SC/49/Rep1

Report of the Intersessional Working Group to Review Data and Results from Special Permit Research on Minke Whales in the Antarctic, Tokyo, 12-16 May 1997

1. INTRODUCTION

1.1 Welcome and Introduction

The Working Group met at the Mariners' Court Hotel, Tokyo, on 12-16 May 1997. The meeting was convened by Schweder. The list of participants is given in Annex A.

Hatanaka welcomed the participants, noting that they comprised some 40 scientists from more than 10 countries. He recalled that the meeting resulted from a proposal made at the 1995 meeting of the Scientific Committee, and thanked Schweder for his efforts as convenor. He stressed that the meeting was important both for Japan and for the Commission, and noted that the numerous papers presented demonstrated the considerable information provided by the Special Permit Research, known as the 'JARPA program' (Japanese Whale Research Program under Special Permit in the Antarctic). He considered it important that the Commission make the best use of this information, and hoped that the meeting would see fruitful discussions towards that end.

As Scientific Committee Chairman, Bannister echoed Hatanaka's welcome and expressed appreciation to Hatanaka, the Japanese Government and Japanese workers for the meeting arrangements. He also expressed, on behalf of the Scientific Committee as a whole and the meeting participants, appreciation to Schweder and his Steering Committee for their dedicated and detailed preparatory work.

Bannister referred to the Working Group's background, in particular the difficulty experienced in the past by the Scientific Committee in doing justice to the considerable volume of information arising from the Japanese research programme on Southern Hemisphere minke whales. He outlined some of the considerations that had led to the structure of the draft agenda, in particular the need to reflect in the discussions two separate components:

(1) the specific research carried out, and its results;
(2) the contribution made by those results to the stated objectives of the research programme, and to the aims of the IWC as expressed in its Resolutions.

He reminded the Working Group of its formal title: *The Meeting of the Intersessional Working Group to Review Data and Results from Special Permit Research on Minke Whales in the Antarctic* (IWC, 1996d), and of its status as category (ii) (IWC, 1996c, p.52) i.e. '*considered confidential until.....discussed by the Scientific Committee at an Annual Meeting*'.

He stated that it was not his intention to participate in detailed scientific discussions at the meeting, and that he had decided that as Scientific Committee Chairman it would not be appropriate for him to Chair the Working Group himself, particularly as the Working Group's Report would be presented to the full Committee, with himself in the Chair, at the Scientific Committee's next Annual Meeting in Bournemouth. However, he expected to be present for much of the discussion of Agenda Item 1.

In regard to working arrangements during the meeting, it was agreed that in line with current Scientific Committee practice, automatic consecutive translation from English to Japanese, or *vice versa*, was not appropriate. Some flexibility would be allowed, however, to permit translation of specific points or discussions as they arose, for example in presentation of documents or ensuing debate, but subject to the Chairman's decision at the time.

1.2 Election of Chairman and appointment of rapporteurs

Reilly was elected Chairman. Butterworth, De la Mare, DeMaster and Walløe agreed to act as rapporteurs, assisted by Kato.

1.3 Adoption of Agenda

Schweder, as Convenor, stated that the draft agenda had been based upon the items listed in IWC (1996d). He explained that the intent was to discuss the scientific issues and results first, and subsequently to place them in the context of the Commission's requirements for management and related (e.g. environmental change) concerns.

Considerable discussion ensued on whether this was the best approach to take. A number of participants felt that for effective progress, the discussion under each of the scientific research topic headings had to take place in a context - specifically that of the purpose of the meeting *'to review results in the light of the initial objectives of the research (and in the light of hypotheses and questions that have since emerged) and to attempt at assessing information content and potential of the available data'* (IWC, 1996d). Thus, they felt, such consideration should be addressed within each such scientific topic agenda item, rather than await completion of all scientific discussions. (See also Section 1.5).

Noting, however, that inter-relationships between these scientific agenda items meant that a concluding overview discussion was also needed, the meeting decided to retain the broad structure of the draft agenda, but to allow for an initial discussion of results in the context of the programme objectives and of stock management at the end of the agenda item for each scientific topic.

The question was raised as to whether the order of the agenda needed to be considered in the light of further computations perhaps being requested for completion during the meeting. It was agreed that in general, the meeting should not attempt such work during the limited time available to it; if such requests did arise, time should rather be devoted only to ensuring specifications of what was required were properly set out, with results to be considered at the next Scientific Committee meeting.

The Working Group then adopted the agenda shown in Annex B[1]. The Chairman stressed that discussion on Item 8 (referencing recent Commission Resolutions) would take

[1] During the course of the meeting minor modifications to the agenda were adopted, as reflected in the topic headings in the report.

place only should time permit, noting that the Scientific Committee meeting later in the year would in any case have to address this topic.

1.4 Documents available

The documents presented to the Working Group are listed in Annex C.

1.5 Terms of reference for JARPA review

The Working Group took note of its terms of reference as reflected in the opening paragraph of IWC (1996d) (quoted in the second paragraph of Section 1.3 above). To assist the Working Group in its consideration of each scientific topic on this basis, a subgroup chaired by Smith compiled a 'checklist' which is shown as Annex D.

The original JARPA proposal (Government of Japan, 1987) and the most recent version (Government of Japan, 1996) identified studies on toothed whales as well as on minke whales. Noting that its terms of reference specified minke whales only, the Working Group agreed not to consider those other aspects of JARPA.

1.6 The original research proposal and later additions

Ohsumi summarised SC/M97/10. He stated that Japan's original objectives[2] for the research had been:

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

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

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

The Working Group agreed to defer discussion on the justification or otherwise of the rationale offered (in, for example, SC/M97/10) for these objectives to the pertinent subsequent agenda items (including Item 7).

1.7 Outline of the JARPA research

Fujise presented a brief summary of the programme to date. Two feasibility studies had taken place in 1987/88 and 1988/89, with the full scale 16 year research commencing the following season and alternating each season in Areas IV and V. In 1995/96 and 1996/97, coverage was extended to Areas IIIE and VIW respectively, for a limited period feasibility study of stock structure.

He stated that the full programme has two components: a sighting survey whose primary purpose is the estimation of trends in abundance; and a sampling component to allow biological parameter values to be estimated given also the abundance information provided by the sighting survey. In the programme as originally proposed, it was planned to take 825 animals in any one season from either Area IV or Area V. For two years of feasibility studies, 300 animals (with an allowance of ±10%) were planned to be sampled in parts of Areas IV and V. Following the results of the feasibility studies, considerations of the balance between the expected precision of estimates of the mortality rate and the research capability available led to the decision to set the number of animals to be sampled each season to 300 with an allowance ±10%. In the 1995/96 season, additional samples of 100 animals with an allowance of ±10% were planned for Area IIIE, and subsequently 100 ±10% in Area VIW in the 1996/97 season, for studying stock structure (see Item 3). Initially three vessels (plus the mothership) had been employed, but a fourth had been added in 1995/96 to allow for an increase in searching effort in the sighting survey. This and some other changes during the progress of the programme had been made in response to comments from the Scientific Committee. Initially both dwarf and ordinary forms of the minke whales had been sampled, but sampling of the former had ceased in 1993/94. A total of 1,546 (Area IV), 1,546 (Area V), 110 (Area IIIE) and 110 (Area VIW) ordinary and 16 dwarf form minke whales had been sampled by the end of the 1996/97 season.

The Working Group noted that more details on the programme are to be found in review documents SC/M97/1-5 and 8. It also noted that some analyses of JARPA data presented to this and previous meetings had used the data collected in the feasibility studies as well as in the full programme. (Data from the research in 1996/97 are not yet available, so have not been incorporated in any of the analyses discussed below). The Working Group noted the comprehensive nature of the JARPA programme. The lists of scientific papers and datasets resulting from the programme are given in Annex E.

1.8 Overview of past discussions of the JARPA programme and its results

The Working Group noted that while both the quantity and quality of the scientific work had been commended by the Scientific Committee, differing views had been expressed in the Committee about its relevance to management considerations.

A suggestion was made that a list of specific issues in contention be compiled from past Scientific Committee reports. The group that had served as the Steering Committee for the Working Group was requested to provide this. Their list is given as Annex F.

2. SIGHTING SURVEYS AND ABUNDANCE ESTIMATION

2.1 Background: original and additional research objectives

Noting that the objectives for the research listed in Item 1.6 did not include the provision of abundance estimates (for input, perhaps, to the RMP) *per se*, clarification was sought on the intent of this component of the programme. Was it solely a necessary part of, for example, the unbiased estimation of certain biological parameters, or an aim of the programme in its own right? Ohsumi stated that though the primary reason for the sighting surveys was their contribution to objective 1 (the estimation of biological parameters), their pertinence to the RMP and the associated implementation process for Southern Hemisphere minke whales should be seen as a derivative objective.

The following question arose concerning the choice of areal coverage for the sampling and surveys: since the objective of obtaining unbiased estimates of biological parameters for the population required representative sampling, why had coverage been reduced from south of

[2] The Working Group noted that at the start of the programme, objective 1 above had been worded '.....*biological parameters required for stock management*.....'. Hatanaka stated that Japan considered the rewording of objective 1 above more appropriate given refocusing towards the RMP as the basis for management.

55°S to south of 60°S after the initial two feasibility exercises in 1987/88 and 1988/89? Ohsumi responded that while the desirability for wider coverage was understood, the feasibility exercises had indicated that there was only a small number of minke whales between 55°S and 60°S compared to the number south of 60°S. It had thus been judged that restricting research to the latter area would still provide adequately representative samples.

2.2 Methodology and data collection

Nishiwaki presented SC/M97/1, which included details of the data collected and associated methodology used on the JARPA surveys, and provided clarification on a number of technical questions. The closing procedures (e.g. to determine school size) were identical to those used in closing mode for the IDCR surveys, excepting the additional time spent on sampling and that closing was limited to minke whales. The vessels engaged in such sampling ('SSVs' - sighting and sampling vessels) surveyed along parallel track lines, but from the 1991/92 season one vessel ('SV') at any one time was devoted to sighting only, in order to investigate the effect of sampling activity on abundance estimates.

Certain changes in JARPA survey procedures over time were noted (e.g. in the placement of observers on different vessel types), but the meeting considered that adequate comparability over time in data collection had been achieved. Hatanaka advised of the intention to retain current procedures for forthcoming cruises to maintain this comparability.

One important difference in survey methodology to that used on the IDCR cruises was noted. On IDCR cruises, survey on one day commences from the position reached at the end of the previous day. However, for the JARPA programme, a target distance per day was established; if this distance has not been achieved by the end of the day, the remainder of the planned trackline for that day is not covered, and survey the next day starts from the 'targeted' (not the actual) position for the end of the previous day. This procedure can lead to under-surveying of higher density areas, because more time is required for closing on and sampling whales, so that less survey distance is covered on the day in question. This has implications for abundance estimates that are discussed immediately below, and for sampling representativeness (see Section 4.2).

2.3 Methods of analysis

Two papers provided analyses of the sighting data to estimate abundance. Nishiwaki *et al.* (SC/M97/1) provided estimates for Area IV for 1989/90, 1991/92, 1993/94 and 1995/96, and for Area V for 1990/91, 1992/93, 1994/95. Estimates were provided separately based on SSV and SV data (except for the first two of these seven seasons, when only SSVs operated). The analyses were restricted to data from a similar period (Jan-Feb, which corresponds to the peak period of abundance of minke whales in Antarctic waters) and similar area (south of 60°S) to the IDCR surveys, in the interests of making comparisons.

In the second paper, Burt and Borchers (SC/M97/23) undertook similar analyses for the 1991/92 (Area IV) and 1992/93 (Area V) surveys, but using general methodology developed for the IDCR data, which is implemented on the IWC sightings database. The key differences between the methods of analysis in SC/M97/1 and SC/M97/23 are that the former stratifies by school size in estimating effective search half-width (w), whereas the latter estimates w for all schools combined and then multiplies an estimate of the total number of schools by another of mean school size. Furthermore, SC/M97/23 stratifies data to a lesser extent, based on the AIC statistic, to avoid the high variances associated with models that over-fit data. Both analyses assumed $g(0) = 1$.

In addition, SC/M97/23 attempted an approach to adjust for the under-surveying of higher density areas in the JARPA surveys arising from the difference in survey methodology described in the final paragraph of the preceding section. This involved scaling the number of sightings made each day upward by the ratio of the target distance for that day to the searching distance actually achieved. Previously concern had been expressed in the Scientific Committee that estimates of minke whale abundance from JARPA reported at that time had been considerably less than IDCR estimates. One of the motivations for this part of the Burt and Borchers' analysis was to investigate whether this factor was a primary cause of this difference.

