

Report of the Review Meeting of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA) called by the Government of Japan, Tokyo, 18-20 January 2005¹

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 Terms of Reference of the meeting were to review available data and research results in light of the objectives of 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. The list of participants is given in Annex A.

Masayuki Komatsu, Director for Research and Environmental Protection, Fishery Agency, Government of Japan and Japan's Alternate Commissioner to the IWC, welcomed the participants. He noted that the IWC Scientific Committee will undertake a review of JARPA after the completion of the 16-year program. During the 2004 IWC Scientific Committee meeting Japan proposed to host a meeting reviewing JARPA results limited to the first 15 years of JARPA, so that relevant recommendations and comments from such a meeting could be taken into account in the JARPA II proposal. Komatsu briefly outlined the JARPA research objectives and noted that a large amount of valuable data and samples had been accumulated and that the Scientific Committee had positively evaluated JARPA in the Committee's mid-term review conducted in 1997. He hoped that the meeting would produce fruitful discussions in order to make the best use of JARPA information for management of whale resources in the Antarctic.

1. ELECTION OF CHAIR

Kato was elected Chairman.

2. APPOINTMENT OF RAPPORTEUR

Pastene agreed to act as rapporteur assisted by Mori, Murase and Kanda.

3. ADOPTION OF THE AGENDA

The meeting adopted the agenda shown in Annex B.

4. REVIEW OF DOCUMENTS

The documents available to the meeting are listed in Annex C and are available on the following web site: www.icrwhale.org/eng-index.htm

5. REVIEW OF JARPA RESEARCH OBJECTIVES

JR1 reviews JARPA research objectives and the work on the JARPA tasks recommended by the IWC Scientific Committee in 1997 (IWC, 1998). The Government of Japan has been conducting JARPA since the 1987/88 austral summer season under Article VIII of the International Convention for Regulation of Whaling, as a long-term research project. The last survey of JARPA will be completed in the 2004/05 season. The original objectives for the research had been:

- (1) estimation of the biological parameters to improve the stock management of the Southern Hemisphere minke whale;
- (2) elucidation of the role of whales in the Antarctic marine ecosystem.

Subsequently, as part of the natural evolution of the program and in response to developing requirements, two further objectives had been added:

¹ This report is available in the following website: www.icrwhale.org/eng-index.htm

- (3) elucidation of the effect of environmental changes on cetaceans;
- (4) elucidation of the stock structure of Southern Hemisphere minke whales to improve stock management.

The tasks recommended by the IWC Scientific Committee in 1997 were the following:

- (1) Abundance estimates
 - (a) Development of method to correct bias of abundance estimate.
- (2) Stock structure
 - (a) Stock definition.
 - (b) Statistical analysis of mtDNA data considering inclusion of school size as a covariate.
 - (c) Pilot study on nuclear DNA on JARPA minke samples.
 - (d) Effort to obtain biological materials for genetic analysis from low latitude areas of the Southern Hemisphere.
 - (e) External morphology/morphometry analysis.
 - (f) Examination of possible stock boundaries (geographical and temporal) in Areas IV and V.
- (3) Biological parameters
 - (a) Segregation study
 - (b) Recalculation of biological parameters by biological stocks
- (4) Marine ecosystem and environmental change
 - (a) Meso-scale survey plan

JR1 concluded that reasonable progress had been made on these tasks.

The meeting noted that the research objectives at the start of JARPA had been designed to meet management needs at that particular time. Although these needs have changed, the meeting **agreed** that JARPA work remains relevant for providing data important for management, for example for estimating *MSYR* now compared to natural mortality *M* in the past, because the two are interrelated in the interpretation of catch-at-age data.

6. REVIEW OF JARPA SURVEY PROCEDURE AND DATA COLLECTED

6.1 Survey procedure

JR2 presents a review of the general methodology and survey procedures of JARPA. Following two-year feasibility surveys in the austral summer seasons of 1987/88 and 1988/89, full JARPA surveys have been conducted annually since the 1989/90 season. JARPA is designed to repeat surveys in the Antarctic Areas IV and V in alternate years (Fig. 1). Although the whole research period was from the end of November to March, the primary research in Areas IV and V was concentrated in January and February. Two or three sighting/sampling vessels (SSVs) conducted sighting and sampling surveys on a predetermined track-line with parallel sub-track lines. A dedicated sighting vessel (SV) was introduced from the 1991/92 season and the SSVs followed the SV to avoid any influence of sampling activity on the sighting survey. One or two Antarctic minke whales were sampled randomly from each primary sighting of a school by the SSVs. A total of 300 (with 10% allowance) Antarctic minke whales were taken from Area IV or V in alternate seasons. From the 1995/96 season onwards, the survey area was expanded into parts of Areas III and VI and 100 (with 10% allowance) further samples were added. A summary of research procedures and results for each survey cruise were also provided in JR2.

A table showing an outline of the JARPA program was presented to the meeting. This included summary information for each survey conducted from 1987/88 to 2003/04. Several suggestions to improve the table were offered by the meeting. An improved version of the table is shown in Annex D.

It was suggested that three pieces of information, in addition to those presented in JR2, could be helpful for the interpretation of abundance estimates from JARPA data: specification of the relationships between searching effort (number and positioning of dedicated observers) on SV and SSVs in JARPA in comparison to those in IDCR/SOWER surveys; more information on changes in the extent of

‘skipping’ in the JARPA track design for surveys over time and provision of information on observer experience.

6.2 Data collected

A list of the data sets produced by JARPA was presented to the meeting. Several suggestions to improve the list were offered by the meeting. An improved version of the list is shown in Annex E.

7. REVIEW OF RESULTS IN THE LIGHT OF JARPA OBJECTIVES

7.1 Stock structure of Antarctic minke whale

7.1.1 Genetic analyses

JR3 presented the results of mtDNA RFLP (six restriction enzymes) and microsatellite (six loci) analyses for identifying stock structure from the samples of Antarctic minke whales obtained during JARPA surveys from the 1987/88 to the 2003/04 austral summer seasons in Areas III E, IV, V and VI W. The mtDNA and microsatellite analyses involved a total of 5,838 and 5,808 samples respectively. Statistical analyses were based upon the geographical strata defined for the JARPA surveys. Both analyses showed substantial spatial heterogeneity in some of the comparisons between whales from different geographic strata. The general pattern of spatial variation was concordant among the two approaches: a) no evidence for differences between the whales in Area III E and in Areas IV W and IV E, b) no evidence of differences between the whales in Area VI W and in Area V E, and c) evidence for differentiation between the whales in Areas III E, IV W, IV E and in Areas V E, VI W. These results were therefore consistent with the hypothesis of two stocks that were possibly related to the proposed breeding areas in the eastern Indian and the western South Pacific Ocean. A fine-scale mtDNA analysis suggested a ‘soft’ boundary at 165°E.

The meeting considered that JR3 is an important paper given that elucidation of the stock structure of the Antarctic minke whale is one of the objectives of JARPA.

Participants commented that the results presented in JR3 strongly rejected the scenario of a single stock in the JARPA research area. Questions were raised whether results presented also gave evidence of more than two stocks in this area. Pastene responded that the results presented are most readily explained by the two-stock scenario. In this context Pastene briefly presented For Info 5 (Kasamatsu *et al.*, 1995). This paper used sighting data derived from the Japanese sighting surveys in low latitudes during 1976 to 1987 to attempt to locate breeding areas of Antarctic minke whales. The spatial distribution in tropical and subtropical waters during the latter half of the conception period suggested two breeding grounds in the eastern and western South Pacific and two in the eastern and western Indian Ocean. Pastene suggested that the two stocks proposed in the JARPA research area could be related to these breeding grounds suggested in the eastern Indian and western South Pacific Oceans. Butterworth pointed out that from the geographical point of view there is the possibility that animals from the western Indian Ocean breeding ground could contribute to the minke whales found in Area III E. If so, a scenario with three stocks in the JARPA research area is possible.

Hatanaka believed that the two stocks hypothesis is more consistent with the results and asked if there was a basis for the multiple stocks hypothesis. Walloe responded that although the two-stock hypothesis was the simplest and most likely explanation, it was still premature to rule out the possibility of more than two stocks.

