Report of the Intersessional Workshop to Review Data and Results from Special Permit Research on Minke Whales in the Antarctic, Tokyo 4-8 December 2006

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1. INTRODUCTORY ITEMS

1.1 Welcome and introduction

The Workshop met at the Institute of Cetacean Research (ICR), Tokyo, on 4-8 December 2006. The list of participants is given in Annex A. The Chair of the Scientific Committee (SC), Bjørge, welcomed the participants, in particular the invited experts that do not normally attend the meetings of the SC. Bjørge also thanked the Government of Japan and the ICR for the venue and facilities made available for the meeting and he acknowledged the Japanese scientists for their considerable work in preparation for this meeting.

A Steering Group chaired by Zeh had planned this meeting over several years and Bjørge conveyed to the meeting Zeh's regrets that she could not attend and address the meeting in person. She sent her sincere thanks to all members of the Steering Group, and to all those who had contributed to the preparations for the meeting. The meeting agreed to ask Bjørge to forward its thanks and appreciation to Zeh for her work in the Steering Group.

Morishita welcomed the participants on behalf of the Government of Japan who was hosting the Workshop. He particularly thanked those scientists who had travelled far to attend the Workshop. He explained the importance Japan attached to the forthcoming discussions and looked forward to a full and fair scientific discussion of the items on the Agenda.

1.2 Election of Chair and appointment of rapporteurs

Bjørge noted that the SC58 Convenors Meeting had agreed that Bannister should chair the Workshop. Donovan co-ordinated production of the report with assistance from Hedley, Kitakado, Hoelzel, Cooke, Reid, Mori, Aguilar and Pastene.

1.3 Meeting procedures and time schedule

Practical arrangements were dealt with by the ICR. The meeting agreed to a time schedule proposed by the Chair.

1.4 Adoption of Agenda

The Working Group adopted the agenda shown in Annex B.

1.5 Documents and data available

The documents presented to the Working Group are listed in Annex C. The Workshop was pleased to note that the data from the programme listed in Annex D had been available for participants under the Committee's Data Availability Agreement.

1.6 Terms of reference for this review

The Scientific Committee had agreed two years ago to hold an intersessional scientific workshop to assist in its review of the results of the Japanese special permit research in the Antarctic (JARPA) programme, 1987/88-2004/05 and established a Steering Group under Zeh to prepare for the Workshop. The Committee agreed that the objectives of the full review are to evaluate:

(1) how well the initial and revised objectives of the research have been met;

(2) other contributions to important research needs;

(3) the relationship of the research to relevant IWC resolutions and discussions, including those dealing with the Antarctic marine ecosystem, environmental changes and their impact on cetaceans and Committee reviews of special permit research; and

(4) the utility of the lethal techniques used by JARPA compared to non-lethal techniques.

The Committee had agreed that the full review will consider only scientific issues; ethical issues are beyond its competence. This agreement was taken into account in the discussion under Item (3). The Committee had also agreed that some discussion of the respective merits of lethal and non-lethal methodology (Item (4)) is important and that Invited Participants would be able to contribute to that debate. However, the Committee noted that main focus of the Workshop would be on Items 1-8 of the Agenda (Annex B); the more contentious issues under Item 9 will mainly be discussed at the subsequent Annual Meeting (IWC, 2006a, p.48). In fact, time constraints at the Workshop meant that Item 9 could not be discussed

1.7 Objectives of JARPA as stated in the original research proposal and subsequently

SC/D06/J1 presented an outline of the JARPA research objectives. The Government of Japan has conducted JARPA surveys since the 1987/88 season under the Article VIII of the International Convention for Regulation of Whaling, as a long-term project. The last survey of the JARPA was completed in the 2004/05 season. As the programme progressed, the objectives of the project evolved from two in the original plan to four after the 1995/96 season. The authors noted that the additional objectives were not an alteration of the original plan, but rather its development. The IWC Scientific Committee held a mid-term Workshop in 1997 to review JARPA data and results (IWC, 1998a) and during its 1997 Annual Meeting (IWC, 1998b), the Scientific Committee discussed the report of the workshop and identified several future tasks to be addressed in the programme. The authors concluded that reasonable progress had been made on most of the tasks.

The two original research objectives as defined in the JARPA project, submitted as SC/39/O4 (Government of Japan, 1987) to the 1987 Committee meeting (IWC, 1998b), were:

Objective 1. Estimation of biological parameters to improve the stock management of the Southern Hemisphere minke whale;

Objective 2. Elucidation of the role of whales in the Antarctic marine ecosystem.

The addition of a third objective occurred in 1995/96 (Government of Japan, 1995)

Objective 3. Elucidation of the effect of environmental change on cetaceans (a development of Objective 2).

The final addition was made in 1996/97 (Government of Japan, 1996):

Objective 4. Elucidation of the stock structure of Southern Hemisphere minke whales to improve stock management (already implicit in Objective 1).

The Workshop did not spend time discussing the objectives of the programme in any detail. Annex E provides the wording of the original proposal and the changes included for the 1995/96 season. The Workshop's conclusions on the extent to which the objectives have been or can be met are given under Item 8.

1.8 General outline of the JARPA research

SC/D06/J2 presented a general outline of JARPA, including sighting and sampling protocols as had been requested at the 2006 Annual Meeting. JARPA was conducted every year from the 1987/88 to 2004/05 seasons. After two seasons of feasibility research, full-scale research began in 1989/90. The programme was designed to repeat surveys in Antarctic Areas IV and V alternately in each of the sixteen years of the research period. Area IV was divided into five strata and Area V into four strata. Although the whole research period ranged from the end of November to March, regular research in Areas IV and V was concentrated in January and February. A Special Monitoring Zone was established to investigate seasonal variation of whale density from the 1992/93 to 1994/95 seasons. From the 1995/96 season, the survey area expanded into a part of Areas III and VI to improve the stock structure study. In order to achieve its four objectives JARPA comprises a combination of sighting and sampling surveys. In general, a saw tooth (right triangles) shape track line at intervals of 4° longitude or IDCR/SOWER style zigzag track line were used in the southern strata and a zigzag track line at intervals of 15°longitude (or flexibly as in IDCR/SOWER) was used in the northern strata. In order to obtain biological samples representing whole population in the research area, a random sampling method coupled to line transect sighting surveying was adopted. Two or three sighting/sampling vessels (SSVs) conducted sighting and sampling survey on the predetermined track-line with parallel sub-track lines. A dedicated sighting vessel (SV) was introduced from 1991/92 and the SV preceded the SSVs by a distance of over 12 n.miles, to avoid influence of sampling activity on the sighting survey. One or two Antarctic minke whales were sampled randomly from each primary sighted school within 3 n.miles of the trackline of each SSV. Individuals to be sampled in a school were chosen by a researcher on board using a series of tables of random sampling numbers. All the whales sampled were subject to biological sampling and measurements on the research base vessel. Some experiments with respect to sampling method were conducted to improve the methodology of the sighting/sampling survey. In parallel with the lethal sampling survey, a variety of non-lethal studies were conducted e.g. oceanographic surveys, prey surveys, and photo-identification and biopsy sampling for large baleen whales. A summary of research procedures and results in each cruise was also presented in the document.

The Workshop welcomed this report which provided valuable information for many topics on the agenda.

1.9 Overview of the 1997 JARPA review and subsequent discussions

The Workshop considered the report of the 1997 JARPA review Workshop (IWC, 1998a) and the discussions at the subsequent Annual Meeting (IWC, 1998b). Relevant issues are considered in detail under the appropriate agenda items below.

2. SIGHTING SURVEYS AND ABUNDANCE ESTIMATION

2.1 Background

The proposers noted that the primary reason for conducting JARPA sightings surveys was their contribution to the improvement of the management of Southern Hemisphere minke whales. Their pertinence to the RMP and the associated implementation for Southern Hemisphere minke whales was seen as a derivative objective. From the beginning of the programme in 1987, the first objective of JARPA was to estimate an age-specific mortality coefficient through stochastic sampling (later modified to an average mortality rate), in combination with systematic sampling surveys. One of the improvements to the original plan adopted at the start of the full programme (following two years of feasibility study) was the conduct of line transect surveys.

In contrast to the IWC IDCR/SOWER surveys which have recently completed the third of three circumpolar surveys in the Southern Ocean (covering up to 60º of longitude each year for almost 30 years), JARPA surveys have been conducted in IWC Areas IV and V for 18 years with more recent extensions to the east and the west of this. During the mid-term JARPA review meeting in 1997, it was noted that JARPA provides more frequent repetition of surveys of the same localities than the IDCR/SOWER programme, which could better facilitate estimation of the extent on inter-year variability in local abundance, and in turn lead to improved trend estimation. In examining the JARPA sighting survey results at this Workshop, attention focussed on the suitability of absolute abundance estimates for use in biological parameter studies (Item 4) and estimation of trend from these estimates for input to models of the marine ecosystem (Item 5), although inevitably there will be some inter-relation between the two.

2.2 Issue raised in previous IWC meetings

2.2.1 1997 JARPA review

The 1997 JARPA review meeting recommended that more research was required to develop a reliable method for adjusting for negative bias in abundance estimates induced by undersampling of high density areas resulting from the JARPA survey design (sampling of whales in high density areas meant that these areas were under-represented in the sampling effort). It considered that once this had been achieved, the resultant abundance estimates should be useful both as absolute and relative abundance indices.

The Workshop noted that a number of contributions addressing this issue had been considered by the Committee since 1997. Further discussions of this are found under the relevant agenda items.

2.2.2 Humpback whale Workshop

The 2006 Hobart humpback whale Workshop (IWC, 2006b) recommended that the following seven items be presented to the Scientific Committee:

(1) clearer/enlarged displays of effort and sightings data, in particular to show details of the southern strata and the ice edge;

(2) display/analyses of the temporal distribution of searching effort within-season, particularly with respect to latitude and the ice edge, in order to allow evaluation of any changes over time and to evaluate whether following the path of any migration may be of concern;

(3) a full description of the policy that determines when the vessels steam/transit without sampling/sighting effort, how and when this may change over the course of a survey and displays/analyses of any potential bias that may result from policy decisions;

(4) analyses of sightings cues by *inter alia* area, time, season, sighting distance etc;

(5) separate analyses of sighting effort for vessels that carry out sightings only (SV) and vessels that also catch whales (SSV)

(6) separate analyses of school size by SV and SSV, taking into account time within a season and area, especially with respect to latitude and ice edge;

(7) evaluate/display how the fraction/density of whales in the northern and southern areas covered by the vessels may have changed over time (taking into account seasonal differences in timing of effort etc.).

The first four of these were presented to the 2006 Annual Meeting (IWC, 2007b). The analyses requested in Item 4 did not reveal that heterogeneity in sighting cue needed to be accounted for directly in the analyses. The last three items were recognised as matters that would be relevant when considering the analyses presented to this Workshop.

2.2.3 Other

At the 2006 Annual Meeting (IWC, 2007b), three further issues were raised when examining line transect analyses. The first of these was the question of how to deal with apparently unsurveyed areas within strata (for example due to ice edge movement), and it was recommended that abundance estimates be based on the surveyed (ice-free) portion of the stratum. The second concerned the saw-tooth trackline design employed in some southern strata. It was suggested that this design might be biased if there was a density gradient of whales from the ice edge and that as a sensitivity analysis, abundance for these strata should be estimated using data from the north-south transects only and compared with estimates which used data from all the transects. The third issue raised was the question of uneven coverage probability within some of the southern strata.

Furthermore, the Committee recommended that the JARPA survey design, its protocols, how they have changed over time, and any differences between the design and the implementation of it were set out in a single document and presented to the JARPA review meeting. It noted that this should clarify the following three specific questions, which would help determine the appropriate method to estimate variance:

(1) How are tracklines adjusted 'real-time' on the vessels, including when the ice edge is encountered unexpectedly?

(2) How do the vessels interact at the end of the survey day, and how is the amount of night steaming by each vessel independently decided?

(3) Which vessels were used in the surveys, and were they used any differently in different years?

Information on how the location of the ice edge changed during the course of a survey was also requested.

2.3 Data collection methods and results

The Workshop welcomed the provision of SC/D06/J2 that had been provided in part as a response to the request from the Scientific Committee. The authors had concluded that the sightings data obtained from JARPA were reliable enough to use for abundance estimation purpose because (a) in principle, tracklines were set systematically so as to collect random data and (b) JARPA has surveyed Areas IV and V alternatively for 18 years with the maximum survey effort being spent in Areas IV/V during January and February, which was considered to be the peak migration period of the minke whales. The authors noted that sighting surveys had been conducted eight times in Areas IV and V, respectively. During the survey period searching effort was distributed uniformly in these Areas (the starting position of the sighting survey was selected randomly).

The Workshop noted that the sighting survey procedures that have been used in JARPA were similar to those used in IWC IDCR/SOWER surveys. The closing procedures (e.g. to determine school size) were identical to those used in closing mode for the IDCR/SOWER surveys, except that additional time was spent on sampling and that closing was limited to minke whales. The vessels engaged in such sampling (termed 'SSVs') surveyed along parallel tracklines, but from the 1991/92 season, one vessel (the 'SV') at any one time was devoted to sighting only, in order to investigate the effect of sampling activity on abundance estimates. Since 1995/96, the SV conducted a sighting survey and an active acoustic survey independently, using closing and passing mode procedures on tracklines surveyed independently from those of the SSVs.

One key difference between JARPA and IDCR/SOWER was noted, namely that IDCR/SOWER has operated in alternate IO (Independent Observer) and closing modes, whilst JARPA operated in (different types of) closing and passing modes without IOs. Conventional line transect analyses of IDCR/SOWER data have assumed $g(0)=1$ and have standardised on IO mode, correcting for possible bias in closing mode, but the Committee is moving towards more elaborate estimation methods that do not make these assumptions.

Relevant data obtained in JARPA sighting surveys are:

(1) number of angle/distance experiments: 6,426

(2) sighting data (number of schools): 48,600

(3) survey effort data: primary effort of 293,811 n.miles covered in 6,188 ship-days

(4) weather data (number of observations): 94,840.

Information on other data can be found in Annex D.

2.4 Data analysis methods and results

In considering the issue of abundance estimates from the survey, the Workshop noted that any estimates refer to the number of animals present in a particular geographical area at a particular time of the year and that this (given the discussion of stock structure and mixing on the feeding grounds summarised under Item 3) will not be indicative of biological population abundance, although abundance for one possible stock structure hypothesis (see Item 3) is presented.

2.4.1 Minke whales

SC/D06/J3 examined the possibility of correcting for the effect of skip. Four types of skip arose in JARPA surveys: night steaming (type A); catching up with the schedule of the survey (type B); closing and chasing of whales targeted (type C); and bad weather condition (type D). Amongst these, Hakamada *et al.* (2006) suggested that the estimate of minke whale density is only affected by skip types A and C. In this paper, a modification of the method of Burt and Borchers (1997) was developed to correct bias due to skip type A which affected only the surveys from 1989/90 to 1992/93 (after which a different survey protocol applied). Corrected abundance estimates in Area IV obtained from SSV data were 32,630 (CV=0.142) in 1989/90 and 34,982 (CV=0.171) in 1991/92. Those in Area V were 108,457 (0.124) in 1990/91 and 84,813 (CV=0.162) in 1992/93. The corrected abundance estimates were greater than the uncorrected ones. This suggested that skip type A resulted in negatively biased estimates although the level was not substantial. Corrected abundance estimates obtained from the method developed in the paper tended to be smaller than those from the method of Burt and Borchers (1997). A further correction was made by using Haw's method (Haw, 1991) to calibrate the difference between survey vessels. The estimated abundance series were used to estimate annual increase rates and their CV's, and results showed that the estimates were -1.10% [-4.25%, 2.02%] and -2.16% [-4.83%, 0.44%] in Area IV and V, respectively. Neither estimate was significantly different from 0, and the authors concluded that skip type A would not substantially affect estimates of trends in abundance trend for Antarctic minke whales.

The Workshop noted that this was an issue raised at the 2006 Annual Meeting and **welcomed** this analysis that represented progress in correcting bias due to skip. However, some concerns were raised about the approach employed and it was suggested that it would be difficult to remove this bias completely. The need for further investigation of the approach using simulation studies to assess correction performance was also suggested. It was noted that a slight difference in estimates for annual increase rate with and without the correction could still lead to the large differences over a longer period. Given that the estimates of abundance from 1989/90-1992/93 might reflect overcorrection of the bias caused by skip, it was noted that this implied that estimated annual increase rates based on abundance series that incorporate this correction were probably lower bounds. Thus the results in this paper contributed to limiting the possible ranges of annual increase rates.

SC/D06/J4 reviewed the spatial modelling analyses (density surface models (DSM)) that have been conducted on JARPA survey data. These analyses were originally proposed as a potential means to correct for the negative biased induced by skip type 'A'. Initial results from simulation studies which looked at a range of densities and clustering scenarios were promising, with little or no bias evident from one of the model-based approaches examined in the simulation study when appropriate levels of smoothing were chosen. However, some problems were encountered when applying this approach to real JARPA survey data. In particular, the available spatially-referenced covariates (latitude, longitude and distance from ice edge as recorded from the vessels when in the southern strata) were frequently inadequate to describe the distribution of sightings. Model-fitting was difficult, particularly in the more topographically complex Area V, and sometimes low coverage in the edges of the survey region caused undesirable behaviour in the smooth surface. This was especially apparent when estimating variance, because the non-parametric bootstrap was unable to reproduce the spatial coverage in effort achieved by the actual data. The authors concluded that whilst spatial modelling methods in principle can correct for a non-random sampling design, the current application of the methods relies on appropriate model specification and this has proved difficult with the JARPA data. Furthermore, they anticipate that some of the specific problems related to appropriate smoothers and complex geographical areas may be alleviated when methods that deal with these issues directly (see, e.g. Wood *et al*., submitted) are fully developed.

In discussion, it was suggested that determination of the appropriate scale of the grids was important for such purposes. If the length of skip type A is larger than the scale of whole clusters, then effects of large and small densities in the part of a leg skipped leg might cancel out, and hence the impact of skip would be negligible. In this sense, local clustering would not affect skip type A. However, it was pointed out that the effect of local clustering could not be ignored in examination of skip type C. Local clustering also affects the assessment of uncertainty in abundance estimation even if the effect of the skip is small. It was also suggested that the possibility of the post-application of the adaptive sampling (Thompson and Seber, 1996) to closing mode survey for finding better correction formulae should be investigated.

In the DSM approach (see SC/D06/J4), the abundance estimate is derived by summing up the grid-based abundance estimates predicted by the smoother, which are correlated. However, the variance of the abundance estimate is estimated without taking this covariance into account, and therefore is negatively biased. Bootstrap methods that incorporate covariance were suggested as a possible way to address this. Over-smoothing also causes underestimation of variance. It was noted that a new model allowing for trend and clustering being developed by Bravington may provide better variance estimates. It was also suggested that satellite data may provide more accurate information on the ice-edge for the DSM.

In summary, the workshop noted potential difficulties in correcting for skip effects by applying spatial models to estimate abundance, and **agreed** that standard design-based estimates were best at this stage even if those need some sorts of correction as put forward in SC/D06/J3.

SC/D06/J5 introduced a model for the estimation of *g*(0) under a single-platform sighting survey. The surfacing probability in a unit time was used as a known parameter. A detection probability function with covariates such as sighting conditions and group size is employed, and estimated by the maximum likelihood method. Simulation studies showed that the estimator of *g*(0) was unbiased when the true detection probability function was assumed although it was not robust to misspecification of this function. The method was applied to the JARPA survey data in Area IV, and provided estimates of *g*(0) that were significantly less than 1.

