessarily zero. If it is found out that the value of μ is larger than a non zero value, then RMP would provide a higher catch limit without prejudice of safety.

Analysis of catch-at-age data will provide estimates of recruitment and its variability as well as information on the value of M, and then direct information on MSYR, which is still an important parameter for the management of whale stocks.

5. BIOLOGICAL PARAMETERS RELATED TO SEXUAL MATURITY

5.1. Body length at sexual maturity

5.1.1. Previous works
Ohsumi *et al.* (1970) estimated body lengths at sexual maturity of the Antarctic minke whale from Area IV. The estimations were 7.1 m and 7.9 m for males and females, respectively, as represented as the 50 % mature body length. Using the same method, Ohsumi and Masaki (1975) estimated this biological parameter in whales caught mainly from Area IV, to be 7.2m and 8.0m for males and females, respectively. Masaki (1979) examined yearly change in this parameter, and he found there was no trend of yearly change in this parameter in Area IV during years 1971/72-1976/77. However, the data were provided from commercial whaling, and there is a possibility of bias due to selection of larger whales and position of whaling ground.

5.1.2. Interim results by JARPA
Using the same method applied to materials collected by JARPA, Zenitani *et al.* (in prep.) estimated the body length at sexual maturity to be 7.3m and 8.2 m in males and females, respectively in Area IV, and 7.2-7.3m and 8.0 m for males and females, respectively in Area V.

5.1.3. Comparison of results obtained using JARPA and commercial whaling samples
It was found that the body lengths at sexual maturity in Area IV from JARPA are 0.1-0.2 m larger than those estimated from commercial whaling data. Two possibilities are considered: one is the yearly change in this parameter and the other is the bias by selection of larger whales and selection of whaling ground to the pack ice margin where minke whales are distributed highly in the case of commercial whaling.

Considering the fact that the body length at sexual maturity keeps the same size even if population level changes (Kato, 1987), the possibility of the latter case will be more plausible. Then, this indicates that the JARPA is useful to estimate actual figure of this biological parameter.

5.2. Age at sexual maturity
This kind of biological parameter is regarded as a driving function of change in recruitment rate of whales, so that it is an important biological parameter for population dynamics. This parameter has been estimated by several different techniques as; age at which 50% of animals attained sexual maturity (age at 50% sexual maturity); mean age first ovulation; mean age at sexual maturity estimated from transition phase. The most common way is to use age at 50% sexual maturity, but values of this parameter for southern minke whales based on materials from the commercial whaling are usually under-biased due to catching selectivity which tend to take larger whales and reproductive segregation which mature animals dominated in the whaling ground while the other estimators are not subjected to such bias (Kato, 1987).

5.2.1. Previous works

Ohsumi *et al.* (1970) estimated the age at 50% sexual maturity of males from Area IV at7-8 years, and that of females as a little later than males. Ohsumi and Masaki (1975) also estimated age at sexual maturity of females using three methods. From the change in sexual maturity with age, age at 50% sexual maturity was 6.3 years, from the relation between age and corpora number, age of firstly ovulated female was estimated at 5.6 years, and from the growth curve and body length at sexual maturity corresponded to age at sexual maturity was 5.5 years. Masaki (1979) studied this parameter by use of four kinds of approaches such as age at 50 % sexual maturity, relationship between age and ovulation number, growth curve and transition phase. He found that the age at sexual maturity of the Antarctic minke whale had changed drastically from 13-15 years in the middle of 1940s to 6-7 years in the middle of 1960s, from the analysis of transition phase of earplugs which were recognized as an age character to represent age at sexual maturity in baleen whales (Lockyer, 1972).

However, it was argued at the SC meeting that the demonstrated declining trend was subject to the truncation sampling problem which leads to downward bias in mean age at maturity in recent cohort (Free and Beddington, 1980). The trend was also criticized from view points of possible ageing error by Cooke and de la Mare (1983), they considered observed trend must be artificial since large variability in ageing error. Subsequently this led to have the minke whale ageing workshop including experiment to assess the magnitude of ageing error in 1983, but such big bias to produce artifact declining trend was not detected there (IWC, 1984). Sakuramoto *et al.* (1985, 1986) examined nature of declining trend in relation to ageing error and they concluded that the declining trend could not be produced by ageing error of 2-4 years absolute value which is realistic value for the error.

Kato (1985) incorporated the method to neglect truncation bias by using only individuals enough old free from biases of the truncation bias and of possible delay for recognition of the transition phase layer after the sexual maturity and examined further based on the temporal trend of mean age at maturity using additional transition phase counts 1977/78 - 1982/83, and confirmed declining trend of a sexual maturity as 12-13 years in pre-1940 cohorts to about 7-8 years in the cohorts at the end of 1960s.

Kato (1987) further extended his previous analysis on temporal trend of age at sexual maturity using more updated data series and confirmed the declining trend again. He also noted the trend is supported by other several evidences such as; changes in growth curve with cohort which recent cohort grew faster than the older while length at sexual maturity has remained constant; mean age of females at sexual maturity by transition phase almost agree with direct estimate of age at sexual maturity (mean age of females having only one corpus); possible increase in food intake in recent cohorts suggested by analysis on heavy metal concentration (Honda *et al.*, 1987).

On the other hand, Cooke and de la Mare (1984) noted the age specific effect originally considered by Bengtson and Laws (1985) in analysis of temporal trend of age at sexual maturity of crabeater seal which gives one of evidence the declining trend is artifact and he found similar effect for the Icelandic fin whales and southern minke whales based on subset of 360 individuals used in the minke whale aging workshop. Kato and Sakuramoto (1991) examined on southern minke whales using more large data set, but they did not find such effect.

Although Horwood (1990) also concluded the declining trend might be real in 1950s cohorts to 1960s from his overall review on the transition phase analyses and associated bias, there are still some disagreements on the demonstrated declining trend of age at sexual maturity in pre-exploitation at the IWC SC as described above. Butterworth *et al.* (1996; this meeting) has started their new analyses.