Ohsumi noted that the sighting effort in the study by Kasamatsu *et al.* (1995) was very limited. He presented information on the distribution of fetus size in relation to the migration distance from breeding areas. Females with small (≤ 6 cm) and large (≥ 280 cm) fetuses are those which are close to their breeding areas. Based on such information he suggested that there is the possibility of a single breeding ground for minke whales in the central Indian Ocean; these then migrate to feeding areas from Area III E to approximately 150-160°E, thus supporting the results and interpretation of the genetic data.

Hester asked about the actual age difference between a fetus of 6cm and one of 280cm. Ohsumi responded that the difference might be about 9 and a half months, but depended on their growth rate. The Chair added that based on a period of 70-75 days to reach 15cm, a fetus of 6cm would be 40 days old.

Butterworth pointed out that the difference in sampling time in Areas III E and VIW should be considered in future analyses because small fetuses might have been preferentially obtained from females collected early in the season. Ohsumi agreed to consider that factor in future analyses.

The Chair advised that a Russian scientist had found females with mummified fetuses in the Indian Ocean, suggesting that this was one of the breeding areas for Antarctic minke whales. Ishikawa commented that there were a few reports of fetus mummification in the JARPA samples, but no obvious linkages to breeding areas have been found thus far.

The meeting noted that the suggested boundary at 165°E was based on mtDNA only, and that the 'soft' boundary concept suggested in JR3 could alternatively be interpreted as two stocks mixing near that longitude. Hatanaka mentioned that the analysis of biological parameters also supported a boundary at 165°E.

In terms of setting a boundary, Butterworth suggested estimation of mixing proportions around this boundary, treating the westernmost and the easternmost areas in JARPA as 'pure' stocks. Pastene agreed to conduct such an analysis in future.

Walloe noted that the number of microsatellite loci used (6) in the analysis was smaller than that used for the North Pacific minke whale (17).

Butterworth asked for an explanation on why females showed more structure than males in some analyses. Pastene responded that one possible reason was sex difference in site fidelity.

7.1.2 Non-genetic analyses

JR3 also presented the results of an analysis of the stock structure of the Antarctic minke whales that utilized the following non-genetic methods: mean body length of physically matured whales (n=2,323), morphometrics (5,549) and distribution of the parasite *Anisakis simplex* (n=6,338). Samples obtained during JARPA surveys from the 1987/88 to the 2003/04 austral summer seasons in Areas III E, IV, V and VIW were used in the analyses. Grouping of samples in these analyses was the same as for the genetics analyses. Similar to the genetic approaches, the results supported the hypothesis of two stocks in the JARPA research area.

The meeting noted that the pattern of stock structure found by non-genetic approaches was similar to that found by the genetic approaches. There was a suggestion that the statistical analysis used for examining morphometric data could be further elaborated. Genetic population structure in *Anisakis simplex* has been studied in other areas. The question was therefore raised of whether any such studies are included in JARPA. Pastene responded that no such study has been conducted at the ICR. Otani added that a genetic research plan for *Anisakis* collected by JARPA was now being discussed. He further introduced a phylogenetic study of *Anisakis* conducted in the North Pacific.

7.1.3 Summary of results

The meeting noted that the part of the JARPA program addressing issues of stock structure had been designed in accordance with a number of studies that had concluded that the most effective way to address questions on stock identity is to consider results from several techniques. 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, and that the aim of the JARPA design to sample randomly had aided in obtaining representative samples from the research areas covered. With regard to the tasks that needed to be pursued to facilitate interpretations of stock structure from JARPA data that were recommended by the IWC Scientific Committee in 1997 (see section 5), the meeting **agreed** that good progress had been achieved on all of these tasks. However, the meeting also **stressed** the importance of examination of samples from low latitudes for obtaining a clearer genetic delimitation of breeding stocks.

The results from the different techniques provide strong evidence to reject the hypothesis of a single stock in the research area. The most parsimonious explanation of the results is that there are two stocks present in the research area: an eastern Indian (I) and a western South Pacific (P) stock. These stocks would mix across a soft boundary, which would probably best be placed near 165°E. Further analyses could usefully estimate the proportion of I and P animals in an overlap area such as VW using a method such as that applied in the case of North Pacific minke whales (IWC, 2003). However, the

possibility of more than two stocks cannot as yet be ruled out. For example there could be some presence of a stock from the western Indian Ocean in the western most part of the research area (following the postulate of Kasamatsu *et al.* (1995) based on sighting rates in low latitudes of two breeding stocks in the Indian Ocean). It was noted, however, that the study by Kasamatsu *et al.* (1995) was based on limited searching effort thus there is uncertainty regarding the occurrence of two breeding grounds in the Indian Ocean as proposed in that study. Information on distribution of fetus length suggested that there is possibly only one breeding ground in the central Indian Ocean.

Overall the meeting **agreed** that these results suggested the need to revise the IWC's current specifications for management Area boundaries. The results will also assist in calculating abundance and biological parameter values that relate more closely to biological stocks units. They will also inform the specifications and testing of appropriate *Combination Areas* for cascading under the RMP.

7.2 Biological parameters of Antarctic minke whales

7.2.1 Unbiased estimation of abundance and trends

JR4 examined the effect of sampling activities, particularly closing mode, on the estimation of abundance using the methods of Haw (1991). The bias originating from under-surveying in high density areas was examined. Correction factors were estimated by comparing uncorrected abundance estimates among SSV, SV in closing mode and SV in passing mode. As significant differences between estimates for these different modes were detected, abundances were adjusted using correction factors. Corrected abundance estimates are not significantly different to those from IDCR surveys during CP II, and are larger than those derived from spatial modeling. This last matter should be investigated further. No significant trend in abundance was detected in either Area IV or Area V. The authors concluded that the underestimation of abundance pointed out at the JARPA review meeting in 1997 is largely due to the effects of closing mode and of sampling activity. Abundance estimates derived by the method proposed can be used to estimate biological parameters with higher precision.

Butterworth commented that the two correction factors for the abundance estimates (R1: correction factor between SSV and SV; R2: correction factor between SV closing mode and SV passing mode) should be examined carefully, especially the R1 correction factor. The reason for this is that there had been some change in "skipping" protocol over the course of the JARPA survey period. To examine the annual effect of this factor might be difficult because of data limitations; therefore Butterworth suggested that it might instead be useful to categorize this factor as "large" or "small" and then incorporate this into the model as a covariate. He emphasized that these abundance estimates are key input to other analyses, and also raised the importance of conducting possible sensitivity tests to check the robustness of the estimates.

Hakamada responded that the reason why he did not consider skipping in this analysis is that in his preliminary calculations, no significant difference was found in relation to skipping between the early and late surveys using ANOVA.

Butterworth commented that he was pleased that Hakamada has looked into this effect, but also stressed the importance of considering Type II error. Even though there is no significant difference, he suggested conducting the analysis with and without the skipping factor to ascertain the difference in the abundance estimates and their precision. Hakamada agreed to consider this effect in more detail in future analyses.

Walloe pointed out that some of the detection functions shown in Figure 3 of JR4 do not fit the data well, and suggested that these aspects should be re-examined.

Butterworth noted that due to considerable stratification of the data, some of the sample sizes in the analysis have become small. This may lead to false impressions of the detection function and hence to biased estimates of abundances. It might be important to conduct the analysis by first pooling the data to see whether there are any significant differences between the covariates. He further commented that though pooling the data may not show different results to the analysis in JR4, it is important to show such results as sensitivity tests. He also noted that the R2 factor was appreciably lower than for the IDCR surveys, and suggested that reasons for this be sought.

Hakamada expressed appreciation for these comments and agreed to consider them in future work.

JR20 presented a study based on a spatial model of minke whales using JARPA data from 1990/1991 to 2000/2001 in Area V. A Horvitz-Thompson estimator was used to obtain estimates of the expected school size, by stratum, based on estimated detection probabilities which allow for the effects of covariates. Estimates of minke whale abundance, as well as abundance of schools of size 1 and abundance of individuals in schools of size greater than 1, were presented to use for estimation of biological parameters. The resultant abundance estimates in Area V are notably lower than those in JR4.