The Workshop recognised the value of developing methods to estimate *g*(0) from single platform surveys such as JARPA. It thanked the author for his paper but for a number of reasons it did not believe that the approach given in SC/D06/J5 was appropriate. For example, the method assumes that Q (0,0) = 1 where Q is the detection probability function. Furthermore, as the model assumes constant surfacing rates, which imply essentially Poisson processes for surfacing pattern, well-established hazard probability models under the Poisson assumption can be applied without the complication of the model developed. The Workshop strongly **encouraged** the author to consider previous literature and discussions of the Committee on the issue of *g*(0). The Workshop also draws attention for the need for any proposed new techniques to be tested using the IWC simulated datasets.

SC/D06/J6 presents updated abundance estimates for Antarctic minke whale based on JARPA sighting data using IWC 'standard' methodology and the inter-mode calibration method of Haw (1991). All estimates assumed *g*(0)=1. In order to address some of the recommendations and comments made at the 2006 Annual Meeting (Item 2.2), the following adjustment and sensitivity tests were conducted. The effects of closing mode and of sampling activities on abundance estimates were investigated using a linear model approach. The area size was recalculated to reconsider boundaries of survey strata to address the issue of unsurveyed areas. In addition, the effect on estimation of including and excluding certain tracklines along the ice edge was investigated by estimating abundance using option A, all tracklines (P_A), exclusion of tracks that appeared to follow the ice edge (P_B) and finally excluding all but N-S tracks (P_C). The authors concluded that their results showed that including tracklines along ice edge in the analysis does not lead to overestimates of abundance. After recalculation of areas, the abundance estimates differed by typically up to about 10%. The average of P_B/P_A was not significantly different from 1 in each case; the average of P_c/P_A is significantly larger than 1 in some cases. The authors concluded that including all completed tracklines would not greatly impact estimates of abundance while improving estimates of precision. The estimates of abundance in Areas IV and V presented were 44,564 (CV=0.291) in 2003/04 and 72,087 (CV=0.146), respectively and those for the putative I and P stocks proposed in SC/D06/J12 (see discussion under Item 3) were 118,956 (CV=0.164) in 2003/04 and 91,819 (CV=0.147) in 2004/05, respectively, based on the calibration method of Haw (1991). The estimated annual rates of increase are discussed under Item 2. and their 95% CIs in Areas IV and V were -0.42% [-4.02%; 4.59%] (1989/90-2003/04) and -1.54% [-4.91; 2.18%] (1990/91-2004/05), respectively. For the putative I and P stocks the values were 7.93% [-0.05%; 11.45%] (1995/96-2003/04) and -5.88%. No significant increase or decrease in abundance trend was detected.

The Workshop **acknowledged** the considerable work that had gone into the analyses of SC/D06/J06, and in particular was appreciative of progress made in addressing questions raised by the previous IWC meetings discussed under Item 2.2. One of these issues was the estimation of a correction factor due to survey mode. SC/D06/J6 considered two approaches to this question: estimation of 'Haw-type' calibration factors that standardise on SV passing mode and use inverse-variance weighting to adjust estimates in SSV mode to SV closing mode and in turn SV closing mode to SV passing mode. One drawback of this two-stage process is that it fails to account fully for covariances. The Workshop **agreed** that a better approach, similar to that applied in SC/D06/J06, is to fit a model which is able to account for heteroscedascity in sampling variance and incorporate additional variance. Such a model could also be more readily adapted to examine other factors, such as changes in mode effect over time (depending on sample size).

In further discussion, a number of technical issues with the analyses presented in SC/D06/J6 were raised. A small group under Hedley was convened to discuss these issues in detail, to recommend alternative or additional analyses where appropriate and to consider, possibly in the light of these new analyses, the utility of abundance and trend estimates from JARPA data. Their discussions and recommendations have been incorporated into the report below.

DETECTION FUNCTION ESTIMATION

In SC/D06/J6, different detection functions were estimated for each stratum. In some cases, this led to estimating detection functions using very few sightings (possible due to the 'smearing' technique used). The Workshop **recommended** that as a guideline, detection functions should be estimated using an absolute minimum of 15 sightings. Where fewer sightings occur pooling should be undertaken. The preferred option for this is to pool East-West strata as sighting conditions and school size distributions would be expected to be fairly similar. Although a suggestion that pooling options for analysis of data for a small number of specific years could be selected using an objective criterion such as AIC, the Workshop recognised that this could be difficult to apply consistently when considering the full series of JARPA data.

VARIANCE ESTIMATION FROM THE SSV DATA

In SC/D06/J6, variance in encounter rate was estimated separately for each transect covered by the SSVs. (Survey protocols dictated that the SSVs rotated transects daily.) This estimation method assumes that the three parallel SSV transects are located independently of each other, and would be expected to underestimate the true variance (since the variability between any two parallel transects on the same day would be expected to be less than any two randomly selected transects). Whilst recognising that this issue has only relatively recently been raised within the Committee, the Workshop nevertheless considered it important and **recommended** that the data be re-analysed, treating all three parallel transect legs as the sampling unit.

ACCOUNTING FOR THE ORDER THAT THE STRATA WERE SURVEYED (RELEVANT FOR TREND ESTIMATION)

In the first half of the JARPA surveys, both the northern and southern strata had been surveyed in the early part of the survey period, but latterly survey effort at this time was primarily in the northern strata. This change may cause a problem particularly when estimating trends in abundance and considering other processes such as changes in the location of the ice edge (and ice type) and whale migration. This issue is not simple to resolve but as an appropriate first step the Workshop **recommended** that a generalised linear modelling approach (similar to that conducted in SC/D06/J6) be taken whereby appropriately chosen covariates or factors (such as the middle date that a stratum was surveyed in a given year) could be included to enable more valid between-year comparisons. The Workshop also **recommended** that additional variance be estimated as well as taking due account of estimates of sampling variance for each stratum (e.g. IWC, 2006c).

WHALE REACTION TO SAMPLING ACTIVITIES

The general question of the possible effect of chasing and sampling whales by one vessel on the sightings made by other vessels (and thus abundance estimates) was raised. This is particularly relevant to the three SSVs travelling in parallel 7 miles apart and potentially disturbing individuals from one line to another. The Workshop was informed of an experiment conducted in four of the JARPA surveys to examine how minke whales may respond to such activities. In the summary of these experiments provided in SC/D06/J2, the authors stated that there was no evidence of obvious whale reaction to sampling activity apart from one case (out of 69 schools observed) where there was discernible movement away from the sighting vessel when it approached to 1.5 n.miles. Furthermore, the Workshop was reminded of the protocols on JARPA to alleviate the effects of such disturbance to the whales by the sightings survey. If the chasing of a whale by one vessel was considered by the Cruise Leader (stationed on the *Nishin Maru*) to be affecting the sighting activities of a vessel on an adjacent trackline, then the affected vessel would stop and wait until those activities were over (or no longer considered to be within the surveyable strip of the affected vessel), before resuming effort. Given this additional information (more fully explained in SC/D06/J2), no further analyses were specifically recommended at this stage. Nevertheless, it was noted that an empirical way of examining the existing data to see if these activities might be problematic would be to check that sightings on the three SSV tracklines were located in three (along-trackline) distance bands (in front, in between, behind) in equal proportions in the presence of chasing/sampling on an adjacent trackline.

The general question of responsive movement to vessels was also raised. The Workshop **agreed** to refer this matter to the IA sub-committee as it was relevant to estimating minke whale abundance for both the IDCR/SOWER and JARPA surveys.

ESTIMATION OF EFFECTIVE STRIP WIDTH AND MEAN SCHOOL SIZE FROM THE SSV DATA

The analyses in SC/D06/J6 had pooled across the three SSV tracklines for estimation of effective strip width and mean school size. Although recognising that the rotation of vessels between these tracklines would help to 'average out' any potential vessel effect, the Workshop **recommended** that sensitivities to this pooling be investigated. Furthermore, because of the rotation, not only should a potential vessel effect be examined but also a potential 'transect effect'. These sensitivity tests are considered particularly important for effective strip width estimation and less so for the estimation of mean school size.

EXTRAPOLATION INTO UNSURVEYED AREAS

As reported under Item 2.2.3, the Committee had recommended at the 2006 Annual Meeting that abundance estimates be based only on the ice-free areas within a surveyed stratum (so that when converting density estimates to abundance estimates, areas covered by ice were excluded). As part of the analyses presented in

SC/D06/J6, this issue was specifically examined. Abundance in the unsurveyed area was in fact estimated using densities estimated from the northern stratum. The Workshop noted the process which led to these areas not being surveyed, that they did not occur very often and that they occurred only in Area IV (Table 1). The authors of the paper concluded that this treatment typically made a difference of up to about 10% of the total estimates and therefore would not substantially impact on trend estimation. After considerable discussion, while the Workshop broadly **agreed** with the authors' conclusion, it also **recommended** that it would be valuable to bound the problem by examining results for which the abundance in the unsurveyed area is treated as zero, as had been recommended at the 2006 Annual Meeting. During discussion of the report, Childerhouse noted that in some cases, different treatment of unsurveyed areas could make up to about 20% difference.

Table 1

Unsurveyed area (between northern and southern strata) expressed as a percentage of the total Area IV south of 60°S

Season	Percentage	Season	Percentage
1995/96	8.6	2001/02	2.8
1999/00	4.3	2003/04	11.1

As in any survey, poor weather and other factors can affect the cruise schedule and may lead to some planned tracklines in an area not being completed. Occasionally this occurred in the JARPA surveys so that, for example, only the tracklines in the western part of a stratum were covered and not those in the eastern part. Whilst extrapolation into unsurveyed areas is not generally desirable, when looking at trends in abundance it is helpful to do so for comparable areas. The Workshop **recommended** that where such (primarily E-W) extrapolations are necessary, the ratio of density in the unsurveyed area to the surveyed area be calculated from data in other years. The product of this ratio and the density in the surveyed area in that year would be used as the estimated density to extrapolate into the unsurveyed area in that year.

ANALYSIS USING THE SAW-TOOTH TRACKLINE DESIGN

At the 2006 Annual Meeting, the Committee had recommended that the saw-tooth trackline design employed in some southern strata be examined. In particular, it had considered that design-unbiased estimates would be obtained from the N-S transects and that as a sensitivity test, estimates from these transects alone should be compared with estimates from all saw-tooth transects (i.e. using those constructed at an angle to the next planned waypoint as well). SC/D06/J6 reported the results of this sensitivity analysis, which somewhat counter-intuitively seemed to indicate that estimates using all transects were all appreciably and in most cases significantly less than for the N-S transects only (Table 4 of that document). Noting concerns about a reduction in precision using the data from the N-S transects alone, the authors of SC/D06/J6 concluded that it was better to use data from all transects.

Ishikawa (Cruise leader on several JARPA surveys) commented that JARPA adopted both the saw-tooth design and IDCR/SOWER design tracklines in the southern strata and the latter had been introduced in the complex region where the ice-edge could be changing substantially, such as in the Ross Sea, adding that all tracklines were implemented in conformity with the protocols (i.e. trackline construction was not arbitrary even in 'difficult' regions). Nevertheless, it was evident to the Workshop from examination of the plots of tracklines that the practical logistics of designing tracklines real-time in complex regions where the ice edge could be changing were so difficult that it was impossible to implement the saw-tooth design as intended in some years.

There was considerable discussion of this issue, during which it became apparent that for some ice edge configurations, particularly the more complex ones frequently encountered in Area V, it was not necessarily true that estimates using the N-S transects alone would be design-unbiased. The Workshop **agreed** that all transects would be useful at least in estimating effective strip width and mean school size (and their variances). However, it was unable to resolve the issue of which transects to use for abundance estimation at this Workshop. In order to more fully understand the results in Table 4 of SC/D06/J6 and their implications, the Workshop **recommended** that the sensitivity analyses of SC/D06/J6 are repeated but with appropriate weighting of the data (e.g. in proportion to the number of sightings within a stratum), and/or by bootstrapping (conditional on the total number of sightings). These new analyses should also be categorised into 'successful' implementation of the saw-tooth design and 'unsuccessful' implementation (i.e. situations where the saw-tooth pattern is not clearly seen because of complex ice edge configurations). Although recognising that this would be a substantial piece of work, it was also suggested that the data be post-stratified (for example into three bins) with distance from ice-edge, and re-analysed. Noting that it is not necessary to have results from every year of the JARPA programme to look at trends, a further possible pragmatic way forward suggested was to use only those surveys where the saw-tooth design was subjectively considered to have been successfully implemented.

The Workshop recognised the progress that had been made with respect to obtaining abundance estimates from the JARPA surveys but it believed that progress would probably have required fewer iterations if the Committee and analysts had adopted a more co-operative approach. Some of the additional work required has been due to either a misunderstanding of recommendations made by the Committee or due to the lack of detail given in the Committee's report. It therefore **agreed** to establish an Advisory Group (comprising Kitakado (convenor), Butterworth, Hedley, Hakamada and Matsuoka) to facilitate the undertaking of the recommendations given here (and the recommendations made with respect to abundance estimates and trends given elsewhere under Item 2). This group will work by email to ensure that the work to be done is fully specified, review the results and if necessary suggest modifications with a view to consolidated analyses being presented, ideally in time for consideration at the 2007 Annual Meeting.

Towards the end of the meeting, Wade presented a working paper reviewing coverage of strata and the sequence of surveys relative to the ice edge during JARPA. Some of these points had arisen during discussions in the Workshop and sub-groups but there had not been time for full consideration. He noted that the logistics of surveys in the Southern Ocean are difficult, particularly with regard to surveying along the ice edge. The fact that the surveys take three to four months to be completed means that considerable changes can occur in the location of the ice edge during the survey. In Area IV, there were trends in (a) the timing of the survey of the ice edge (i.e. southern) strata, (b) in the extent of sea ice at the time of coverage of the ice edge strata and (c) in whether a gap occurred between the northern and southern strata. In particular, the last three surveys (from 1999/00 to 2004/05) were different from the previous five surveys in all these categories. In Area V there was also a trend in the sequence in which the strata were surveyed, with a different sequence occurring particularly during the last three surveys. The ice edge stratum (SW) was surveyed later (March) during the last three surveys than during the first five surveys (December-February); furthermore, he noted that coverage was relatively low during the last two surveys. The SE stratum (Ross Sea) was surveyed earlier during later surveys, and the extent of ice was high or medium during three of the last four surveys whereas it was low in all of the first four surveys. Given that minke whale density is relatively high in the ice edge strata, he considered that changes in timing of the coverage of these strata could have influence on the trends in abundance resulting from the JARPA surveys. Such changes can potentially confound interpretation of trends in abundance of any whale species from JARPA data if that species' density has some relation to the ice edge. He also noted that the large changes in the extent of ice at the time of the surveys changes the size of the overall survey area considerably, with the survey area larger in Area IV but smaller in the Ross Sea in the more recent surveys. This could influence absolute abundance, as the proportion of minke whales south of 60°S (and therefore in the study area at the time of the survey) could vary according to the amount of open ocean available at that time. He believed that it was important to try to determine methods to account for such changes in the sequence and timing of the survey of the southern strata.

The Workshop noted that given the lack of time, it was not possible to discuss the working paper in any detail. It was **agreed** to append an abbreviated version to the present report as an authored Annex (Annex F). Wade was encouraged to present the full version or a modified version to the Scientific Committee for consideration at the Annual Meeting, particularly by the IA sub-committee. The Advisory Group established above to examine abundance estimates further would also consider these general issues to the extent possible in its intersessional work.

Finally, it was noted that within the Committee, much time has been devoted to discussing potential sources of bias in estimating abundance and trend from IDCR/SOWER surveys. Many of the generic issues (i.e. those not related to specific IDCR/SOWER methodology) could also be sources of bias for JARPA estimates, such as changes in the locations of the ice edge, changes in the proportion of animals south of the ice edge and changes in the proportion of animals north of 60°S (see SC/58/IA4). The magnitude of some of these biases could be large and in either direction with resulting impacts on the estimates.

2.4.2 Other species

SC/D06/J7 reported information on current distribution abundance for humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus)* and blue (*B. musculus intermedia*) whales in the Antarctic Areas IIIE, IV, V and VIW, south of 60°S. The sighting survey under JARPA was designed as a large-scale and long-term monitoring exercise using line-transect surveys. As noted above, it was carried out in a broadly consistent way every year alternating between Areas IV and V from 1987/88 to 2004/05 austral summer seasons. Sighting surveys were repeated in the same area in the same month (mainly January and February) for 18 years. For the whole period, a total search distance on primary effort of 293,811 n.miles was achieved during 6,188 ship-days. The survey protocols were similar to those used IWC/IDCR-SOWER surveys. Analyses were conducted using the program DISTANCE, taking into account the suggestions offered in recent Committee meetings. The largest concentration of humpback whales has occurred recently to the east of the Kerguelen Plateau between 80° and 120°E, and the authors commented on apparent latitudinal and longitudinal expansions of this area over time. In general, fin whales were said to be more widespread in Area V than Area IV. However, in recent years they have also been observed frequently in the western part of Area IV. Furthermore, high density areas were observed to the west of the Balleny Islands and Kerguelen Plateau. Blue whales were widely distributed in the research area although no apparent regional aggregation was evident. The eight full-scale surveys in each of Areas IV and V provided estimates of abundance for these species with reasonable precision given the relatively large number of sightings. The effect of survey mode on the estimates was examined by the authors. Sensitivity to alternate selection from tracklines in southern strata showed that possible biases in estimates were very small. The resultant abundance estimates of humpback whales were 27,783 (CV=0.12) in Area IV in 2003/04 and 9,342 (CV=0.34) in Area V in 2004/05. Abundance estimates of fin whales were 6,514 (CV=0.27) in 2003/04 for the Indian Ocean stock and 5,241 (CV=0.38) in 2004/05 for Western South Pacific stocks, although it must be remembered that fin whales are mainly found north of 60°S. The abundance of blue whales for the whole research area was estimated as 1,265 (CV=0.33). A total abundance estimate for fin whales based on the two recent surveys for the half of Antarctic Areas (35°E -145°W) south of 60°S was 12,000 (CV=0.22). The authors proposed a 'shift in baleen whale dominance' from Antarctic minke to humpback whales in Area IV since the 1997/98 survey.

As noted above, several suggestions and recommendations had been made at previous IWC meetings regarding the estimation of abundance as well as its trend (e.g. see Item 2.2.2). The Workshop **appreciated** that the considerable amount of work had been undertaken in the relatively short time available since the 2006 Annual Meeting. It **agreed** that a large dataset on distribution and abundance for humpback, fin and blue whales has been accumulated by sighting surveys conducted under JARPA. The Workshop noted that some of the points raised in the discussion of the Antarctic minke whale analyses are also relevant to the analyses of these other species. In the limited time available for discussion, some specific points that require further consideration were made, including the fact that in some cases the effective strip widths in some strata/years were estimated to be rather small, indeed smaller than for minke whales in the same strata/years. Overall, the Workshop **agreed** that the abundance estimates provided in this paper represented useful steps forward in working towards acceptable estimates of abundance. It also **agreed** that the future work can best be facilitated by the Advisory Group appointed above.

2.5 Estimates of trends in abundance

In considering the issue of trends, the Workshop **reiterated** that any estimates refer to trends in the number of animals present in a particular geographical area at a particular time of the year and that this (given the discussion of stock structure and mixing summarised under Item 3) is not necessarily indicative of trends in populations, although abundance for one possible stock structure hypothesis (see Item 3) is presented.

2.5.1 Minke whales

The extensive discussion of the abundance estimates for Antarctic minke whales presented under Item 2.4.1 is clearly relevant to the discussion of the trends presented in SC/D06/J6. Table 2 provides the estimates of trend and associated confidence intervals from the JARPA surveys as reported in SC/D06/J6 (tables 8 and 9).