5.2.2 Interim results by JARPA survey
Age determination by use of earplugs and maturity determination by use of ovaries and testes have been finished for the samples collected from 1987/88 to 1995/96. Other data such as sex and body length are also collected for the same period. Zenitani *et al.* (in prep.) analysed age at sexual maturity by use of these data and materials using four kinds of approaches: age at 50 % of individuals are mature, transition phase, average age of the individuals with one corpora luteum or albicans in ovaries, relationship between age and ovulation numbers.

In the case of males, 50 % mature age and transition phase can be used, and in addition, average age of one ovulation and relationship between age and ovulation number can be also used in females.

The 50% mature ages are 6.9-7.4 and 8.3-8.5 years in Areas IV and V, respectively, in the case of females, and these are 3.6- 4.7 and 4.5-5.3 years in Areas IV and V, respectively, in the case of males.

5.2.3. Comparison of above results
The 50% mature age of males in Area IV by the JARPA survey is larger than that by the commercial whaling in which they were 2.5 years in males and 6.6 years in females (Kato, 1982). This indicates that the figures from the commercial whaling was biased due to the selection of whales and reproductive segregation in the whaling ground, so that the JARPA is superior to the commercial whaling to estimate this kind of biological parameter.

However, those figures in Area V are larger than those in Area IV for both sexes in the case of the JARPA. Under the assumption that most individuals in both Areas belong to a core stock, distribution patterns of minke whales in two Areas are different due segregation, and the result of the JARPA represents this phenomenon.

The age at sexual maturity (6.6 years) of females in Area IV from the commercial whaling during 1970s is slightly younger than those (7.0 years) in the same Area from the JARPA survey in 1987/88- 1995/96. If the effect of selection in commercial whaling is considered to be small in the case of females, this suggests that the age at sexual maturity may turn to increase in 1980s although it is extremely inconclusive. This estimation is supported from the possibility of decrease of growth of the Antarctic minke whale which is examined by Zenitani *et al.* (in prep.).

6. DISCUSSION

6.1. Research area and stock structure

We must recognize correctly on the range of the distribution of a population for the estimation of biological parameters of the population. Therefore, population structure research has been an important item of the JARPA survey from the beginning of the research program. In the first stage, it was assumed that two stocks (one in Area IV and another in Area V) of the minke whale existed in the survey area. However, accompanying with the accumulation of data on stock structure, it has been gradually recognized that a stock named by 'the core stock' could be distributed in both Areas IV and V as reviewed by Pastene and Goto (1997).

Then, "the elucidation of the stock structure" has been separated and become independent from the first and main objective of the JARPA, that is the estimation of biological parameters, because we realize that the knowledge of the stock structure is the base of the estimation of biological parameters and it is valuable as an independent objective of the JARPA.

At present, the hypothesised 'core stock' is found to be distributed outside of the west and east sides of the research area, and we need to identify the range of distribution of the 'core stock', as soon as possible.

The combination of data from Areas IV and V is needed to obtain the total population of the 'core stock'. However, the method of combination has not been developed yet. Further research will be needed to improve this area of study

6.2. Migration and segregation

Accompanying with the progress of JARPA survey, the phenomenon of segregation by sex and age and migration of the minke whale has become gradually to be understood (Fujise *et al*, 1990a;1991;1992;1994, Kato, 1995).

This phenomenon should be taken into consideration to obtain the structure of total population to estimate biological parameters.

6.3. Contribution of estimation of biological parameters by the JARPA surveys for stock management

There are some opinions among the SC members that the RMP do not need any biological parameters for its application, so that, the JARPA will not contribute to the stock management. However, it is wrong. Before the application of the RMP to a whale stock, the implementation trial must be carried out, and if we have accurate information about the rate of the maximum sustainable yield (MSYR), the range of accuracy will increase. At the practical application of the RMP, the biological parameters contribute to calculate more catch limit figure with safe guard of the population, as discussed in section 4.5.

The knowledge on the stock structure and its boundaries which is provided accompanying with the research on biological parameters is directly contribute to the application of the RMP.

6.4. Need of continuation of the JARPA surveys

The JARPA program is designed to continue for 16 years, and the present stage is at the middle of the project. We understand from some analyses that the M value gradually becomes precise accompanied with the progress of the survey.

It has been recognized that the data obtained through the commercial whaling are biased by the selection of catch of larger whales in more densely distributed waters by the motive of whalers to produce more products within limited catch quater and limited time. On the other hand, the JARPA survey is designed to collect data and materials of the minke whale population randomly and systematically from wide range of research area. Such kind of biological survey is ideal to continue even if the commercial whaling will resume in near future.

The monitoring of whale population is important to watch the marine ecosystem, and it will not be satisfied only by whale sightings. Monitoring of yearly change in biological parameters will be useful not only for the understanding of mechanism of population change, but also for independent characters of the yearly change in population.

7. REFERENCES

Bengtson, J.L. and Laws, R.M. 1985. Trends in crabeater seal age at maturity: an insight into Antarctic marine interaction. pp.669-75. *In.* W.R. Siegfried, P.R. Condy and R.M. Laws (eds.) *Antarctic Nutrient Cycles and Food Webs.* Springer-Verlag, Berlin.

Bregh, M.O., Butterworth, D.S. and Punt, A.E. 1991. Further examination of the potential information content of age-structure data from Antarctic minke whale research catches. *Rep. int. Whal. Commn* 41:349-361.

Butterworth, D.S. and Punt, A.E. 1990. Some preliminary examinations of the potential information content of age-structure data from Antarctic minke whale research catches. *Rep. int. Whal. Commn* 40:301-315.