Butterworth commented that a reason why the abundance estimates shown in this paper are smaller than those of Hakamada is that this analysis considers the survey mode factor by year and omits it as non-significant, whereas JR4 considers this effect in combination over all years and finds significance given the larger sample size. Butterworth suggested that the authors of JR20 should also consider the effect of survey mode as in JR4, and then compare the results for the two methodologies.

Hakamada responded that it is possible to examine this effect. However, he also pointed out that at the 2004 IWC Scientific Committee meeting, it was shown through simulation tests that spatial modeling gives unbiased results regardless of survey mode, and the JR20 analysis is based on that assumption.

The meeting noted that the methods presented in JR20 and JR4 used different assumptions and **agreed** that it is important that these analyses are presented in a more comparable way so that valid comparisons between these different analytical methods become possible. There is a need for further discussion between the respective authors to achieve this.

7.2.2 Estimation of biological parameters

JR5 used materials collected by the JARPA surveys in Areas III, IV, V and VIW in 1987/88 to 2003/04, to estimate some biological parameters of the Antarctic minke whales by incorporating a new sample grouping at 165°E based on the new stock scenario ('Eastern Indian Ocean Stock (I-stock)' and 'Western South Pacific Stock (P-stock)'). These parameters included sex ratio, sexual maturity rate, body length and age at sexual maturity, body length and age at physical maturity, proportion of pregnant in matured female (PPF), foetal sex ratio and the occurrence of multiple births. Significant differences were detected between the two stocks for sex ratio, sexual maturity rate for both sexes, PPF and foetal sex ratio by application of the χ^2 -test and for body length at 50% sexual maturity for females, age at 50% sexual maturity for females and body length at 50% physical maturity for both sexes by likelihood ratio analysis. Significant yearly trends were detected among males for the following parameters by linear regression analysis: sexual maturity rate in the I-stock, body length and age at 50% sexual maturity in the I-stock and body length and age at 50% physical maturity in the P-stock. Year was also selected as an explanatory variable for age at physical maturity and body length at physical maturity by use of stepwise logistic regression analysis, but for age and body length at sexual maturity were not selected. These results suggest the possibility that expansion of the carrying capacity for the minke whales has ceased and that the ecosystem begun to return towards the conditions that existed before the expansion had taken place.

Participants commented that the yearly trends of some biological parameters shown in this paper are interesting, and it is important to discuss these trends together with the results from other studies (i.e. minke VPA, abundance estimates).

JR6 provides a point estimate for the natural mortality coefficient for Antarctic minke whales using JARPA data, by modifying the original method proposed by Tanaka (1990). Skewed age distributions arising from mature/immature segregation were corrected using the maturity rate at age. Net rates of natural increase of stock sizes corresponding to the new interpretation of a stock boundary were estimated by maximum likelihood. Under a zero increase rate for stock size (which corresponded to the statistical model selected by the c-AIC criterion), the point estimates of the natural mortality coefficient were 0.0486 (per year) for the Eastern Indian Ocean Stock and 0.0490 for the Western South Pacific Stock.

Butterworth commented that it is very important to have this analysis in addition to VPA. He also noted the importance of showing confidence intervals for the estimate of natural mortality (M) shown in Table 3 of JR6. He further suggested that results for the M estimate when the increase rate parameter (r) was estimated should also be shown in the Table, even if it was not selected by the model selection

criterion, and that the sensitivity of the M estimates to different assumptions should be discussed in the paper. Tanaka responded that at present bootstrap data to be able to calculate the confidence intervals have still to be generated, but this is planned for future work. Tanaka also commented that once the input data for the model are finalized, the estimates will be re-calculated.

JR7 examined longer term changes in the age at sexual maturity of Antarctic minke whales by counting transition phase layers in earplugs using a total of 4,547 earplugs collected from the 1971/72 to the 1986/87 commercial whaling operations and from the 1987/88 to the 2003/04 special permit surveys under the JARPA research program in Area IV. The paper incorporated the same correction methods for biases due to the truncation and the 'age-specific' effects that were addressed in past debates. No systematic ageing errors were detected between the two primary age readers. The present analysis revealed again that the age at sexual maturity declined from around 12-13 years for the 1940s cohorts to about 7 years for the late 1960s'. Using the new data set produced by JARPA, it was further found that the age at sexual maturity had remained about constant at 7 - 8 years, with perhaps a slight increase in cohorts from the early 1970s to the late 1980s.

The meeting welcomed this contribution. Walloe pointed out that it would be of interest to see the trend in age at sexual maturity shown in Fig. 7 extended to more recent years, rather than to 1993 only as shown in this figure. He further suggested using the median rather than the mean age, since this may increase number of years for which an estimate can be made. Zenitani responded that the reason why the results had been shown to 1990 only is because recent data suffer from truncation biases. Zenitani expressed appreciation for the useful comments, and will consider using the median for future analyses.

Butterworth commented that this analysis is important for interpreting trends obtained from abundance estimates. He also suggested that the analysis could provide estimates for more recent years using the model of Thompson *et al.* (1999). The meeting **recommended** that future analyses of this kind be carried out in collaboration between ICR and UCT.

Participants also commented that the effect of time lags should be considered when considering the results in relation to abundance trends .

Butterworth commented that it may be useful if a plot similar to Fig.8 of JR7 showing the age at sexual maturity from direct observations and the age at transition from the earplug for the same animal, could be provided. This type of plot would help understand the relationship between transition phase and sexual maturity of the animal.

In **JR21** Virtual Population Analyses were performed to infer natural mortality coefficients for Antarctic minke whales in Areas IV and V using catch-at-age data from both commercial whaling (1971/2-1986/7) and scientific whaling (JARPA 1987/88-2003/2004). Abundance estimates from IWC and JARPA surveys were used as tuning indices. Some sensitivity tests related to the estimation of the natural mortality coefficients were also performed. A clear difference in the estimates of the natural mortality coefficients between Areas IV and V was observed. Sensitivity analyses showed the estimate of the natural mortality coefficient in Area IV was slightly influenced by both grouping of data (such as 2-year-2-age and 3-year-3-age) and the assumption made for the maximum age used in the log-likelihood for the catch-at-age data, while the estimate in Area V was rather stable by comparison. In addition, the amount of bias in the abundance estimates arising from setting $g(0)=1$ affected the estimates of the natural mortality coefficient in Area IV to some extent. As expected, the extent of additional variance did not impact the point estimates in either Area, but it did lessen their precision.

In **JR18** the ADAPT-VPA assessment methodology of Butterworth *et al.* (1999) is applied to abundance estimates (from both IDCR/SOWER and JARPA surveys) and catch at age data (both commercial and scientific) for Areas IV and V. The methodology is extended to be able to take account of inter-annual differences in the distribution of the population between the two Areas when they are assessed jointly. An important feature of these updated results is that revised JARPA estimates of abundance are shown to be statistically comparable with estimates from the IDCR/SOWER program (i.e. calibration factor not significantly different from 1). The general pattern shown by results is of a minke whale abundance trend that increased over the middle decades of the 20th century to peak at about 1970, and then declined for the next three decades. The recruitment trend is similar, though with its peak slightly earlier. The factor to which the results are most sensitive is the value of natural mortality M . The assessments do show retrospective patterns, primarily related to changes in the best

estimate of M as time has progressed. This in turn seems linked to the IDCR/SOWER survey trends suggesting higher, and the JAPRA survey trends lower estimates of M . For the assessment of the two Areas combined, M is estimated at 0.068 with a CV of 0.12; this compares with CVs of typically 0.35 for the Area-specific assessment of Butterworth *et al.* (1999), which were based on eight seasons' fewer data. The paper reflects an account of work in progress, and suggestions are made of areas where further analysis would be desirable.

In response to an enquiry about JR21, Kitakado commented that further sensitivity analyses to different selectivity functions and to age-dependent natural mortality will be conducted. He also commented that from preliminary calculations, he had found that assuming various functions for age-dependent natural mortality led to unreasonable estimates because of a lack of information content in the data.

The meeting **noted** that the estimation of the coefficient of variation (CV) of M was greatly improved compared to previous similar analyses. Two reasons for this improvement were given: (1) addition of data obtained from further JARPA cruises, and (2) the abundance estimates of Hakamada *et al.* (JR4) (which corrected for biases between survey modes) could now be treated as comparable to those from the IDCR/SOWER surveys.