2.4 Estimates of abundance and trends

Estimates of abundance by subarea and year for Areas IV and V are given for the SSV and the SV platforms in table 5 of SC/M97/1. Comparable unadjusted and adjusted (for under-surveying) estimates for the 1991/92 and 1992/93 data are given by SC/M97/23 (table 8). The SC/M97/23 unadjusted estimates generally have lower variance than those from SC/M97/1 - presumably as a consequence of the lesser degree of stratification in the SC/M97/23 analysis. The authors of SC/M97/23 suggest that:

(i) their unadjusted estimates are in broad agreement with those of SC/M97/1; and
(ii) their adjusted estimates (with one exception) are not systematically lower than comparable IDCR closing mode abundance estimates, but that confidence in this conclusion would be enhanced if analysis of the JARPA surveys in seasons other than the two they had analysed yielded similar results.

In respect of (i), the Working Group felt that no strong inferences could be drawn given the limited number of comparisons.

In discussions arising from (ii), a number of concerns were raised as to whether the 'adjusted' approach applied to the JARPA analysis is an appropriate means of correcting for the higher-density-under-surveying effect to yield comparable estimates of absolute (or even relative) abundance. There was some discussion of whether these concerns compromised the ability of the unadjusted estimate to provide an unbiased estimate of relative trend, though it was recognised that the standard error of this estimate of trend would be negatively biased. If the process underlying the spatial density variation is stationary, trend estimates would be unbiased. However, for reasons discussed below, stationarity may not apply, which could lead to a bias in estimates of trend.

These concerns arose primarily from considerations of the mechanisms that lead to clustering of whales, and hence areas of higher and lower density. The oceanographic and/or food distribution features that result in this clustering can vary from year to year, changing the scale of the clustering. Because of this clustering, the high densities initially encountered on some days would not be likely to have been maintained throughout the target distance for that day, so that the adjustment factor over-corrects; but this would not be balanced by days for which densities were initially low, because greater proportions of the target distance would tend to have been covered on such days. This means both that the adjustment approach used in SC/M97/23 may be unreliable, and that estimates of variance will be negatively biased. Furthermore, the clustering process may be density dependent - it was noted that the net adjustment factor was larger for the SSV analysis for Area V, which has generally higher densities, than for Area IV. This then would bias estimates of trends in abundance unless an approach that achieves reliable adjustment is applied. The fact that the adjustment approach used in SC/M97/23 involved a random variable (the searching distance achieved on a day) in the denominator would also introduce positive bias, possibly of minor importance.

The Working Group considered that further research to develop such an approach was required. A specific suggestion made was that this be based on modelling the extent of the clustering each year by a Neyman-Scott process. The fact that the JARPA surveys operate three vessels in close proximity in space and time should facilitate estimation of the parameters of this model.

2.5 Potential of the results to achieve the objectives of JARPA and of stock management

In relation to Annex D, the meeting agreed that this topic was pertinent to items B2.1, B2.4, B3.1 and B3.2. Relevance to item 2.4 related to the agreed research requirement (IWC, 1996c) of consolidating the Southern Hemisphere minke whale abundance estimates provided by different programmes for different areas of coverage and using different methodologies (e.g. IDCR, JARPA, JSV). The fact that JARPA provides more frequent repetitions of surveys of the same localities than the IDCR programme would facilitate estimation of the extent of inter-year variability in local abundance, which would in turn lead to improved results from the consolidation exercise.

The Working Group agreed that more research was required to develop a reliable method for adjusting for the higher-density-under-surveying feature of the JARPA survey design. Once this had been achieved, the resultant abundance estimates should be useful both as absolute and relative indices.

3. STOCK STRUCTURE

3.1 Background: original and additional research objectives

The authors presented a summary of their paper SC/M97/3, which reviewed the studies related to the species and stock identity of minke and other baleen whales that have been undertaken as part of JARPA.

As noted by the authors, one of the original objectives of JARPA was to elucidate the stock structure of minke whales to improve stock management. It was further noted that at the time of the Comprehensive Assessment for Southern Hemisphere minke whales in 1990, none of the molecular genetic techniques nor any of the non-genetic techniques provided any evidence of stock level differences between minke whales in Areas IV and V. Based primarily on distribution data and limited tagging data, the Scientific Committee proposed that Southern Hemisphere minke whale population contained five distinct breeding grounds and should therefore be managed as five separate management units (IWC, 1991, pp.125-6). Subsequent recommendations of the Scientific Committee included the continuation of mitochondrial DNA studies using available samples from Areas IV and V and the initiation of studies using ecological markers.

Therefore, the current objectives of JARPA related to stock identification following the Comprehensive Assessment of 1990 were described in SC/M97/3 as using both genetic and non-genetic techniques to investigate the stock structure of minke whales in the Southern Ocean.

3.2 Methodology of data collection

The authors of SC/M97/3 commented that the details of the data collection methods were described in the primary references summarised in the review article. It was noted that the information presented at the Comprehensive Assessment in 1990 on stock structure was based on biological samples collected during commercial whaling operations. Because of the nature of this fishery, these samples tended to be from animals distributed along the pack ice edge and were not evenly distributed within Areas IV and V. In contrast, during JARPA 2,887 minke whales were systematically collected from between 1987/88 and 1995/96, where survey effort was evenly distributed within the study area.

As noted previously, the objectives of JARPA relative to stock identification included both genetic and non-genetic techniques. The following types of samples were reported to have been collected as part of JARPA (sample size is in parentheses):

(1) liver, heart, muscle, kidney, and skin tissues for genetic analysis (2,887);
(2) standard length plus 19 additional body measurements for morphometric analysis (2,887);
(3) photographs of dorsal surface, dorsal fin and flippers for morphological studies (2,887);
(4) internal and external parasites (external parasites were collected from 962 different whales, internal parasites were collected from 154 different whales);
(5) muscle, liver, and kidney tissues for heavy metal analysis (1674);
(6) liver and skin samples for organochlorine analysis (1,788); and
(7) body length of foetuses over 10 cm in standard length (751) plus 19 additional body measurements (627).

Taylor asked whether an analysis to estimate the sample size necessary to detect significant mtDNA differences among putative stocks had been undertaken. Pastene responded that a simulation exercise had been conducted which indicated that a sample of at least 150-200 individuals using mtDNA (restriction fragment length polymorphism (RFLP) technique) was needed (Pastene *et al.*, 1996c; d).

3.3 Data analysis

3.3.1 Genetics

Genetic studies, based on mitochondrial DNA (mtDNA) were conducted to investigate the phylogenetic relationships between ordinary and dwarf forms of minke whale and the stock structure in the ordinary form of the minke whale. Two methods using mtDNA were employed to investigate phylogenetic relationships between ordinary and dwarf forms of minke whale: (1) RFLP of whole mtDNA and (2) sequencing of the mtDNA control region (Pastene *et al.*, 1996c). Both methods indicated a clear genetic differentiation between dwarf and ordinary forms. The sequencing analysis also indicated that the southern dwarf, southern ordinary, North Pacific and North Atlantic forms represent independent genetic populations. Further, based on genetic data the dwarf form was found to be more closely related to minke whales in the North Atlantic and North Pacific than to the ordinary form of the Southern Hemisphere minke whale.

All of the stock identity research using JARPA samples on the ordinary form of the minke whale has been done to date based on the analysis of mtDNA. The first study (see Pastene *et al.*, 1993a) was based on the analysis of samples from 318 whales from Areas IV and V. A total of 71 different haplotypes was reported, which were divided *a priori* into three geographical strata: (1) western (70°-110°E), (2) central (110°-150°E), and (3) eastern (150°E-180°). Stock structure was evaluated using chi-square statistics for heterogeneity on the observed haplotype frequencies. The resulting chi-square was significant and supported the alternate hypothesis that substructure was evident in Areas IV and V (i.e., the western and eastern strata likely contained minke whales that were genetically distinct, but where mixing of them occurred in the central stratum).

A second and third study (see Pastene *et al.*, 1993b; 1994) using JARPA samples considered both geographical and temporal factors. The results of both were consistent with the hypothesis that different stocks occurred in Areas IV and V, where the composition of animals from the two putative stocks changed both longitudinally and temporally during the feeding season.

A fourth study (Pastene *et al.*, 1996a; b) reported the results of an analysis of molecular variance (AMOVA). *A priori* strata were established using four longitudinal sectors (Area IV western and eastern and Area V western and eastern) and two time periods (December to 15 January, referred to as the early time period and 16 January – March, referred to as the late time period). Of 137 haplotypes identified, none were unique to any single geographic stratum. The AMOVA test results were significant, where the PHIst value (0.0090) obtained between Area IV-western, early and all other strata had a probability of 0.0025. Excluding stratum IV-western, early, none of the other contrasts among strata were statistically significant.

3.3.2 Morphometrics and morphology

There is no documented information on comparative morphological and morphometric analyses among dwarf and ordinary forms of the minke whale using JARPA samples. It was reported that a comparative study between both forms, involving body coloration, and morphometric and skeletal measurements, is underway.

With regard to the study on stock identity in the ordinary form, a single morphometric analysis was summarised in SC/M97/3, which was based on samples collected in Area IV in 1989/90. Following the analysis methods described in Pastene *et al.* (1994), the sample of morphometric measurements from 326 animals were grouped into three strata (Area IV western early, Area IV western late, and Area IV eastern early). A principal components analysis and an analysis of covariance were performed. The results indicated that differences among strata were significant. A canonical discriminant analysis revealed that the three strata were not separated exactly, but nonetheless whales from Area IV western, early stratum were found to be significantly different from whales found in the other strata.

3.3.3 Other

SC/M97/3 noted that there were only limited or preliminary results from the other non-genetic techniques used to evaluate stock structure in the ordinary form of minke whale in the Antarctic. Regarding ecological indicators, to date only data from 1988/89 on the species composition and incidence of parasites found associated with minke whales in Area V were available. Further, differences in mercury levels between animals collected in Areas IV and V were reported to have been not significant, although the sample size was limited (see SC/M97/20). Also, research regarding differences in the mean date of conception, while planned, has not been initiated. Finally, although about 60 Discovery tags were recovered from Areas IV and V during past commercial whaling operations, to date only two recoveries of Discovery tags have been reported during JARPA.

3.4 Synthesis

The authors of SC/M97/3 noted that they were not proposing new stock boundaries at this time, but that their results were consistent with the hypothesis that minke whales collected in the western part of Area IV early in the feeding season are a distinct stock from whales taken in strata further east or later in the feeding season. The authors summarised their primary conclusions based on their genetic analyses as follows:

(1) the Southern Hemisphere ordinary and dwarf forms are genetically different at least at the subspecies level;
(2) a high degree of genetic diversity (as measured by mtDNA) exists within the Antarctic ordinary form of the minke whale relative to the Antarctic dwarf form and minke whales from the North Pacific and North Atlantic;
(3) a high degree of genetic heterogeneity (as measured by mtDNA) exists with the ordinary form of the minke whale within Areas IV and V;
(4) the heterogeneity observed in Areas IV and V is attributable to both longitudinal and temporal components in distribution;
(5) the observed pattern of genetic heterogeneity is not consistent with current stock boundaries (i.e., Areas IV and V); and
(6) there are at least two distinct 'genetic stocks' in Areas IV and V.

The authors of SC/M97/3 further noted that the results of the one morphological study reported was consistent with the results of their genetic analyses and that additional research was planned regarding the use of ecological markers and differences in date of mean conception among putative stocks.

It was noted by all participants that the recent work by Pastene, Goto and others added considerably to our understanding of the taxonomy and stock structure of minke whales. Without question, the results reported by these authors at this meeting and at previous meetings of the Scientific Committee address the information needs for determining the stock structure of minke whales in the Southern Hemisphere.

There was also discussion as to what level of genetic distinctness was significant at the stock and species level. It was noted that general standards for species level differences have been established based on a comparative approach (i.e., the genetic distance between 'good' species in a taxon are typically used as the standard for putative species). Regarding stock structure, the answer is less clear. Several approaches were described, in which their application typically proceeds in a stepwise fashion: (1) are there genetic markers unique to a particular stock? and (2) if not, are there statistically significant differences in gene frequency?