Butterworth, D.S. and Geromont, H.F. 1996. On the provision of advice on the effect on stock(s) of scientific permit catches, with particular reference to proposed research catches of minke whales from Antarctic Area IV. *Rep. int. Whal. Commn* 46:653-655.

Butterworth, D.S., Punt, A.E., Geromont, H.F., Kato, H. and Miyashita, T. 1996. An ADAPT approach to the analysis of catch- at-age information for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 46:349-359.

Chapman, D.G. 1983. Some considerations on the status of stocks of Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 33:311-314.

Cooke, J.G. 1985. Has the age at sexual maturity of Southern Hemisphere minke whales (*Balaenoptera acutorostrata*). *Rep. int. Whal. Commn* 35:335-340.

Cooke, J.G. and de la Mare, W.K. 1983. The effects of variability in age data on the estimation of biological parameters of minke whales (*Balaenoptera acutorostrata*). *Rep. int. Whal. Commn* 33:333-338.

Cooke, J.G. and de la Mare, W.K. 1984. A note on the estimation of time trends in the age at sexual maturity in baleen whales from transition layer data, with reference to the North Atlantic fin whale. *Rep. int. Whal. Commn* 34:701-9.

Cooke, J.G. and De La Mare, W.K. 1993. A comparative note on demographic parameters of right and minke whales. Paper SC/45/O25 presented to the IWC Scientific Committee, May 1993 (unpublished). 12pp.

Free, C.A. and Beddington, J.R. 1980. A technique for estimating mean and variance of the age at sexual maturity for data obtained from the transition phase of ear plug laminae. *Rep. int. Whal. Commn* 30:375-7.

Fujise, Y., Kato, H. and Kishino, H. 1990a. Reproductive segregation of the minke whale population in high latitudinal waters with some estimations of pregnancy and sexual maturity rates, data from Japanese research takes in 1987/88 and 1988/89. Paper SC/42/SHMi10 presented to the IWC Scientific Committee, June 1990 (unpublished). 20pp.

Fujise, Y., Yamamura, K., Zenitani, R., Ishikawa, H., Yamamoto, Y., Kimura, K. and Komaba, M. 1990b. Cruise report of the research on Southern minke whales in 1989/90 under the Japanese proposal to the scientific permit. Paper SC/42/SHMi25 presented to the IWC Scientific Committee, June 1990 (unpublished). 56pp.

Fujise, Y., Kato, H. and Kishino, H. 1991. Some progress in examination on age distribution and segregation of the Southern minke whale population using data from the Japanese research take. Paper SC/43/Mi18 presented to the IWC Scientific Committee, May 1991 (unpublished). 17pp.

Fujise, Y., Kato, H., Zenitani, R. and Kishino, H. 1992. Seasonal and areal changes in age distribution and segregation of the Southern minke whales in Antarctic areas IV and V using data from the Japanese researches. Paper SC/44/SHB10 presented to the IWC Scientific Committee, June 1992 (unpublished). 37pp.

Fujise, Y., Ishikawa, H., Saino, S., Nagano, M., Ishii, K., Kawaguchi, S., Tanifuji, S., Kawashima, S. and Miyakoshi H. 1993a. Cruise report of the 1991/92 Japanese research in Area IV under the special permit for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 43:357-71.

Fujise, Y., Zenitani, R., Saino, S., Itoh, S., Kawasaki, M., Matsuoka, K. and Tamura, T. 1993b. Cruise report of the 1992/93 Japanese research under the special permit for Southern Hemisphere minke whales. Paper SC/45/SHB12 presented to the IWC Scientific Committee, April 1993 (unpublished). 39pp.

Fujise, Y. and Kishino, H. 1994. Patterns of segregation of minke whales in Antarctic Areas IV and V as revealed by a logistic regression model. Paper SC/46/SH11 presented to the IWC Scientific Committee, May 1994 (unpublished). 23pp.

Fujise, Y., Zenitani, R., Kato, H. and Kishino, H. 1994. Age distributions of minke whales in the Antarctic Areas IV and V in 1991/92 and 1992/93 seasons. Paper SC/46/SH20 presented to the IWC Scientific Committee, May 1994 (unpublished). 22pp.

Government of Japan. 1987a. The program for research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic. Paper SC/39/O4 presented to the IWC Scientific Committee, June 1987 (unpublished). 28pp.

Government of Japan. 1987b. The research plan for the feasibility study on "the program for research on the Southern Hemisphere minke whale and for preliminary research on the marine ecosystem in the Antarctic". Paper SC/D87/1 presented to the IWC Scientific Committee, December 1987 (unpublished). 36pp.

Government of Japan. 1988. 1988/89 research plan for the feasibility study "the program for the research on the Southern Hemisphere minke whale and for the preliminary research on the marine ecosystem in the Antarctic". 19pp.

Government of Japan. 1989. The research plan in 1989/90 season in conjunction with note for "The Program for the Research on the Southern Hemisphere minke whale and for the preliminary research on the marine ecosystem in the Antarctic (SC/39/O4)." Paper SC/41/SHMi13 presented to the IWC Scientific Committee, June 1989 (unpublished). 19pp.

Government of Japan. 1990. The 1990/91 research plan of whale resources in the Antarctic. Paper SC/42/SHMi9 presented to the IWC Scientific Committee, June 1990 (unpublished). 13pp.

Government of Japan. 1991. The 1991/92 research plan of whale resources in the Antarctic. Paper SC/43/Mi19 presented to the IWC Scientific Committee, May 1991 (unpublished). 5pp.

Government of Japan. 1992. The 1992/93 research plan of whale resources in the Antarctic. Paper SC/44/SHB14 presented to the IWC Scientific Committee, June 1992 (unpublished). 7pp.

Government of Japan. 1993. The 1993/94 research plan of whale resources in the Antarctic. Paper SC/45/SHBa 10 presented to the IWC Scientific Committee, April 1993 (unpublished). 6pp.