Table 2

Estimates of trend in abundance of Antarctic minke whales taken from SC/D06/J6

Area	Estimate	95%CI	Period
Area IV	-0.42%	(-4.02%, 4.59%)	1989/90 to 2003/04
Area V	-1.54%	(-4.91%, 2.18%)	1990/91 to 2004/05
Area IIIE+IV+VW (35°E to 165°E)	7.93%	(-0.05%, 11.45%)	1989/90/91 to 2003/04/05
Area VE+VIW (165° E to 145°W)	-5.88%	(-12.19%, 0.18%)	1989/90/91 to 2003/04/05

The Workshop noted that the current confidence intervals for the estimates of trend are relatively wide. These results are, therefore, consistent with a substantial decline, a substantial increase, or approximate stability in minke whale abundance in these geographic areas over the period of JARPA. These trend estimates were based on abundance estimates for which several important re-analyses and re-evaluations had been recommended, and these could lead to changes to the point estimates and variance estimates noted above. Given the importance of the recommended re-analyses, the Workshop **agreed** that the estimates of trend as presented in SC/D06/J6 need to be re-evaluated once revised analyses have been completed.

2.5.2 Other species

SC/D06/J7 reported estimates of trends in abundance for humpback, fin and blue whales. For humpback whales, the annual increase rates from 1989/90 to 2004/05 seasons in Area IV and V were estimated as 12.4% (95%CI 7.5% - 23.4%) and 9.7 % (95%CI 1.5% - 18.0%), respectively (i.e. significantly greater than zero). Abundance estimates for humpback whales from IDCR/SOWER surveys, which were noted at the 2006 Hobart workshop as being broadly comparable to those from JARPA surveys, also indicated high increase rates for this species in both the Areas (IWC, 2006). The authors suggested that the apparent habitat expansion of humpback whales to the south of the Antarctic Circumpolar Current observed in Area IV might had been related to high increase rates south of 60°S for humpback whales. A significant increase for fin whales of 10.2% (95%CI 8.9%-19.3%) was observed for the 1995/96 to 2004/05 period; an estimate of 7.4 % (-1.4%-29.0%) was obtained for blue whales from 1989/90 to 2004/05 in Areas IV and V combined. Catch data showed that in summer fin whales were once widely distributed from middle latitudes to south of 60°S over a wide longitudinal range; they concentrated in Area III (between 10°E-60°E), in Area IV (between 80°E-110°E), Area V (between 140°E-170°E) and Area VI (between 170°W-150°W). During the Japanese Scouting Vessel (JSV) period, fin whales were rarely found south of 60°S. However, large numbers of fin whales have been observed south of 60°S during the JARPA period (1987/88-2004/05) and the authors noted that this change in the distributional pattern might bias the increase rate estimated as a measure of that for the population as a whole. They also commented that the point increase rate for blue whales for the JARPA survey is similar to that obtained using the IDCR/SOWER data for the whole Antarctic pooled (7.8 %) (Branch and Ensor, 2004). Finally, they noted that the present estimates of absolute abundance show that the blue whale remains well below its pre-exploitation abundance.

The Workshop welcomed the information presented in SC/D06/J7. It drew attention to the comments made during the discussion of trends for Antarctic minke whales (Item 2.5.1), many of which are also applicable to these other species. Discussion focussed on the trends reported for humpback whales. The Workshop noted that there have been reports of recent increases of humpback whale numbers from studies on the breeding grounds, feeding grounds and migratory corridors. This was discussed extensively at the 2006 Hobart Workshop. Regarding the estimation of trend, the Workshop **recommended** further refinement of the linear model, as discussed for minke whales, by incorporating process error as well as a trend parameter, an area effect and examination of survey sampling error. This model should also allow estimation of the additional variance, which might lead to better estimation of the uncertainty of abundance estimates from feeding ground surveys.

The Workshop noted that the estimates of increase rate and associated precision for humpback whales from the JARPA surveys would change when abundance estimates were refined in the light of the recommendation above. It noted further that the precision of these estimates is appreciably less than those from coastal surveys; this is as to be expected, as spatial movements from year to year would be greater on feeding grounds than in the migration corridor. Turning to the fin and blue whale estimates, the Workshop **recommended** that refinement of the method for estimating trend be applied also to fin and blue whales. It emphasised that overlap between areas surveyed and distribution of fin whales be carefully considered. It noted that the wide range of the 95% CI for the increase rate for blue whales arose from one particular influential abundance estimate, deletion of which would greatly improve the estimated 95% CI. However, considering the wide confidence intervals, it remained difficult to identify a clear trend for fin and blue whales from the JARPA surveys.

The Workshop **agreed** that the details of the improved analyses be considered by the Advisory Group established under Item 2.4.1.

3. STOCK STRUCTURE (ANTARCTIC MINKE WHALE)

3.1 Background

The Workshop noted that the study on stock structure in the Antarctic minke whale was conducted under the JARPA research objective 'elucidation of the stock structure of the Southern Hemisphere minke whales to improve stock management'. Information on stock structure is important for (a) the estimation of biological parameters, which should ideally be carried out on the basis of biologically identified stocks and (b) the future application of the multi-stock rules of the Revised Management Procedure (RMP) (IWC, 1994). When JARPA surveys began in IWC Antarctic Areas IV and V in 1987/88, the assumption was that these two Areas were occupied by different genetic stocks. At that time there was little scientific evidence supporting such an assumption. At the time of the 1990 Comprehensive Assessment (IWC, 1991) none of the molecular genetic techniques nor any of the non-genetic techniques that examined past commercial data provided any evidence of stock level differences between minke whales in Areas IV and V. Subsequently, JARPA samples were used in genetic studies (mtDNA) which suggested substantial genetic heterogeneity in Areas IV and V and some stock structure hypotheses were proposed, which were not consistent with the current boundaries of Areas IV and V. Results were presented and discussed during the JARPA review meeting in 1997. That meeting recommended that additional analyses be conducted (in addition to mtDNA) and the possibility of different stock structure than implied by the traditional management areas was not discarded. Subsequently, in 1997, the Scientific Committee recommended that several tasks be completed to improve understanding of stock structure (IWC, 1998b). In reviewing the results on stock structure derived from JARPA in 2004, the Committee noted that only preliminary conclusions can be drawn at that time and that more concrete conclusions will be able to be made following the completion of additional analyses. It further supported the suggestion that additional analyses using alternative groupings and analytical methods should be conducted (IWC, 2004b). Consequently the JARPA stock structure study was extended by the use of several biological markers, both genetic and non-genetic, and a more detailed grouping of samples.

3.2 Issues raised in 1997 JARPA review

3.2.1 Stock definition

During the 1997 meeting the Committee had agreed that the lack of a working definition of stocks and sub-stocks is a general problem, not for JARPA alone, and therefore needed to be addressed by the Committee (IWC, 1998b). The Committee consequently established a Working Group on Stock Definition, where this particular topic is discussed annually. However, the Committee has not yet reached agreement on the definition of stocks for management purposes. In discussion at this Workshop, a question was raised about the consideration of 'soft' boundaries, and it was reported that this had not been dealt with specifically by that Working Group, but reference was made to the 'TOSSM' approach (IWC, 2007a).

3.2.2 Statistical analysis of mtDNA data considering the inclusion of school size as a covariate

Analyses considering the inclusion of school sizes as a covariate in the mtDNA survey were carried out by Pastene and Goto (1999). Results were presented during the 1999 SC Meeting (IWC, 2000a). These authors found no significant differences in haplotype frequencies among different categories of school sizes.

3.2.3 Pilot study on nuclear DNA analysis on JARPA minke samples

Studies on stock identity in JARPA based on nuclear DNA markers (microsatellites) started in 1998 and preliminary results were presented to the 1999 Committee meeting (Abe *et al.*, 1999). Currently all samples taken by JARPA have been examined with a set of six microsatellites (see SC/D06/J9).

3.2.4 Effort to obtain biological materials for genetic analysis from low latitude areas of the Southern Hemisphere (potential breeding grounds) and compare with feeding ground data

Results of a survey of biological materials from minke whales from low latitude institutions of the Southern Hemisphere were presented to the 1996 Committee meeting (IWC, 1997b); apart from the Brazil region, no other comprehensive materials of the Antarctic minke whale from low latitudes were available. Pastene reported that 61 samples from Brazil had been compared with 119 samples from combined Areas IV and V in a mtDNA control region sequencing analysis, and no significant differentiation was found based on K_{ST} (Pastene *et al.*, 2007). Of interest for the JARPA studies are the materials from low latitudinal areas of the eastern and western side of the Indian Ocean and the western side of the South Pacific Ocean. Japanese scientists have been informed of a collection of 200 baleen plate samples of the Antarctic minke whales taken in Durban, South African (western part of the Indian Ocean). These samples have been stored in formalin for some decades. Effort is being made to develop suitable genetic techniques to examine such samples. Hoelzel noted that it is the acidity of formalin that degrades DNA, and that buffered solutions preserve DNA better, although useful DNA can sometimes be extracted even from un-buffered formalin (dependent in part on the age and permeability of the samples).

3.2.5 External morphology/morphometry analyses

Morphometric analysis to examine stock structure had been conducted using all Antarctic minke whale samples taken by the JARPA (see SC/D06/J10 below).

3.3 Data collection methods and results

Samples of Antarctic minke whales for studies of stock structure were taken along pre-defined track-lines covering both offshore and ice-edges regions (see SC/D06/J2). From 1987/88 to 1991/92 a maximum of two whales were taken randomly from primary sighted school within 3 n.miles of the track line by SSVs (see SC/D06/J2). From 1992/93 only one whale was randomly sampled regardless of school size. The rational for this change was that the sampling then covers all schools sighted by the SSVs. The objectives of JARPA relative to stock identification included both genetic and non-genetic techniques. As a result the following samples collected as part of JARPA (sample size in parenthesis) are particularly relevant to stock structure studies:

(1) liver, heart, muscle, kidney (6,777 samples each) and skin (6,778[1]) tissues for genetic analyses
(2) standard body length plus 19 additional body measurements for morphometric analysis (6,777)
(3) photographs of dorsal surface, dorsal fin and flippers for morphological studies(6,777)
(4) external and internal parasites occurrence observed (6,777).

Information on other data can be found in Annex D.

[1] One skin tissue sample collected from one individual taken but lost during transportation to the research base vessel.

While this represents an extremely large and comprehensive dataset for the feeding grounds, it was noted that the lack of samples from the breeding grounds precluded description of this as a completely comprehensive dataset for stock structure analyses, given the importance of such samples for a full interpretation of stock structure (and see Item 3.5 below). This applies to studies on stock structure in any other baleen whale species. Pastene suggested that the effect size for the Antarctic minke whale is low, and therefore a large sample size is necessary. While this may be the case it was also noted that the apparent low effect size may simply reflect mixing. It was further noted that a power analysis should be undertaken to determine the relationship between sample size and power for these analyses. Pastene indicated that a preliminary study had been undertaken, and agreed that further analyses would be useful. It was suggested that in addition to genetic studies, it would be useful to include potential alternative stock markers such as stable isotopes (e.g. carbon, oxygen, hydrogen and strontium). Aguilar noted that pollutant markers may have limited power in the Antarctic, as this habitat is far from the point sources of pollution.

3.4 Data analysis methods and results

3.4.1 Genetics

SC/D06/J09 investigated stock structure of Antarctic minke whales in the feeding grounds using mitochondrial DNA (mtDNA) restriction fragment length polymorphism (RFLP, six restriction enzymes) and microsatellites (six loci). Samples used were obtained during JARPA surveys from 1987/88 to 2004/05 austral summer seasons in Areas IIIE, IV, V and VIW. Samples were grouped into six longitudinal strata used by JARPA surveys: IIIE (35°-70°E); IVW (70°-100°E) (north and south); IVE (100°-130°E); VW (130°-165°E); VE (165°E-170°W) (north and south) and VIW (170°W-145°W). Both genetic approaches showed substantial spatial genetic heterogeneity among the strata. For both genetic markers, whales in the most distant geographic strata (IIIE, IV and VE, VIW, respectively) were differentiated genetically. The authors noted that mitochondrial DNA (mtDNA) was better able to detect structure in the middle longitudinal strata. Results were consistent with the hypothesis of at least two stocks, possibly related to proposed breeding areas in the Indian and western South Pacific Oceans, respectively. The pattern of spatial differentiation found provides little support for IWC stock boundaries for Areas III, IV, V and VI. The dispersal pattern of males and females in the feeding grounds was similar according to the mtDNA analysis, which is consistent with the previous view on whale longitudinal movement based on mark-recapture analysis. The microsatellite heterogeneity tests suggested more structure in females than males. However no significant differences were found when the allele frequencies of males and females were compared in each of the strata. The authors stated that the results of a fine-scale mtDNA analysis suggested a stock division in the longitudinal sector 150-160ºE and that the possibility of an area of mixing of stocks around that longitude cannot be discarded. They noted that site fidelity to particular areas of krill concentrations could explain the spatial segregation of stocks of Antarctic minke whales in the feeding grounds.

In discussion, Pastene noted that an earlier analysis (Pastene and Goto, 1997) based just on mtDNA and smaller sample sets had suggested population structure that is no longer supported. He also indicated that independence with respect to linkage disequilibrium had been tested. The Workshop noted that for many relevant analyses, power is more effectively increased by an increase in the number of polymorphic markers used, and Pastene reported that further microsatellite loci would be included in future. Given that the sampling area is in the feeding grounds and may well represent a mixed assemblage of stocks, it was noted that clustering methods based on individual genotypes, that avoid *a priori* assumptions about population boundaries may be usefully applied. Further, methods such as MDS (multidimensional scaling) or PCA (principal component analysis) were **recommended**, as assignment methods based on violation of equilibrium assumptions (such as STRUCTURE) may have too little power.

With respect to the area of transition, it was suggested that methods that address the question of isolation by distance (such as spatial autocorrelation and Mantel tests) would help resolve the position and nature of this transitional pattern. It was further suggested that other analyses based on individual genotypes, such as landscape genetics as assessed in the program '*alleles in space*' (Miller, 2005) may help resolve the pattern of structure and mixing (though this would likely require 15+ microsatellite loci to provide sufficient power). Hoelzel related a relevant experience with the analysis of minke whale population structure in the North Atlantic whereby analyses based on individual genotypes (in this case using likelihood assignments implemented in the program *Geneclass*) revealed structure that could not be detected using Wright's inbreeding coefficients (such as F_{ST}) or exact tests. SC/D06/J9 indicated heterogeneity by year, and it was suggested that these anomalous samples be investigated further as this could conceivably be indicative of breeding stocks that were at other times obscured by more extensive mixing. Schweder suggested that the transitional area be studied by fitting a mixing model where the fraction of whales belonging to one putative population is a function of the longitude at which it was sampled. This could be a simple logistic regression model coupled with two-product multinomial models describing the allele frequencies in the two putative stocks either side of the transition area. It could also be extended beyond two populations, and incorporate both genetic and morphometric data.

The Workshop **stressed** the importance of obtaining samples from the breeding areas, noting the potential problems with interpreting the results of mixing models without this. Given lack of knowledge of the location of the breeding areas, the value of satellite tracking studies was emphasised. The question of the existence of historical/ archive samples for the potential extension of the analyses geographically, and to enable further comparisons among years (especially over a longer timeframe) was raised. An initial enquiry indicated that at least some of these samples are still available. Goto and Pastene reminded the workshop that in 1998 the Committee noted that because the commercial catch had been mainly near the ice-edge, the analysis of past commercial catches would not be particularly useful for stock identification (IWC, 1999, p.25).

3.4.2 Morphometrics and morphology

SC/D06/J10 provided a comparison of morphology based on 10 external measurements from 2,629 male and 1,803 female mature Antarctic minke whales undertaken across the JARPA research area. Males and females were separated into two groups at 130°E and 165°E, respectively. Some concerns were expressed about the fact that not all measurements were included in the comparisons, and that the sex ratio varied between areas. This was explained by noting that some measurements were difficult or unstable when assessed by different researchers, and therefore excluded. The Workshop **agreed** that finer scale geographic analyses would be worth undertaking in future. The broad consistency of the morphological and genetic data was noted, and it was suggested that they be investigated together.

SC/D06/J11 investigated stock structure in the Antarctic minke whale in the feeding grounds by examining body length of physically mature whales based on samples collected during JARPA surveys from 1987/88 to 2004/05. Grouping of the samples was the same as that used in the genetic analysis. Significant differences were found for this biological parameter among the geographical strata examined, which rejected the scenario of a single stock in the research area. Whales in the western strata (IIIE, IVW, IVE, VW) are significantly larger than those in the eastern strata (VE, VIW) for both sexes. Results were consistent with the hypothesis of at least two stocks in the JARPA research area, possibly related to the proposed breeding areas in the Indian and western South Pacific Oceans.

There was some discussion about the potential that this could instead reflect the age structure of the respective populations. To address this, it was noted that most of the final body length is reached by sexual maturity, and that much of the subsequent growth is with respect to increased girth. It was also noted that length could reflect differences in nutrition or other environmental factors.

3.5 Synthesis

SC/D06/J12 provided an overview of the studies on stock structure in the Antarctic minke whale with the purpose of establishing a plausible hypothesis for the stock structure of this species in the JARPA research area (Areas IIIE-Area VIW). Studies on stock structure started at the end of the 1970s and results were reviewed by the Committee during the Comprehensive Assessment in 1990 (IWC, 1991). All the analyses were conducted using samples and data from commercial pelagic whaling in the Antarctic. Most genetic studies were based on allozymes although some studies based on mitochondrial and nuclear DNA were conducted. Most of these analyses involved small sample sizes from Areas IV and V only. Non-genetic studies reviewed in 1990 involved morphology, catch and sighting distribution pattern, analysis of Discovery marks and ecological markers. Results from the different approaches failed to identify unambiguously any isolated population in the Antarctic. Ecological markers were identified as a potentially useful approach. Analysis of sightings data suggested the occurrence of five breeding areas. Studies on stock structure under JARPA began after the CA. The author believed that samples taken by JARPA were more useful for studies on stock structure given the wider geographical coverage of the surveys and because minke whales were taken along tracklines in a random mode design. Initially, the JARPA studies on stock structure were based on mtDNA and considerable genetic heterogeneity in Areas IV and V was found. More recently, the total minke whale samples taken by JARPA in Areas IIIE, IV, V and VIW have been examined using different analytical approaches (genetics and non-genetics) using similar groupings. In general, the results of the different approaches were inconsistent with the single stock scenario. The author concluded that the results of the different approaches were consistent with the occurrence of at least two stocks in the research area, probably related to the breeding areas in the eastern Indian Ocean and western South Pacific suggested by previous sightings data. The author proposed that these be termed the Eastern Indian Ocean Stock (I-Stock) and Western South Pacific Ocean Stock (P-Stock). In order to estimate biological parameters in JARPA, he proposed that a boundary between I and P Stocks should be adopted at the division between Areas VW and VE (165°E). This is consistent with the results of mark-recapture that showed marked movements of whales between Areas IV and VW. Although the most recent analyses indicated that whales in Area IIIE belong to the I stock, other analyses suggested some degree of heterogeneity between Areas III and IV. Therefore the possibility of additional stock structure in Area III (e.g. the occurrence of animals from the western Indian Ocean breeding ground) should be investigated in the future. The author noted that any stock boundary (or sectors of mixing) among stocks in the Antarctic should be considered to vary according to oceanographic conditions, which in turn controls the distribution of the key prey species of the Antarctic minke whale, the krill. He finally identified several future research needs for stock structure studies.