Taylor (Annex G) commented that the number of members exchanged between populations exists on a continuum in nature. In statistical terms, the amount of difference one requires before designating a particular grouping of individuals into one stock or two is referred to as effect size. It is important that effect size be explicitly stated prior to undertaking research on stock structure, as it is not possible to determine the sample size necessary to reliably detect a specific effect size without specifying it. Taylor recommended that the Scientific Committee should develop criteria regarding the effect size required to designate two putative stocks as separate management units. She further recommended a particular approach to designating effect size, which uses the number of individuals dispersing per generation. Because the level of genetic distinctness is a function of both the dispersal rate and effective population size, it is not possible to designate a specific level of genetic distinctness that would be used in defining stock structure. It was further noted in Annex F that if Small Areas (in the RMP) are used to manage removal levels and where harvests are carried out such that their geographical distribution matches the distribution of the targeted stock, there is less risk that any one stock will be over harvested. The more uneven the harvest, the higher the risk that incorrect stock definitions could lead to over harvest of some stocks.

Several members responded that for the *Implementation Simulation Trials* for the RMP the key issue regarding stock identity was the number of breeding groups and not the number of or distribution on feeding areas. However, it was noted that the distribution and number of breeding groups for the ordinary form of the Antarctic minke whale were poorly understood. After some discussion, there was general agreement that additional samples were needed from the various breeding areas. In addition, effort should be directed at better integrating the RMP and currently available data on stock structure.

One final point was discussed regarding the ability of different genetic techniques to resolve questions related to stock structure. It was noted that only information on mtDNA had been used to date to investigate the stock structure of the ordinary form of the Antarctic minke whale, but that efforts were underway to use existing tissue samples to look for stock structure using nuclear markers. In general, the latter techniques are more efficient, given a specific sample size, in detecting substructure. Taylor also noted that discrepancies from the Hardy-Weinberg equilibrium could also be used to test for mixing between putative stocks, with data derived from nuclear DNA, but not from data derived from mtDNA.

It was also recognised that the statistical analysis of the genetic data should consider the inclusion of school size as a covariate because (1) schools of different sizes are not detected with equal probability and (2) of the schools encountered, animals from smaller schools are oversampled relative to animals from larger schools.

3.5 Potential of the results to achieve the objectives of JARPA and of stock management

Participants agreed that the following points listed in Annex D were pertinent to items A (objectives 1 and 4) and B1, B2.1, B2.4, B3.2 and B3.3. It was noted that research on stock structure is clearly related to objective 4 in Annex D, but is also important regarding the manner in which specific biological parameters are both estimated and interpreted.

There was general agreement that the data presented on stock structure, particularly the new genetic data, were important contributions to the objectives of JARPA and stock management. It was further noted that based on the new genetic information, at least some of the historic Management areas were inappropriate for stock definitions for minke whales in the Southern Hemisphere.

Two additional lines of research were also recommended. First, the development of more theory on use of genetic information for estimating mixing rates among putative stocks. Second, participants supported an earlier recommendation of the Scientific Committee that efforts should be undertaken to collect tissue samples from minke whales on breeding grounds in the Southern Hemisphere to allow contrasts regarding the distribution and frequency of specific haplotypes from the breeding and feeding grounds.

Regarding the RMP, the new genetic information indicated that there was a temporal component to the stock structure of the ordinary form of the Antarctic minke whale in Area IV, which was not recognised at the time of the Comprehensive Assessment. Implementation trials are designed to simulate plausible scenarios specific to the species under consideration for harvest. When multiple stocks are involved these trials use mixing matrices to represent the proportion of each stock present in each area being harvested. This is a factor that needs to be taken into account in the normal process of implementation review (IWC, 1994b). In the long term, genetic information could be used in implementing an improved version of the RMP.

It was also suggested, and agreed, that a protocol should be developed that specifies how such data (i.e., data on genetic relatedness of putative stocks from the breeding or feeding areas) would be used in either developing specific *Implementation Simulation Trials* or in the general management of commercial harvests.

In addition, it was noted that the information discussed here did not exclude the possibility that there are more than two genetically distinct stocks of this form of minke whale in Areas IV and V. Additional analyses, including for example the use of nuclear DNA, could reveal additional structure.

To avoid a repetition of past debates within the Scientific Committee regarding alternative methods to lethal removals, the Chair asked proponents of the two different viewpoints to summarise their views. These summaries are presented in Annex H.

4. BIOLOGICAL PARAMETER STUDIES

4.1 Background: original and additional research objectives

Estimation of biological parameters, especially natural mortality rates, was originally the main research objective of the JARPA, since knowledge of some of these parameters was at the time considered to be necessary for a rational management of whale stocks by many scientists.

Ohsumi presented a review of the studies on estimation of biological parameters (SC/M97/2) with a focus on natural mortality rates and age at sexual maturity, as these parameters has been the subject of many discussions and much disagreement in the Scientific Committee meetings. The review stressed the necessity of the biological studies, and presented and discussed interim results.

4.2 Methodology of data collection

SC/M97/14 outlined the random sampling scheme that has been incorporated in the JARPA programme and presented some analyses relating to whether such random sampling had been achieved. The sampling had targeted primary sightings only. From 1987/88 to 1991/92, sampling involved taking up to two whales from the targeted school, but from 1992/93 the protocol was to take one whale from each school, subject to a time limit for chasing. Sampling success from the targeted school was 0.52–0.75 for the scheme of taking up to two whales from a school, but increased to 0.8 or more after implementation of the change to a maximum of one whale. In order to compare the first and second sampled whales in the initial scheme in terms of their biological characteristics, the authors examined differences in body length, sex and sexual status as a fraction of school size, but no significant differences were found. In addition, yearly variation in body length frequencies by sampling stratum and school size was examined and again no significant differences were detected. The authors therefore considered that no substantial differences in the samples taken from schools of size 2 and above had resulted from the change in sampling scheme.

Schweder pointed out that the sampling method resulted in over-sampling from small schools. On the other hand, large schools are easier to detect. He asked if there had been attempts to estimate the resulting sampling selectivity. Fujise answered that they had not yet been able to fully address the problem, but that they tried to control for the selectivity by post-stratification. He explained that the sampling scheme is a two stage process, with random sampling of schools, and then random sampling of one animal from each sampled school.

Schweder also commented that another source of sampling bias results from the aspects of the survey and sampling methodology discussed in Section 2.2. The problem is that, although the protocol induces under-surveying in areas of high whale density, it will result in over-sampling where density is high. To estimate the size of this selectivity towards whales in high density areas, a point process model of the Neyman-Scott type could be estimated, and post stratification could possibly be used to correct for this selectivity.

Kato briefly explained the age reading process currently adopted. Both earplugs were removed from external auditory meatus during the flensing and were preserved in a 10% formalin solution. The age reading was initially done on the left earplug, but if that earplug was broken, the right plug was used. The earplugs were cut longitudinally and their surfaces were polished with wet-stone. Age-reading was conducted by counting growth layers composed of dark and pale laminae using a stereoscopic microscope under reflected light. For interpretation of age and the layer, the annual deposition rate of growth layers indicated by Best (1984), Lockyer (1984) and Kato (1986) was assumed. The transition phase is determined (if this layer is recognised) during process of counting growth layers from the neo-natal layer to the germinal layer. The counting is usually repeated three times independently under the guidance of statistician. If two or more of the numbers agree, this number is automatically accepted as the animal's age. If all three counts disagree, the median is used for the age. Following the recommendation at the 1984 Minke Whale Ageing Workshop, intra- and inter-reader variation in the counting were sometimes examined, and the results have been incorporated in some major analyses. Regarding age-reading for earplugs collected under the JARPA programme, counts for the earplugs for 1987/88-89/90 and 1992/93 were made mainly by Kato, and by Zenitani for 1990/91, 1991/92 and 1993/94-95/96.

4.3 Data analysis and results

4.3.1 Catch-at-age data

Three papers were presented.

SC/M97/6 presented an extension of methods previously presented to the Scientific Committee (Butterworth and Punt, 1996; Butterworth *et al.*, 1996) for the joint analysis of catch-at-age and abundance data. The extension involved taking account of assumed separability of the fishing mortality matrix for the ages of 16 and above in the commercial catch. The method was applied to catch-at-age (both commercial and JARPA) and sightings survey (both IDCR and JARPA) data for both Areas IV and V, with extensive sensitivity tests for the Area IV application also presented. The Area IV analysis provided an estimate for (age-independent) natural mortality (M) of 0.057 yr^{-1}, and of the trend in recruitment over the 1947-68 period showing an increase of 5.5 % yr^{-1} (90% confidence interval [1.4 %; 9.1%]). The positivity of the estimate and its associated confidence interval was robust under the sensitivity testing conducted. A number of possible reasons were advanced for the marked drop in recruitment from 1970 to the mid-1980s evident in the results, including super-compensation as the population reached its new larger carrying capacity following earlier depletion of competitors (e.g. blue whales). The results were also used as a basis to evaluate the level of the accuracy to be expected in estimates of M and other quantities for Area IV by 2001/2.

SC/M97/11 presented an interim result for the estimation of the natural mortality rate by the method originally proposed by S. Tanaka (1990) using the JARPA age data. The paper used the estimated age composition of these data taking account of whale abundance, selectivity and ageing error. Resultant estimates of average natural mortality rate by the four models ranged from 0.0165 (SE = 0.13) to 0.167 (SE = 0.116) while the estimate of additional variation for the abundance surveys was negligibly small. The authors concluded that it is necessary to repeat the survey at least nine times to attain an SE of 0.02 for the estimate.

SC/M97/21 analysed the age data obtained from JARPA expeditions 1987/88 through 1995/96 in two stages. First, the ages were grouped into three broad categories (under 10; 10-19; and 20+ yrs). The dependence of the proportions in the three groups on various covariates was examined by logistic regression analysis. The analyses found that the proportion of young (under 10 yr) animals was related to latitude and school size, and further that this dependence varied from year to year. Amongst 10+ animals, the proportion of older (20 +) animals was not related to any of the factors examined, although it did show a trend with time. It was concluded that the 10+ samples may represent a random sample of the population of 10+ animals. An analysis was then conducted of the matrix of samples by age and year for age groups 10-30. Since the recruitment and mortality cannot be estimated separately each year, it was assumed that these vary smoothly by year and can thus be approximated by their Taylor expansions. The data supported estimation of terms up to the third order. It is not possible to estimate recruitment and mortality separately, because each term in the expansion involves pairs of aliassed parameters: mortality is aliassed with the rate of change (first derivative) of recruitment, the first derivative of mortality is aliassed with the second derivative of recruitment, etc. Nevertheless linear combinations can be estimated and some example results were shown.

There was considerable discussion of the implications of the results of papers SC/M97/6 and SC/M97/21. In this discussion two opposing views crystallised as follows.

It was noted that analyses of age and abundance of data do not yield unique results because of the aliassing of parameters. SC/M97/21 makes this aliassing explicit. In SC/M97/6, choices have been made about which parameters to fix, yielding estimates of remaining parameters but other choices would have been equally justifiable. For example, virtual absence of pre-1947 cohorts in the Area V data is accounted for in SC/M97/6 by supposing a very small minke whale population in this Area at that time, whereas an equally plausible explanation is that pre-1947 cohorts have not survived to the present.

In response to a question as to whether there was evidence that mortality had changed, it was noted that there is no evidence in the data that mortality is definitely changing, but there is evidence that certain linear combinations of recruitment and mortality have been changing - the JARPA data are not consistent with a constant age distribution.

Additionally, estimates of trends in recruitment are sensitive to estimates of natural mortality and selectivity. It was noted that these factors interact in the estimation of recruitment trends. Therefore, constraints imposed by the functional forms used when estimating factors from the data may affect the estimates of recruitment trend. In particular, it was suggested that the mortality function used should be based on the competing risk model (Siler, 1979) which has been shown to provide a good fit to age dependent mortality for a wide range of mammalian species. This model has only five parameters and should not be too difficult to fit. It was also noted that the current estimates fail to make allowance for the estimation of a correction factor for the bias in the JARPA surveys and that this would reduce their contribution to the estimates of recruitment trends. The meeting was reminded of the possibilities for non-linearity in JARPA estimates of abundance outlined earlier. It was suggested that future analyses should be based on correcting the JARPA estimates so that they could be used as absolute abundance estimates.

In response to comments above about the results for Area V in SC/M97/6, it was pointed out that the paper already stated that the low recruitment estimates for 1947 were an artefact of the anomalously small single sample (of size 3 animals in 1974) from that cohort available to the analysis. That particular estimate would therefore have a very high variance and was clearly unreliable. The argument of an equally plausible explanation for the poor representation of cohorts from this period in the catch-at-age data was already shown in SC/M97/6 (table 11 and fig. 6) to lead to trends in recent levels of total abundance scarcely compatible with sighting survey estimates.