Government of Japan. 1994. The 1994/95 research plan of Japanese whale research programme under special permit in the Antarctic. Paper SC/46/SH16 presented to the IWC Scientific Committee, May 1994 (unpublished). 7pp.

Government of Japan. 1995. The 1995/96 research plan of Japanese whale research programme under special permit in the Antarctic. Paper SC/47/SH3 presented to the IWC Scientific Committee, May 1995 (unpublished). 9pp.

Government of Japan. 1996. The 1996/97 research plan for the Japanese whale research program under special permit in the Antarctic [plus Addendum]. Paper SC/48/SH3 presented to the IWC Scientific Committee, June 1996 (unpublished). 14pp.

Hamada, N., Yamazaki, S., Toda, S., Fujise, Y. and Zenitani, R. 1989. X-Ray Fluorescence Analysis of Earplug of Minke Whales. The Japanese Society for Anatomical Chemistry. October 1989, Sendai.

Honda, K., Yamamoto, Y. and Kato, H. 1987. Heavy metal accumulations and their recent changes in southern minke whale, *Balaenoptera acutorostrata. Arch. Environ. Contam. Toxicol.* 16:209-16.

Horwood, J.W. 1990. *Biology and Exploitation of Minke Whale*. CRC Press, Boca Raton. 238pp.

Institute of Cetacean Research. Progress Report. 1990. Japanese research program on Southern Hemisphere minke whale and preliminary research on the marine ecosystem in the Antarctic and program on its feasibility studies. Paper SC/42/SHMi28 presented to the IWC Scientific Committee, June 1990 (unpublished). 16pp.

Institute of Cetacean Research. 1991. Research activities of the Institute of Cetacean Research during May 1990 to April 1991. Paper SC/43/O23 presented to the IWC Scientific Committee, May 1991 (unpublished). 4pp.

Institute of Cetacean Research. 1992. Research activities of the Institute of Cetacean Research during May 1991 to April 1992. Paper SC/44/O19 presented to the IWC Scientific Committee, June 1992 (unpublished). 17pp.

Institute of Cetacean Research. 1993. Research activities of the Institute of Cetacean Research during May 1992 to April 1993. Paper SC/45/SHBa11 presented to the IWC Scientific Committee, April 1993 (unpublished). 6pp.

Institute of Cetacean Research. Progress Report. 1994. Research activities of the Institute of Cetacean Research during May 1993 to April 1994. Paper SC/46/O24 presented to the IWC Scientific Committee, May 1994 (unpublished). 16pp.

Institute of Cetacean Research. 1995. Research activities of the Institute of Cetacean Research May 1994 to April 1995. Paper SC/47/O7 presented to the IWC Scientific Committee, May 1995 (unpublished). 10pp.

Institute of Cetacean Research. 1996. Research activities of the Institute of Cetacean Research May 1995 to June 1996. Paper SC/48/O16 presented to the IWC Scientific Committee, June 1996 (unpublished). 11pp.

International Whaling Commission. 1979. Report of the special meeting on Southern Hemisphere minke whales, Seattle, 1978. *Rep. int. Whal. Commn* 29:349-358.

International Whaling Commission. 1983a. Chairman's report of the Thiety-fourth Annual Meeting. *Rep. int. Whal. Commn* 33:20-42.

International Whaling Commission. 1983b. Report of the age at sexual maturity working group. *Rep. int. Whal. Commn* 33:106-109.

International Whaling Commission. 1984. Report of the minke whale aging workshop. *Rep. int. Whal. Commn* 34:675-699.

International Whaling Commission. 1985a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 3531-58.

International Whaling Commission. 1985b. Report of the Sub-committee on Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 35:75-89.

International Whaling Commission. 1988a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 38:32-66.

International Whaling Commission. 1988b. The Japanese scientific permit proposal for Southern Hemisphere minke whales: background and comments (Annex R). *Rep. int. Whal. Commn* 38:139-149.

International Whaling Commission. 1989a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 39:33-70.

International Whaling Commission. 1989b. Reviews of scientific permits (Annex O). 1989. *Rep. int. Whal. Commn* 39:154.

International Whaling Commission. 1989c. Report of the special meeting of the Scientific Committee to consider the Japanese research permit (feasibility study). *Rep. int. Whal. Commn* 39:159-168.

International Whaling Commission. 1990a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 40:39-86.

International Whaling Commission. 1990b. Comments on the Japanese scientific permit proposal for 1989/90 (Annex O). *Rep. int. Whal. Commn* 40:172-174.

International Whaling Commission. 1991. Report of the Scientific Committee. *Rep. int. Whal. Commn* 41:51-89.

International Whaling Commission. 1992a. Report of the Scientific Committee. *Rep. int. Whal. Commn* 42:51-86.

International Whaling Commission. 1992b. Comments arising out of the Japanese research permit discussion (Annex O). *Rep. int. Whal. Commn* 42:263-264.

International Whaling Commission. 1993. Report of the Scientific Committee. *Rep. int. Whal. Commn* 43:55-92.

International Whaling Commission. 1994. Report of the Scientific Committee. *Rep. int. Whal. Commn* 44:41-73.

International Whaling Commission. 1995. Report of the Scientific Committee. *Rep. int. Whal. Commn* 45:53-103.

International Whaling Commission. 1996. Report of the Scientific Committee. *Rep. int. Whal. Commn* 46:49-106.

Kasamatsu, F., Yamamoto, Y., Zenitani, R., Ishikawa, H., Ishibashi, T., Sato, H., Takashima, K. and Tanifuji, S. 1993. Report of the 1990/91 Southern minke whale research cruise under scientific permit in Area V. *Rep. int. Whal. Commn* 43:505-22.

Kato, H. 1982. Some biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 32:935-945.

Kato, H. 1985. Further examination of the age sexual maturity of the Antarctic minke whale as determined from earplug studies. *Rep. int. Whal. Commn* 35:273-7.