The Workshop welcomed this review, and with respect to stock structure studies, **recognised** the very considerable amount of work undertaken since the mid-term review and the progress that has and can be made given the data collected. Based on the analyses of the genetic and morphometric data presented, it **agreed** that there are at least two stocks of Antarctic minke whales present in the JARPA research area. The data do not support the current IWC management Areas. The data also suggest an area of transition in the region around 150-165°E across which there is an as yet undetermined level and range of mixing. Some of the genetic analyses suggest the possibility of further subdivision (e.g. for microsatellite DNA data, pairwise comparisons for females showed heterogeneity between IIIE and IVWS), and the Workshop identified the need for further analyses of the existing samples (together with available historical samples from commercial whaling, but see comment under Item 3.4.1), related especially to new statistical analyses, genetic marker development, and additional non-genetic markers, to further assess the number of putative stocks. Such analyses should allow a more thorough specification of stock structure and the relative plausibility of different hypotheses. The Workshop recognised that samples from the breeding areas (e.g. as could be obtained through a combination of satellite tracking and biopsy sampling) would greatly facilitate these analyses, and are likely to be required to resolve issues relevant to stock structure and mixing within the JARPA research area. Analysis of historical samples (as available) from areas to the east and west of the study area may also be useful towards resolving stock issues within the JARPA research area, especially with respect to Areas III and VI.

4. BIOLOGICAL PARAMETER STUDIES

4.1. Background

The original primary objective for JARPA, as specified in SC/39/O4, was to estimate the age-specific natural mortality coefficient for Antarctic minke whales (IWC, 1988), since knowledge of this parameter was at the time considered to be the key to determining the replacement yield rate and hence important for the rational management of Antarctic whale populations. After five seasons, a change in the immediate focus of the primary objective was reported, from estimating the age-specific natural mortality to the average natural mortality rate (IWC, 1993). The Scientific Committee completed the Revised Management Procedure (RMP) in 1992. Since the RMP does not require biological parameters such as *M*, Japanese scientists reconsidered whether or not the first objective be further modified. By the 1997 workshop to review the results of JARPA to date, this objective had evolved to the current ‘estimation of the biological parameters to improve the stock management of the Southern Hemisphere minke whale’ (IWC, 1998b).

Hatanaka explained that Japan considered that estimation of the natural mortality rate (*M*) was still useful for understanding the population dynamics of minke whales, and therefore important for the management of whale stocks. Furthermore, there is the possibility of estimating *MSYR*, an important parameter for the RMP, from catch at age data. Other parameters such as recruitment rate, age at sexual maturity and reproductive rates are also potentially useful for stock management and could contribute to improving *Implementation Simulation Trials* for the RMP.

At the JARPA review meeting in 1997, it was agreed that, although not required for management under the RMP, the information presented provided valuable information on recruitment, natural mortality, decline in age at sexual maturity and reproductive parameters in Areas IV and V. However, that meeting had also recognised that there some unsolved problems in the analyses and that further analysis was necessary, for which some recommendations were made (see below).

4.2. Issues raised in the 1997 JARPA review

In relation to biological parameters, the Committee recommended a number of tasks (IWC, 1998b, p.103, table 2) of which the following relate to biological parameters:

(i) segregation study;

(ii) recalculation of biological parameters by biological stocks (IWC, 1998b, p.103, table 2).

4.2.1. Segregation study

A study on segregation was conducted in the context of the distribution pattern of minke whales in relation to the pack ice edge. Results (Fujise *et al.*, 1999) for Area IV were reported to the Scientific Committee (International Whaling, 2000, p.168). The authors used regression analyses to suggest the following segregation pattern:

(a) males (especially matures) predominated in the research area in all seasons although their proportion tended to decrease with increasing latitude;

(b) mature males tended to be found in larger school sizes;

(c) females (especially matures) tended to be found in the southern part of the research area.

4.2.2. Recalculation of biological parameters by biological stocks
Many biological parameters were estimated on the basis of proposed (SC/D06/J12) new biological stocks (the putative I and P stocks with their boundary set at 165°E discussed under Item 3).

4.3. Data collection and results
Following the cessation of commercial whaling, biological data and samples have been accumulated under the JARPA programme from 1987/88 to 2004/05 in Areas IIIE, IV, V and VIW. A total of 6,779 individuals, including 2 animals taken but lost in transit, were taken. Each whale was examined in detail and a variety of samples were collected, including:

(1) body length measurements (6,777)

(2) earplugs for age determination (6,777)

(3) Testis (3,636) and ovaries (3,151) for sexual maturity status.

Other available biological samples and data can be found in the list of JARPA data (Annex D).

Reliability of age determination
The issue of the reliability of the age determination results arose in several contexts in the discussion of biological parameters. The catch-at-age analyses by Punt and Polacheck (Polacheck and Punt, 2006) showed that there was an inconsistency in the age determination of younger animals between the commercial and scientific catches that can not yet be explained. Hatanaka and Kato noted that the procedures had been much improved in the JARPA programme relative to the data collection from commercial whaling. They believed that, at least for the JARPA data, the age readings could be treated as reliable. A particular problem with the commercial data had been the large number of broken or incomplete earplugs: better handling of the material meant that this rarely occurred in JARPA, and that 85% readability had been achieved. The residual fraction of unreadable earplugs was mainly due to the absence of a clear pattern of layering in those earplugs.

Childerhouse asked what effect the residual proportion of unreadable earplugs might have on the estimates of biological parameters. This had not been assessed quantitatively, but Butterworth considered that the unreadable earplugs would have to come from an extremely select component of the population in order to materially bias parameter estimates.

The Workshop noted that to date there were no readings from known age animals with which to directly verify earplug readings. Butterworth noted that for southern blue fin tuna, otolith readings had been calibrated with radiocarbon signals corresponding to atomic bomb tests of known date. Brownell recalled paper SC/48/NP25 where the bomb signal had been examined in a Bryde's whale sample in order to determine its year of capture. The Workshop **recommended** that the feasibility of detecting the bomb radiocarbon signal in earplug laminae be looked into.

The Workshop **agreed** that the earplug laminae probably were annual layers that were deposited independently of feeding, migration and other external factors, analogous with tooth layers that are laid down in odontocetes even in populations that do not migrate. However, Aguilar pointed out that accessory layers often occur which can confuse the reader: because of this, experience and inter-reader calibration are important. He suggested that there should be at least three readers, and earplugs or teeth that yield inconsistent results be omitted from the analyses.

Kato drew attention to the inter-reader calibration study between himself, Ohsumi and Zenitani (Kato *et al.*, 1991) which showed good agreement between experienced readers (Kato and Ohsumi) and a CV of age readings of only 6.6%. Cooke recalled the analyses of SC/M97/21 to the 1997 JARPA review which showed notable shifts between years, for example the Zenitani readings for the first two years of overlap were significantly lower than the Kato readings by 1.5 years on average, while in the third year her readings were an average of 0.5 years higher than the Kato readings. Kato explained that this occurred during the training period, after which the two readers obtained comparable results.

Walløe and Ohsumi drew attention to the good correlation between age readings and corpora counts in females shown in SC/D06/J17 (see Item 4.4.3).

The Workshop **recommended** that the comparability of commercial and JARPA age data be investigated by re-reading a subset of the commercial samples in an appropriately designed blind test.

4.4. Data analysis methods and results

The Workshop noted that many of the results in this section are presented in terms of the putative I and P stocks (see SC/D06/J12 and Item 3), by partitioning the data at 165°W by catch location, which represent one stock structure hypothesis. The Workshop emphasised that there is no agreement yet that these represent valid stock designations, but **agreed** that it was useful, for the purpose of comparing results from different data and methods, that the same partition was used for all analyses.

4.4.1. Natural mortality

SC/D06/J13 derived estimates of the average natural mortality rate of the 10+ population for the I and P stocks from JARPA abundance and age sample data, using the method originally proposed by Tanaka (1990). The estimate of annual mortality rate was 0.038 (SE=0.036) for the I-stock and 0.040 (SE=0.035) for the P-stock. The method uses both catch age composition and abundance estimates from the surveys, both stratified by stock area (I/P), school size (solitary vs. schools of size 2+) and sex. The method estimates the decline in abundance of groups of cohorts over time: for example the 10+ population in 1990 becomes the 12+ population in 1992, and the decline in their numbers represents natural mortality over 2 years. The authors considered that these estimates are valuable because they are direct estimates from large scale surveys. The estimates are lower than the value of *M* used in the *Implementation Simulations Trials* and also that in the assessment by Hitter runs (e.g. IWC, 1991). Use of these estimates will lead to some results different from those in the past and the authors expected that will reduce the extent of uncertainty in *M*.

In discussion, it was noted that the main contribution to the variance of the estimate is from the variance in the abundance trend, and this limits the precision of the results. The high standard error implies that the confidence interval extends from negative values to greater than 0.10. A much smaller standard error would be obtained if it could be assumed that the abundance had zero trend, but the Workshop **agreed** that this assumption should not be made, especially given that one of the original motivations for estimating the natural mortality rate was to better determine the trend in stock size.

Cooke noted that the variance of the age composition was probably underestimated, because previous studies (e.g. Cooke *et al.*, 1997) had shown that there is considerable overdispersion in the age composition, even after stratifying by more covariates that had been considered in SC/D06/J13. However, it was likely that the variance in the abundance trend would still be the dominant factor.

Cooke further noted that the very low precision of the estimate had been predicted in the review of the initial JARPA feasibility study proposal in 1987 (IWC, 1989), for example as calculated in his document (Cooke, 1987). The authors of SC/D06/J13 responded that the precision was lower than had been anticipated at the start of the programme because: (i) the abundance data showed considerable inter-annual additional variance in addition to the sampling variance of the abundance estimates, and this was taken into account in SC/D06/J13; (ii) the data showed that even with the JARPA sampling scheme, it was not possible to sample the younger animals representatively, because they did not all migrate beyond 60°S; consequent restriction of the analysis to the 10+ population diminished the effective sample size.

The Workshop **agreed** that the method used to derive the estimates in SC/D06/J13 was broadly valid, and in particular was free of assumptions about stock-recruitment relationships, but some members felt that the extremely low precision meant that the result was that the natural mortality rate had, for practical purposes, not been determined. In particular, even a zero value was not excluded by the analysis. Butterworth countered that, prior to JARPA, the commercial whaling age data were suggesting an apparent mortality rate of around 0.14, but this was confounded with a suspected trend in stock size. At that time, a finding that the true mortality rate was less than 0.11 would have been regarded as very valuable information.

In SC/D06/J14, the ADAPT-VPA assessment methodology originally developed by Butterworth *et al*. (1999) was improved by taking into account various comments made during recent Scientific Committee discussions. It was applied here to abundance estimates (from both IDCR/SOWER and JARPA surveys) and catch-at-age data (both commercial and scientific) for the putative I and P-stocks of Antarctic minke whales. The improvements to the methodology reported at the 2006 Scientific Committee meeting (IWC, 2007b) allowed account to be taken of various further aspects, primarily: (1) inter-annual differences in the distribution of the population between different management Areas; (2) a stock-recruitment relationship; and (3) the effects of possible ageing error. Furthermore sensitivities to various functional forms for selectivity and natural mortality with age were explored.

The general pattern shown by the results for both stocks was of a minke whale abundance trend that increased over the middle decades of the 20th Century to peak at about 1970, and then stabilised or declined somewhat for the next three decades. The recruitment trend was similar, although with its peak slightly earlier. The annual natural mortality rate, *M*, was estimated to be 0.056 with a CV of 0.16 for the I-stock, and 0.069 with a CV of 0.15 for the P-stock for the 'reference case' assessments. When only the JARPA abundance estimates are used for tuning, *M* is estimated as 0.038 and 0.060 for the I- and P-stocks, respectively. The estimation of *M* is fairly robust to the various assumptions of the model. The CVs of these *M* estimates for the 'Reference case' assessments, when compared with those of typically 0.35 for the Area-specific assessments of Butterworth *et al.* (1999), which were based on fewer data, indicate an appreciable improvement in the precision of these estimates due to the accumulation of data over the long-term of the JARPA surveys. The fits of the stock-recruitment model generally required a carrying capacity for minke whales that first increased and then stabilised or declined somewhat during the last century, and suggested *MSYR(1+)* values in the 4-6% range. The improved precision in the estimation of *M* may contribute to the improvement of management and assessment of this species on a stock-specific basis, since it can reduce the uncertainty concerning the value of *M* and provide an improved prior distribution for *MSYR*. The latter in particular, in the context of providing a measure of the productivity of which the species is capable, is essential information for effective RMP implementation through reduction of the range of plausible scenarios which need to be considered in *Implementation Simulation Trials.*

The Workshop noted that SC/D06/J14 was an integrated analysis that involved simultaneous estimation of natural mortality and recruitment rates. It was discussed both under this Item and under Items 4.4.3 and 4.4.4.

With regard to natural mortality, discussion focussed on how SC/D06/J14 was able to produce more precise estimates of *M*, and hence of other linked parameters, than SC/D06/J13. That is, which additional assumptions or data are driving the results. The additional data used were:

(i) the commercial age data; and (ii) the IDCR abundance data, which provided a longer time series of abundance data than JARPA alone. The additional assumptions included: a stock-recruitment relationship; and alternative options for the selectivity of the commercial age data.

In analyses of catch-at-age data there are three factors that are confounded in the present context: (i) the natural mortality rate; (ii) the past recruitment trend; and (iii) the selectivity slope. The role of the trend in abundance provided by the sightings surveys in removing one element of this confounding had been illustrated in earlier analyses presented on this issue (e.g. Butterworth *et al.*, 1999; Mori, 2006) but specification of the selectivity slope remained influential. Butterworth drew attention to the results of the sensitivity tests reported in SC/D06/J14 that showed in particular that it would require a very marked downward trend in selectivity of older animals in the commercial catch to invalidate the finding of an increased recruitment trend prior to exploitation. Furthermore, the overall pattern in recruitment (rising from low levels to a peak in 1968, followed by a quick decline to lower levels and little change thereafter) did not depend on the introduction of a stock-recruitment relationship into the estimation method, as previous analyses without such inclusion had provided similar results.

Some members expressed considerable unease arising from apparent dependence of the finding of increasing recruitment before 1968 on the inclusion of the commercial age data, especially in the light of the problems with the commercial age data (if taken at face value, these implied a sudden change in somatic growth when JARPA started). A sensitivity test in SC/D06/J14 to exclusion of the first half of the commercial age data reduced estimated rate of increase of the I stock from 0.057 to 0.014. Wade considered that if the change in age distribution from the commercial to the JARPA period is the factor that is driving the results, that would place a major question mark over the results.

Butterworth argued that the problems found by Punt and Polacheck with the commercial data applied only to growing animals, whereas SC/D06/J14 had used the commercial age data only for ages 16+. Cooke responded that Punt and Polacheck had only discovered the problem through the inconsistencies in the age-length distributions for younger animals. Since length for older animals was not a function of age, the problem would not be detectable in this way for older animals, even if they were also affected by it. It was, therefore, not safe to assume that the problem was restricted to the younger animals.

Maunder considered that if the aging of the older cohorts is acceptable, the trend in recruitment ought to be correctly estimated, but wanted to see what extent of bias or error in aging could account for the apparent trend. He asked to what extent the precision of the mortality estimate depended on the stock recruitment relationship. Butterworth replied that the sensitivity to this could be checked by downweighting its contribution to the likelihood. Maunder also considered it useful to determine to what extent the precision of the *M* estimate in this analysis depended on inclusion of the data from the lethal part of the JARPA programme, i.e. the catch at age.

Implications of the 'reference case' results of SC/D06/J14 are discussed further under Item 4.4.4.

4.4.2. Growth curves and age at sexual maturity

4.4.2.1. GROWTH CURVES

SC/D06/J17 presented growth curves from JARPA data, stratified by the putative I and P stocks, sex and cohort (grouped by decade). The results indicated that there had been no discernible changes in growth rate over the JARPA period. Data from the commercial period presented in SC/D06/J26 (reproduced from (Kato, 1987)) showed an apparent increase in growth rate from the 1940s through to the 1970s.

In discussion, it was noted that in the JARPA data, cohorts prior to 1970 are already at maximum body length, such that one would not necessarily expect an earlier increase in growth rate to show itself in the JARPA data. Further analyses of growth rates had been presented to the 2006 Scientific Committee Annual Meeting in SC/58/IA3 (Punt and Polacheck) which showed an apparent sudden drop in growth rates between the commercial and JARPA periods, but the authors cautioned against taking these results at face value because of unexplained residual features in the commercial age/length data and the difference in sample size between the two data sets.

4.4.2.2. AGE AT SEXUAL MATURITY

SC/D06/J15 provided an updated analysis of the trend in age at sexual maturity, using transition phase (TP) and age readings from a total of 2,803 individuals collected during 1987/88 to 2004/05 under JARPA. The analyses were stratified by the putative I and P stock areas, and confirmed the previously noted decline from about 10-12 years in pre-1955 cohorts to around 7 years in the late 1960s and early 1970s cohorts, for both stocks. Since the early 1970s, the mean age at transition phase for both stocks has remained constant at 7-8 years or increased slightly from the early 1970s to the early 1990s cohorts.

SC/D06/J16 applied a model-based approach similar to that of Thomson *et al*. (1999) to the transition phase data obtained from JARPA surveys to examine trends in the age at maturity for the putative I and P stocks of Antarctic minke whales. The results, which take into account various potential biases related to examining trend in transition phase data (i.e. truncation and fringe effects, differences between readers, and readers learning over time) suggest that the age at maturity of Antarctic minke whales declined from about 11 years in the late 1940s to 7 years in the late 1960s for both stocks, and that these declining trends are statistically significant at the 5% level. The analyses also suggest that the age at maturity increased slightly from the late 1960s to the late 1970s and has stabilised thereafter. These trends are broadly consistent with the results obtained from VPA (Mori, 2006), which suggest that for both the I and P stocks, abundance increased from the 1940s to the late 1960s and thereafter has been stable or declined somewhat. This consistency enhances the confidence to be placed in estimates of parameters (such as natural mortality and MSYR) from such VPA analyses that may be of value for management purposes. It also serves to demonstrate the utility of age-at-maturity as an index to monitor stock status, and suggests that continued monitoring of this parameter is desirable both for this purpose and for contributing to the understanding of the dynamics of the Antarctic ecosystem.

SC/D06/J17 contained estimates of age at maturity based on the fraction mature by age (for both sexes) and the age at first ovulation for females. The age at 50% sexual maturity for males was 5.3 years (I stock) or 5.4 years (P stock), and for females 7.6 years (I stock) or 8.0 years (P stock). The age at 50% physical maturity was 16.0 years (I stock) or 17.0 years (P stock for males, and 21.2 years (I stock) or 20.6 years (P stock) for females. The mean age at first ovulation was 7.9 years (I stock) and 8.4 years (P stock). There was a significant decline in mean age at first ovulations over the period for the P stock (0.11yr/yr or about 1.5-2 yr for the whole period 1987/88-2004/05), but no significant trend for the I stock. A summary of the findings of SC/D06/J17 is given in Table 3.

Table 3

Summary of biological parameters estimated according one stock hypothesis presented at the workshop.

		I-stock (Area IIIE+IV+VW)		P-stock (Area VE+VIW)	
		Male	Female	Male	Female
Length at sexual maturity (m)	*Lmov*		8.40m		8.30m
	Lm50%	7.29m	8.16m	7.17m	7.97m
Age at sexual maturity	*tmov*		7.9		8.4
	tm50%	5.3	7.6	5.4	8.0
Length at physical maturity (m)	50%mature	8.32m	9.12m	8.22m	8.73m
Age at physical maturity	50%mature	16.0	21.2	17.0	20.6
Growth curve		$y = 8.61(1-e^{-(0.27x+0.54)})$	$y = 9.16(1-e^{-(0.23x+0.49)})$	$y = 8.45(1-e^{-(0.29x+0.51)})$	$y = 8.93(1-e^{-(0.21x+0.59)})$
Percentage of matured females pregnant			92.9%		85.4%
Foetal sex ratio (male%)			51.8%		46.8%
Mean litter size			1.007		1.013

The 1997 JARPA review had noted an apparent discrepancy between the JARPA results and the earlier results using commercial age data which implied a much higher average age at transition phase for the early cohorts than did the JARPA data (IWC, 1998b). This had not been investigated further, and in the analyses presented to this workshop, only the JARPA data had been used.