It was added that the approach and assumptions of SC/M97/6 were in line with the norm for assessments of catch-at-age and abundance data used worldwide by the scientific committees of international fisheries commissions to provide a basis for their advice on the management of fish populations. Research by ICES scientists during the 1980s had shown that essentially three degrees of freedom remain in the analysis of catch-at-age data despite the fact that assumptions of a constant M and separability of the fishing mortality matrix render the problem deterministically overdetermined (see, for example, Butterworth and Punt, 1990). In this minke whale case, information on two of these is provided by data on absolute population size and trend from sighting surveys. The third involves the trend in age-specific selectivity over some part of the age range. SC/M97/6 takes this to be flat for large ages in the scientific catch on the basis of the intended random nature of the sample and likelihood ratio tests; furthermore SC/M97/21 finds no evidence for heterogeneity for samples of whales above age 10 in this catch. Regarding the possibility of time dependence of M, clearly random variability occurs and would increase estimates of standard error, but hardly seems likely to bias estimates of trends in recruitment. Certainly systematic trends in time in M could bias the estimates of trends in recruitment reported SC/M97/6. However plausible supporting hypotheses, rather than speculation alone, have sensibly to be offered to motivate alternatives to the assumption of an absence of systematic temporal trends in M. One such possibility is density-dependence in M; the consequences of this merit investigation, but such a mechanism would by no means necessarily render past recruitment trends indeterminate.

The meeting was cautioned against drawing a too strong analogy between fish and whale stocks as had been done in SC/M97/6. Most fish stocks were subject to substantial year-to-year fluctuations in recruitment, which had to be taken into account since mortality and recruitment rates are aliassed in the data. This focus on recruitment necessitates the assumption of a constant M. In the case of minke whales, pregnancy rates seem to be high and fairly constant. In this case, the rationale for assuming that all the variation occurs in recruitment and none in M is less compelling. One way forward would be to examine the implications for stock recruitment relationships of alternative interpretations of the data.

In response to the points reported above, it was stated that the analyses of SC/M97/6 could readily be repeated making use of a Siler function for natural mortality, but that the parabolic form already used in robustness test constituted a reasonable approximation to that form, and that key results in SC/M97/6 had already been shown to be relatively insensitive to changing the dependence of natural mortality on age from constancy to a parabola (see table 6 of that paper). Furthermore, while adjusting the JARPA estimates of abundance used in SC/M97/6 for the higher-density-under-surveying bias would increase their variance and therefore the standard errors of the results of SC/M97/6, it should also be noted that:

(i) the JARPA abundance estimate variances used in SC/M97/6 were taken from SC/M97/1, and are probably positively biased as a result of over-stratification (see Section 2.4); and
(ii) the key results of SC/M97/6 had been shown to be robust to the incorporation of additional variation of 10% CV in abundance estimates (confidence intervals widened only slightly - see table 9 of that paper).

Schweder expressed his opinion that SC/M97/6 was a surprisingly successful analysis. The meeting felt that there was merit in pursuing the approaches of SC/M97/6 and SC/M97/21 further, but that estimates from the application of such methods could not be considered reliable until difficulties associated with the estimates of abundance from JARPA (see Section 2.4) had been resolved.

4.3.2 Transition phase data

SC/M97/7 presented the results of attempting to fit two different models to the transition phase data for the commercial and some scientific catch data for Area IV. The first model based on the assumption that the transition phase is an artefact, related only to the total age indicated by the earplug, provided a poor fit to the data, manifesting clear systematic trends in residuals. The second model, which assumed the transition phase to be a real signal manifesting a possible trend in time, and made allowance for biases introduced by the transition and fringe effects (the latter reflecting the difficulty of identifying a transition of phase only a few layers from the edge of the plug), provided a much better fit to the data. It indicated a drop in the mean age at the transition phase from 11 years for the 1950 cohort to 7 years for the 1970 cohort. The models both incorporated the effects of the 'learning' evidence in the data that the readers (primarily Masaki and Kato) had tended to identify an increasing proportion of plugs as having transition phases as time progressed.

SC/M97/22 examined maturity stage and transition phase data from JARPA samples in Area IV. The maturity stage data showed that the age-specific maturity rate is dependent on school size and hence that stratification by school abundance is needed to obtain an unbiased estimate of the age at maturity. The data show an apparent male age at sexual maturity three years lower than the female age at maturity. Analyses of the age-specific sex ratio revealed this difference to be mainly real and subject only to a small bias. The transition phase data were analysed for evidence of age-related bias. Evidence of bias was found only for animals aged less than 15 years. The mean age at transition phase was estimated to have declined by 1.86yr (SE 0.23yr) from the 1950 cohort reaching 8.08yr (SE 0.13) in 1970. Subsequent trends, if any, are still unclear. There was no difference between males and females.

The discussion focused on possible spurious relationships introduced in the time series by reader - related effects, and on the difference between results obtained by the two studies. De la Mare pointed out that effects of learning seems to be important for the result. He pointed especially to figs 2 and 3 of SC/M97/7 which indicate that part of the decline in the average age at maturity prior to 1978 and after 1978 could be related to the parallel increase in the proportion of mature animals identified by Masaki and Kato, respectively.

The two studies had used different, but overlapping, data sets. Both analyses were restricted to Area IV, but the analysis of SC/M97/7 was based on data from commercial whaling and from the first two JARPA expeditions in Area IV. The analysis of SC/M97/22 used only JARPA data, and from all five expeditions to Area IV.

Both analyses showed decline in age at transition phase, but, for the same period of cohorts, 1950-70, the analysis of SC/M97/7 indicated a decline in age at transition phase roughly the double that estimated in SC/M97/22.

It was noted that, for the cohorts around 1950, the commercial data gave many transition ages much higher than the maximum observed in the JARPA data. The difference did not appear to be due to age-related effects, since SC/M97/22 found evidence for such effects only in ages up to fifteen. He believed it was important to identify and resolve the source of the difference between the two datasets, and until this was done it would be premature to attempt to provide a final estimate of the extent of decline in the true mean age at transition phase. He outlined three possible steps in this process:

(1) to reanalyse both data sets to better describe the differences;
(2) if this did not resolve them, to re-read a sample of the older material in order to check whether the difference could be due to reading differences; and
(3) if this revealed that reading differences could not account for the differences, possible biological hypotheses would need to be formulated and explored as to why the later data give different results for the same cohorts.

The Working Group was referred to a paper by Kato and Sakuramoto (1991), that reviewed past analyses and discussion on the transition phase issue. This study indicated that the mean ages at sexual maturity estimated by the transition phase in the earplug core did not conflict with those estimates obtained directly, e.g. the mean age of first ovulation - and which are relatively free from the biases associated with transition phase estimates. Results in Kato (1987) indicated that in both sexes, the length at a given age in younger cohorts was greater than that of older cohorts. This suggests increasing growth rate by cohort and would be expected to lead to a decline in the *age* at sexual maturity by cohort, because the *length* at sexual maturity has remained constant over time and hence cohort. It was observed that both sets of evidence independently support the contention that the age at sexual maturity of Southern Hemisphere minke whales did decline before exploitation of this population commenced.

The Working Group agreed that it was important to resolve the differences between the two transition phase studies, but it also agreed that the transition phase observations could not be explained as an age related effect alone. A number of participants considered that the evidence overall was sufficient to conclude that there had been a real decline in age at maturity over the cohorts studied. The Working Group noted the following statement from the Report of the Comprehensive Assessment Special Meeting on North Atlantic Fin Whales (IWC, 1992):

> 'The Committee agreed that fig. 7a of SC/F91/F19 showed that hypotheses suggested previously that trends in age at sexual maturity indicated by transition phase data were entirely an age-related effect could not be valid in this particular case' (i.e. of North Atlantic fin whales).

4.3.3 Reproductive data

SC/M97/12 examined biological parameters other than the natural mortality rate such as the sexual maturity rate, apparent pregnancy rate, length and age at sexual maturity, annual ovulation rate and growth curves based on the data collected during JARPA from 1987/88 to 1995/96. It concluded that by introducing the random sampling scheme and achieving wider areal coverage in the JARPA surveys, the resultant estimates were much improved from those by data obtained from past commercial whaling. The authors also drew attention to the following three points:

(1) ages at 50% of sexual maturity for both sexes, which are biased downward in the commercial whaling data, are higher than those in the commercial whaling (the values are 4.2 in Area IV, 4.9 in Area V and 7.2 in Area IV, 8.4 in Area V for males and females respectively);
(2) the ages at 50% sexual maturity for females are very close to the mean age at first ovulation (7.2 in Area IV, 9.1 in Area V) which are free from segregation bias; and
(3) growth curves for both sexes had for the first time been obtained on a reliable basis by incorporating data on younger age classes - such data are usually very rare in samples from commercial whaling.

The authors considered that the above estimates could be regarded as representative values for the population (or very close to such).

It was enquired whether part of the differences between Areas could possibly be explained by differences between the two stocks identified in the genetic investigations. The suggestion was made that discriminant analysis could be used to assign individual animals to each of the two stocks, and then determine the extent to which the available genetic data are consistent with that *a priori* grouping.

It was noted that the ovulation rate is estimated to be just over one, but with great individual variation. Pregnancy rate is very high. The question was asked whether it is possible that corpora scars disappear over time. The meeting was reminded that age-ovulation plots are markedly affected by cohort specific changes in the age at sexual maturity. This and other age specific effects might be confounded in the given age-ovulation plots presented, so that some caution would be necessary in attempting to infer annual ovulation rates from such plots. Most analyses assumed that corpora albicans persist in ovaries throughout life. It was pointed out that part of the apparent inconsistency could be explained by the uncertainty in the ageing.

Fukui *et al.* (1997) examined factors affecting *in vitro* maturation of minke whale follicular oocytes using materials collected during the JARPA survey in 1995/96. The interesting result in the context of the JARPA review is that some female minke whales have mature oocytes in their ovaries in the Antarctic waters.

4.3.4 Other and *4.3.5 Results including mortality and reproductive rates*

SC/M97/13 presented additional analyses to an earlier paper by the same authors on the nature of segregation (Fujise and Kishino, 1994). It was found that the proportion of males was negatively correlated with the latitude of the sighting position, and decreased with latitude especially in Area V. The maturity rate for both sexes was high throughout all Areas and months, and increased with school size. Mature females dominated in higher latitudes such as Prydz Bay and the Ross Sea. Yearly variation in the maturity rate was evident for both sexes in Area V.

4.5 Potential of the results to achieve the objectives of JARPA and of stock management

A. JARPA objectives

The Working Group agreed that the papers presented have given valuable information on recruitment, natural mortality, decline in age at sexual maturity and reproductive parameters of minke whales in Areas IV and V. However, there are some unresolved problems in the analyses, and further work is necessary.

One of the specific objectives of the programme was to collect random samples for the estimation of biological parameters. The results had demonstrated that this was a more difficult task than had been envisaged. Despite the considerable attention given to the sampling scheme, it has not been completely successful at obtaining random samples. The meeting further noted that the geographical delimitation of the sampling areas has not resulted in either distinct biological populations being sampled or the entire ranges of the population being sampled. The implications of this for the representativeness of the sample should be given further consideration. However it was noted that the VPA analyses (as, for example, SC/M97/6) required representative sampling over only part of the range of ages in the population. There were no indications that this had not been achieved for animals of age 10 and above. The meeting also considered that the results of the genetic studies should be used to redefine the geographical boundaries for any future analysis.

The Working Group noted that there was still uncertainty whether information that fully represents a biological stock could be obtained, but considered that much progress had been made towards that end. Before JARPA was initiated, whales occurring in Area IV and Area V were managed as different stocks, but a clearer picture about the biological stocks in these Areas was now emerging. Although the present state of knowledge still leaves much to be desired, considerable data reflecting the status of the whale stocks occurring in Areas IV and V have been collected, and have produced many valuable results.

B.1 Non-lethal methods

The Working Group noted that there were non-lethal methods available that could provide information about population age structure (e.g. natural marking) but that logistics and the abundance of minke populations in Areas IV and V probably precluded their successful application.

B.2 Relevance to stock management

In 1993, the Scientific Committee proposed mechanisms for amendment of the RMP (IWC, 1994a: 47-48). The Scientific Committee distinguished between mechanisms for the amendment of case-specific implementations and mechanisms for amendment of the RMP itself. The Working Group discussed the relevance of a better knowledge of biological parameters to management objectives in this context, i.e. it distinguished between short-term improvements, which would be amendments of the case specific implementations, and long-term improvements which could imply more fundamental changes to the RMP itself.

In the short term perspective the three key considerations identified were:

(1) changes in the definition of *Small Areas*;
(2) changes to the selection between RMP options such as *catch-capping* and *catch-cascading*; and
(3) changes in the range of plausible MSYRs to use in *Implementation Simulation Trials*.