Kato, H. 1987. Density dependent changes in growth parameters of the Southern minke whale. *Sci. Rep. Whal. Res. Inst., Tokyo* 38:47-73.

Kato, H., Kishino, Y. and Fujise, Y. 1988. The age composition and age-different habitat utilization of Southern minke whales based on samples collected by 1987/88 Japanese whale research program. The 11th Symposium on Polar Biology, November, 1988, Tokyo.

Kato, H., Hiroyama, H., Fujise, Y. and Ono, K. 1989. Preliminary report of the 1987/88 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 39: 235-248.

Kato, H. and Zenitani, R. 1990. The notch on baleen plate of Southern minke whales, as a neonatal mark. The 1990 Spring Meeting of the Japanese Society of Fisheries Science, April, 1990, Tokyo. Supplement p.32.

Kato, H., Fujise, Y., Yoshida, H., Nakagawa, S., Ishida, M. and Tanifuji, S. 1990a. Cruise report and preliminary analysis of the 1988/89 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 40: 289-300.

Kato, H., Kishino, H. and Fujise, Y. 1990b. Some analyses on age composition and segregation of Southern minke whales using samples obtained by the Japanese feasibility study in 1987/88. *Rep. int. Whal. Commn* 40:249-56.

Kato, H. and Miyashita, T. 1991. Migration strategy of Southern minke whales in relation to reproductive cycles estimated from foetal lengths. *Rep. int. Whal. Commn* 41:363-369.

Kato, H. and Sakuramoto, K. 1991. Age at sexual maturity of Southern minke whales: a review and some additional analyses. *Rep. int. Whal. Commn* 41:331-337.

Kato, H., Fujise, Y. and Kishino, H. 1991a. Age structure and segregation of Southern minke whales by the data obtained during Japanese research take in 1988/89. *Rep. int. Whal. Commn* 41: 287- 92.

Kato, H., Zenitani, R. and Nakamura, T. 1991b. Inter-reader calibration in age readings of earplug from Southern minke whale, with some notes of age readability. *Rep. int. Whal. Commn* 41:339- 343.

Kato, H. 1995. Migration strategy of Southern minke whales to maintain high reproductive rate. *in:* Blix, A.S., Walloe, L. and Ultang, O. (eds.) *Whales, seals, fish and man.* Elsevier, Amsterdam. 465-478.

Kishino, H., Kato, H., Kasamatsu, F. and Fujise, Y. 1989. Statistical method for the estimation of age composition and biological parameters of the population. Paper SC/41/SHMi3 presented to the IWC Scientific Committee, June 1989 (unpublished). 39pp.

Kishino, H., Fujise, Y., Kato, H. and Taga, Y. 1991a. Maximum likelihood procedure for the estimation of the mean age at sexual maturity of minke whales using the data from the Japanese research take. Paper SC/43/Mi23 presented to the IWC Scientific Committee, May 1991 (unpublished). 9pp.

Kishino, H., Kato, H., Kasamatsu, F. and Fujise, Y. 1991b. Detection of heterogeneity and estimation of population characteristics from the field survey data: 1987/88 Japanese feasibility study of the Southern Hemisphere minke whales. *Annals of the Institute of Statistical Mathematics* 43 (3):435-53.

Lockyer, C. 1972. The age at sexual maturity of the Southern fin whale (*Balaenoptera physalus*) using annual layer counts in the earplug. *J. Cons. int. Explor.* 34(2):276-294.

Masaki, Y. 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn* 29:375-395.

Matsuishi, T. and Kishino, H. 1991. Precision of the estimated natural mortality coefficient and recruitment rate evaluated by Monte Carlo simulation. Paper SC/43/Mi21 presented to the IWC Scientific Committee, May 1991 (unpublished). 9pp.

Nakamura, T. 1991. A new look at a Bayesian cohort model for time-series data obtained from research takes of whales. *Rep. int. Whal. Commn* 41:345-348.

Nakamura, T. 1992. Simulation trials of a Bayesian cohort model for time-series data obtained from research takes of whales. *Rep. int. Whal. Commn* 42:421-427.

Nakamura, T. 1993. Two-stage Bayesian cohort model for time- series data to reduce bias in the estimate of mean natural mortality rate. *Rep. int. Whal. Commn* 43:343-348.

Nakamura, T., Ohnishi, S. and Matsumiya, Y. 1989. A Bayesian cohort model for catch-at-age data obtained from research takes of whales. *Rep. int. Whal. Commn* 39:375-382.

Nishiwaki, S., Ishikawa, H., Itoh, S., Matsuoka, K., Yuzu, S., Nagatome, I., Yamagiwa, D., Murase, H., Tanifuji, S., Miyakoshi, H. and Ono, K. 1994. Report of the 1993/94 cruise of the Japanese whale research programme under special permit in the Antarctic Area IV. Paper SC/46/SH15 presented to the IWC Scientific Committee, May 1994 (unpublished). 42pp.

Nishiwaki, S., Ishikawa, H., Itoh, S., Shimamoto, K., Mogoe, T., Kawazu, H., Machida, S., Yamane, T., Ono, K. and Ohkoshi, C. 1995. Report of the 1994/95 cruise of the Japanese whale research programme under special permit (JARPA) in the Antarctic Area V. Paper SC/47/SH5 presented to the IWC Scientific Committee, May 1995 (unpublished). 38pp.

Nishiwaki, S., Ishikawa, H., Tohyama, D., Kawasaki, M., Shimamoto, K., Yuzu, S., Tamura, T., Mogoe, T., Hishii, T., Yoshida, T., Hidaka, H., Nibe, H., Yamashiro, K., Ono, K. and Taguchi, F. 1996. Report of the 1995/96 Japanese whale research program under special permit in the Antarctic (JARPA) in Area IV and eastern part of Area III. Paper SC/48/SH12 presented to the IWC Scientific Committee, May 1996 (unpublished). 48pp.