Komatsu questioned whether it is really necessary to collect samples from young animals (i.e. age 1 or 2 years old) for which the estimation of M seems to be difficult. Zenitani responded that from an age-determination point of view, it is difficult to distinguish ages 1 and 2 groups and thus these are often not used for analyses. Ishikawa commented that from a sampling point of view, there is no difficulty in collecting young animals. Kitakado remarked that changes in selectivity pattern would introduce additional estimable parameters in the model and their estimation may compromise precision. Butterworth was also concerned that changed sampling patterns might complicate data interpretation, and urged careful consideration before any changes might be implemented.

Morishita enquired about the importance of conducting similar analysis for other Areas such as Area III E and VI W for which JARPA data are also available. Butterworth responded that the extension of the analysis at this stage to Areas III E and VI W will introduce some difficulties as the sampling design was not random in those regions, so that it was likely best to postpone such initiatives for the moment while concentrating on analyses for Areas IV and V.

Kawahara asked about estimating fishing mortality (F) in the analysis. The response to this query was that the main important results from the minke VPA are the population trend and the $MSYR$ estimates (see below). The F matrix is calculated in the VPA and values can be provided if requested.

The meeting **agreed** that these analyses were valuable contributions toward the main objective of the JARPA, which is the estimation of biological parameters. Participants offered several suggestions on how these analyses could be further developed. For example, the suggestion was made to consider a U shape function for age dependent M for future analyses. There was a further suggestion to conduct the analysis on the basis of the proposed new stock structure scenario (the I and P stocks). Butterworth responded that for future studies, various functions for age dependent M will be explored, but as Kitakado had noted, due to lack of information content in the data, this may not lead to better estimation overall. He also remarked that different scenarios for stock boundaries can be explored, but extensive analyses on this matter might be better conducted after some feedback from the IWC Scientific Committee had also been obtained.

JR22 analyzed the results of the Base Case assessment of Areas IV and V to better understand the dynamics of Antarctic minke whales in the region. A stock-recruitment model of the Pella-Tomlinson form was fit to recruitment and adult female abundance estimates. The underlying assumptions were that carrying capacity of minke whales first increased, then later decreased during the 20th Century. An initial attempt at this fit suggested that the carrying capacity increased about five fold from 1930 to the mid-1960s, and then decreased again by about half. The estimated $MSYR_{1+}$ for the model was 4.0%.

Kitakado thanked the authors for the analysis presented and suggested that in equation (6) of JR22, it may be better to weight the observed recruitment data depending on the precision of the estimates. He also suggested consideration of a smoother functional form for changes in carrying capacity (K) in the model. Butterworth endorsed these comments and advised that further analysis would be conducted incorporating these suggestions.

Kawahara asked what would be the consequences of taking account of changes in the age at sexual maturity of minke whales by year for the stock-recruitment plot. Butterworth responded that qualitatively, probably the stock recruitment plot shown in Fig. 1b of JR22 would stretch toward the upper left side, in better agreement with the stock-recruitment function suggested. This would be examined in further analyses.

The meeting was **pleased** to note that the approach in JR22 allowed for estimation of *MSYR*.

7.2.3 Summary of results

Incorporation of inter-mode calibration factors (cf. Haw, 1991) in design-based estimation (JR4) of minke whale abundance from JARPA sighting surveys provides results that are comparable with those from IDCR/SOWER surveys. The model-based abundance estimates (JR20) are appreciably lower, but do not explicitly allow for the possibility of inter-mode differences; the meeting **recommended** that possibilities to make such allowance in the model-based approach be investigated to ascertain whether this would lead to comparability between the results of the two approaches. Estimated annual increase rates in abundance from the design-based results, together with associated 95% confidence intervals, are 0.3% [-4.6%; 3.9%] for Area IV and 2.5% [-1.4%; 6.2%] for Area V, i.e. not significantly different from zero, but also not excluding either positive or negative trends.

Time series of biological parameter values were reported on a biological stock basis, as requested by the mid-term JARPA review meeting (specifically for the I and P stocks, with their boundary set at 165°E – see section 7.1.3). Some significant differences between the stocks were reported, and there were significant recent increases in the age at physical maturity. Consistent with this, an examination of the transition phase in earplugs for Area IV suggested a slight increase after the 1970 cohort following an earlier appreciable decline.

Two different methods for estimating age-independent natural mortality *M* from catch-at-age and abundance data provided comparable results. The VPA method, for example, estimates $M=0.068$ ($CV=0.12$) if both Areas IV and V are assessed in combination. The meeting **noted** that this reflects much greater precision than obtained from earlier analyses, in part because of the further data now available. The VPA results all broadly reflect both recruitment and abundance increasing until about 1970, and then declining. Initial fits of these results to a population model suggest that carrying capacity for minke whales must have first increased, but subsequently declined during the 20th Century, and also allow *MSYR* to be estimated. The meeting **noted** that the results reported reflected work in progress, and identified the desirability of conducting VPA calculations assuming two stocks with a 165°E boundary.

The meeting also **noted** the broad consistency between trends in some biological parameters and in abundances predicted by VPA models, as discussed further under section 8 below.

7.3 Role of whales in the Antarctic marine ecosystem

7.3.1 Krill consumption and body condition of Antarctic minke whale

In **JR8** feeding habits and prey consumption of Antarctic minke whales were examined using stomach content data collected in JARPA. A total of ten prey species, including one amphipod, four euphausiids and five fish species were identified. Antarctic krill (*Euphausia superba*) was the most important prey species throughout the survey period. The analyses of prey digestion showed that whales tended to feed on prey in the early morning and late evening. Daily prey consumption for the Antarctic minke whale was estimated using two methods: a direct method (diurnal changes of stomach contents mass) and an indirect method (energy requirements). Daily consumption estimates were similar between the two methods and ranged from 3.6 to 5.3 % of body weight. Annual consumption of Antarctic krill from the 1990/2000 to the 2002/03 season was calculated as being equivalent to 4% and 26 % of the krill biomass in Areas IV and V, respectively. These results indicate that Antarctic minke whales are one of the dominant top-predator species in Areas IV and V.

It was noted that the decreasing trends in the mean mass of stomach contents was consistent with results that showed that the age at sexual and physical maturity has stabilized and then increased in recent years. In response to a question from Ohsumi on why minke whales occur in the Ross Sea, a region with low food availability, Tamura responded that this paradox is still unresolved. Vikingsson

noted that energy intake, and consequently consumption estimates by the indirect method, might be underestimated if residence times in the Antarctic exceed the four month period (December-March) covered in the study. It was suggested that an index related to the mean mass of stomach contents should be defined to assess changes in food availability. Currently, daily food consumption is estimated over combined areas because available samples are not sufficient to allow estimation by area.

Because area specific daily consumption rates are important to understand the change in food availability to Antarctic minke whales, the meeting **agreed** that this aspect should be considered in future analyses.

JR9 presented an analysis of recent trends in blubber thickness and factors that affect this thickness in Antarctic minke whales for both mature males and pregnant females in Areas IV and V. The results showed that a decrease of blubber thickness occurred over the JARPA survey period. This indicated that food availability for those minke whales has decreased over this survey period, quite possibly caused by either or a combination of intra- and inter-species competition among baleen whales.

The appropriate part of the animal at which to measure blubber thickness of baleen whales was discussed. Previous JARPA workers examined several body parts for blubber thickness and concluded that blubber thickness on the lateral side of the body was most practical to measure. The meeting **agreed** that the appropriate part of the body for blubber thickness measurement would be species specific.

7.3.2 Distribution and abundance trends of Antarctic minke and large (blue, fin and humpback) whales

JR10 investigated the distribution and abundance of large whales (blue, fin and humpback whales) using JARPA data from 1989/90 to 2003/04. A shift in baleen whale dominance from the Antarctic minke to humpback whales was evident in Area IV. In the 1989/90 season, the biomass of Antarctic minke was higher (382,000 tons) than that of humpback whales (128,000 tons); but 15 years later, in the 2003/04 season, the biomass of humpback (841,000 tons) was twice that of Antarctic minke whales (335,000 tons). Expansion of humpback whale distribution was also observed in Area IV between the earlier (1989/90-1996/97) and the later half of the surveys (1997/97-2002/03). Increases of fin whales were also observed in Areas III and IV. Current abundances of fin whales were estimated as 7,000-11,000 in the 2001/02 and 2003/04 seasons. A preliminary estimate of the number of fin whales south of 40°S between 35°E and 130°E based on JARPA and Japanese Scouting Vessel (JSV) data was 21,000 (CV=0.27). Abundance of blue whales was still less than 1,000 (biomass: less than 80,000 tons) in the JARPA research area. The authors commented that long term cetacean sighting surveys are very important for the management of baleen whales in the Antarctic.