In the longer term perspective, better knowledge of biological parameters could lead to modifications of the *CLA* in the RMP.

SC/M97/2 states that knowledge of M would improve knowledge of MSYR and MSYL. The question was raised as to whether MSYR and MSYL can be estimated from the biological data collected. The meeting noted that the recruitment data from analyses such as those in SC/M97/6 could be fitted by stock recruitment models to provide estimates of MSYR once reliable input data are available. Trends in recruitment from SC/M97/6 and SC/M97/21 could be used directly when conditioning future *Implementation Simulation Trials* for Southern Hemisphere minke whales. It was agreed that if the caveats expressed concerning abundance estimates from JARPA could be resolved, and with some further methodological development in estimating the essential biological parameters, the results from the JARPA could be directly relevant for management, both in the short term and the long term.

5. MARINE ECOSYSTEM

5.1 Background: original and additional research objectives

The second of the two original JARPA objectives was:

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

In the 1996/97 research plan this 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.

A review of the studies undertaken under JARPA related to this objective was presented by Ichii (SC/M97/4).

5.2 Methodology of data collection

Data on the feeding ecology of minke whales is obtained from the weight and species composition of stomach contents of the sampled whales. The whole body mass of each whale is measured using a weighing platform. Body length, girth and blubber thickness is also measured. Information on sex, age and reproductive status has been used in the feeding ecology analyses, as well as whale densities obtained from the sightings surveys. Other information on the physical marine environment is obtained using expendable bathy-thermographs (XBTs) and from satellite information on sea-ice distribution.

5.3 Data analysis

An index of body fat condition has been calculated as the ratio of mean girth to body length. This information has been analysed by reproductive class and month and correlated with stomach contents mass, geographic location and sea-ice extent (SC/M97/16).

Data analyses of feeding rates (SC/M97/17) have used three methods:

(1) direct estimation of the stomach contents mass by time of day;
(2) energetic methods using standard allometric relationships to calculate metabolic requirements, and using the energy density of prey;
(3) and by estimating the body mass increase of whales during the summer feeding period and calculating the food required to achieve the mass increase.

An alternative form of body fat condition index was calculated as the ratio of the whole body mass to the cube of the whale's length (SC/M97/18). This was analysed by reproductive status, latitude and season, as well as for yearly change. A time series of blubber thickness data from both commercial and JARPA data have been analysed.

5.4 Results

Interannual changes in body fat condition stomach contents and distribution are described in SC/M97/16. Of the six years included in the study, two were categorised as years of poor body fat condition and three as years of good condition. Estimated body weight gain during the feeding season in poor years was estimated to be 25% lower than in good years. The relationship between girth and stomach content mass in the ice-edge zone suggests that girth can be a useful indicator of food availability. In Area IV and the northern part of Area V, krill (*Euphausia superba*) was the dominant prey species, but in the Southern part of the Ross Sea (in Area V), *Euphausia crystallorophias* was the dominant prey species. Distribution of minke whales showed greater inter-annual variability in Area V than in Area IV, reflecting a greater degree of variability in sea-ice extent in Area V. In Area V, in years of high sea-ice extent, the krill rich slope region of the western part of the area is covered by ice. This leads to poor food availability and results in a very low density of minke whales along the ice-edge. The Ross Sea zone was an area of low food availability throughout the study period. Paradoxically, this zone always contained numerous whales, especially pregnant females.

Estimates of daily and annual krill consumption by minke whales are given in SC/M97/17. Daily food consumption estimates ranged from 3 to 4% of body mass. The annual consumption estimates of prey for Area IV ranged from 1.42 to 1.78 million tonnes. For Area V, the range was 5.98 to 7.49 million tonnes. The value for Area IV is roughly 25% of the total estimate of krill biomass in the area. Consumption of krill by minke whales in Area V was an order of magnitude greater than that estimated for Adelie penguins and crabeater seals. These results indicate the importance of minke whales in the ecosystem in Areas IV and V during the summer feeding period.

Yearly changes in a fatness index were presented in SC/M97/18. No difference was found in this index between the sexes. From seasonal changes in the index and from its distribution by foetus size it was suggested that some whales over-winter in Antarctica and that others arrive on the feeding grounds late in the season. Analyses from earlier commercial catches and from the JARPA samples show a gradual decline in blubber thickness since 1978/79.

5.5 Potential of the results to achieve the objectives of JARPA and of stock management

The Working Group agreed that the following points listed in Annex D were pertinent to items A2, B1, B2.3, B2.5, B3.4.

In discussions of the results of SC/M97/16, it was suggested that there would be a correlation between variations in body condition and subsequent recruitment. Short-term variability in recruitment can be estimated from age data, even when there is uncertainty about long-term trends in recruitment from age based analyses. Variations could also be used to seek relationships between whale population dynamics and physical environmental factors such as the sea-ice extent. However, errors in age determination may hinder the resolution of recruitment variability at time scales of less than 2 to 3 years.

The Working Group noted the striking similarity in the results obtained from the three methods for estimating daily food consumption reported in SC/M97/17. It was agreed that these estimates could be used with confidence for the estimation of total food consumption by Antarctic minke whales.

The Working Group considered that the body condition index presented in SC/M97/18 required further refinement. In particular it was suggested that a power less than three should be used for the length exponent in the index, and that this could be estimated by regression. Other aspects of the analyses presented also needed further consideration. It was suggested that multiple regression should be used to correct for the effects of time of season when examining the relationship between the index and other variables such as latitude. It was noted that the index was highly variable, and that this might be reduced by including an additional term to account for individual variation in body shape, and hence better show the effects due to condition factor. The Working Group was not convinced that the analyses could be used to infer that some whales over-winter in high latitudes and that others arrive late in the feeding season. The high degree variability in the index may arise from feeding outside the Antarctic, and in any case, patchiness in prey distribution will lead to a high degree of variability in feeding success even among individuals on the feeding grounds.

The Working Group agreed that the studies being undertaken were contributing to the objective of the 'elucidation of the role of whales in the marine ecosystem through whale feeding ecology'. However, it was suggested that elucidating the role of whales in the marine ecosystem also 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. Such studies should be conducted on a smaller scale, possibly obtained from radio tagging, than that covered by JARPA, perhaps of the order of ten to one hundred kilometres. A number of smaller scale study regions may be required. It was considered that such studies should be set up to examine specific hypotheses about ecological interactions. The Working Group agreed that the JARPA studies provided useful information for both the formulation of such hypotheses and for the selection of study areas. The marginal sea-ice zone is an obvious candidate for process oriented studies. The Working Group noted that such studies would be of interest to CCAMLR and Southern Ocean GLOBEC.

The Working Group noted the reported decrease in blubber thickness since the late 1970s and it was suggested that, among other 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.

6. ENVIRONMENTAL CHANGE

6.1 Background: original and additional research objectives

The 1995/96 research plan added the following objective:

Elucidation of the effect of environmental changes on cetaceans.

The objective was added in response to resolutions adopted by the Commission on research on the environment and whale stocks (IWC Resolution 1994/13) and on the promotion of research on the conservation of large baleen whales (IWC Resolution 1994/12). This objective is also related to the resolution on research on the environment and whale stocks (IWC Resolution 1995/10).

A review of studies undertaken under JARPA related to this objective was presented by Fujise (SC/M97/5).

6.2 Methodology of data collection

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 the data collected as described in Section 5.2, data have been collected on marine debris and body burdens of pollutants, including organochlorines and heavy metals. Tissue samples, including liver, muscle, kidney and blubber have been collected for these analyses. Marine debris observations 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.

6.3 Data analysis

Data analyses on pollutants are reported in SC/M97/5 and SC/M97/20. Trends in blubber thickness reported in SC/M97/18 may be used for studies on climate change.

6.4 Results

The atmospheric and sea-water concentrations of organochlorines such as PCBs in the Southern Hemisphere were lower than in the Northern Hemisphere. Five organochlorine compounds (PCB, DDT, HCB, CHL and HCH) have been detected in blubber of Southern Hemisphere minke whales. The concentrations of these compounds are much lower than in baleen whales from the Northern Hemisphere except for HCB. Levels of DDT showed no yearly variation, but an increasing trend in PCB levels was detected in the period 1984 to 1993. This implies the continuing discharge of PCBs into the Southern Hemisphere.

Analyses of hepatic mercury concentrations were grouped by sex, geographical position and by time within season. Hepatic mercury levels are highly correlated with mercury concentrations within muscle. Hepatic mercury concentration can thus be used as an indicator of whole body mercury burden. No significant differences were observed between sexes, between geographical positions or between periods within the summer season. In the 1980/81 and 1981/82 summer seasons, no correlation was observed between hepatic mercury concentration and age. However, in 1994/95 hepatic mercury concentrations increased with age. It is inferred that an increasing trend in mercury intake is a consequence of an increase in food availability. Changing hepatic mercury concentrations with age could not be due to changes in the mercury content of krill, because analyses of mercury levels in krill showed no evidence of change.

Hepatic mercury concentration in the younger animals seems to have decreased in the last decade. This suggests that the increased mercury intake had begun to decrease in that decade. This is supported by the results of analyses of blubber thickness and condition indices in minke whales.

6.5 Results and their potential in the context of the objectives of JARPA and of stock management

It was noted that organochlorine concentrations in blubber are strongly influenced by seasonal variation. Analyses should therefore include a correction for the effects of increasing blubber thickness during the season.

The Working Group referred to the recommendations of the Bergen Workshop on Chemical Pollution and Cetaceans (Reijnders *et al.*, 1999). It was noted that pollutant levels in the Antarctic were very low, and monitoring Antarctic minke whales would provide a baseline for biological parameters or physiological 'normality', as called for in recommendation 1 of the Bergen Workshop. The Working Group also noted recommendation 4 that *'temporal and spatial trends in the concentrations of pollutants should continue to be sought from different species and geographical regions'*, and recommendation 5 that *'all available data on each specimen from which material has been taken for pollutant analysis should be properly documented; at least sex, age and nutritional status should be collected wherever possible'*.

The Working Group considered that the pollutant studies under JARPA were pertinent to these recommendations.

One of the currently contentious issues in Antarctic research is the relative weight to give to the competing hypotheses that changes in abundance of Antarctic predators are due to either 'krill surplus' or due to the effects of environmental change. The Working Group recognised that distinguishing between these hypotheses will be difficult. In the meantime, the observations on changes in blubber thickness and variations in recruitment should be used to formulate specific hypotheses on the possible effects on cetaceans of environmental change, for use in constructing scenarios for further RMP implementation trials for Southern Hemisphere baleen whales.

7. OVERVIEW OF RESULTS AND THEIR POTENTIAL IN THE CONTEXT OF THE STATED AIMS AND OBJECTIVES OF THE JARPA PROGRAMME AND OF STOCK MANAGEMENT

7.1 Contribution to minke whale management

Several main points were agreed to regarding the contribution of JARPA to minke whale management in the Antarctic.

First, under the objective of estimating biological parameters the information produced by JARPA has set the stage for answering many questions about long term population changes regarding minke whales in Antarctic Areas IV and V. Not surprisingly, at this halfway point in the JARPA programme there are few definitive answers because of the time scale required to obtain sufficient age distribution and abundance data, and because of unanticipated problems in designing representative sampling regimes and in understanding the stock structure of minke whales in the Southern Hemisphere. For example, JARPA has already made a major contribution to understanding of certain biological parameters (e.g., direct measures of the age at sexual maturity) pertaining to minke whales in Areas IV and V, yet such analyses have not fully addressed potential problems related to stock structure.

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

Third, under the objective of 'Elucidation of the effect of environmental change on cetaceans', there is considerable uncertainty in how biological parameters of minke whales may vary in relation to environmental change. This is exacerbated by our lack of knowledge regarding processes related to environmental change (e.g., interdecadal signals, global warming, etc.). For example, long term trends related to the annual positioning of the extent of the pack ice during the feeding season have implications regarding the interpretation of trends in various biological parameters. Therefore, more effort is needed to develop mesoscale studies to integrate physical and biological oceanography and prey distribution with minke whale studies.

Fourth, under the objective of 'Elucidation of the stock structure of minke whales to improve stock management', deciding on the amount of genetic data required to meet this objective is difficult because the Scientific Committee has provided only a vague definition as to what constitutes a stock. Proper delineation of stocks has implications for interpretations of data gathered for all other JARPA objectives.

Finally, the results of the JARPA programme, while not required for management under the RMP, have the potential to improve the 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 the depletion risk above the level indicated by the existing *Implementation Simulation Trials* of the RMP for these minke whales.

7.2 Implications regarding future work

Constraints on the amount of time available precluded a thorough review of this section of the agenda. However, consensus was reached on the following points regarding the future of JARPA over the next eight years.