Nishiwaki, S., Matsuoka, K., Kawasaki, M., Kishino, H. and Kasamatsu, F. 1997. Review of the sighting surveys in the JARPA. Paper presented at this meeting.

Ohsumi, S. 1979a. Interspecific relationships among some biological parameters in cetaceans and estimation of the natural mortality coefficient of the Southern Hemisphere minke whale. *Rep. int. Whal. Commn* 29:397-406.

Ohsumi, S. 1979b. Population assessment of the Antarctic minke whale. *Rep. int. Whal. Commn* 29:407-420.

Ohsumi, S. 1986. Yearly change in age and body length at sexual maturity of a fin whale stock in the eastern North Pacific. *Sci. Rep. Whales Res. Inst., Tokyo* 37:1-16.

Ohsumi, S. 1995. The necessity of employing lethal methods in the study of whale resources. Research on Whales:13-22. *The Inst. Cet. Res.*

Ohsumi, S. 1997. Significance, history and current situation of research take of whales under special permit. IBI Rep., 8: The 9th Annual International Symposium of IBI, Kamogawa, Japan.

Ohsumi, S. and Masaki, Y. 1975. Biological parameters of the Antarctic minke whale at the virginal population level. *J. Fish. Res. Bd. Canada*, 32 (7):995-1004.

Ohsumi, S., Masaki, Y. and Kawamura, A. 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whal. Res. Inst., Tokyo* 22:75-125.

Okamoto, H. 1988. Age determination of juvenile Southern minke whales. BA thesis, Tokyo Fisheries University. 28pp. (in Japanese).

Pastene, L.A., and Goto, M. 1997. A review of the studies on stock/species identity in the minke and other baleen whale specieds, conducted under the Japanese whale research program under special permit in the Antarctic (JARPA). Paper presented at this meeting.

Sakuramoto, K., Kato, H.and Tanaka, S. 1985. A simulation study of several factors which may influence the estimates of a trend in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whale. Commn* 35:285-9.

Sakuramoto, K., Tanaka, S. and Kato, H. 1986. A simulation study of the effects of ageing error on trends in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn* 36:213-9.

Tanaka, S. 1988. A preliminary consideration on a method for estimating age-dependent natural mortality from age-composition obtained by random sampling. *Rep. int. Whal. Commn* 38:140-142.

Tanaka, S. 1990. Estimation of natural mortality coefficient of whales from the estimates of abundance and age composition data obtained from research catches. *Rep. int. Whal. Commn* 40:531- 536.

Tanaka, S., Kasamatsu, F. and Fujise, Y. 1992. Likely precision of estimates of natural mortality rates from Japanese research data for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 42:413-420.

Tanaka, E. and Nakamura, T. 1995. Preliminary estimation of average natural mortality coefficient of Southern minke whales using JARPA data. Paper SC/47/SH8 presented to the IWC Scientific Committee, May 1995 (unpublished). 10pp.

Tillman, M.F. and Chapman, D.G. 1981. Further consideration of reasons for a more conservative approach to whale management. *Rep. int. Whal. Commn* 35:31-5

Table 1. Comparison of advantages between lethal and non-lethal methods for the study related to estimation of biological parameters of the minke whale (modified from Ohsumi, 1995).

Research items	Lethal	Non-lethal
Total and proportional body length	Body characteristic measurement:advantageous and practical	Photogrametry, visual estimation:disadvantageous
Total and partial body weight	Direct or dissection measurement:advantageous	Live capture:disadvantageous
Age determination	Collection of age characteristics: advantageous	External observation of physical characteristics:disadvantageous and impractical
Growth	Body length measurement, age determination:advantageous	Long-term observation through individual identification:almost impossible
Sexual maturation	Reproductive organ collection:advantageous	External genital observation:disadvantageous and dangerous
Breeding season	Reproductive organ collection and foetal growth:advantageous	Observation of mating behavior:disadvantageous
Pregnancy	Verification of foetus:advantageous	Collection of biopsy and analysis of sex hormones:disadvantageous
Nursing and lactation	Analysis of mammary gland and calf stomach contents: advantageous	Observation of mother-calf behavior:dis advantageous
Reproductive cycle	Pregnancy or ovulation rate: advantageous	Long-term monitoring via individual identification:disadvantageous

Table 2. Comparison of surveys of research take with those in commercial whaling.

Items	Commercial whaling	Research take
Schedule of convention	Need to follow the rules decided by IWC	Need not apply any rule to survey
Design of research	Should be followed by operation of whaling company	Scientist can design independently
Scale of research	Determined by plan of production of company	Scientist can determine accepting the research purpose
Research area	Concentrate to productive area	Can operate widely accepting purpose
Research season	Concentrate into productive season	Can operate long accepting purpose
Research method	Follow circumstance	Scientist can decide accepting purpose
Selection of whales caught	Select larger whales	Scientist can decide accepting purpose
Processing	Treat whale carcass within short time	Can use long time for research

APPENDIX

Scientific works on estimation of biological parameters in the Southern Hemisphere minke whale based on data and material obtained by the JARPA.

Bregh, M.O., Butterworth, D.S. and Punt, A.E. 1991. Further examination of the potential information content of age-structure data from Antarctic minke whale research catches. *Rep. int. Whal. Commn* 41:349-361.

Butterworth, D.S. and Punt, A.E. 1990. Some preliminary examinations of the potential information content of age-structure data from Antarctic minke whale research catches. *Rep. int. Whal. Commn* 40:301-315.

Butterworth, D.S. and Geromont, H.F. 1996. On the provision of advice on the effect on stock(s) of scientific permit catches, with particular reference to proposed research catches of minke whales from Antarctic Area IV. *Rep. int. Whal. Commn* 46:653-655.