The Workshop recalled the previous discussions of the Committee, including the workshop held in 1983 (IWC, 1984) as to whether the transition phase was an indicator of sexual maturity, and as to whether trends in the transition phase readings reflected genuine trends in age at maturity. The 1997 JARPA review meeting had found that there did seem to be a genuine decline over time, rather than merely an age-specific effect, because later cohorts showed a lower age at maturity than earlier cohorts, even when comparing animals of the same age (captured in different years).

It was noted that even for older animals, there was not always a transition phase; this did not imply that these animals were not mature, but that for some earplugs, the transition from the irregularly spaced younger layers to the narrower, evenly spaced older layers did not occur at a well-defined point but was a more gradual transition, and in these earplugs the readers found it safer not to identify a transition layer.

There was some discussion as to what event in the life of the animal the transition phase was measuring. Lockyer (1972) had suggested it may be related to skull growth. The age at transition phase of 7-8 years in recent decades is consistent with the age at sexual maturity of females reported in SC/D06/J17. However, the transition phase occurs at a similar mean age in males and females, and the age at 50% maturity for males is much lower.

In discussion of SC/D06/J16, comments were made that the analyses had compared the patterns based on retaining the observed trends in age at transition phase as a real phenomenon, versus the patterns expected if the change were a certain kind of artefact. The fact that the latter hypothesis did not fit the data well did not necessarily imply that the effect was real, although it was agreed that such an exercise involving an alternative hypothesis was useful. Butterworth responded that the various kinds of artefact suggested to date could sometimes explain a decline but it was hard to see how they could ever cause an increase, as has been observed in Icelandic fin whales (IWC, 1998) and now in recent years in Antarctic minke whales.

The consistency claimed by the authors of SC/D06/J16, between the age at maturity trends and the results of catch at age analyses (SC/D06/J16) is discussed under Item 4.4.4.

4.4.3. Reproductive and sustainable yield rates

SC/D06/J17 examined pregnancy rate data among mature females. These averaged 93% for the I stock and 85% for the P stock. There were some fluctuations between years, in particular low values (below 80%) occurred in 1997-99 for the I stock and 1990/91 and 1994/95 for the P stock. Regression of ovulation rate against age showed ovulation rates close to one per year (0.98/yr for the I stock and 1.01/yr for the P stock). Cohorts prior to 1970 had been omitted from the regression, to avoid the confounding effect of a higher age at maturity in earlier cohorts.

Without a more careful spatial and temporal analysis, the Workshop **agreed** that it was difficult to judge whether the apparent fluctuations in pregnancy rate might be due to inter-annual changes in population pregnancy rate, or due to segregation of reproductive classes and fluctuations in the sampling of each. Kato considered that the JARPA pregnancy rate data indicated a genuinely high pregnancy rate in this species, and that if pregnancy rate is density dependent, as some studies have reported for fin whales, it is probably currently close to its upper limit for Antarctic minke whales. Clapham noted that this could imply that the stocks are well below their carrying capacity (*K*).

The regression plots of ovulation were found hard to interpret without seeing the scatter around the regression line. Assuming that actual pregnancies cannot exceed one per year per individual, the scatter around the line would places an upper bound on the pregnancy rate consistent with these data. Only if the scatter is sufficiently small, would the results be consistent with average pregnancy rates as high as those observed.

In general, the Workshop **agreed** that the results confirmed the high pregnancy rates found in this species in the previous commercial data, and correspond essentially to a 1-year reproductive cycle. However, pregnancy rates are not necessarily well correlated with effective recruitment rate (production of age 1 animals) because of potentially high losses before full term and in the first year of life.

SC/D06/J14 presented an integrated analysis of catch-at-age and abundance data, which provided estimation *inter alia* of the history of annual recruitment (production of aged 1 animals) to the stocks, and of the adult female stock sizes, and hence also *per capita* recruitment. The analysis also estimated the natural mortality rate, and the paper is summarised under Item 4.4.1, where some concerns are discussed. The paper showed that *per capita* recruitment rate (recruits per mature female) was apparently high at around 0.4 in the 1950s and early

1960s in both stocks, but declined thereafter to much lower levels (0.1-0.2) by 1980 and has remained low since. The decline started about 1965 in the I stock and about 1970 in the P stock.

The Workshop noted that the analyses had assumed a constant age at maturity throughout. If account was taken of a decline in the age at sexual maturity as suggested by SC/D06/J15 and SC/D06/J16, then the mature female stock would be lower in the earlier period and hence the estimated recruitment per mature female would have been higher. Butterworth explained that the estimates of MSY rates (4%-6%) were largely driven by the estimated increasing trend in recruitment in the earlier years. Under the model, the stock needed to have a high MSY rate to show such an increase. Hatanaka noted that the estimates of MSY rate, if they are reliable, would be very important for management.

4.4.4. Synthesis of information on biological parameters from different sources

SC/D06/J26 examined historical changes in the Antarctic minke whale stocks based on various results obtained from JARPA including age at sexual maturity, growth curve, blubber thickness, prey consumption, and ADAPT-VPA analysis of the stocks as well as research on mercury accumulation etc. It was assumed that feeding conditions of the minke whale improved with the removal of large baleen whales such as the blue whale by commercial whaling, which promoted rapid growth and younger age at sexual maturity; however, around 1970, conditions gradually shifted unfavourably, resulting in slower rates of change in the foregoing parameters. These changes were then arrested by the 1980s to the 1990s. Observations reflecting these unfavourable changes, were reductions in blubber thickness and stomach content weight, which indicated less prey consumption. There was also a decrease in the accumulation of mercury, perhaps resulting from less prey consumption (see Item 6.3.1). In addition, the authors noted that the distribution area of humpback and fin whales in the feeding season expanded southward in the Antarctic from around 1990, suggesting further deterioration of feeding conditions for the Antarctic minke whales. The apparent consistency between the different trends was also noted in the discussion sections of other papers to the Workshop, e.g. SC/D06/J16.

Discussion focussed on whether the apparent trends in various minke whale parameters were indeed consistent with this general picture, also indicated by the results of the VPA-ADAPT catch at age analysis in the manner suggested. To assist discussion, results from various studies were replotted to aid comparison as shown in Annex G. It was recognised that the projections back prior to 1950 were based on very few data from old individuals, and were largely model-driven. Discussion therefore focussed on the post-1950 period.

With respect to the apparent trends in minke age maturity, the transition phase data suggested a decline from around 11 years in pre-1955 cohorts to 7-8 years in post-1980 cohorts. The ADAPT-VPA analyses suggested that *per capita* recruitment was high in the 1950s and 1960s but low post-1980. The age-length relationship from the commercial data suggested higher growth rates in the post 1970-cohorts and lower rates in the pre-1960 cohorts.

The Workshop recognised that these results are in apparent contradiction to the conventional expectation that high ages at maturity and low somatic growth rates would tend to be associated with low *per capita* recruitment rates, while low ages at maturity and high somatic growth rates would tend to be associated with high *per capita* recruitment rates. In discussion, a number of alternative suggestions (summarised below) were made to explain the apparent discrepancy, but in the time available it was not possible to evaluate them further, and in particular to compare the consequences of alternate VPA results to those of the 'reference case' in SC/D06/14 upon which these comparisons were all based.

(i) It was suggested that the paradox may be a temporal phenomenon, in that the response of some of the indices, such as age at maturity, may be subject to time lags. However, Walløe reported that studies of terrestrial mammals showed that age at maturity expressed by cohort is determined primarily by nutrition very early in life, and considered it unlikely that this parameter would be subject to much time lag.

(ii) The concern was noted under Item 4.4.1 that the trends in recruitment estimated by the ADAPT-VPA analysis may be unreliable, because they seemed to depend on inclusion of the commercial age data, with which some unresolved problems had recently been identified (Polacheck and Punt, 2006).

(iii) The question of whether the pre-1970 decline in age at maturity indicated by the transition phase analyses was real had been discussed extensively at the 1997 JARPA review and in previous Scientific Committee meetings, and some members still considered this to be an open question. However, others considered that the results of SC/D06/J16 and those of (Thomson *et al.*, 1999) had demonstrated that the declining trend had been real. The 1997 JARPA review had reached a similar conclusion.

(iv) The reality or otherwise of the apparent somatic growth rate increase shown by the commercial data had been questioned when it was presented to the Scientific Committee in the 1980s (IWC, 1990), and furthermore the recently identified problems with the commercial age and length data identified in (Polacheck and Punt, 2006) placed it in further doubt. Some members considered that little weight be attached to these data.

(v) Some members considered that even though the pre-1970 decline in age at maturity was hard to reconcile with the ADAPT-VPA results, the slight increasing trend in age at maturity post-1970 indicated by the transition phase data may be consistent with other data, such as declining blubber thickness. However it was surprising that, if the earlier decline had really been so large, the later rise was not more pronounced, as the VPA-ADAPT assessment suggested that the stocks were now close to their current carrying capacity. In addition, the age at first ovulation appeared to have declined during the JARPA period, at least for the P stock (see Item 4.4.2).

There was some discussion about the plausibility of the ADAPT-VPA results that the carrying capacity *K* was estimated to have increased about 5-fold prior to its peak in the 1960s. However, the issues relating to the high estimated *per capita* recruitment rates pre-1960s relative to their recent values could also be considered without reference to *K*.

There was insufficient time to discuss in detail what analyses might resolve the questions, and the Workshop **recommended** that the matter be discussed further in the Scientific Committee. In the meantime, the following tasks were identified as providing potentially useful information:

(i) the ADAPT-VPA could be run without using the commercial age data;

(ii) a subset of the commercial age data could be re-read as discussed under Item 4.3.

In summary, the Workshop **concluded** that there were differing views expressed about the level of reliability that could be assigned to the estimates of historical trends in biological and population parameters of minke whales prior to the JARPA period. For the JARPA period, no marked trends in biological parameters were found. The growth rates were apparently fairly constant, while the pregnancy rate remained high with some annual fluctuation. The transition phase data suggested a possible small increase in the mean age at maturity over the JARPA period, but the age at first ovulation showed a decrease, at least for the P stock. The natural mortality rate estimates from JARPA data alone (SC/D06/J13), were, at around 0.04, within the plausible range, but the confidence limits (from below zero to above 0.10) spanned such a wide range that the parameter is still effectively unknown. The ADAPT-VPA provided estimates of natural mortality rates with a CV of about 0.15 but these depend on the use of commercial catch-at-age data, about which, as discussed above, there are some problems.

5. MARINE ECOSYSTEM

5.1 Background

One of the objectives of the JARPA established in 1987 was the ‘Elucidation of the role of whales in the Antarctic marine ecosystem’. In the 1996/97 research plan, this second objective was restated as ‘Elucidation of the role of whales in the Antarctic marine ecosystem through whale feeding ecology’.

The research plan concentrates on the feeding ecology of minke whales by the analysis of stomach contents and blubber volume. Changes in prey availability and their possible effects on minke whales are expected to be detected by monitoring the feeding conditions and consequential fat storage of minke whales.

In the JARPA review meeting in 1997, the striking similarity in the results obtained from the three methods for estimating the daily prey consumption was noted. That meeting agreed that these estimates could be used with confidence for the estimation of total prey consumption by the Antarctic minke whale. It also noted the decrease in blubber thickness since 1970s and it was suggested that, among possible explanations, this might be due to changes in food availability due to inter-specific or intra-specific competition. Such information could contribute to the specification of a range of krill surplus hypotheses for use in further *Implementation Trials* for the RMP. Finally, that meeting suggested that elucidating the role of whales in the marine ecosystem also requires concurrent studies on the distribution and abundance of prey species.

5.2 Issues raised in 1997 JARPA review: Meso-scale survey plan

The JARPA review meeting in 1997 suggested that elucidating the role of whales in the marine ecosystem requires concurrent studies on the distribution and abundance of prey species. It was also suggested that process-oriented studies would be useful which integrated information from physical and biological oceanography with zooplankton and predator studies.

In response to that suggestion, acoustic surveys for krill have been conducted since 1998/99 and a cooperative prey species survey was conducted concurrently from 25 December 2004 to 27 February 2005 (65 days) in the Ross Sea and adjacent waters by R/V *Kaiyo-Maru* of the Fisheries Agency of Japan as part of the meso-scale survey programme (see Item 5.4).

5.3 Data collection methods and results
Data on the feeding ecology of the minke whale were obtained from the species composition and mass of stomach contents. Body mass, length, girth and blubber thickness of each whale were also measured. The abundance of the whales obtained from the sighting surveys was used to extrapolate food consumption to a larger area. The *Kaiyo Maru* – JARPA joint survey in the Ross Sea in 2004/05 was designed as a multi-disciplinary study combining surveys on cetaceans, krill and oceanography. During the multi-disciplinary study, the JARPA vessel conducted the cetacean sighting and sampling surveys while *Kaiyo Maru* conducted detailed oceanographic and cetacean prey species surveys. Oceanographic data were collected using CTD and XCTD; prey species data were collected using the RMT 8 net (the multiple rectangular mid-water trawl net) and quantitative echo sounder.

The following main types of data were collected for this particular objective, with sample sizes as indicated:

(1) stomach content weight: 6,777

(2) stomach content (prey species): 6,777

(3) body weight: 6,491

(4) blubber thickness: 6,777

(5) diatom adhesion record: 6,777.

Information on other data can be found in Annex D.

5.4 Results

5.4.1 Food habit and krill consumption of Antarctic minke whales.
In SC/D06/J18, 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 results indicated that the timing of feeding had strong diurnal variation with most feeding occurring at night. The authors suggested that there had been a decrease in average mass of fresh stomach contents for mature males and females from 1991-present. In Area V, there was same trend for mature females. The daily prey consumption of Antarctic minke whales was estimated using a direct method (diurnal changes of stomach contents mass) and an indirect method (energy requirement). The results of daily consumption estimates were similar for the two methods and ranged from 2.6 to 5.0 % of body weight. The annual consumption of Antarctic krill from the 1990/2000 season to the 2004/05 season in Areas IV and V was calculated as being equivalent to 3-4 % and 21-35 % of the krill biomass, respectively.

In discussion, the Workshop noted that the daily prey consumption estimates presented in SC/D06/J18 were similar to those from North Atlantic common minke whales (Haug *et al.*, 1995) and to those predicted by Lockyer (1981). The issue of the specific method used to subsample stomach material, and whether this might bias the results compared to larger prey items was considered.

Childerhouse believed that the key biological findings of the research did not represent an increase in knowledge, namely that 99% of the minke whale diet is krill and that the estimated prey consumption rates simply confirmed results of previous analyses by Lockyer (1981) and Bushuev (1986).

Some participants expressed their disappointment and concern at how little analysis had been undertaken given the enormous dataset available. The Workshop **recommended** that more sophisticated analyses should be undertaken that more fully utilise the considerable dataset available. The following factors at least should be taken into account:

(1) determination of the duration of the feeding period is fundamental to estimating total consumption and must be adequately addressed;

(2) examination at smaller spatial scales;

(3) use of GLM or similar approaches to examine trends, incorporating covariates such as age, size and reproductive status of whales as well as the date and time of day.

It was also noted that since some whales are not killed instantaneously, they might vomit during capture. This could be examined by comparing the stomach contents of whales killed instantaneously with those that were not killed instantly. In response it was noted that although no quantitative analysis had been undertaken, scientists present had not observed this phenomenon.

SC/D06/J19 examined annual trends in energy storage in the Antarctic minke whale. The results of stepwise multiple linear regression analyses showed that blubber thickness has been decreasing over the JARPA period at -0.0190 cm/year. Date, extent of diatom adhesion, sex, body length, foetus length and longitude were all identified as partially independent predictors of blubber thickness. Possible explanations for this were discussed in the paper and the authors suggest that this indicated that food availability for Antarctic minke whales in the Antarctic has decreased over the JARPA survey period, presumably caused by either or combination of intra- and inter-species competition among baleen whales.

There was considerable discussion of this paper. Although the authors' analysis as presented showed a declining trend in the blubber thickness measurement chosen, some members argued that the conclusion of a trend in energy storage was premature and could not be confirmed until improved analyses had been conducted. In particular this involves the examination of other factors including age, latitude, distance from ice-edge and non-linearity in trends. In addition, even if it is assumed that the trend is real, consideration should be given to whether the particular blubber thickness measurement chosen was actually a good proxy for energy storage (for example, lipid content can vary considerably without necessarily affecting the thickness of blubber). The Workshop **recommended** that the analysis be expanded to incorporate, in an integrated manner, the other extensive information available from the JARPA dataset that relates to energy storage (e.g. other blubber measurements, organ weights, etc).

Tamura pointed out that the reliability of the body condition indicators of Antarctic minke whales was also analysed using indicators such as girth, body mass and other measurements of blubber thickness by Konishi (2006), that paper was not presented to the Workshop.

There was considerable discussion over the authors' view that a likely explanation for the results was that it reflected declining body condition of Antarctic minke whales as a result of 'competition'. The differing views expressed can be summarised as follows:

(1) the idea of interspecific competition between minke and humpback whales is overly simplistic in the context of the rest of the Antarctic marine ecosystem (simply because two species feed on the same species of prey does not mean that there is competition *per se* unless there is evidence that species are food limited) and is not supported by the data presented; or

(2) as both minke and humpback whales are feeding on krill in the same area, then competition is happening *de facto* - what is of importance, however, is to identify the extent of this competition relative to the other factors influencing the dynamics of the populations.

SC/D06/J20 presented the results of a comparison between the length-frequency distribution of krill in the stomach contents of Antarctic minke whales and from net sampling using a multiple rectangular mid-water trawl (RMT(1+8)M). Whales fed mostly on Antarctic krill in offshore areas and ice krill (*E. crystarollophias*) on the continental shelf of the Ross Sea. For both species, there was almost complete overlap in the length-frequency distribution from stomach contents and RMT net samples (although it was noted that RMT nets do not provide an unbiased sample). In the western slope area, the stomach content weights of the minke whale were the highest (no empty stomachs were found), indicating that the continental slope of the Ross Sea is an important feeding ground for the Antarctic minke whales.

SC/D06/J21 reported the results of krill biomass estimation using a quantitative echo sounder onboard *Kyoshin Maru 2* (KS2) since 1998/99 season in JARPA. The survey covered the region 35°E-145°W using an EK500 (Simrad, Norway) echosounder. Acoustic backscatterings were identified as krill when the difference between the mean volume backscattering strength (ΔMVBS) of 120 and 38 kHz fell between 2 and 16 dB. Similar biomass estimates were obtained in Area IV in the 1999/2000 (34.2 million t) and 2001/2002 (34.1 million t) seasons. In Area V, biomass in the 2000/2001 (20.7 million t) and in the 2002/2003 (22.6 million t) seasons were similar but biomass in 1998/1999 (29.7 million t) was higher than the other two years. In 2004/2005, *Kaiyo Maru* (KM) conducted a standardised krill biomass estimation survey applying methods adopted by CCAMLR, using both RMT net sampling and acoustic surveys. The other vessel, KS2, conducted only an acoustic survey as in previous JARPA cruises. The results of biomass estimates for Antarctic krill from the two vessels were comparable (KM 5.36 (95% CI 7.45) gm^{-2}; KS2 2.64 (95% CI 2.35) gm^{-2}).