Butterworth suggested that it would be important to investigate differences in the sighting rates of humpback whales 1) between passing and closing modes and 2) between SV and SSV modes using GLM. It is expected that, in comparison to minke whales, the effect for this species would not be strong (because these whales are bigger and hence easier to sight), but the results of such an exercise would be important to provide justification as to why the bias correction is necessary in the case of Antarctic minke whale abundance estimation but not necessary for humpbacks.

It was noted that during the 2004 IWC Scientific Committee meeting, several recommendations for further analyses of abundance of large whales were made (IWC, 2004). The meeting **agreed** that considerable progress has been made in addressing them.

JR19 presented results of dynamic production model analyses of the West and East Australian humpback breeding populations using the most recent JARPA survey abundance estimates as well as data from Australian coastal surveys. The model incorporated the information on mixing of the two breeding populations on the feeding grounds of Areas IV and V. Best estimates projected under continuing zero harvest indicated that the western population will approach its pristine level in some 10 years, and the more depleted eastern population in 15-20 years.

In the discussion Komatsu remarked that results of the analysis will be affected by how the carrying capacity of humpback whales is defined. Butterworth advised that the context of the analysis is a "single species" one in which humpback population carrying capacities are assumed to remain unchanged over time. Pastene pointed out that the IWC Scientific Committee defined the Western

Australian breeding stock as “Stock D” and the Eastern Australian breeding stock as “Stock E”. He suggested standardizing terminology among the reports.

The meeting **agreed** that the status of the western stock of humpback whales provided a unique opportunity to study changes in biological parameters as a population approaches carrying capacity, with the eastern stock serving as a control.

7.3.3 Inter-species relationships

JR11 presented the results of krill biomass estimation using quantitative echo sounder surveys conducted in JARPA since the 1998/99 season. This is to achieve one of the main objectives of JARPA, which is elucidation of the role of whales in the Antarctic marine ecosystem. The surveys were conducted concurrently with cetacean surveys. Similar biomass estimates were obtained in Area IV in the 1999/2000 (36.4 million t) and 2001/2002 (36.1 million t) seasons. In Area V, biomass estimates in the 2000/2001 (18.7 million t) and in the 2002/2003 (21.0 million t) seasons were similar, but biomass in 1998/1999 (32.3 million t) was higher than for the other two years. Higher biomass in 1998/99 could be explained by seasonal effects and area coverage differences. The biomass in Area IV was higher than in Area V. Regional krill distribution pattern differences in response to the southerly shift of the SB-ACC were observed in Area IV. Because krill biomass surveys in the whole of Areas IV and V were rarely conducted in the past, krill data collected by JARPA provided especially valuable information to understand krill-baleen whale relationships in the Antarctic.

Butterworth commented that some of the values in the paper had large CVs, so that care should be exercised in arguing evidence for temporal trends. He also raised concerns about target strength and analyses without concurrent species identification. Kim also mentioned some concerns about the large scale survey design and the species identification method for acoustic abundance estimation of small prey species. Murase advised that JARPA and CCAMLR use the same procedures with regard to target strength and species identification of krill. In future surveys species would be identified by conducting concurrent net sampling from the Japanese fisheries research vessel, *Kaiyo-Maru*. This vessel joined JARPA for the first time in 2004/2005, engaging in a krill and oceanographic survey. The outcome of the survey would contribute to improving future JARPA surveys and would address the concerns raised by Butterworth and Kim.

It was noted that the Government of Japan is prepared to provide the *Kaiyo-Maru* on a regular basis for future surveys in the Antarctic. The meeting **agreed** that this will provide an excellent opportunity to conduct ecological and biological research in the area.

The meeting **noted** that density estimate differences between the Australian survey (BROKE) and JARPA could be attributed to either or a combination of 1) actual inter-year fluctuations, and 2) uncertainty associated with survey methodology problems and species identification of krill in JARPA. These differences should be further investigated to attempt a more detailed explanation.

JR12 assessed the magnitude of food consumption by Antarctic minke, humpback and fin whales, on krill based on data collected by JARPA in Areas IV and V from 1999/2000 to 2002/2003. Three data sets - whale abundance, daily krill consumption rate of whales and krill biomass - were used in the analysis. All data used in this analysis were collected *in situ* except for the daily krill consumption rate of humpback and fin whales because of lack of biological information. Three baleen whales consumed 10-21% and 30-35% of the krill standing stock in Areas IV and V respectively. In Area IV, humpback whales consumed about twice as much krill as Antarctic minke whales. The results indicated that the krill surplus period for Antarctic minke whales in Area IV could now be at an end because of the increase of humpback whales, though this point should be investigated quantitatively in future using multi-species models which included both baleen whales and krill.

Butterworth commented that the overall distribution of fin whales did not overlap exactly with other whales considered in the paper and asked whether their consumption north of 60°S was also primarily krill. In response, advice was provided that fin whales north of this latitude also consumed other euphausiid species, but that for the area south of 60°S the assumptions of the paper were reasonable.

JR 23 introduced a multi-species predator-prey model of whales, seals and krill in the Antarctic that is currently being developed, and illustrated some example results that had been obtained from the model. Due to limited time, sensitivities of model outputs to various input parameter values and functional

response forms have not yet been investigated. This is planned for future work. Preliminary results show the possible role of predator-prey interactions in influencing the dynamics of the Antarctic species considered in the model.

It was suggested that consideration be given to including some of the biological parameters that were obtained by JARPA in the model in future work. Mori responded that currently the biological parameters used in the model were static but she would try to use dynamic biological parameters in the model in future. Butterworth suggested that it is premature to include those parameters in the model at this stage: the current model uses a simple age-aggregated approach, and advance to age-structured models which could take explicit account of such changes would better first await more progress with the simpler form. The meeting **encouraged** the further development of multi-species models.

7.3.4 Summary of results

Feeding studies conducted during JARPA have confirmed Antarctic krill as the main prey of minke whales, which in their turn remain a major predator of krill. However 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 (see item 7.4.1) are also consistent with a recent decline in per capita food consumption by minke whales.

Estimates of abundance from JARPA surveys indicate increases in both humpback and fin whale populations, and population modeling of humpbacks taking account also of the results from coastal surveys suggests that the breeding stock off Western Australia (stock "D" as defined by the IWC) has already recovered to its MSY level.

Contrary to the situation at the start of the JARPA program, estimates of krill consumption in recent years by humpback whales in Area IV now exceed those for minke whales. Acoustic estimates of krill biomass have been obtained during recent JARPA surveys, and estimates of krill consumption by minke, fin and humpback whales constitute an appreciable fraction of the krill abundance estimates obtained.

Taken together, these results are indicative of possible growing competition for krill amongst the baleen whale species in the region covered by the JARPA program. Initial multi-species population modeling studies (which implicitly incorporate such competitive effects) are able to broadly reproduce the various Antarctic whale population trends indicated by sighting surveys. These models need to be developed further to ascertain whether closer correspondence can be attained, and hence whether such approaches might have utility as predictive tools for management purposes.

The meeting **emphasized** the value of the availability of the research vessel *Kaiyo Maru* for mesoscale studies.