Butterworth, D.S., Punt, A.E., Geromont, H.F., Kato, H. and Miyashita, T. 1996. An ADAPT approach to the analysis of catch- at-age information for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 46:349-359.

Cooke, J.G. and De La Mare, W.K. 1993. A comparative note on demographic parameters of right and minke whales. Paper SC/45/O25 presented to the IWC Scientific Committee, May 1993 (unpublished). 12pp.

Fujise, Y., Kato, H. and Kishino, H. 1990. Reproductive segregation of the minke whale population in high latitudinal waters with some estimations of pregnancy and sexual maturity rates, data from Japanese research takes in 1987/88 and 1988/89. Paper SC/42/SHMi10 presented to the IWC Scientific Committee, June 1990 (unpublished). 20pp.

Fujise, Y., Yamamura, K., Zenitani, R., Ishikawa, H., Yamamoto, Y., Kimura, K. and Komaba, M. 1990. Cruise report of the research on Southern minke whales in 1989/90 under the Japanese proposal to the scientific permit. Paper SC/42/SHMi25 presented to the IWC Scientific Committee, June 1990 (unpublished). 56pp.

Fujise, Y., Kato, H. and Kishino, H. 1991. Some progress in examination on age distribution and segregation of the Southern minke whale population using data from the Japanese research take. Paper SC/43/Mi18 presented to the IWC Scientific Committee, May 1991 (unpublished). 17pp.

Fujise, Y., Kato, H., Zenitani, R. and Kishino, H. 1992. Seasonal and areal changes in age distribution and segregation of the Southern minke whales in Antarctic areas IV and V using data from the Japanese researches. Paper SC/44/SHB10 presented to the IWC Scientific Committee, June 1992 (unpublished). 37pp.

Fujise, Y., Ishikawa, H., Saino, S., Nagano, M., Ishii, K., Kawaguchi, S., Tanifuji, S., Kawashima, S. and Miyakoshi H. 1993. Cruise report of the 1991/92 Japanese research in Area IV under the special permit for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 43:357-71.

Fujise, Y., Zenitani, R., Saino, S., Itoh, S., Kawasaki, M., Matsuoka, K. and Tamura, T. 1993. Cruise report of the 1992/93 Japanese research under the special permit for Southern Hemisphere minke whales. Paper SC/45/SHB12 presented to the IWC Scientific Committee, April 1993 (unpublished). 39pp.

Fujise, Y. and Kishino, H. 1994. Patterns of segregation of minke whales in Antarctic Areas IV and V as revealed by a logistic regression model. Paper SC/46/SH11 presented to the IWC Scientific Committee, May 1994 (unpublished). 23pp.

Fujise, Y., Zenitani, R., Kato, H. and Kishino, H. 1994. Age distributions of minke whales in the Antarctic Areas IV and V in 1991/92 and 1992/93 seasons. Paper SC/46/SH20 presented to the IWC Scientific Committee, May 1994 (unpublished). 22pp.

Hamada, N., Yamazaki, S., Toda, S., Fujise, Y. and Zenitani, R. 1989. X-Ray Fluorescence Analysis of Earplug of Minke Whales. The Japanese Society for Anatomical Chemistry. October 1989, Sendai.

Institute of Cetacean Research. Progress Report. 1990. Japanese research program on Southern Hemisphere minke whale and preliminary research on the marine ecosystem in the Antarctic and program on its feasibility studies. Paper SC/42/SHMi28 presented to the IWC Scientific Committee, June 1990 (unpublished). 16pp.

Institute of Cetacean Research. 1991. Research activities of the Institute of Cetacean Research during May 1990 to April 1991. Paper SC/43/O23 presented to the IWC Scientific Committee, May 1991 (unpublished). 4pp.

Institute of Cetacean Research. 1992. Research activities of the Institute of Cetacean Research during May 1991 to April 1992. Paper SC/44/O19 presented to the IWC Scientific Committee, June 1992 (unpublished). 17pp.

Institute of Cetacean Research. 1993. Research activities of the Institute of Cetacean Research during May 1992 to April 1993. Paper SC/45/SHBa11 presented to the IWC Scientific Committee, April 1993 (unpublished). 6pp.

Institute of Cetacean Research. Progress Report. 1994. Research activities of the Institute of Cetacean Research during May 1993 to April 1994. Paper SC/46/O24 presented to the IWC Scientific Committee, May 1994 (unpublished). 16pp.

Institute of Cetacean Research. 1995. Research activities of the Institute of Cetacean Research May 1994 to April 1995. Paper SC/47/O7 presented to the IWC Scientific Committee, May 1995 (unpublished). 10pp.

Institute of Cetacean Research. 1996. Research activities of the Institute of Cetacean Research May 1995 to June 1996. Paper SC/48/O16 presented to the IWC Scientific Committee, June 1996 (unpublished). 11pp.

Kasamatsu, F., Yamamoto, Y., Zenitani, R., Ishikawa, H., Ishibashi, T., Sato, H., Takashima, K. and Tanifuji, S. 1993. Report of the 1990/91 Southern minke whale research cruise under scientific permit in Area V. *Rep. int. Whal. Commn* 43:505-22.

Kato, H., Kishino, Y. and Fujise, Y. 1988. The age composition and age-different habitat utilization of Southern minke whales based on samples collected by 1987/88 Japanese whale research program. The 11th Symposium on Polar Biology, November, 1988, Tokyo.

Kato, H., Hiroyama, H., Fujise, Y. and Ono, K. 1989. Preliminary report of the 1987/88 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 39: 235-248.

Kato, H. and Zenitani, R. 1990. The notch on baleen plate of Southern minke whales, as a neonatal mark. The 1990 Spring Meeting of the Japanese Society of Fisheries Science, April, 1990, Tokyo. Supplement p.32.