SC/D06/J22 attempted to assess the magnitude of the interspecific competition among three baleen whale species, Antarctic minke, humpback and fin whales, for their major prey, Antarctic krill. Whale abundance (see SC/D06/J6 and SC/D06/J7) and daily krill consumption rate of Antarctic minke whales (SC/D06/J18) and krill biomass (SC/D06/J21) were used. Daily food consumption of humpback and fin whales (assumed as mature males) and average body masses of those species reported in Trites and Pauly (1998) were used. The authors reported that the three baleen whales consumed 10-21% and 31% of krill standing stock in Area IV and V, respectively. In Area IV, humpback whales (7-12%) consumed krill twice to three times as much as Antarctic minke whales (4%). In contrast, 21-25% of krill biomass was consumed by Antarctic minke whales in Area V. The authors suggested that in order to accurately assess the feeding impact of humpback and fin whales on krill, long term biological data sets for those two species are critically important. The mechanism of the interactions among baleen whales for krill should be tested using a minimum realistic ecosystem model such as Mori and Butterworth (2006).

Some participants expressed particular concern that these analyses ignored the many other important krill predator populations, as well as ignoring the substantial uncertainties around krill biomass estimates, environmental controls on krill population dynamics and a number of other, what they considered to be, prerequisites to demonstrate competition.

SC/D06/J23 also used data from the joint survey of the R/V *Kaiyo Maru* and JARPA and examined interactions between oceanography, distribution of krill and baleen whales in the Ross Sea and its adjacent waters in 2004/05. The results indicated close relationships between oceanography, krill and baleen whales. The oceanography of the surface layer was summarised as an oceanographic environmental index that integrated mean temperature from 0 to 200m in depth (ITEM-200). Distribution of ITEM-200 was used as background information for comparing with distribution patterns of each species. Antarctic krill were mainly found in the Antarctic Surface Water (ASW) area (ITEM-200 = 0 to -1^{o}C) and extended into the Shelf Water (SW) area (less than -1^{o}C). Ice krill were widespread in SW but not ASW. Humpback whales were mainly found in the Antarctic Circumpolar Current (ACC) waters with high density around 0^{o}C near the Southern Boundary of ACC and slightly extended in ASW. Antarctic minke whales were mainly found in ASW and SW with high densities around -1 ^{o}C in the continental shelf slope frontal zone. The interaction between distributions of krill and baleen whales with ITEM-200 provide quantitative information to identify the boundary of distribution of Antarctic krill and ice krill for biomass estimation using acoustic data in the surveys. A conceptual model of the relationships between oceanography relating water mass and circulation pattern of the oceanic surface layer with ITEM-200, will be able to describe adequately the distribution and abundance of krill and baleen whales.

The Workshop **welcomed** the multi-disciplinary approach presented in this analysis, noting that it provided a clear indication that there was oceanic habitat segregation of Antarctic minke, humpback, blue and fin whales in the Ross Sea part of the JARPA research area.

SC/D06/J24 reported on the results of the study of distribution patterns and biomass of Antarctic and ice krill in the Ross Sea in 2004/5 using *Kaiyo Maru*-JARPA joint survey data. Ice krill were found on the continental shelf region (<1,000m water depth). In contrast, Antarctic krill were found mainly in the oceanic waters (depth >1,000m) although they were also found on the continental shelf where the integrated mean water temperatures between 0-200m were higher than -1°C. The distribution of Antarctic minke whales was related to the distribution of Antarctic krill. School sizes of Antarctic minke whales were large where the densities of Antarctic krill were high. The distribution of Antarctic minke whales in the Ross Sea could also be related to the distribution patterns of Antarctic krill. The biomasses of Antarctic and ice krill in this study were estimated as 1.46 (CV=0.32) and 0.82 (CV=0.18) million t, respectively. The authors suggested that Antarctic minke whales could be considered as a biological sampler to monitor krill, which plays key role in the Antarctic ecosystem. They concluded that multi-disciplinary studies such as the *Kaiyo Maru*-JARPA survey can reveal the ecological relationships between krill and baleen whales.

SC/D06/J25 reported the results of examination of influential environmental factors on distribution patterns of Antarctic minke whales at a small scale. At the JARPA review meeting in 1997, it was suggested that small scale (of the order of ten to one hundred kilometres) study of physical and biological oceanography with zooplankton and predators should be conducted to elucidate the role of whales in the marine ecosystem (one of the main objectives of JARPA). This study was conducted in response to that suggestion. Influential environmental factors on distribution patterns of Antarctic minke whales at small scale (30 n.miles segments) in the Ross Sea in 2004/05 were examined based on the *Kaiyo Maru*-JARPA joint survey data using the generalized additive model (GAM) approach. Three abiotic factors, distance from physical boundary (combination of coast, ice edge and shelf ice lines), integrated temperature and salinity mean from surface to 200m (ITEM-200 and ISAM-200) as well as latitude and longitude were used as covariates in the study. The distribution of krill was described by ITEM-200 and ISAM-200 as well as latitude and longitude. Mean krill density increased at salinity values higher than 34.5. The results indicated that krill distribution could be related to the presence of Modified Circumpolar Deep Water (MCDW). Distributions of Antarctic minke whale schools were explained by krill density and ISAM-200 as well as latitude and longitude. In contrast to krill, the distributions of Antarctic minke whales increased at salinity values lower than 34.4. The presence of Antarctic minke whales could be related to Antarctic Surface Water (ASW). The peak number of schools of Antarctic minke whales was observed around the 1g/m^2 of krill density and it levelled off toward both lower and higher densities of krill. The authors hypothesised that at the scale of this study, Antarctic minke whales might not be directly searching for krill aggregations but following the retreating sea ice (low salinity water) where the occurrence of moderate densities of krill could be found with high probability. It is promising that distribution patterns of baleen whales in relation to environmental factors can be related if good data sets from multi-disciplinary studies are available. However, the authors stressed that the modelling used in this study was preliminary and much improvement is necessary

The Workshop **agreed** that this approach could provide important information required for model-based estimation of cetacean distribution and density in unsurveyed areas.

5.5 Synthesis

SC/D06/26 examined historical changes in the Antarctic minke whale stocks based on various results from JARPA including age at sexual maturity, growth curve, blubber thickness, prey consumption, ADAPT-VPA analysis and pollutant (mercury) accumulation. It proposed the following hypothesis of changes in the Antarctic ecosystem in the 20th Century: minke whale feeding conditions improved with the removal of large baleen whales such as the blue whale by commercial whaling, which promoted rapid growth and younger age at sexual maturity; however, around 1970, conditions gradually became unfavourable, resulting in slower rates of change in these parameters. These changes were then arrested by the 1980s-1990s. SC/D06/26 further suggested that, reflecting these unfavourable changes, blubber thickness and stomach content weight were reduced (indicating less prey consumption). There was also a decrease in the accumulation of mercury which was also attributed by the authors to less prey consumption. Furthermore, the distribution of humpback and fin whales in the feeding season had expanded southward in the Antarctic from around 1990, suggesting further deterioration of feeding conditions for Antarctic minke whales.

The Workshop noted that in the presentation of SC/D06/J26, a general hypothesis of inter-specific competition had been used to provide a framework for the analysis.

In considering the synthesis of the different components of JARPA presented in SC/D06/J26, some members suggested that this was simplistic and ignored many other components of the Antarctic marine ecosystem. They thus believed that it was not particularly informative regarding what may have occurred.

Some members (Clapham, Gales and Childerhouse) noted that demonstration of interspecific competition was not a simple matter, and listed prerequisites derived from other ecological studies together with comments on how JARPA had addressed them: (i) that the species in question must be shown to be resource-limited (JARPA has not provided data on total krill abundance and on total consumption by all krill predators); (ii) that there must be substantial overlap in spatio-temporal distribution of the two species (JARPA has shown this is some areas, but found evidence for segregation in others); (iii) other variables must be categorically excluded as causes of failure to recover (JARPA has not collected the data to address this); and (iv) that both species must occupy essentially similar ecological niches. With regard to the latter, they noted that the only directed study of this involving Antarctic minke whales (Friedlaender *et al.*, 2006) has shown strong evidence for avoidance of competition through niche separation. They also commented that the term *competition* is consistently used loosely in JARPA, and was not defined; furthermore it was surprising that the JARPA papers made no reference to the large body of literature on competition from terrestrial and marine studies. They concluded that conducting any investigation of interspecific competition without reference to this body of work almost guarantees that interpretation of results, and indeed of the study design itself, would be inadequate or wrong.

Other members (Tamura, Fujise, Konishi, Murase, Ishikawa, Mori and Hatanaka) commented that the study described in (Friedlaender *et al.*, 2006) was conducted in April/June. This is much later than the peak feeding season of these species and thus inferring that this also applies to the peak feeding season required great caution. Further, the study was conducted in Area I. The estimated annual rate of increase (ROI) in abundance for humpback whales in Area I is 4% while it is 15% in Area IV (part of the JARPA survey area) (Branch, 2006). Given the differences in area-specific ROIs, it is important to take into account the status of the populations in a given area when evaluating the extent to which competition for limited resources is occurring. The results of the recent JARPA surveys suggested that the spatial distribution of Antarctic minke and humpback whales appreciably overlapped (Ishikawa, 2003; Ishikawa *et al.*, 2004; Ishikawa *et al.*, 2002). These direct observations strongly suggest the possibility of competition between Antarctic minke and humpback whales for krill at the same spatio-temporal scale.

During the Workshop, several recommendations for more comprehensive analysis of the time series summarised in SC/D06/J26 had been suggested. For example, the Workshop **agreed** that a more complete analysis of energy storage over time is required to evaluate the hypothesis of a long-term decline (see recommendations above). The Workshop also recalled the **recommendation** for further analysis of the stomach content mass data before any trend analysis could be undertaken.

Some members considered that the multiple strands of evidence, notwithstanding the recommendations for improved/reanalysis, were generally indicative and provided support for the hypothesis of interspecific competition. However, other members considered that, when considering the current state of the analyses and being aware of the considerable uncertainties involved, there was not necessarily consistency in the support provided for the hypothesis of inter-specific competition outlined in SC/D06/J26.

The Workshop **agreed** that it would be valuable to have the opportunity to review the trends summarised in SC/D06/J26 when the recommended analysis had been conducted, in order to formulate alternative hypotheses that set the observed changes in the context of a broader suite of indicators from the Southern Ocean.

Finally, the Workshop **agreed** that the JARPA dataset provides a valuable resource to allow investigation of some aspects of the role of whales within the marine ecosystem. With appropriate analyses, this has the potential to make an important contribution to the Scientific Committee's work in this regard, as well as the work of other relevant bodies such as CCAMLR. In order to facilitate the comprehensive analyses that this dataset warrants, the Workshop **strongly recommended** that an advisory group is established to work co-operatively to guide such analyses.

6. ENVIRONMENTAL CHANGE INCLUDING POLLUTION

6.1. Background

As already noted, the 1995/96 research plan added the following objective 'Elucidation of the effect of environmental changes on cetaceans'. This objective was added in response to resolutions adopted by the Commission on research on the environment and whale stocks (IWC, 1995b) and on the promotion of research on the conservation of large baleen whales (IWC, 1995a). This objective is also related to the resolution on research on the environment and whale stocks (IWC, 1996).

In the Scientific Committee, environmental changes are addressed under the following topics (IWC, 1995c): (1) global warming; (2) ozone depletion; (3) pollution; (4) direct (intentional and incidental mortality) effects of fisheries and indirect (ecological ramifications) effects of fisheries; (5) noise; and (6) other human activities (e.g. tourism, coastal developments). The Committee had noted that it was not feasible to address all these topics simultaneously; this would be a longer-term iterative project (IWC, 1995c). Given this, it was agreed that initially two specialised workshops should be held, one relating to chemical pollutants and cetaceans, and the other on potential ecological effects on cetaceans of climate change and ozone depletion. The former Workshop was held from 27-29 March 1995 in Bergen (Reijnders *et al.*, 1999b), and the latter Workshop was held from 25-30 March 1996 in Hawaii (IWC, 1997a). These meetings emphasised that studies related to such topics should be conducted in the Antarctic.

At the JARPA review meeting in 1997, reference was made to the recommendations of the Bergen Workshop; it was considered that the pollutant studies under JARPA were pertinent to recommendations 1, 4 and 5 of the Bergen Workshop.

6.2 Data collection methods and results

There is a close relationship between the data collected for studies on the marine ecosystem and those required for studies on environmental change. In addition to these, data have been collected on marine debris and body burdens of pollutants, including organochlorines and heavy metals. Tissues samples, including liver, muscle, kidney and blubber have been collected for these analyses. Marine debris data have been based on visual observations, but recently the use of nets has been introduced to estimate prevalence of smaller items of marine debris. Air and sea water samples have been collected to monitor pollutant levels in the environment. The main relevant data collected during JARPA are:

(1) blubber tissues for organochlorine analysis: 113
(2) liver tissues for heavy metal analysis: 1,072
(3) stomach content of Antarctic minke whales for heavy metal analysis: 100
(4) air samples for organochlorine analysis: 4
(5) sea water samples for organochlorine analysis: 4

Oceanographic data have been collected from the JARPA research area. Vertical oceanographic structure was observed by using XBT (eXpendable Bathy Thermograph), CTD (Conductivity-Temperature-Depth profiler) and the more recent XCTD (eXpendable CTD). XBT was mainly used in the first stage of JARPA (1987/88-1996/97) and XCTD was used from the late 1990's. Relevant data collected during JARPA are as follows:

(1) XBT surveys: 916
(2) XCTD surveys: 915
(3) CTD surveys: 499
(4) EPCS surveys: 1,307.
Information on other data can be found in Annex D.

6.3 Data analysis methods and results

6.3.1 Pollution

SC/D06/J27 examined concentrations of Mn, Fe, Ni, Cu, Zn, Cd, Hg and Pb determined in Antarctic krill collected from Areas III, IV, V and VI, as well as their temporal and spatial variations during the period 1989/90 to 1998/90. Differences associated with body size were found for some elements and size groups. Although some temporal variation was observed in some trace elements, concentrations of toxic elements (Hg and Cd) did not show any significant variation through the study period. Changes within season were only found for Cd. As compared to other regions, concentrations were low except for Cd, which showed relatively high values.

SC/D06/J28 examined concentrations of trace elements in the liver of 1,056 minke whales taken from Areas IIIE, IV, V and VIW during the period 1988/89 to 2004/2005 and their variations in the liver of Antarctic minke whales. Levels of all elements except Fe were overall low and significantly lower than those in cetaceans from the Northern Hemisphere, which the authors took as an indication that whale health was not affected. Age- and sex-related differences were observed for some elements. A decrease in Hg levels in the juvenile class (1-15 years old) was proposed to occur through the study period and the authors attributed this to a decrease in food intake rates since the mid-1980s.

There was some discussion on this hypothesis and several members considered that the apparent decrease might be either an artefact or due to other biological factors not necessarily related to food intake. Further work is required to address this.

SC/D06/J29 described yearly changes on organochlorine pollutants. Concentrations of DDTs, PCBs, HCHs, HCB and chlordanes were determined on the blubber of minke whales. The research focused on adult males only to avoid interference of age- and sex-related variations. The levels of PCBs and DDTs in blubber of Antarctic minke whales were one order of magnitude lower than those of other whales in the mid and low latitude areas of the Northern Hemisphere, and the authors suggest that such levels would not have an adverse effect on whale health. Some variation was observed between Areas. All organochlorine blubber levels in Area V and HCHs and HCB levels in Area IV decreased with time. The decrease was particularly marked for HCHs. The authors suggested that this might be an indication of decreased food availability throughout the period.

In discussion, several members noted that since organochlorines are more difficult to mobilise than lipids, a decrease in fatness caused by lowered food availability would probably produce an increase of organoclorine blubber concentrations with time rather than a decrease.

6.3.2 Oceanography

SC/D06/J30 examined oceanographic data obtained by JARPA and provided some information on possible environmental changes in recent years in JARPA areas. The time series of oceanographic data obtained by JARPA surveys has allowed for the study of temporal changes in environmental conditions. It is important to link JARPA oceanographic observations with the monitoring by other *in situ* observation projects (Argo, IPY, etc.) and satellite observations. In order to contribute to research of the Southern Ocean, it is also important to make the JARPA oceanographic data available internationally. Development of all aspects of Southern Ocean research adds to the understanding and improved management of all marine resources in the area.

7. OTHER RESULTS

7.1 Stock structure of humpback whales

SC/D06/J31 used biopsy samples from 411 humpback whales obtained during JARPA and the IDCR/SOWER cruises to describe their genetic population structure in parts of the Antarctic feeding grounds. Samples were obtained from the IWC management Areas III (n=81), IV (n=172), V (n=97) and VI (n=61), and were examined for (i) sex determination; (ii) the sequence variation of the first 334bp nucleotides of the mtDNA control region; and (iii) genetic variation at the genotypes of six microsatellite loci. Duplicated samples were excluded from the analysis. The level of genetic diversity in the Antarctic was high for both genomes: the nucleotide diversity at the mtDNA was estimated at 0.0263 and the mean expected heterozygosity at the nuclear loci at 0.7820 for the total samples. In general, results based on both mtDNA and microsatellites were similar and they suggest population structure among humpback whales in the Antarctic feeding grounds. These genetic results are consistent with the previous view based on non-genetic data that Areas III, IV, V and VI are occupied by different populations. The most plausible pattern of structure in the Southern Hemisphere therefore is multiple breeding and feeding grounds with some degree of site fidelity. Marked differences were found between whales in Areas IV and V for both mtDNA and microsatellites, and the same pattern was found for both sexes. Results of the other pair-wise comparisons among Areas showed more subdivisions in females than in males. A possible explanation for this is that the difference is due to the lower sample sizes for males in these comparisons. The possibility of intermingling of populations in bordering sectors cannot as yet be discarded and a comprehensive analysis that involves genetic data from low and high latitudes is recommended.

The Workshop **welcomed** this paper. Hoelzel noted that some genetic data suggested the possibility of male-biased dispersal, but that further analyses would be required to assess this (including assignment tests). Pastene noted that in the case of Areas IV and V, the Areas with the largest sample sizes, the pattern of genetic differentiation was the same for females and males for both mtDNA and microsatellites, based on the analyses undertaken to date. The Workshop was reminded that at the 2006 meeting, the Scientific Committee endorsed the Hobart workshop recommendation that every effort be made for scientists to share data from low and high latitude and carry out DNA analyses under the IWC Data Availability Access protocol (IWC, 2007b). Such co-operative analyses would allow for a more comprehensive study of stock structure of humpback whales of Breeding Stocks D, E and F (see IWC, 2007b).

7.2 Other

SC/D06/J08 presented a brief review of genetic studies on southern dwarf minke whale. Prior to the JARPA surveys, dwarf minke whales were believed to be only found between 7-41°S. However, the distribution of the JARPA catches in Areas IV and V was mainly between 55-62°S (one animal was caught at 65°S), showing that the dwarf minke whale can be found, very rarely, much further south than that indicated by the previous data. A total of 16 dwarf minke whales was sampled by JARPA and these animals were examined genetically with the purpose to investigate their relationship to the southern 'ordinary'minke whale and to minke whales in the Northern Hemisphere. Early studies showed that the level of mtDNA differences between the southern minke whale 'forms' was large and similar to that found between the 'ordinary' minke whales and Northern Hemisphere minke whales. Phylogenetic analyses showed that the dwarf minke whale was more closely related to Northern Hemisphere minke whales than it was to the southern 'ordinary' minke whale. In 1993, the Scientific Committee recommended the inclusion of the dwarf minke whale in the Schedule, so that catch limits for Antarctic minke whales recognise the distinction between the two 'forms'. The genetic analysis undertaken with JARPA samples greatly assisted the taxonomic review of minke whales conducted by Rice (1998) who confirmed the existence of two species, the larger ('ordinary') Antarctic minke whale confined to the Southern Hemisphere, and the smaller, common minke whale distributed in both hemispheres. The distribution of dwarf minke whales and Antarctic minke whales overlap partially in the feeding grounds; the former is considered by some authors as a sub-species of the common minke whale. More recent studies have revealed genetic structure in dwarf minke whales in the Southern Hemisphere (Pastene *et al.*, 2007).