Future efforts should expand research on the environmental change component of JARPA.

The lack of a working definition of stocks and substocks is a general problem, not for JARPA alone, and therefore, needs to be addressed by the Scientific Committee.

8. OVERVIEW OF RESULTS AND THEIR POTENTIAL IN THE CONTEXT OF RECENT IWC RESOLUTIONS AND DISCUSSIONS

8.1 With respect to Resolutions on proposals for Scientific Permits (IWC Resolutions 1995-8 and 9, IWC, 1996b).

8.2 With respect to the Resolution on the Antarctic marine ecosystem (Appendix 2, IWC, 1993).

8.3 With respect to the Resolution on the environmental change and cetacean response (IWC Resolution 1995-10, IWC, 1996a; IWC Resolution 1996-8).

There was no time to discus these items. They are forwarded to the full Committee for consideration.

9. OTHER MATTERS

Ohsumi stated that since the initiation of the JARPA, Japan has encouraged international scientists to participate in this research. For this meeting, Borchers, Burt, Butterworth, Cooke, Geromont, Leaper, Punt and Thomson have contributed to the analysis of JARPA data with Japanese scientists. In the future, these effects should be expanded, including co-operative work in the field. He hoped that over the next eight years JARPA would become recognised as an international programme by the IWC community and evolve into collaborative international research like the IDCR programme.

The Working Group expressed appreciation for the two non-minke whale papers submitted (SC/M97/15 and 17), and regretted that time had not allowed discussion of them.

Komatsu expressed appreciation of the indulgence and co-operation of the Chair and participants to allow the consecutive and summary translation from English to facilitate the better understanding and mutual communications of the meeting.

10. ADOPTION OF REPORT

The report was adopted.

11. CLOSURE

Reilly expressed his appreciation to the Working Group for the spirit of cooperation and the scientific approach taken by all to the difficult task of reviewing results to date of the JARPA programme.

Hatanaka thanked the Chairman for successfully leading a difficult meeting. He also acknowledged the hard work of the rapporteurs, and thanked Schweder for his outstanding work as Convenor.

On behalf of the Working Group, Smith thanked the hosts for their hospitality, and for the well-organised meeting arrangements.

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Annex A
List of Participants

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* Attended for Agenda Item 1 only.
I = Interpreter.

Annex B
Agenda

1. Introduction
    - 1.1 Welcome and introduction
    - 1.2 Election of chairman and rapporteurs
    - 1.3 Adoption of Agenda
    - 1.4 Documents available
    - 1.5 Terms of reference for JARPA review (*Rep. int. Whal. Commn* 46:224)
    - 1.6 The original research proposal and later additions
    - 1.7 General outline of the JARPA research
    - 1.8 Overview of past discussions of the JARPA program and its results
2. Sighting surveys and abundance estimation
    - 2.1 Background: original and additional research objectives
    - 2.2 Methodology and data collection
    - 2.3 Methods of analysis
    - 2.4 Estimates of abundance and trends
    - 2.5 Initial discussion of results and their potential in the context of the objectives of JARPA and of stock management
3. Stock structure
    - 3.1 Background: original and additional research objectives
    - 3.2 Methodology of data collection
    - 3.3 Data analysis
        - 3.3.1 Genetics
        - 3.3.2 Morphometrics and morphology
        - 3.3.3 Other
    - 3.4 Synthesis
    - 3.5 Initial discussion of results and their potential in the context of the objectives of JARPA and of stock management
4. Biological parameter studies
    - 4.1 Background: original and additional research objectives
    - 4.2 Methodology of data collection
    - 4.3 Data analysis
        - 4.3.1 Catch-at-age data
        - 4.3.2 Transition phase data
        - 4.3.3 Reproductive data
        - 4.3.4 Other
    - 4.4 Results including mortality and reproductive rates
    - 4.5 Initial discussion of results and their potential in the context of the objectives of JARPA and of stock management
5. Marine ecosystem
    - 5.1 Background: original and additional research objectives
    - 5.2 Methodology of data collection
    - 5.3 Data analysis
    - 5.4 Results
    - 5.5 Initial discussion of results and their potential in the context of the objectives of JARPA and of stock management
6. Environmental change
    - 6.1 Background: original and additional research objectives
    - 6.2 Methodology of data collection
    - 6.3 Data analysis
    - 6.4 Results
    - 6.5 Initial discussion of results and their potential in the context of the objectives of JARPA and of stock management
7. Overview of results and their potential in the context of the stated aims and objectives of the JARPA programme and of stock management
    - 7.1 Contribution to minke whale management
        - 7.1.1 Stock abundance and trends
        - 7.1.2 Stock identity
        - 7.1.3 Biological parameters
            - 7.1.3.1 Mortality rates
            - 7.1.3.2 Reproductive rates
    - 7.2 Marine ecosystem
    - 7.3 Environmental change
8. Overview of results and their potential in the context of recent IWC Resolutions and discussions
    - 8.1 With respect to Resolutions on proposals for Scientific Permits (IWC Resolutions 1995-8 and 9, *Rep. int. Whal. Commn* 46:46)
    - 8.2 With respect to the Resolution on the Antarctic marine ecosystem (Appendix 2, *Rep. int. Whal. Commn* 43:39-40)
    - 8.3 With respect to the Resolution on the environmental change and cetacean response (IWC Resolution 1995-10, *Rep. int. Whal. Commn* 46:47-8; IWC Resolution 1996-8, *Rep. int. Whal. Commn* 47:52)
9. Other matters
10. Adoption of report
11. Closure

Annex C
List of Documents

SC/M97/1. NISHIWAKI, S., MATSUOKA, K., KAWASAKI, M., KISHINO, H. and KASAMATSU, F. Review of the sighting surveys in the JARPA.

SC/M97/2. OHSUMI, S., TANAKA, S. and KATO, H. A review of the studies on estimation of biological parameters conducted under the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA).

SC/M97/3. PASTENE, L.A. and GOTO, M. A review of the studies on stock/species identity in the minke and other baleen whale species, conducted under the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA).

SC/M97/4. ICHII, T. A review of studies on marine ecosystem under the JARPA.

SC/M97/5. FUJISE, Y. A brief review of studies related to research on effects of environmental changes on cetaceans in the JARPA survey.

SC/M97/6. BUTTERWORTH, D.S., PUNT, A.E., GEROMONT, H.F., KATO, H. and FUJISE, Y. Further ADAPT analyses of catch-at-age information for Southern Hemisphere minke whales in Areas IV and V.

SC/M97/7. THOMSON, R.B., BUTTERWORTH, D.S. and KATO, H. Has the age at maturity of Southern Hemisphere minke whales, as indicated by transition phase readings, declined over recent decades?

SC/M97/8. ANONYMOUS. List of data sets produced by the Japanese Whale Research Program Under Special Permit in the Antarctic (JARPA).

SC/M97/9. ANONYMOUS. Scientific contribution of the Japanese Whale Research Program under Special Permit in the Antarctic (JARPA).

SC/M97/10. OHSUMI, S. Development of objectives in JARPA project.

SC/M97/11. TANAKA, E. and FUJISE, Y. Interim estimation of natural mortality coefficient of southern minke whales using JARPA data.

SC/M97/12. ZENITANI, R., FUJISE, Y. and KATO, H. Biological parameters of southern minke whales based on materials collected by the JARPA survey under special permit in 1987/88 to 1995/96.

SC/M97/13. FUJISE, Y. and KISHINO, H. Further examination of segregation pattern of minke whales in Antarctic Areas IV and V as revealed by a logistic regression model.

SC/M97/14. FUJISE, Y., NISHIWAKI, S. and PASTENE, L.A. An examination of the random sampling scheme of the JARPA surveys.

SC/M97/15 PASTENE, L.A., GOTO, M., KIMURA, T. and NISHIWAKI, S. Population structure of the humpback whale in the Antarctic feeding ground based on analysis of mitochondrial DNA control region sequences.

SC/M97/16. ICHII, T., TAMURA, T., FUJISE, Y., NISHIWAKI, S. and MATSUOKA, K. Inter-annual change in body fat condition stomach-content mass and distribution of minke whales in Areas IV and V.

SC/M97/17. TAMURA, T., ICHII, T. and FUJISE, Y. Consumption of krill by minke whales in Areas IV and V of the Antarctic.

SC/M97/18. OHSUMI, S., FUJISE, Y., ISHIKAWA, H., HAKAMADA, T., ZENITANI, R. and MATSUOKA, K. The fattyness of the Antarctic minke whale and its yearly change.

SC/M97/19. NISHIWAKI, S., MATSUOKA, K., HAKAMADA, T. and KASAMATSU, F. Temporal change of distribution and abundance estimates on large baleen whales in Areas IV and V in the Antarctic.

SC/M97/20. FUJISE, Y., HONDA, K., YAMAMOTO, Y., KATO, H., ZENITANI, R. and TATSUKAWA, R. Changes of hepatic mercury accumulations of Southern minke whales in past fifteen years.

SC/M97/21. COOKE, J., FUJISE, Y., LEAPER, R., OHSUMI, S. and TANAKA, S. An exploratory analysis of the age distribution of minke whales collected during JARPA expeditions 1987/88 through 1995/96.

SC/M97/22. COOKE, J., FUJISE, Y. and KATO, H. A analysis of maturity stage and transition phase data from minke whales collected during JARPA expeditions in Area IV, 1987/88 through 1995/96.

SC/M97/23. BURT, M.L. and BORCHERS, D.L. Minke whale abundance estimated from the 1991/92 and 1992/93 JARPA Sighting Surveys.

Annex D
Questions for Agenda Items 2.5, 3-5, 4.5, 5.5, 6.5

(Extracted from *Rep. int. Whal. Commn* 46:224, SC/39/O 4 and Resolutions 95-8, 95-9, 95-10 and 96-8)

Smith, Hatanaka, de la Mare

A. Likelihood of research meeting its objectives
For each general objective (below), identify specific objectives, specific variable to be estimated, the current estimate of that variable, main caveats, and judge likelihood of future success in estimating it.

General Objectives:
1. Estimation of biological parameters to improve stock management
2. Elucidation of the role of whales in the Antarctic marine ecosystem
3. Elucidation of the effect of environmental changes on cetaceans
4. Elucidation of the stock structure of minke whales to improve stock management

B. Other questions
1. Possibility for non-lethal alternatives
(identify variable and method, and judge likelihood of success)

2. Relevance of research to identified research needs
(identify specific recommendation, specific variables, likelihood of success)
2.1 Comprehensive Assessment Recommendations
2.2 Pollution Workshop Recommendations
2.3 Environmental Change Workshop Recommendations
2.4 Other IWC Scientific Committee Recommendations
2.5 Other Scientific Recommendation (e.g. CCAMLR)

3. Relevance to stock management
3.1 Abundance estimates for RMP
3.2 Specifying *Implementation Simulation Trials* (plausible ranges)
3.3 Implementation per se (e.g. Area definitions)
3.4 Improve basis for management (e.g. MSYR range, multispecies management)

Annex E1
List of Scientific Papers Arising out of JARPA

1. List of scientific papers based on data and material obtained during JARPA (revised version)

Aono, S., Tanabe, S., Fujise, Y. and Tatsukawa, R. 1996. Specific accumulation of persistant organochlorines in minke whale (*Balaenoptera acutorostrata*) and their prey species from the Antarctic and the North Pacific. Paper SC/48/O 22 presented to IWC Scientific Committee, June 1996, Aberdeen (unpublished). 10pp.

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Butterworth, D.S. and Thomson, R.B. 1995. An initial analysis of updated transition phase data for minke whales in Antarctic Area IV. Paper SC/47/SH24 presented to the IWC Scientific Committee, May 1995 (unpublished). 16pp [And paper SC/47/SH24(Rev) presented to the IWC Scientific Committee, June 1996 (unpublished). 18pp.].

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Fujise, Y. 1995. A preliminary morphometric study in minke whales from Antarctic Area IV using data from the 1989/90 JARPA Survey. Paper SC/47/SH7 presented to the IWC Scientific Committee, May 1995 (unpublished). 15pp.

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

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

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

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

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

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Annex E2
List of Data Sets

CODES FOR THE TABLE

Categories (CA)
A = Data already submitted to the IWC (original or coded).
Aa: Data already submitted to the IWC. Free access for the Scientific Committee members (the reviewers).
Ab: Data already submitted to the IWC. The users should have an agreement with ICR.

B = Studies using the data have already been published (Data have not yet been submitted to the IWC Secretariat).
Ba: Data holders have already agreed (or permitted) to open the data for the JARPA review.
Bb: Users should have permission from the data holder.