Kato, H., Fujise, Y., Yoshida, H., Nakagawa, S., Ishida, M. and Tanifuji, S. 1990. Cruise report and preliminary analysis of the 1988/89 Japanese feasibility study of the special permit proposal for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 40: 289-300.

Kato, H., Kishino, H. and Fujise, Y. 1990. Some analyses on age composition and segregation of Southern minke whales using samples obtained by the Japanese feasibility study in 1987/88. *Rep. int. Whal. Commn* 40:249-56.

Kato, H. and Miyashita, T. 1991. Migration strategy of Southern minke whales in relation to reproductive cycles estimated from foetal lengths. *Rep. int. Whal. Commn* 41:363-369.

Kato, H. and Sakuramoto, K. 1991. Age at sexual maturity of Southern minke whales: a review and some additional analyses. *Rep. int. Whal. Commn* 41:331-337.

Kato, H., Fujise, Y. and Kishino, H. 1991. Age structure and segregation of Southern minke whales by the data obtained during Japanese research take in 1988/89. *Rep. int. Whal. Commn* 41: 287- 92.

Kato, H., Zenitani, R. and Nakamura, T. 1991. Inter-reader calibration in age readings of earplug from Southern minke whale, with some notes of age readability. *Rep. int. Whal. Commn* 41:339- 343.

Kato, H. 1995. Migration strategy of Southern minke whales to maintain high reproductive rate. *in:* Blix, A.S., Walloe, L. and Ultang, O. (eds.) *Whales, seals, fish and man.* Elsevier, Amsterdam. 465-478.

Kishino, H., Kato, H., Kasamatsu, F. and Fujise, Y. 1989. Statistical method for the estimation of age composition and biological parameters of the population. Paper SC/41/SHMi3 presented to the IWC Scientific Committee, June 1989 (unpublished). 39pp.

Kishino, H., Fujise, Y., Kato, H. and Taga, Y. 1991. Maximum likelihood procedure for the estimation of the mean age at sexual maturity of minke whales using the data from the Japanese research take. Paper SC/43/Mi23 presented to the IWC Scientific Committee, May 1991 (unpublished). 9pp.

Kishino, H., Kato, H., Kasamatsu, F. and Fujise, Y. 1991. Detection of heterogeneity and estimation of population characteristics from the field survey data: 1987/88 Japanese feasibility study of the Southern Hemisphere minke whales. *Annals of the Institute of Statistical Mathematics* 43 (3):435-53.

Matsuishi, T. and Kishino, H. 1991. Precision of the estimated natural mortality coefficient and recruitment rate evaluated by Monte Carlo simulation. Paper SC/43/Mi21 presented to the IWC Scientific Committee, May 1991 (unpublished). 9pp.

Nakamura, T. 1991. A new look at a Bayesian cohort model for time-series data obtained from research takes of whales. *Rep. int. Whal. Commn* 41:345-348.

Nakamura, T. 1992. Simulation trials of a Bayesian cohort model for time-series data obtained from research takes of whales. *Rep. int. Whal. Commn* 42:421-427.

Nakamura, T. 1993. Two-stage Bayesian cohort model for time- series data to reduce bias in the estimate of mean natural mortality rate. *Rep. int. Whal. Commn* 43:343-348.

Nakamura, T., Ohnishi, S. and Matsumiya, Y. 1989. A Bayesian cohort model for catch-at-age data obtained from research takes of whales. *Rep. int. Whal. Commn* 39:375-382.

Nishiwaki, S., Ishikawa, H., Itoh, S., Matsuoka, K., Yuzu, S., Nagatome, I., Yamagiwa, D., Murase, H., Tanifuji, S., Miyakoshi, H. and Ono, K. 1994. Report of the 1993/94 cruise of the Japanese whale research programme under special permit in the Antarctic Area IV. Paper SC/46/SH15 presented to the IWC Scientific Committee, May 1994 (unpublished). 42pp.

Nishiwaki, S., Ishikawa, H., Itoh, S., Shimamoto, K., Mogoe, T., Kawazu, H., Machida, S., Yamane, T., Ono, K. and Ohkoshi, C. 1995. Report of the 1994/95 cruise of the Japanese whale research programme under special permit (JARPA) in the Antarctic Area V. Paper SC/47/SH5 presented to the IWC Scientific Committee, May 1995 (unpublished). 38pp.

Nishiwaki, S., Ishikawa, H., Tohyama, D., Kawasaki, M., Shimamoto, K., Yuzu, S., Tamura, T., Mogoe, T., Hishii, T., Yoshida, T., Hidaka, H., Nibe, H., Yamashiro, K., Ono, K. and Taguchi, F. 1996. Report of the 1995/96 Japanese whale research program under special permit in the Antarctic (JARPA) in Area IV and eastern part of Area III. Paper SC/48/SH12 presented to the IWC Scientific Committee, May 1996 (unpublished). 48pp.

Okamoto, H. 1988. Age determination of juvenile Southern minke whales. BA thesis, Tokyo Fisheries University. 28pp. (in Japanese).

Tanaka, S. 1988. A preliminary consideration on a method for estimating age-dependent natural mortality from age-composition obtained by random sampling. *Rep. int. Whal. Commn* 38:140-142.

Tanaka, S. 1990. Estimation of natural mortality coefficient of whales from the estimates of abundance and age composition data obtained from research catches. *Rep. int. Whal. Commn* 40:531-536.

Tanaka, S., Kasamatsu, F. and Fujise, Y. 1992. Likely precision of estimates of natural mortality rates from Japanese research data for Southern Hemisphere minke whales. *Rep. int. Whal. Commn* 42:413-420.

Tanaka, E. and Nakamura, T. 1995. Preliminary estimation of average natural mortality coefficient of Southern minke whales using JARPA data. Paper SC/47/SH8 presented to the IWC Scientific Committee, May 1995 (unpublished). 10pp.