7.4 Effects of the environmental changes on cetaceans

7.4.1 Pollutant analysis

In **JR13** the concentrations of Mn, Fe, Cu, Ni, Zn, Cd, Hg, and Pb were reported from the liver and prey species (krill) from the stomach contents of Antarctic minke whales taken from Antarctic Areas IV and V during the 1988/89 to 2002/03 seasons. The ranges of concentrations for each compound were, in µg/g wet wt: Mn, 1.4-7.4; Fe, 1.6-10591; Ni, <0.1-0.1; Cu, 3.1-10; Zn, 18-103; Cd, 0.10-66; Hg, 0.004-0.43, Pb, <0.3-0.5. The levels of essential elements, such as Mn, Cu and Zn, in Antarctic minke whales were comparable to those of other baleen and toothed whales in the Northern Hemisphere. Hepatic Hg levels for Antarctic minke whales were one order of magnitude lower than other baleen whales in the Northern Hemisphere, while their Fe levels were one order of magnitude higher than for other whales elsewhere in the world. Hepatic Pb and Ni levels were close to the lower limit of detectability. There were remarkable sex differences for hepatic Fe levels for Antarctic minke whales. Before the 1995/96 season, no correlation with age was evident for Fe, Cd and Hg concentrations in livers. However, in recent years, these concentrations showed increases with age. Small changes of accumulation in Antarctic minke whales could be detected in the early 1990's.

During discussion it was noted that obtaining separate values of methyl mercury and ionic mercury concentrations would be informative. It was pointed out that while methyl mercury is toxic and

accumulates in e.g. brain tissue, the ionic form of mercury is secreted by the kidney and does not represent a threat.

The global distribution and long range transport of mercury in the environment was discussed. Because of the transport of Atlantic deep water from the North Atlantic to the upwelling zone in the Antarctic, it was suggested that the low values of Hg may only represent a delay compared to the relatively higher concentration of Hg in the Northern Hemisphere. In response, it was explained that airborne particle dispersion is the most important way of dispersing mercury in the environment, and following the industrial revolution there was a rapid increase in mercury concentrations over large geographic regions. However, Antarctica remained little influenced, and the remoteness from industrial centers and the patterns of atmospheric circulation systems therefore seem to be the main reason for the continued low concentration of mercury in Antarctic minke whales. It is therefore reasonable to assume that Hg concentrations in Antarctic minke whales will continue to be very low.

JR14 examined environmental changes in the Antarctic Ocean through analysis of concentrations of organochlorines (PCBs, DDTs, HCHs, HCB and CHLs) in blubber tissues of mature male Antarctic minke whales (from 21 to 25 years) from the Antarctic Areas-IV and V. The ranges of concentrations for each compound were, in ng/g fat wt: PCBs, 44.8-88.7; DDTs, 29-340; HCHs, 0.20-4.3; HCB, 75-430; CHLs, 10-120. Residue levels of PCBs, and DDTs in blubber of Antarctic minke whales from the Southern Ocean were apparently lower than those levels in other baleen whales from middle latitude areas. Significant regional differences between Areas IV and V were observed in PCBs, HCHs, HCB and CHLs levels in Antarctic minke whales. Furthermore, their HCHs and HCB levels decreased significantly over the 1988/89 to 2002/03 austral summer seasons. The directions of trends in PCB and DDT levels are unclear over the 1988/89 to 2002/03 austral summer seasons, suggesting that the trends in levels of organochlorines may be near a turning point in the Antarctic Ocean.

The mechanisms for the very low concentrations in Antarctic minke whales compared to most other cetaceans globally were discussed. It was pointed out that organochlorines (OC's) enter cetacean tissues mainly through the food web. Therefore, both the pristine conditions of the Antarctic feeding grounds due to the remoteness from sources of OC pollution, and the feeding ecology of Antarctic minke whales may contribute to the low OC levels recorded in the tissue of whales sampled in the JARPA program. While toothed whales and minke whales in other areas feed at higher trophic levels on a mixed diet including e.g. fish, the Antarctic minke whales are at a low trophic level and feed only on planktonic crustaceans. The effect of feeding on low trophic levels is also shown by the low OC levels recorded in the plankton-feeding bowhead whales off the North Slope of Alaska.

It was further pointed out that not all OCs are toxic to humans, and that it is important to present values for the different compounds included in the analysis.

The OC concentrations (except for DDTs) in Antarctic minke whales from Area IV (1987/88 to 2001/02 seasons) were significantly higher than those recorded from Area V (1988/89 to 2002/03 seasons), and the possibility of using contaminants as a supplement to stock identification evaluations was suggested. In response it was pointed out that stock identification requires larger sample sizes and that OC analyses are expensive and time consuming.

7.4.2 Environmental changes examined through oceanographic analysis

In **JR15** oceanographic observation data obtained by JARPA were analyzed to clarify physical oceanographic conditions in the JARPA area as a basis for understanding of characteristics of the habitat of whales. Accumulated XBT, XCTD and CTD data were stored in the HydroBase format and utilized to describe the oceanographic features of the JARPA area. The Southern Boundary (SB) of the Antarctic Circumpolar Current was clearly observed as a 0°C temperature contour line on the 27.6 sigma-theta isopycnal surface. It is evident that the position of the SB is controlled by major features of bottom topography such as the Kerguelen Plateau and the Pacific-Antarctic ridge. The analyses presented evidence for year-to-year variations in oceanographic conditions, including large year-to-year meridional shifts of the SB that were found east of the Kerguelen plateau. The JARPA data also provided new evidence of Antarctic Bottom Water formation in the Prydz Bay region. Comparison between the JARPA data and satellite-derived chlorophyll distribution indicates that the intensity of the wintertime cooling determines the primary productivity south of the SB in the following seasons.

In the discussion it was pointed out that the surveys were primarily designed to study minke whales and the cruise lines therefore were not ideal for exploration of oceanographic conditions. However, the oceanographic data have revealed some interesting results, e.g. it was demonstrated that El Nino events could be traced into Antarctic SST and temporarily impact the distribution of minke whales. It was noted that this information could be used to explain observed temporal differences in minke whale abundance. Continuation of the oceanographic studies was therefore encouraged as a supplement to collection of abundance estimation data.

In a discussion of the possibilities of using oceanographic conditions to define stock boundaries, it was demonstrated that the position of the southern boundary of the Antarctic Circumpolar Current is controlled by the bottom topography: the current runs near the continent west of 150°E and then moves away from the continent at about 150°-165°E following the Pacific Antarctic Ridge. These longitudes coincide with the stock boundary for Antarctic minke whales suggested by genetic data.

7.4.3 Summary of results

The meeting **noted** that the most important findings of the environmental studies were the following:

- The bottom topography may contribute to the explanation of minke whale stock boundaries through its effect on the southern boundary of the Antarctic Circumpolar Current.
- While Fe showed very high concentration in Antarctic minke whales, the Hg values were very low.
- The concentrations of OC in Antarctic minke whales were also documented to be very low, also in comparison with concentrations recorded in minke whales harvested in other geographic areas.

These 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). The meeting **emphasized** the importance of further studies of minke, humpback and fin whale abundance, distribution and feeding ecology with concomitant continued monitoring of biological and physical oceanography.

7.5 Other results

7.5.1 Stock structure of humpback and fin whales

JR16 presented the results of mtDNA and microsatellite (humpback whale only) analyses conducted on the biopsy samples of 287 humpback and 23 fin whales obtained during JARPA surveys. The humpback whale samples from their feeding grounds were grouped according to the stock distribution in the feeding grounds proposed by the IWC Scientific Committee's comprehensive assessment of the species. Analysis of mtDNA control region sequences clearly discriminated the Stocks C, D, E, F and G on the feeding grounds. However, analysis of the six microsatellite loci failed to discriminate these stocks, although some degree of genetic heterogeneity among the samples was evident. These results suggested a different degree of fidelity to breeding areas between females and males. Analysis of mtDNA suggested that the historically mixed sector between the Stocks D and E at 110-130°E was occupied in recent years mostly by the D stock. For the fin whales, the level of observed mtDNA diversity was similar to that for the Antarctic minke whales. No significant differences were found when comparing fin whales from Areas III+IV and V that correspond approximately to the Indian and western South Pacific Oceans populations respectively. However the lack of observed differences in this study could be due to the small number of samples available.

The meeting welcomed this contribution. Walloe commented on possible differences in the pattern of stock structure between North Atlantic and Southern Hemisphere humpback whales. He noted that structure in the Antarctic was more evident in mtDNA than microsatellites. Pastene responded that site fidelity to either feeding, breeding, or both areas is less in males than in females, resulting in more structure in mtDNA than in microsatellites.

Butterworth remarked that results in this paper are broadly consistent with those in JR19. He further suggested the use of biopsy samples from lower latitudes, if available. Pastene responded that a limited number of mtDNA control region sequences from the D and E stocks are available from low latitudes and that these will be used in future analyses.