The Workshop **recognised** the important contribution of the genetic analyses of dwarf minke whale samples from JARPA to the understanding of the phylogenetic relationships among minke whales from different ocean basins. Genetic results had contributed to the taxonomic review of minke whales conducted by Rice (1998) that confirmed the existence of two species of minke whales, the Antarctic minke whale and the common minke whale. Hoelzel suggested that the apparent paraphyly of dwarf minke whales should be investigated further, and suggested that if further supported, it may have implications for the taxonomic classification of dwarf minke whales, including the possibility of parallel evolution in different ocean basins. Pastene responded that discussion on classification of the common minke whale (including the dwarf minke whale) should await the completion of ongoing morphometric and morphological studies, as well analyses based on nuclear DNA. Finally it was noted that only one of the dwarf minke whales sampled by JARPA was sampled in more southerly latitudes.

SC/D06/J32 presented an overview of other JARPA results. JARPA systematically collected a comprehensive data/sample set over a long time period in order to conduct studies related to the four objectives of the programme. Samples collected by both the lethal and non-lethal components of JARPA have also been used in several studies with different objectives than the four objectives of the programme. The paper presented an overview of these studies. They have contributed to knowledge of whales primarily in three areas: reproductive physiology of Antarctic minke whale, taxonomy and phylogenetic relationships among large whales and distribution and movement of baleen whales.

In discussion, the Workshop **recognised** the contribution of JARPA research to other aspects of whale biology, genetics, movement and distribution. Danielsdóttir noted that several co-operative studies have been conducted successfully between ICR scientists and international scientists. She also noted that DNA data from minke whales sampled from JARPA were included in the Japanese DNA register for large whales and that this represented a potentially useful scientific tool, aside from its use in management. Matsuoka commented that in addition, *in situ* observation projects (Argo, IPY, etc.) and satellite observations are being conducted.

8. OVERVIEW OF RESULTS IN THE CONTEXT OF THE STATED OBJECTIVES OF THE JARPA PROGRAMME AND OF STOCK MANAGEMENT

Although the Terms of Reference (ToR) specified this overview to include how well the initial and revised objectives of the research had been met, it was inevitable that the discussions at the Workshop would give rise to suggestions for further and/or refined analyses. Thus it was unclear whether or not the conclusions of the Committee under this component of the ToR should or should not await consideration of the results of further analyses.

8.1 Contribution to minke whale management

The Workshop noted that the Southern Ocean Sanctuary established in 1994 covers most of the Antarctic waters south of 40°S and all of the waters to the south of 60°S; within the Sanctuary, commercial whaling is prohibited although the Government of Japan has an objection with respect to Antarctic minke whales. If catch limits were to be set at some time in the future, the present approach the Scientific Committee has agreed to use for providing advice to the Commission on commercial whaling catch limits is that specified by the RMP. When it last considered this issue in 1997, the Committee agreed to the statement below.

> The results from the JARPA programme, while not required for management under the RMP, have the potential to improve management of minke whales in the Southern Hemisphere in the following ways: (1) reductions in the current set of plausible scenarios considered in *Implementation Simulation Trials;* and (2) identification of new scenarios to which future *Implementation Simulation Trials* will have to be developed (e.g. the temporal component of stock structure). The results of analyses of JARPA data could be used in this way perhaps to increase the allowed catch of minke whales in the Southern Hemisphere, without increasing depletion risk above the level indicated by the existing *Implementation Simulation Trials* of the RMP for these minke whales.

The present Workshop **concurred** with that view.

In its discussions of possible contributions to management, the 1997 Workshop also referred to: (1) questions about long-term changes in abundance of minke whales in Areas IV and V; (2) elucidation of the role of minke whales in the Antarctic ecosystem (including the possible 'krill surplus' model); (3) elucidation of the effect of environmental change on cetaceans and variation of minke whale biological parameters; and (4) elucidation of stock structure to improve management. Progress and conclusions on these are considered below.

8.1.1 Stock structure

The issue of stock structure is fundamental to the analyses of the data collected under JARPA, the interpretation of the results and a view of whether it has reached its stated aims and objectives. As noted in 1997, the Scientific Committee at that time had no clear definition of a 'stock' in a management context. Despite the ongoing work of the Working Group on Stock Definition, the Committee is still not in a position to provide such a definition, although it recognises that any definition has to be linked to the management implications of such a definition, particularly with respect to feeding areas. This is being investigated as part of the Committee's TOSSM project. In an RMP context, the approach has been to use the available data to establish 'plausible' hypotheses and to examine the management implications of these in the context of *Implementation Simulation Trials*. Given this background, it is not surprising that the Workshop cannot conclude that this issue has been resolved for Antarctic minke whales in the JARPA research area at the present time; however, it recognises that considerable progress has been made in addressing the issue of stock structure since the 1997 review. For example, the Workshop **agreed** that there are at least two stocks of Antarctic minke whales present in the JARPA research area and that the data suggest an area of transition in the region around 150-165ºE within which there is an as yet undetermined level and range of mixing. The Workshop has made a number of suggestions and recommendations for future work (see Item 3). The results of this additional work will have major implications for determining the level to which the programme will meet its other objectives. It is also clear that this work is essential to any future *Implementation Review* under the RMP.

8.1.2 Stock abundance and trend

Information on stock structure is also important for the interpretation of abundance and trend information obtained during surveys on feeding grounds. As stressed earlier in the report, such surveys provide information on numbers of animals (and trends in those numbers) within a geographical area. Information on abundance and trends in abundance is relevant to aspects of all of the objectives of JARPA including the estimation of biological parameters and changes in those over time, and the role of whales in the Antarctic ecosystem. At the 1997 Workshop it had been agreed that more research was needed to develop a reliable method to use the JARPA data to obtain estimates of absolute abundance and trends.

There are general unresolved issues related to estimating abundance and trends in these waters that apply not only to the JARPA data but also to the IDCR/SOWER data that require further work by the Committee. Given that, it is not surprising that the Workshop has not developed agreed estimates of abundance and trend for Antarctic minke whales in the JARPA research area at the present time; however, it recognises that considerable progress has been made in addressing the issues related to abundance and trends and provided the recommendations given under Item 2 are followed, the Committee should soon be able to agree estimates. The Workshop draws attention to its comments on the confidence intervals surrounding the preliminary estimates of trends presented that suggest that even the revised estimates may only be able to detect very major changes in the abundance of animals using the JARPA area over long time periods. The implications of this latter finding for addressing the other objectives (e.g. biological parameter estimation) require further investigation. The abundance estimates will be valuable for any future *Implementation Review* under the RMP.

8.1.3 Estimation of biological (life history) parameters to improve the stock management of the Southern Hemisphere minke whale

As noted above, issues of stock structure are directly relevant to the question of biological parameter estimation. The 1997 review had noted that the information from JARPA had set the stage for answering many questions about long term changes in minke whales in the JARPA research area and had recommended that biological parameters be analysed by stocks. Some advance towards that had been made at the present Workshop in that estimates had been presented for one possible hypothesis based on the stock structure analyses undertaken thus far, in accordance with a Committee recommendation made in 2006. However, further work will be required as progress is made with respect to stock structure and mixing in accordance with the recommendations made under Item 3. Given that background and notwithstanding further comments below, the Workshop cannot conclude that this objective has been fully met at present; however, the Workshop acknowledged that considerable effort had been put into attempting to obtain agreed estimates of biological parameters (and changes in these over time) for one stock structure hypothesis. In discussion of the analyses presented at this Workshop, the Workshop **agreed** that no marked trends in life history parameters were found for the JARPA period. However, problems were identified with the age data for the commercial period and for this reason, there were differing views on the reliability of estimates of historical trends in life history and population parameters prior to the JARPA period. It was also noted that the confidence intervals around the estimates of natural mortality estimated from the JARPA data alone spanned such a wide range that the parameter remains effectively unknown at present (narrower confidence intervals were estimated for the ADAPT-VPA analysis but this relies on commercial age data). The Workshop **agreed** that every effort should be made to try to resolve the issue of the commercial age data as this has important implications as to how well the objectives of the programme can be met.

8.2 Elucidation of the role of whales in the marine ecosystem

At the 1997 Workshop, it had been noted that the data on body condition and biological parameters should result in a better understanding of the status of Antarctic minke whales in the research area and be useful to test hypotheses related to aspects of the 'krill surplus' model. The importance of understanding the feeding ecology of Antarctic minke whales has been recognised by the Committee and formed an important part of its SOWER 2000 programme (IWC, 2000b). The importance of but the inherent difficulties in ecosystem modelling are also recognised by the Committee (IWC, 2004a;2007b). The Committee has long been unable to reach agreement on interspecific competition among baleen whales in the Antarctic, particularly with respect to the so-called 'krill surplus' model. The Committee **welcomed** the oceanographic and krill-related work undertaken since the 1997 Workshop. The Workshop also **agreed** that considerable relevant data had been collected by the JARPA programme on matters related to body condition and feeding. However, it is clear from the discussion under Item 5 that the simple nature of several of the analyses presented at the present Workshop means that relatively little progress has been made in addressing this objective, even allowing for the complexities of the subject. Issues related to the 'krill surplus' model remain as controversial as ever. The Workshop **strongly recommended** the establishment of an advisory group (Item 5.5) to ensure that the extensive dataset is used to its full potential and progress is made. It also **agreed** that it is essential that information on other krill predators as well as information on krill dynamics is incorporated into analyses of the role of whales in the ecosystem and notes that planned discussions in the IWC/CCAMLR joint workshop would assist in this.

8.3 Environmental change

At the 1997 Workshop, it was noted that the pollutant analyses undertaken by the JARPA programme should take into account the recommendations made at the 1995 IWC Workshop on Chemical Pollutants and Cetaceans (Reijnders *et al.*, 1999a). The Workshop **welcomed** the presentation of the pollutant analyses at this Workshop, although there was some disagreement over the implications of the results drawn by the authors (see Item 6.3.1). The Workshop also **welcomed** the oceanographic work presented, noting that in addition to its potential to assist in the ecosystem work, it also has the potential to contribute to other environmental monitoring programmes in the Antarctic.

9. OVERVIEW OF RESULTS IN THE CONTEXT OF IWC RESOLUTIONS AND DISCUSSIONS

The Workshop agreed that there was insufficient time to address these items and refers them to the Committee.

10. OTHER MATTERS

There were no other matters discussed.

11. ADOPTION OF REPORT

The report was adopted on 8 December 2006. The Chair thanked all of the participants for their co-operation and hard work and in particular the rapporteurs under Donovan. He also thanked the Government of Japan and the staff of ICR for the excellent facilities provided. The meeting expressed appreciation to the Chair for his usual firm but fair handling of the Workshop.

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Annex A
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Annex B
Agenda

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10. Other matters

11. Adoption of report

Annex C

List of Documents

SC/D06/J1. 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.

SC/D06/J2. Nishiwaki, S., Ishikawa, H. and Fujise, Y. Review of general methodology and survey procedure under the JARPA.

SC/D06/J3. Hakamada, T., Goto, M. and Ishikawa, H. Examination of the effect of skip on abundance estimates for Antarctic minke whales.

SC/D06/J4. Burt, M.L. and Paxton, C.G.M. Review of density surface modeling applied to JARPA survey data.

SC/D06/J5. Matsuishi, T., Ikeda, H. and Nishiwaki, S. Estimation of g(0) based on the sighting survey data of JARPA incorporating additional information.

SC/D06/J6. Hakamada, T., Matsuoka, K. and Nishiwaki, S. An update of Antarctic minke whales abundance estimate based on JARPA data.

SC/D06/J7. 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).

SC/D06/J8. Pastene, L.A. A brief review of the genetic studies on dwarf minke whale based on JARPA samples.

SC/D06/J9. Pastene, L.A., Goto M. and Kanda, N. Genetic analysis on stock structure in the Antarctic minke whales from the JARPA research area based on mitochondrial DNA and microsatellite.

SC/D06/J10. Hakamada, T. A study on stock structure in the Antarctic minke whale from the JARPA research area based on morphometric analysis.

SC/D06/J11. Bando, T., Zenitani, R. and Fujise, Y. A study on stock structure in the Antarctic minke whales from the JARPA research area based on analysis of body length of physically matured whales.

SC/D06/J12. Pastene, L.A. What do we know about the stock structure of the Antarctic minke whale? A summary of studies and hypotheses.

SC/D06/J13. Tanaka, E., Zenitani, R. and Fujise, Y. An estimate of natural mortality coefficient in Antarctic minke whales using JARPA data.

SC/D06/J14. Mori, M., Kitakado, T. 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.

SC/D06/J15. Zenitani, R. and Kato, H. Temporal trend of age at sexual maturity of Antarctic minke whales based on transition phase in earplugs obtained under JARPA surveys from 1987/88 to 2004/05.

SC/D06/J16. Mori, M., Butterworth, D.S., Zenitani, R. and Kato, H. Model-based transition phase analyses for the Antarctic minke whales in the JARPA research area.

SC/D06/J17. 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 2004/05.

SC/D06/J18. Tamura, T. and Konishi, K. Food habit and prey consumption of Antarctic minke whale *Balaenoptera bonaerensis* in the JARPA research area.

SC/D06/J19. Konishi, K., Tamura, T. and Walloe, L. Yearly trend of energy storage in the Antarctic minke whale *Balaenoptera bonaerensis* in the JARPA research area.

SC/D06/J20. Tamura, T., Konishi, K., Nishiwaki, S., Taki, K., Hayashi, T. and Naganobu, M. Comparison between stomach contents of Antarctic minke whale and krill sampled by RMT net in the Ross Sea and adjacent waters.

SC/D06/J21. Murase, H., Kiwada, H., Matsuoka, K. and Nishiwaki, S. Results of the cetacean prey survey using echo sounder in JARPA from 1998/99 to 2004/2005.

SC/D06/J22. Murase, H., Tamura, T., Matsuoka, K., and Hakamada, T. First attempt of 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.

SC/D06/J23. Naganobu, M., Nishiwaki, S., Yasuma, H., Matsukura, R., Takao, Y., Taki, K., Hayashi, T., Watanabe, Y., Yabuki, T., Yoda, Y., Noiri, Y., Kuga, M., Yoshikawa, K., Kokubun, N., Murase, H., Matsuoka, K. and Ito, K. Interactions between oceanography, krill and baleen whales in the Ross Sea and Adjacent Waters: An overview of *Kaiyo Maru*-JARPA joint survey in 2004/05.

SC/D06/J24. Murase, H., Tamura, T., Nishiwaki, S., Yasuma, H., Matsuoka, K., Yabuki, T. and Naganobu, M. Biomass estimaton of *Euphausia superba* and *E. crystallorophias* in the Ross Sea in 2004/05 using *Kaiyo Maru*-JARPA joint survey data.

SC/D06/J25. Murase, H., Kitakado, T., Matsuoka, K., Nishiwaki, S. and Naganobu, M. Relating the distribution patterns of Antarctic minke whales with abiotic and biotic environmental factors in the Ross Sea in 2004/05 using *Kaiyo Maru*-JARPA joint survey data.

SC/D06/J26. Fujise, Y., Hatanaka, H. and Ohsumi, S. Changes occurred on Antarctic minke whale stocks in the Antarctic and their ecological implications.

SC/D06/J27. Yasunaga, G., Fujise, Y. and Honda, K. Trace element accumulations of Antarctic krill, *Euphausia superba*, in Areas-III, IV, V and VI from Antarctic Ocean during 1989-1999.

SC/D06/J28. 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.*

SC/D06/J29. 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.*

SC/D06/J30. 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.

SC/D06/J31. Pastene, L.A., Goto, M., Nishiwaki, S., Yoshida, H. and Kanda, N. Genetic characteristics and population structure of humpback whales in the Antarctic feeding grounds as revealed by mitochondrial DNA control region sequencing and microsatellite analyses.

SC/D06/J32. Pastene, L.A., Ishikawa, H., Goto, M. and Nishiwaki, S. Overview of the studies on large whales not related with the main objectives of the JARPA.

Annex D

List of JARPA data sets. sighting data, biological data for Antarctic minke whales, genetic data for other large whales and environmental data collected by the JARPA in the period 1987/88-2004/05

I SIGHTING DATA

		Total sample size
1	Angle and distance experiment data (no. of experiments)	6,426
2	Ice edge line	30
3	Photo-ID, humpback whale (no. of photographs)	502
4	Photo-ID, right whale (no. of photographs)	243
5	Photo-ID, blue whale (no. of photographs)	153
6	Sighting data (no of schools)	48,600
7	Survey effort data (searching distance of SV and SSVs in n. miles)	293,811
8	Weather data (number of observation of weather)	94,840

II BIOLOGICAL DATA (ANTARCTIC MINKE WHALE)

		Number of targeted individuals		
		Male	Female	Total
9	Age	3,626	3,151	6,777
10	Blubber thickness (3 point/14 points)	3,626	3,151	6,777
11	Body length	3,626	3,151	6,777
12	Body proportion	3,626	3,151	6,777
13	Body weight	3,466	3,025	6,491
14	Catching date	3,627	3,151	6,778
15	Catching location	3,627	3,151	6,778
16	Corpora albicantia and lutea (number)	-	3,151	3,151
17	Diatom film	3,626	3,151	6,777
18	Discovery-type marks recovery	3,626	3,151	6,777
19	Foetus, body length	-	-	1,876
20	Foetus, body weight	-	-	1,876
21	Foetus, number	-	3,151	3,151
22	Foetus, sex	-	-	1,876
23	Freashness of stomach contents	3,626	3,151	6,777
24	Girth	3,626	3,151	6,777
25	Lactation condition	-	2,064	2,064
26	Main Prey species in stomach contents	3,626	3,151	6,777
27	Maturity stage	3,626	3,151	6,777
28	Mitochondrial DNA control region sequences	555	499	1,054
29	Mitochondrial DNA RFLP-derived haplotype distribution	3,627	3,151	6,778
30	Nuclear DNA microsatellite (6 loci), minke whale	3,389	2,881	6,270
31	Organ weights	606	512	1,118
32	Parasites, external occurrence record	3,626	3,151	6,777
33	Parasites, internal occurrence record	3,626	3,151	6,777
34	Physical maturity	3,531	3,068	6,599
35	Sex	3,627	3,151	6,778
36	Skull (length and breadth)	3,626	3,151	6,777
37	Stomach contents (IWS format)	3,626	3,151	6,777
38	Stomach contents weights	3,626	3,151	6,777
39	Testis weight	3,626	-	3,626
40	Transition phase	3,626	3,151	6,777

III DNA DATA AVAILABLE FOR OTHER LARGE WHALES (Obtained from biopsy sampling)

		Number of targeted individuals		
		Male	**Female**	**Total**
41	Mitochondrial DNA control region sequences, blue whale			22
42	Mitochondrial DNA control region sequences, fin whale			28
43	Mitochondrial DNA control region sequences, humpback whale	176	166	342
44	Mitochondrial DNA control region sequences, sei whale			1
45	Mitochondrial DNA control region sequences, right whale			36
46	Nuclear DNA microsatellite (6 loci), humpback whale	176	166	342

IV ENVIRONMENTAL DATA

		Number of individuals		
		Male	**Female**	**Total**
47	Heavy metals (liver)	921	151	1,072
48	Heavy metals (stomach contents)	67	33	100
49	Marine debris (stomach contents)	3,626	3,151	6,777
50	Organochlorine (blubber)	111	2	113
		Number of samples		
51	Organochlorine compounds (air)	4		
52	Organochlorine compounds (sea water)	4		
53	Marine debris (sighting survey)	255		
54	Temperature (XBT survey)	916		
55	Temperature & Salinity (XCTD survey)	915		
56	Temperature & Salinity (CTD survey)	499		
57	Temperature & Salinity (EPCS survey, days)	1,307		
58	Echo sounder (krill distribution, days)	612		

In addition, there is the dataset from the RV/*Kaiyo Maru* Antarctic Ross sea survey in 2004/05)

Navigation Data
Field Note
- Noon position
- Climate and Sea
- Iceberg

Climate and Sea Satellite Information
- Climate
- Sea Ice

Survey Point Field Book
Physical Environment Data
- Data Excel CSV
- Raw Data/ADCP
  - CTD/Parm
  - Report
  - EPCS
  - XBT
  - XCTD

Chemical Environment Data

Primary Production Data
Acoustic Survey
  - Acoustic Export/Track
  - Checked
- ekset / 1999-2000 Krill / daily backup
  - 2001 Tangaroa
  - Backup
  - Daily backup
- SA Map CSV

Biological Data
- Fish
- Krill
- Salpa
- Squid

RMT
- Sample Photos
- Total Field note

Sighting Data

Annex E

Objectives of JARPA

ORIGINAL OBJECTIVES OF JARPA (IWC, 1988, P. 139)

Objective 1. Estimation of biological parameters to improve the stock management of the Southern Hemisphere minke whale

According to the original proposal, the main reason for the failure of the SC to recommend an agreed catch limit for the Antarctic minke whale stock in 1980s had been that its members were not able to reach agreement on the value of natural mortality coefficient and its age-specific patterns. The proposal stated that its primary purpose was to estimate the age-specific natural mortality coefficient through stochastic sampling, which was carried out in combination with systematic sighting surveys. The programme was also designed to try to estimate reproductive parameters and their changes based on the same samples as well as stochastic changes in stock size.