C = *Neither the original data nor a study using the data have been submitted to the IWC. The data will be available for studies under cooperation between the data holder and the user.*

Stage of data analysis (SDA)
1 = Data not used for analysis yet.
2 = Data analysis in progress.
3 = Data analysis finished.

Stage of data coding (SDC)
1 = Data coding in preparation.
2 = Data coding in progress (including validation).
3 = Data coding and validation finished.

Table 1 and 2 follow

Table 1

	1987-88			1988-89			1989-90			1990-91			1991-92			1992-93			1993-94			1994-95			1995-96			Sample size
	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	
1. Sighting data																												
Angle and distance experiment data	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Ab	2	3	Ab	2	3	Ab	2	3	-
Photo-ID, other than minke whales	-	-	-	-	-	-	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	2	-
Sighting data	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Ab	2	3	Ab	2	3	Ab	2	2	-
Survey effort data	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Aa	3	3	Ab	2	3	Ab	2	3	Ab	2	3	-
Weather data	Aa	1	3	Aa	1	3	Aa	1	3	Aa	1	3	Aa	1	3	Aa	1	3	Ab	1	3	Ab	1	3	Ab	1	3	-
2. Biological data																												
Age	Ba	3	3	Ba	3	3	Ba	3	3	Ba	3	3	Ba	3	3	Ba	3	3	C	1	3	C	1	3	C	1	1	2,130
Baleen plate set mouth cavity	-	-	-	-	-	-	C	1	3	C	1	3	C	1	3	C	1	3	-	-	-	-	-	-	-	-	-	1,274
Baleen plates, length of plate series	-	-	-	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	-	-	-	-	-	-	-	-	-	1,515
Blubber thickness (14 points)	Bb	2	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	Bb	2	3	Bb	2	3	Bb	2	3	528
Blubber thickness (3 points)	Bb	2	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	Bb	2	3	Bb	2	3	Bb	2	3	2,840
Body length	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,887
Body proportion	C	1	2	C	1	2	Bb	3	3	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	2,887
Body weight	-	-	-	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	2	2,599
Brain weight	-	-	-	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	1,568
Catch date	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,887
Catch location	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,887
Corpora albicantia and lutea (no.)	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	1	1	1,122
Craniometric data	C	2	3	C	2	3	C	2	3	C	2	3	-	-	-	C	2	3	C	1	1	C	1	1	C	1	1	35
Discovery-type marks recovery	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2
Endocrinological studies on reproduction	Bb	3	3	Bb	3	3	Bb	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Epididymis weight	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	1,593
Foetus, body length	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	751
Foetus, body proportion	-	-	-	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	627
Foetus, body weight	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	750
Foetus, number	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	783
Foetus, sex	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	738
Jacobson's organ shape	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,887
Lactation condition	Bb	3	1	Bb	3	1	Bb	3	1	Bb	3	1	Bb	3	1	Bb	3	1	Bb	3	1	Bb	3	1	Bb	3	1	1,294
Lipids content	C	3	3	C	3	3	C	3	3	C	3	3	C	3	3	C	3	3	C	3	1	C	3	3	C	2	1	2,887
Mammary gland measurements	Bb	3	1	Bb	3	1	Bb	3	1	C	1	1	Bb	3	1	Bb	3	1	C	1	1	C	1	1	C	1	1	1,294
Maturity stage	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	C	2	2	C	2	2	C	1	1	2,010
MtDNA control region sequences, humpback whale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bb	3	3	Bb	3	3	-	-	-	28
MtDNA control region sequences, minke whale	-	-	-	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	-	-	-	-	-	-	35
MtDNA RFLP-derived haplotype distribution	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	Bb	3	3	C	2	2	2,124
Organ weights	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	532
Parasites-external occurrence record	C	2	2	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,614
Parasites-internal occurrence record	C	2	2	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	-
Ribs (no.)	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,887
Selenium analysis	-	-	-	-	-	-	-	-	-	C	3	3	C	3	3	C	3	3	C	3	3	C	3	3	-	-	-	-

continued...

Table 1 cont.

	1987-88			1988-89			1989-90			1990-91			1991-92			1992-93			1993-94			1994-95			1995-96			Sample size
	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	
Sex	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,888
Skeleton (whole measurement)	C	2	2	-	-	-	C	2	2	C	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Skull (length and breadth)	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	2,841
Stomach contents (IWS format)	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,884
Stomach contents weight, first stomach, excl. liquid	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	2,675
Stomach contents weight, inc. liquid	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	2,675
Stomach contents weight, second-fourth stomachs, excl. liquid	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	1,257
Tail notch shape	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,887
Testis weight	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	1,593
Transition phase	Bb	3	3	C	2	1	Bb	3	3	C	2	1	C	1	1	C	2	1	C	1	1	C	1	1	C	1	1	-
Uterine horn (breadth)	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	1,293
Ventral grooves (no.)	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,887
3. Environmental data																												
Heavy metals	C	2	3	C	2	3	C	2	3	C	1	1	C	1	1	C	1	1	C	1	1	C	2	1	C	1	1	-
Marine debris	-	-	-	-	-	-	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	-
Organochlorine	-	-	-	Bb	2	3	C	2	1	Bb	2	3	C	2	1	Bb	2	3	C	2	1	C	2	1	C	2	1	-
Organochlorine compounds (air, sea water)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	3	3	C	3	3	C	3	3	C	3	3	100
Temperature (XBT survey)	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	C	2	2	751

Table 2

Current status of studies and data related on morphometric, transition phase, ecosystem and environment change produced by the JARPA survey. Characters and figures in **bold** indicate modification in the status of a particular item after the first version of the list.

	1987-88			1988-89			1989-90			1990-91			1991-92			1992-93			1993-94			1994-95			1995-96			Sample size
	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	CA	SDA	SDC	
2. Biological data																												
Blubber thickness (14 points)	Bb	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	Bb	2	3	Bb	2	3	Bb	2	3	528
Blubber thickness (3 points)	Bb	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	Bb	2	3	Bb	2	3	Bb	2	3	2,840
Body length	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,887
Body proportion	C	1	3	C	1	3	Bb	3	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	C	1	3	2,887
Body weight	-	-	-	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	2,599
Brain weight	-	-	-	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	C	2	2	1,568
Foetus, body length	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	751
Foetus, body proportion	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	628
Jacobson's organ shape	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	C	1	2	2,887
Lipids content	Bb	3	3	Bb	3	3	C	3	3	C	3	3	C	3	3	C	3	3	C	3	3	C	3	3	C	3	3	519
Organ weights	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	532
Selenium analysis	-	-	-	-	-	-	-	-	-	Bb	3	3	C	3	3	C	3	3	C	3	3	C	3	3	-	-	-	-
Stomach contents (IWS format)	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	Aa	-	-	2,884
Stomach contents weight, first stomach, excl. liquid	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	2,675
Stomach contents weight, inc. liquid	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	2,675
Stomach contents weight, second-fourth stomachs, excl. liquid	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	C	2	3	1,257
Tail notch shape	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,887
Transition phase	Bb	3	3	C	2	1	Bb	3	3	C	1	1	C	2	2	C	1	1	C	2	2	C	1	1	C	2	2	-
Ventral grooves (no.)	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	2,887
3. Environmental data																												
Heavy metals	C	2/3	3	C	2/3	3	C	2/3	3	C	1	1	C	1	1	C	1	1	C	1	1	C	2/3	3	C	1	1	300
Marine debris	C	1	1	C	1	1	C	1	1	C	1	1	.C	1	1	C	1	1	C	1	1	C	1	1	C	1	1	-
Organochlorine	-	-	-	Bb	2/3	3	C	2	1	Bb	2/3	3	C	2	1	Bb	2/3	3	C	2	1	C	2	1	C	2	1	59
Organochlorine compounds (air, sea water)	-	-	-	-	-	-	Bb	3	3	-	-	-	-	-	-	C	2	3	C	2	3	C	2	3	C	2	3	100
Temperature (XBT survey)	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	Bb	2	3	C	2	3	751

Annex F
JARPA Review: Overview of Past Discussions and Results

Table 1 is a brief listing of points made in plenary discussions of the JARPA programme or supporting the programme as recorded in plenary discussions. Under broad headings supporting statements are given to the left and critical statements to the right. An attempt is made to align the statement by topic. The points are listed under year of discussion.

Related points made later are listed below with reference to year.

1987 *Rep. int. Whal. Commn* 38:55-57; 1988 *Rep. int. Whal. Commn* 39:54-55; 1989 *Rep. int. Whal. Commn* 40:61-63, 64-69; 1990 *Rep. int. Whal. Commn* 41:72-74; 1991 *Rep. int. Whal. Commn* 42:72-73.

Table 1 follows

Table 1

JARPA: overview of past discussions.

Supporting statements	Critical statements
1. Are the objectives necessary or relevant for management?	
1987 Long-term results of the programme would contribute to information essential to *rational management* of minke whales. The estimation of *M* and its age-specific components is a *key issue* in the study of population dynamics.	**1987** *The objective is irrelevant for (the then current) management*, since the principal problem was in the estimation of net recruitment rates, and the estimation of *M* is only part of one possible approach to this. The objective is irrelevant for management under the (coming) RMP since the RMP will be robust. New estimates of *M* are unnecessary. The objectives are not essential for the RMP (1989).
1989 *Improvement in management* is possible when better understanding of the biology is obtained. Estimates of biological parameters could be built into a management procedure to improve performance. Age profiles could be useful to *monitor* management.	**1989** Regardless of whether age-dependant mortality could be reliably estimated or not, the proposal had *not shown* that the whole problem of estimating the relevant management parameters constituted a *feasible* objective. Provides *only ancillary data* to management, not essential data.
2. Are the objectives clearly stated and are they achievable?	
1989 The objectives are adequately stated.	**1989** The objectives are inadequately specified, and they are infeasible by the proposed methods.
1990 Data from JARPA is used in the *Comprehensive Assessment*, and thus no failure. Age-specific mortality estimates are a long-term goal.	**1990** No estimate of age-specific mortality is provided for the *Comprehensive Assessment*. The objective of contributing here thus failed.
3. Can the sampling scheme provide data that gives valid and reliable inferences relative to the objectives?	
1987 The data have the *potential* for reliable estimation of mortality rates, possibly by better methods than are now available. In principle, new data, *free from catch selectivities*, can be used to obtain separate estimates of *M* and (*R*). There might be better estimators than those considered in the simulation study for which reliability is not a major problem (1989). A VPA-type method to estimate recruitment trends was discussed, and also a Bayesian method to estimate linear time-trends in smooth *age-specific mortality* and linear time trends in *recruitment* (1989). As a result of criticism, an improved sampling scheme was developed to allow better representation. Sampling scheme amended (1989).	**1987** Variation in recruitment, past fishing mortality and natural mortality cannot be distinguished in principle. The age-specific mortality is *not identifiable* by the proposed method. Even with estimates of recruitment the variance on mortality estimates would be large. *Lack of reliability*. The lack of reliability was demonstrated by simulations (1989). Longer study needed (1990). *The sampling programme is inappropriate.* Temporal and spatial segregation makes it difficult to get representative data. Post-stratification increases uncertainty, and is difficult due to poor information on strata sizes. Schools of different size have different sightability, and sampling in schools with 3 or less individuals is difficult (1988). Inhomogeneity in sex distribution is problematic, but the sampling method has improved (1989). Still inappropriate sampling plan. Difficulties with post-stratification (1991). The proposed method is *not feasible* either in theory or in practice. **1989** *No extra information in JARPA age data* over and above survey data relative to net recruitment. *No methodology specified* to estimate MSYR and MSYL from mortality and gross recruitment estimates, and if this could be done, the variance would be enormous.
1990 Integrated analysis methods combining absolute abundance estimates and catch-at-age were discussed. Estimates with satisfactory reliability should be achievable within a 20-year period. Unavailability of future catch-at-age data would weaken the inference considerably. The proposed method (Tanaka) did not use a stable age distribution and a sample size of 300 per year would be sufficient to estimate average mortality reliably (not 16,000 total).	**1990** The conclusion that dynamic parameters could be discriminated with abundance and age data over a 20-year period was disputed. The reported precision was suspected to be due to an amendment to the protocol (of the simulation study). Using a demographic model a sample size of 16,000 was necessary to get reliable estimates. **1991** The *balance* between sampling and miles on track line should be re-evaluated, and could be achieved by shifting emphasis from age-specific to average mortality.
1992 More effort into surveying, by modifying sampling protocol (one animal sampled per school).	
4. Additional problems/advantages or extension/modifications to the programme	
1987 Separate estimates of *M* and *R* will allow *better use* of commercial catch data. Sampling over a long time and over a huge ocean area can provide information on *segregation*.	**1987** *No reason to believe* that biases in commercial catch *data can be corrected.*
1991 The estimation of *average rather than age-specific mortality* studied further. *Ecosystem study* is an essential research need, and is included in the programme. Results from JARPA are of *general scientific interest*.	**1991** *Heterogeneity* is important, and more information on seasonal and annual variability is requested.