Miyashita asked whether there was any photo-id matching based on JARPA material. Pastene responded that there had been two matches thus far, one between photos taken from eastern Australia and Area V and the other from IDCR/SOWER and JARPA surveys both in Area VI.

7.5.2 Other

No matters were raised under this Agenda item.

8. OVERVIEW OF RESULTS AND IDENTIFICATION OF FUTURE RESEARCH NEEDS

JR17 discussed changes in the Antarctic minke whale stocks based on various results from JARPA including the age at sexual maturity, growth curve, blubber thickness, prey consumption, and ADAPT-VPA assessments as well as results from research on mercury accumulation.

Following discussion of JR17, the meeting **agreed** that, viewed broadly, results from JARPA are consistent with the behaviour to be expected of baleen whale populations competing for a dominant single food resource, krill. Studies that allow extrapolation back to the middle decades of the last century suggest that minke whales increased coincident with the reductions in the populations of larger baleen whales that were subject to heavy whaling pressure. However, it seems that from about 1970 this situation began to change; some commercial catches of minke whales took place and, as the larger baleen whale species started to recover, there are indications that there have been consequent negative impacts on minke whales. JARPA has, over the period of the program, provided data from a number of studies which are all broadly consistent with this inference. For example:

- abundance estimates from surveys indicate appreciable increases in humpback and fin populations;
- population models incorporating survey abundance estimates and catch-at-age data indicate some decline in minke whale recruitment;
- the age at physical maturity for minke whales has increased;
- a number of indicators, including weights of stomach contents and measures of blubber thickness, confirm deterioration in feeding conditions for minke whales; and
- annual consumption of krill by baleen whales contributes an appreciable fraction of estimated krill abundance.

This provides strong qualitative evidence that competition for prey (krill) plays an important role in the dynamics of the Antarctic ecosystem. Modelling 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. Nevertheless, the meeting **agreed** that the results obtained provide clear support for the need to take species-interaction (ecosystem) effects into account in understanding the dynamics of the baleen whale species in the Antarctic ecosystem, and in predicting future trends in their abundance and population structure. Accordingly, management also needs to be based on ecosystem approaches, rather than upon single species considerations alone, and future data collection plans need to take cognizance of such requirements.

Regarding stock structure the meeting **agreed** that the most parsimonious explanation of the results of JARPA is that there are two minke whale stocks present in the research area. These stocks mix across a soft boundary, which would probably best be placed near 165°E. Further research is necessary to investigate a) whether this mixing region changes from year to year and b) possible additional structure in Area III (e.g. determination of a western boundary for the I stock) (see item 7.1.3). The importance of obtaining samples from low latitudes for developing a clearer genetic delimitation of breeding stocks is **stressed**

The meeting also **agreed** that JARPA has provided valuable information to assist in understanding the physical oceanography in the research area. Bottom topography, and therefore the southern boundary of the Antarctic Circumpolar Current, may contribute to an understanding of minke whale stock boundaries. It is recommended that data collection on physical oceanography and work to examine the relationships with the patterns of distribution of whale stocks and prey be continued.

Overall, the meeting **considered** that JARPA had made good progress in addressing its objectives (see section 5).

In conclusion, the meeting **agreed** that:

- JARPA has collected a very large and consistent data base (Annexes D and E) 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;
- JARPA has contributed to the elucidation of biological parameters of minke whales, and improved the understanding of the Antarctic marine ecosystem;
- JARPA has revealed that changes have occurred in the ecosystem since the 1970's, suggesting competition among minke and other large whales; and
- data obtained through this monitoring will contribute to the development of ecosystem models, which are necessary for ecosystem-based management of whales.

The meeting also **agreed** that tasks identified in the midterm review meeting in 1997 (see section 5) had been appropriately addressed and progressed.

9. OTHER

No matters were raised under this Agenda item.

10. REVIEW OF THE REPORT

A first draft of the report was available to the meeting. Several editorial suggestions were offered. It was agreed that the rapporteurs should complete the final draft of the report for subsequent distribution among participants via e-mail.

11. CLOSURE

Walloe, on behalf of the foreign participants, thanked the Government of Japan for hosting the meeting and for the hospitality provided. In addition he thanked the Chairman Kato, the rapporteurs Pastene, Mori, Kanda and Murase, and the interpreters Ohta, Kawagishi and Yamagiwa. Hatanaka thanked the Chairman for his efficient conduct of the meeting. He also thanked all participants for their constructive approach to the review of results from the JARPA program and noted that the outcome of this review would be taken into account in the planning of the JARPA II program which will be submitted to the IWC Scientific Committee at the end of March.

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Figure 1: Map of the JARPA research area (from JR2).

Annex A

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Kawagishi, Rei	
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Annex B

Agenda

1. Election of Chair
2. Election of rapporteur
3. Adoption of the agenda
4. Review of documents
5. Review of JARPA research objectives
6. Review of JARPA survey procedure and data collected
 - 6.1 Survey procedure
 - 6.2 Data collected
7. Review of results in the light of JARPA objectives
 - 7.1 Stock structure of Antarctic minke whale
 - 7.1.1 Genetic analyses
 - 7.1.2 Non-genetic analyses
 - 7.1.3 Summary of results
 - 7.2 Biological parameters of Antarctic minke whale
 - 7.2.1 Unbiased estimation of abundance and trends
 - 7.2.2 Estimation of biological parameters
 - 7.2.3 Summary of results
 - 7.3 Role of whales in the Antarctic marine ecosystem
 - 7.3.1 Krill consumption and body condition of Antarctic minke whale
 - 7.3.2 Distribution and abundance trends of Antarctic minke and large (blue, fin and humpback) whales
 - 7.3.3 Inter-species relationships
 - 7.3.4 Summary of results
 - 7.4 Effects of environmental changes on cetaceans
 - 7.4.1 Pollutant analysis
 - 7.4.2 Environmental changes examined through oceanographic analysis
 - 7.4.3 Summary of results
 - 7.5 Other results
 - 7.5.1 Stock structure of humpback and fin whales
 - 7.5.2 Other
8. Overview of results and identification of future research needs
9. Other
10. Review of the report
11. Closure

Annex C

List of Documents

- JA/J05/JR1. Hatanaka, H., Fujise, Y., Pastene, L.A. and Ohsumi, S. Review of JARPA research objectives and update of the work related to JARPA tasks derived from the 1997 SC meetings.
- JA/J05/JR2. Nishiwaki, S., Ishikawa, H. and Fujise, Y. Review of general methodology and survey procedure under the JARPA.
- JA/J05/JR3. Pastene, L.A., Goto M., Kanda, N., Bando, T., Zenitani, R., Hakamada, T., Otani, S. and Fujise, Y. A new interpretation of the stock identity in the Antarctic minke whale (*Balaenoptera bonaerensis*) based on analyses of genetics and non-genetics markers.
- JA/J05/JR4. Hakamada, T., Matsuoka, K. and Nishiwaki, S. An update of Antarctic minke whales abundance estimate based on JARPA data, including a comparison to IDCR/SOWER estimates.
- JA/J05/JR5. Bando, T., Zenitani, R., Fujise, Y. and Kato, H. Biological parameters of Antarctic minke whale based on materials collected by the JARPA survey in 1987/88 to 2003/04.
- JA/J05/JR6. Tanaka, E., Zenitani, R. and Fujise, Y. A point estimate of Natural Mortality Coefficient using JARPA data.
- JA/J05/JR7. Zenitani, R. and Kato, H. Long- term trend of age at sexual maturity of Antarctic minke whales by counting transition phase in earplugs.
- JA/J05/JR8. Tamura, T. and Konishi, K. Feeding habits and prey consumption of Antarctic minke whales, *Balaenoptera bonaerensis* in JARPA research area.
- JA/J05/JR9. Konishi, K. and Tamura, T. Yearly trend of blubber thickness in the Antarctic minke whale *Balaenoptera bonaerensis* in Areas IV and V.
- JA/J05/JR10. Matsuoka, K., Hakamada, T. and Nishiwaki, S. Distribution and abundance of humpback, fin and blue whales in the Antarctic Areas IIIE, IV, V and VIW (35°E-145°W).
- JA/J05/JR11. Murase, H., Nishiwaki, S., Ishikawa, H., Kiwada, H., Yoshida, T. and Ito, S. Results of the cetacean prey survey using echo sounder in JARPA from 1998/99 to 2002/03.
- JA/J05/JR12. Murase, H., Tamura, T., Matsuoka, K., Hakamada, T. and Konishi, K. Preliminary estimation of feeding impact on krill standing stock by three baleen whale species (Antarctic minke, humpback and fin whales) in Areas IV and V using JARPA data.
- JA/J05/JR13. Yasunaga, G., Fujise, Y., Zenitani, R., Honda, K. and Kato, H. Yearly trend of trace element accumulation in liver of Antarctic minke whales, *Balaenoptera bonaerensis*.
- JA/J05/JR14. Yasunaga, G., Fujise, Y., Zenitani, R., Tanabe, S. and Kato, H. Spatial and temporal variation in organochlorine contaminants in the Antarctic minke whales, *Balaenoptera bonaerensis*.
- JA/J05/JR15. Watanabe, T., Yabuki, T., Suga, T., Hanawa, K., Matsuoka, K. and Kiwada, H. Results of oceanographic analyses conducted under JARPA and possible evidence of environmental changes.
- JA/J05/JR16. Pastene, L.A., Goto, M., Kanda, N. and Nishiwaki, S. Genetic analyses on stock identification in the Antarctic humpback and fin whales based on samples collected under the JARPA.
- JA/J05/JR17. Fujise, Y., Hatanaka, H. and Ohsumi, S. Changes occurred on Antarctic minke whale stocks in the Antarctic and their ecological implications.
- JA/J05/JR18. Mori, M. and Butterworth, D.S. Progress on application of ADAPT-VPA to minke whales in Areas IV and V given updated information from IDCR/SOWER and JARPA surveys.