Objective 2. Elucidation of the role of whales in the Antarctic marine ecosystem.

The reason for the establishment of Objective 2 was based on the consideration that the most important need to understand the Antarctic ecosystem was the collection of data on the prey-predator relationship among krill, fish, squid and whales. The global scientific interest in the Antarctic ecosystem had been growing, as reflected in the creation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR).

The plan of original research programme was reviewed during the 1987 Annual Meeting (IWC, 1988) and the plan for the feasibility study was reviewed at a Special Meeting in December 1987 (IWC, 1989). After the completion of the feasibility study, the Japan retained the same two objectives but noted it would amend the original plan to: include monitoring of recruitment among the main subjects of the study; shorten the interval between sampling years; and conduct surveys using line transect methods.

Results from the permit studies are reviewed each year and comments can be found in the Scientific Committee reports. A major mid-term review was held in 1997 (IWC, 1998a)

ADDITIONS/CHANGES TO THE OBJECTIVES

An additional objective was added for the 1995/96 season.

Objective 3. Elucidation of the effect of environmental change on cetaceans
Japan added this objective in response to two Commission Resolutions in 1994: Resolution on research on environmental change and whale stocks (IWC, 1995b); and Resolution on promotion of research related to conservation of large whale stocks in the Southern Ocean (IWC, 1995a). Some work on this new objective had been carried out under the original objective 2.

A further (and final) objective was added for the 1996/97 season.

Objective 4. Elucidation of the stock structure of the Southern Hemisphere minke whales to improve stock management.
Japan added this objective (the topic was already included in the original Objective 1), as a consequence of the increased importance of this topic to the proper estimation of biological parameters and for the implementation of the RMP to the Antarctic minke whales.

Annex F

A review of the coverage of strata and the sequence of surveys relative to the ice edge during JARPA

PAUL R. WADE

Note: A longer version of this Annex was developed as a Working Paper presented towards the end of the Workshop. There was insufficient time to discuss the working paper (or this Annex) during the Workshop (see Item 2.3 of the report).

INTRODUCTION

SC/58/SH21 provides detailed maps showing achieved trackline effort (same for all species) during the JARPA surveys in Areas IV and V. The logistics are complex since the surveys attempted to cover the complete area from 60ºS to the ice edge by a Sighting Vessel (SV) and by Sighting and Sampling Vessels (SSV) working in close association. Effort was divided between a southern stratum (ice edge to 45n.miles north of the ice edge) and a northern stratum (from the southern stratum north to 60ºS). The ice edge was usually retreating south during the time period of the surveys (typically December to March) which sometimes meant that the location of the ice edge had changed between the time a northern stratum was surveyed and the time the southern stratum below it was surveyed. The density of minke whales is thought to have some association with the ice edge, so good coverage of the ice edge strata is important to the abundance estimates calculated from JARPA data. For example, in SC/D06/J6, approximately 40-50% of the abundance estimates for minke whales calculated in Areas IV and V over the period of JARPA comes from the southern strata (e.g. Tables 1-h and 1-i), even though the southern strata were typically much smaller than the northern strata.

This review is based on Figs 1-30 in Appendix 4 of SC/58/SH21. Some evaluations were made subjectively from the figures, and the evaluation should be confirmed and improved by quantitative analysis of the survey data. However, this subjective evaluation was all that was possible in the time available at the workshop. The evaluations are given in Table 1 and independent checking can be undertaken intersessionally.

A summary of my interpretation of these results is included in the main report under Item 2.3.

EXPLANATION OF COLUMNS IN THE TABLE

(1) IESC (Ice edge strata coverage)

SC/D06/J2 (fig. 2) shows the 'ideal' method of trackline design for the ice edge strata: one transect due north from the ice edge for 45n.miles followed by a transect at an angle designed to intersect the ice edge again 4º longitude further to the east or the west. However, the maps in SC/58/SH21 show that these ideal tracklines could not always be accomplished in practice. I have subjectively evaluated (for SV and SSV separately) whether: the tracklines provided complete coverage from the ice edge to the northern boundary of the stratum; there were significant gaps in coverage from east to west; and the sawtooth pattern was accomplished as planned. The evaluation is expressed as high (H), medium (M), or low (L), where the goal was to evaluate whether coverage appeared to be >75% (H), 50-75% (M), or <50% (L), with additional consideration given to as to whether a sawtooth pattern extending from the ice edge to the northern boundary was successfully accomplished.

(2) NSC (Northern strata coverage)

Coverage was evaluated subjectively from inspection to be high (>75%), medium (50-75%), or low (<50%).

(3) IE main (Main months in which ice edge stratum was covered)

This lists the 'main' months that the ice edge strata were covered where 'main' is taken as a month that appeared to have more than 20% of the survey coverage, so effort in a month that appeared to be less than that was not recorded here. It provides some information on temporal changes in coverage of survey strata from north to south. For Area V, the Ross Sea is also given in parentheses.

(4) Strata order (Order strata were surveyed)

This lists the order in which the survey strata were surveyed in each year. It provides information on potential shifts in the timing of the survey of the ice edge strata.

(5) Ave order (Average order of survey of the southern strata)
This takes the order (1 to 5 for Area IV or 1 to 4 for Area V) given in the previous column and simply calculates what I have termed the 'average order' in which the southern strata (SE and SW) were surveyed. As an example, if the survey order in Area IV was SE-NE-SW-PB-NW, then the average order would be calculated as:

(1 [since SE was surveyed first] + 3 [since SW was surveyed third]) ÷ 2 (two southern strata were surveyed) = 2

I have calculated this to try to make it easier to see patterns in the timing of the survey of the ice edge.

(6) IESW and IESW (Ice extent in the western and eastern strata)
There is considerable variability in the extent of ice that occurred along the continent in different surveys that may reflect inter-annual variability in ice conditions and/or the timing of the survey. This column lists my subjective view of the amount of ice as either: H (high) for a year in which much of the extent of ice extended more than 2º latitude from the continent; L (low) for a year in which considerable stretches of the continent appeared ice-free; or M (medium) for a year in which the ice extent was less than 2º latitude but there were no large ice free stretches along the continent. However, for the Ross Sea (the SE stratum in Area V): H is for a year in which it had little ice-free area; L is for a year in which most of the width of the stratum was ice-free and the ice-free area extended south to at least 76ºS; and M is intermediate.

(7) Comments
In some years a gap was left between the southern and northern strata which was left unsurveyed. This appeared to happen particularly in years in which the northern stratum was surveyed first, such that when the ice edge stratum was surveyed later, the ice edge had retreated and was further south, and therefore the northern boundary of the southern stratum (extending 45nm north of the ice edge) still fell far short of the southern boundary of the northern stratum. This column also includes information on whether data were missing, if there were east to west gaps in survey coverage within a stratum, and other changes in survey conditions or coverage.

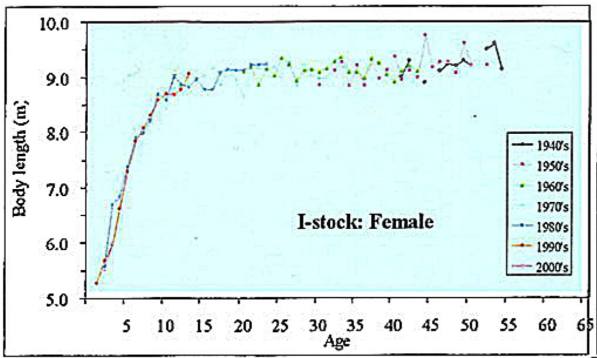
Table 1

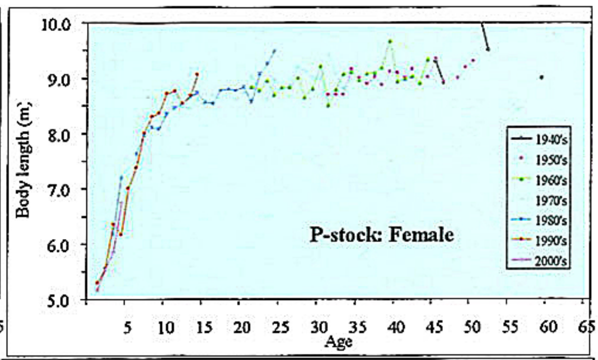
Summary of survey coverage during JARPA. For explanation of column headings see text.

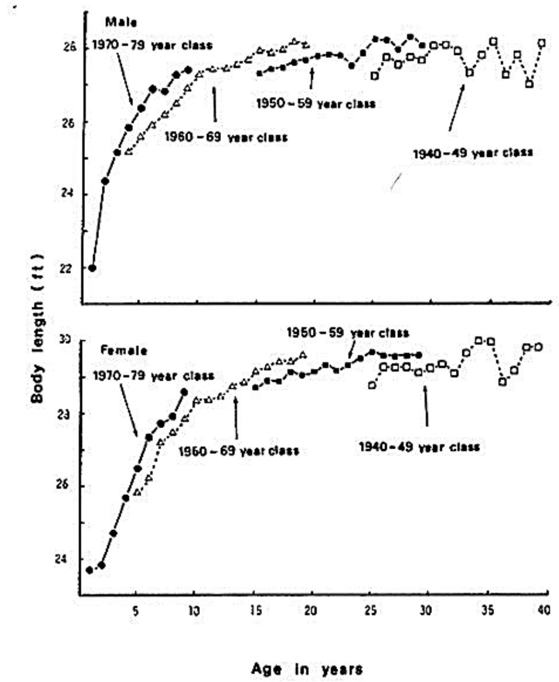
Year	(1) IESC		(2) NSC	(3) IE main	(4) Strata order	(5) Ave order	(6) IESW	(6) IESE	(7) Comments
	SSV	SV							
Area IV									
1989/90	M	--	M	Jan	SE-NE-SW-PB-NW	2	M	M	No SV data
1991/92	M	H	H	Jan/ Feb	NE-SE-SW-PB-NW	2.5	M	M	No SV data in N strata
1993/94	M	M	H	Dec/ Jan	SE-NE-SW-PB-NW	2	M	H	
1995/96	L	L	M	Jan	SW-NW-PB-NE-SE	3	H	M	Gap within SW. SV and SSV strata in W are different
1997/98	M	M	H	Jan/ Feb	NW-SE-NE-SW-PB	3	M	M	Prydz Bay iced up at time of survey
1999/00	L	L	H	Feb/ Mar	NW-NE-SE-SW-PB	3.5	L	L	Gap between NW & SW
2001/02	M	L	H	Feb	NW-NE-SE-SW-PB	3.5	M	L	Gap between NW & SW and between NE & SE
2003/04	H	H	H	Feb	NW-NE-SE-SW-PB	3.5	L	L	Gap between NW & SW. No SSV data in west part of SW
Area V									
1990/91	M		H	Jan (Feb)	SW-NW-SE-NE	2	H	L	Gap between NE & SE (in Ross Sea). No SV data. No N-S transects in ice edge stratum
1992/93	M	M	H	Jan/Feb (Feb/Mar)	NE-SW-NW-SE	3	L	L	Gap between NE and SE (in NE stratum)
1994/95	M	M	H	Dec/Jan (Feb/Mar)	SW-NW-NE-SE	2.5	H	L	
1996/97	M	M	H	Jan/Feb (Feb/Mar)	NE-SW-NW-SE	3	M	L	
1998/99	H	H	L	Feb (Mar)	NE-NW-SW-SE	3.5	L	H	Only year with sawtooth design in Ross Sea due to high ice
2000/01	M	M	H	Mar (Jan/Feb)	NE-SE-NW-SW	3	M	M	Gap in eastern part of SW
2002/03	L	L	H	Mar (Jan/Feb)	NE-SE-NW-SW	3	M	H	No sawtooth design in SW, little open water in Ross Sea
2004/05	L	L	L	Mar (Jan/Feb)	NE-SE-NW-SW	3	M	L	

Annex G

Apparent trends in various minke whale parameters obtained from a variety of studies

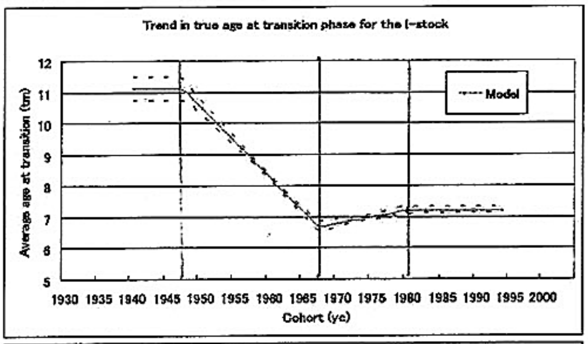


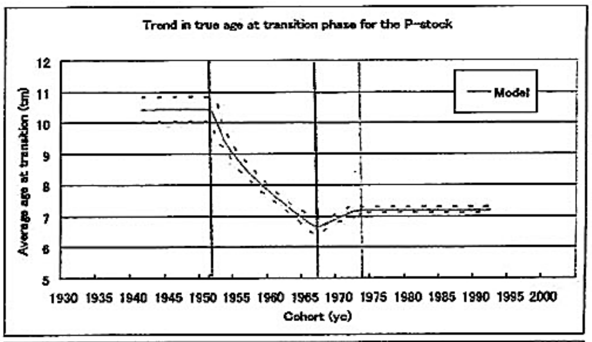


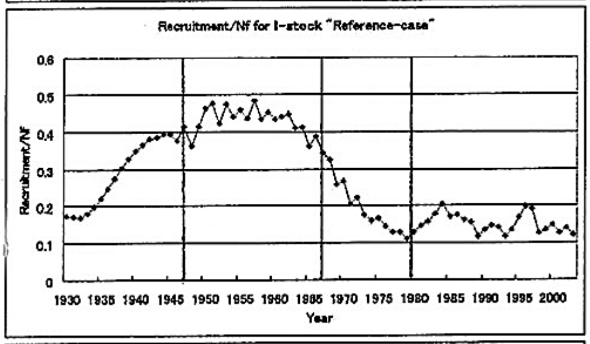


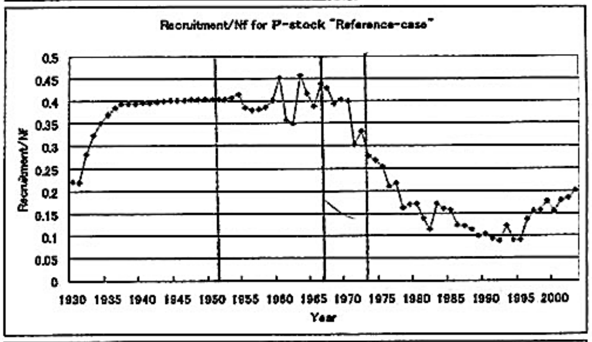
The top two figures are taken from SC/D06/J17

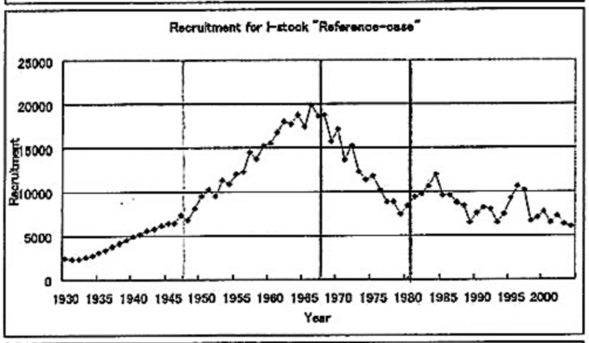
The left figures are taken from Kato (1987).

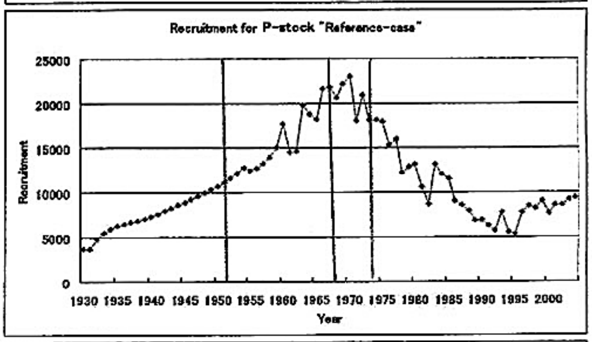


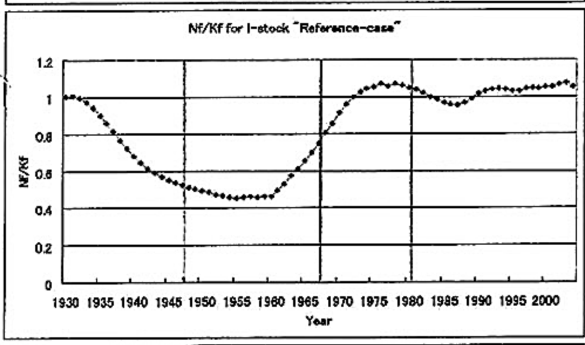


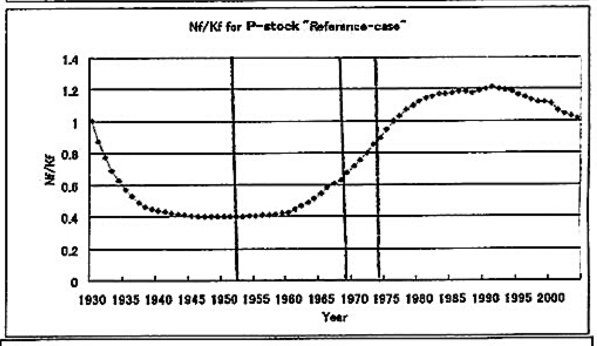


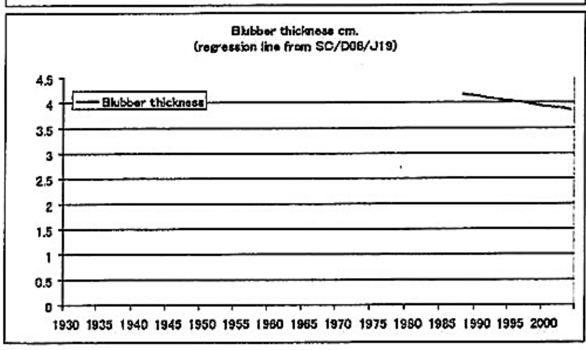












Note:

>Upper 2 figures are taken from document SC/D06/J16

> Middle 6 figures are taken from document SC/D06/J14
Nf is defined as mature (7+) females.
Kf is defined as carrying capacity of the mature (7+) females.

> The left figure is taken from document SC/D06/J19