JA/J05/JR19. Johnston, S.J. and Butterworth, D. Assessment of the west and east Australian breeding populations of southern hemisphere humpback whales using a model that allows for mixing on the feeding grounds and taking account of the most recent abundance estimates from JARPA.

JA/J05/JR20. Burt, M.L., Hedley, S.L., Marques, F.F.C., Hakamada, T. and Matsuoka, K. Spatial modeling of JARPA survey data in Area V.

JA/J05/JR21. Kitakado, T., Fujise, Y., Zenitani, R., Hakamada, T. and Kato, H. Estimation of natural mortality coefficients for Antarctic minke whales through VPA studies.

JA/J05/JR22. Butterworth, D.S. and Mori, M. Implications of the updated ADAPT-VPA assessments for the dynamics of minke whales in Areas IV and V.

JA/J05/JR23. Mori, M. and Butterworth, D.S. Progress on multi-species modelling in the Antarctic.

For information Papers

For information 1. Report of the Intersessional Working Group to Review Data and Results from Special Permit Research on Minke Whales in the Antarctic, Tokyo, 12-16 May 1997. (*Rep.Int,Whal.Commn.* 48: 377-390)

For information 2. Mori, M. and Butterworth, D.S. Consideration of multispecies interaction in the Antarctic: A preliminary model of the minke whale -blue whale- krill interaction. *Ecosystem Approaches to Fisheries in the Southern Benguela, Afr. J. mar. Sci.* 26: 245-259.

For information 3. Murase, H., Matsuoka, K., Ichii, T. and Nishiwaki, S. Relationship between the distribution of euphausiids and baleen whales in the Antarctic (35°E-145°W). *Polar Biology* 25:135-145.

For information 4. Matsuoka, K., Watanabe, T., Ichii, T., Shimada, H. and Nishiwaki, S. 2003. Large whale distributions (south of 60°S, 35°E-130°E) in relation to the southern boundary of the ACC. *Antarctic Biology in a Global Context*, pp 26-30. Edited by A.H.L. Huiske, W.W.C. Gieskes, J. Rozema, R.M.L. Schрно, S.M. van der Vies and W.J. Wolff. Backhuys Publishers, Leiden, The Netherlands.

For information 5. Kasamatsu, F., Nishiwaki, S. and Ishikawa, H. Breeding areas and southbound migration of southern minke whales *Balaenoptera acutorostrata*. *Mar. Ecol. Prog. Ser.* 119: 1-10.

Annex E
List of Data Sets Produced by JARPA

		Total Sample size		
I SIGHTING DATA				
1	Angle and distance experiment data (no. of experiments)	5935		
2	Photo-ID, other species than minke whale (no. of photographs)	879		
3	Sighting data (no of schools)	44531		
4	Survey effort data (research days * no. of SV and SSVs)	5820		
5	Weather data (research days * no. of SV and SSVs)	5820		
II BIOLOGICAL DATA		Number of samples (no. of individuals)		
		•	‰	■ total
6	Age	3,452	2,901	6,353
7	Baleen plate set mouth cavity	681	593	1,274
8	Baleen plates, length of plate series	767	748	1,515
9	Blubber thickness (14 points)	583	492	1,075
10	Blubber thickness (3 points)	1,579	1,261	2,840
11	Blubber thickness (5 points)	1,859	1,606	3,465
12	Body length	3,452	2,901	6,353
13	Body proportion	3,452	2,900	6,352
14	Body weight	3,291	2,773	6,064
15	Brain weight	1,131	975	2,106
16	Catching date	3,453	2,901	6,354
17	Catching location	3,453	2,901	6,354
18	Corpora albicantia and lutea (number)	-	2,896	2,896
19	Craniometric data	19	23	42
20	Discovery-type marks recover	1	3	4
21	Endocrinological studies on reproduction	0	0	4
22	Epididymis weight	3,452	-	3,452
23	Foetus, body length	814	773	1,662
24	Foetus, body proportion	755	720	1,482
25	Foetus, body weight	813	767	1,616
26	Foetus, number	-	2,894	2,894
27	Foetus, sex	817	817	1,692
28	Jacobson's organ shape	3,452	2,900	6,352
29	Lactation condition	-	2,894	2,894
30	Lipids contents	587	493	1,080
31	Mammary gland measurements	-	2,894	2,894
32	Maturity stage	3,452	2,901	6,350
33	Mitochondrial DNA control region sequences, humpback whale	143	133	276
34	Mitochondrial DNA control region sequences, fin whale	0	0	23
35	Mitochondrial DNA control region sequences, minke whale	516	476	992
36	Mitochondrial DNA RFLP-derived haplotype distribution	3,195	2,643	5,838
37	Nuclear DNA microsatellite (6 loci)	3,203	2,610	5,813
38	Organ weights	587	493	1,080
39	Parasites, external occurrence record	3,452	2,900	6,352
40	Parasites, internal occurrence record	3,452	2,900	6,352
41	Ribs (number)	3,451	2,900	6,351
42	Selenium analysis	0	0	74
43	Sex	3,453	2,901	6,354
44	Skeleton (whole skeleton measurement)	5	5	10
45	Skull (length and breadth)	3,345	2,812	6,157
46	Stomach contents (IWS format)	3,451	2,899	6,350
47	Stomach contents weight, first stomach, excluding liquid	3,336	2,802	6,139
48	Stomach contents weight, including liquid	3,336	2,802	6,139
49	Stomach contents weight, second-fourth stomachs, excluding liquid	644	613	1,257
50	Tail notch shape	3,452	2,900	6,352
51	Testis weight	3,452	-	3,452
52	Transition phase	3,452	2,901	6,353
53	Uterine horn (breadth)	-	2,876	2,876
54	Ventral grooves (number)	3,452	2,900	6,352
55	Biopsy sampling (Humpback, blue, right, fin, sei, sperm, killer whales)*			410
III ENVIRONMENTAL DATA		Number of samples (no of individuals)		
		•	‰	■ total
56	Heavy metals (liver)	922	150	1,072
57	Heavy metals (Stomach contents)	67	33	100
58	Marine debris (Stomach contents)	7	2	10
59	Organochlorine (blubber)	105	0	105
		Number of samples		
60	Marine debris (Sighting survey)	255		
61	Organochlorine compounds (air)	9		
62	Organochlorine compounds (sea water)	7		
63	Temperature (XBT survey)	904		

*: This includes 304 humpbacks, 35 right, 26 fin, 22 blue, 20 minke, one sei, one sperm and one killer whales.