Annex G

Comments on Stock Definition with Relation to JARPA Research and Objectives

Barbara L. Taylor

Because genetic systems, data and analysis are not easy for all to understand, these written comments are presented for the convenience of members of the JARPA review. Although there are many interesting scientific revelations through genetics (such as the species distinction between dwarf and ordinary minke whales) only the issue of stock definition is discussed here. Let me first make the distinction between gene flow and mixing. Consider Fig. 1 which has three breeding populations A, B, and C. Breeding areas A and B are separated by rather little distance and there is some gene flow between the areas with on average 0.025% of the populations exchanging each year. Area C is very distant from the other breeding areas and has a very low exchange rate of less than one individual per generation with population B. Population geneticists noted that if exchange was this low, the frequencies of genes would drift apart making the populations genetically distinct. The level of distinction is related by equation 1 where F_{st} is 0 if there is no distinction and 1 if there are fixed genetic differences between the populations:

$$F_{st} = \frac{1}{1+2N_e d} \qquad (1)$$

where N_e is the effective population size (approximately the number of adult females for mitochondrial DNA) and d = dispersal rate (the average probability of an individual dispersing per generation). f_{st}, which was used in the analyses of Pastene and Goto to reveal stock structure within the ordinary form of the minke whale within Area IV, is an analogue to F_{st}. Note that for any given d, the amount of differentiation (F_{st}) decreases as abundance increases. Populations differentiate when separated because gene frequencies change by the process of random sampling (random chances that genes get passed on to the next generation). In large populations, changes in gene frequencies because of random sampling are small and so populations do not easily become very different.

The number of members exchanged between populations exists on a continuum with some populations being so separate that the differences could be significant to the evolution of the species while many populations differ only in small differences in the frequencies of different types of genes. In statistical terms, the amount of difference you are looking for before you say you have one population or two is called effect size. Effect size is required to answer questions of statistical power, such as: 'If populations are connected by an annual dispersal rate of X, what is the probability that these data would have detected subdivision?' The more different the populations are, the larger the effect size and the easier it will be to tell the populations apart.

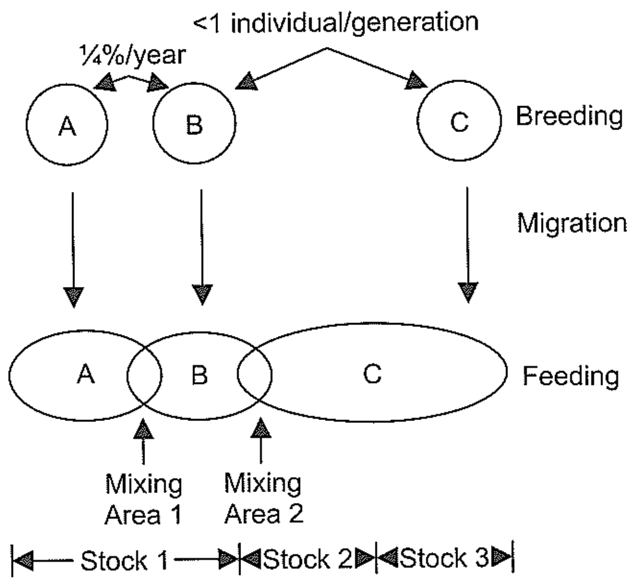

Fig. 1. Hypothetical diagram of population structure.

Now consider the feeding areas in Fig. 1. Note that A and B overlap and that B and C overlap. Within the area where the populations overlap we say the populations are 'mixing', i.e. we have a certain percent from each population that could potentially be harvested in one location. From my understanding of the RMP multistock management trials, this is the mixing that goes into the 'mixing matrix'. That is, data are used to estimate the proportion of each stock (or population) that could be harvested in a particular area.

Therefore, stock definition as regards the RMP is a two-step process. First, scientists must define what the stocks are. Second, the scientists must estimate the spatial arrangement of stocks in the time period of the harvest.

Now to return to the problem at hand: stock definition of minke whales (ordinary form) in the Antarctic. Pastene and Goto have done an excellent job at finalising the distinction between dwarf and ordinary forms and despite numerous comments in past Scientific Committee reports that the lack of land barriers in the Antarctic likely meant a lack of population structure, they have found structure within the area studied. Most remarkably, they have found significant differences with a very small effect size ($F_{st} = 0.0052$). Fig. 2 shows a crude picture of both where the new 'core' and western Area IV stock are along with averages of abundance estimates (in thousands) by 10 degree increment from IDCR cruises. Before continuing with the stock structure discussion it is interesting to note a few things about both the densities of minke whales, the old picture of stocks and the new picture of stocks. Clearly, minke whales are rather patchily distributed along the Antarctic coast with very high densities near the border of Areas V and VI. These densities do not clearly correspond with the Areas or with the old picture of breeding areas and their corresponding feeding areas. The proposed 'core' stock also does not match the old picture and seems to span the area South of Australia, which would seem a natural barrier to gene flow given the general picture of the location of breeding areas and S-N movement patterns depicted in Fig. 2. These new data call into question the validity of any of the old boundaries and suggest further analyses to maximise stock distinctions which are not based on preconceived notions of stock boundaries.

Returning to the more general stock definition discussion, we notice that we really don't know what abundance to assign to the putative stocks. For the sake of illustration, let's say that N_e (unfortunately the analytical equations assume all populations are of equal size, but for our example this is OK). Using Equation 1 we can solve that this means a dispersal rate of 0.0019 (2 tenths of a percent) or about 95.7 whales dispersing per generation. If generation time is 10 years, this would mean about 9.6 whales per year. Thus, although we have quite separate populations, the degree of differentiation is very small and there are small frequency differences in genetic composition. This means that estimating mixing will be difficult.

Now consider a scenario with more gene flow. Let's say that adjoining populations exchange members at the rate of a quarter of a percent per year (assuming a generation time of 10 years, $d = 0.025$/generation). Assuming the same N_e (50,000) the effect size becomes extremely small ($F_{st} = 0.0004$ an order of magnitude less than that found by Pastene and Goto). Thus, there is little chance that these populations could be identified and virtually no chance of estimating mixing rates.

The question is, should these be considered separate stocks. The IWC has never adequately identified the unit that they are trying to conserve. If they are interested in conserving units with unique genetic characters (often called Evolutionary Significant Units in conservation literature) then units that exchange less than one individual per generation are the appropriate unit. This would mean, however, that many areas could be completely harvested without any loss to the genetic diversity. As an analogy, if the city of Boston were eliminated from the United States, there would be no loss to genetic diversity. The use of small areas (in the RMP) may imply that local population units are to be conserved. Defining this management objective is no doubt beyond the scope of this meeting but it is important for members to understand that without defining this objective, it will not be possible to carry out power analyses or a meta-analysis of multiple types of data because we have no effect size! We do not know how different 'populations' must be in order to be considered separate stocks.

If harvest is carried out such that its geographical distribution matches the distribution of the targeted species, there is less risk that one stock will be over harvested. Thus, if small areas (in the RMP) are used, there is little need to precisely understand stock structure. The more uneven the

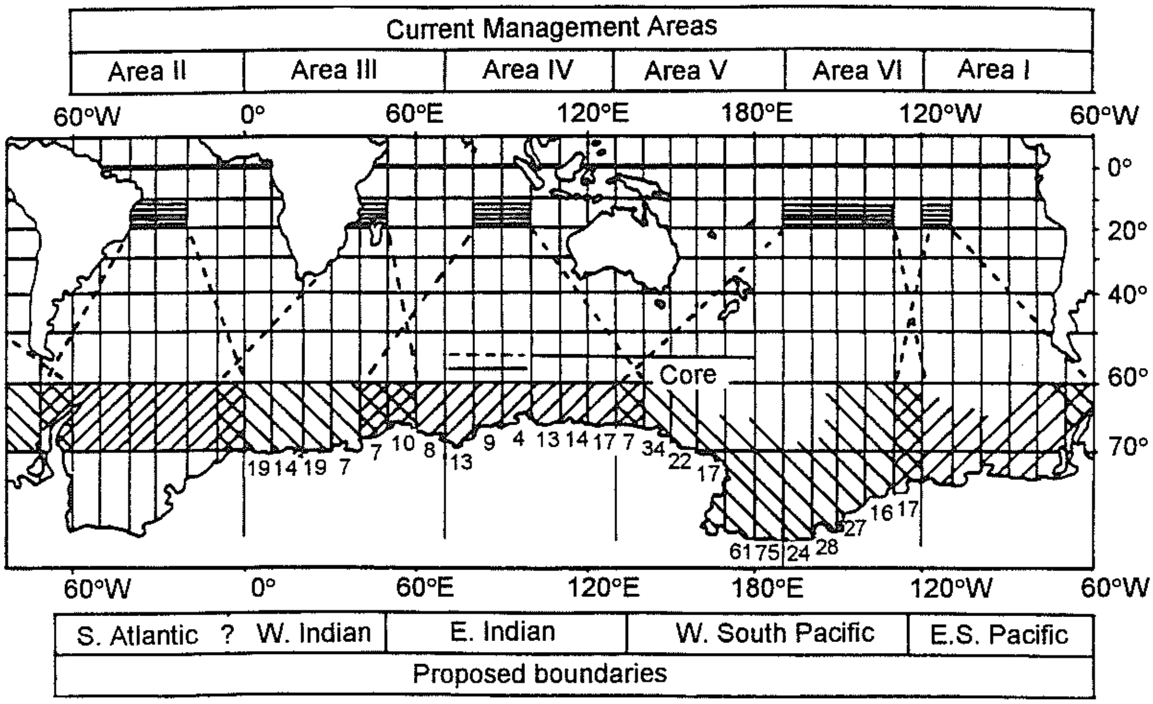

Fig. 2. Modified from fig. 5 in SC/M97/3. Possible location of breeding grounds and Antarctic feeding areas based on sighting distribution data; the location of known breeding ground off Brazil is shown. The hypothetical feeding areas used by the animals from these breeding grounds are also shown (after IWC, 1991). The numbers added below are mean abundance estimates (in 1,000's) by 10° longitudinal band from *Rep. int. Whal. Commn* 43:43:113). Also added is the approximate range of the core stock according to genetic data from JARPA samples taken in Areas IV and V.

harvest, the higher the risk that incorrect stock definitions could lead to over harvest of some stocks. Thus, the harvesting scheme along with the species distribution needs to be integrated before the utility of gathering data on population structure can be assessed. To make this more clear with an example, return again to Fig. 1 where some arbitrary equally sized stock boundaries have been made. The risk posed by these incorrect boundaries will depend on both how large the populations are and on the location and magnitude of the harvest. The most risky situation is where a small stock is next to a large one. Let's imagine that the abundances are A = 70,000, B = 20,000 and C = 150,000. You can see that taking from stock 1 (which assumes a population of approximately 80,000 if you assume that half of B is included) could prove risky to population B. This is especially that case since it will be difficult if not impossible to identify these populations genetically. Of course the importance of losing or reducing B will depend on the management objectives. The situation would be quite different if abundances were such that A = B = C. Even with the incorrect stock boundaries, as long as the harvest were assigned by these stocks in proportion to the abundances in that area no stock should be depleted. Looking at Fig. 2, we see that the abundance of minke whales varies quite dramatically across the Antarctic and that the 'core' stock has a much greater abundance than the area surveyed for the stock that occupies the western portion of Area IV early in the season.

CONCLUSIONS AND RECOMMENDATIONS

Because the new genetic data indicate that current historical Area definitions are inappropriate, and because these genetically defined stocks do not match previous ideas of stock boundaries, scientists should carefully consider how to better draw stock boundaries. The first step to take is to do more analysis of the current data to maximise genetic distinctness by using various 'boundaries' (in this case both different longitudinal boundaries and different seasons). The genetic data can best be analysed only if analysts know the level of differentiation (effect size) they are looking for. This calls for better definition of management units (stocks).

Annex H
Summary Statements Supporting the Use of Lethal Removal and Refuting its use, as it Pertains to the Collection of Information on Stock Structure

1. A STATEMENT REFUTING THE NEED FOR LETHAL REMOVALS

All of the genetic information required for purposes of stock identity can be obtained by non-lethal methods. First, there is a large archive of samples from both JARPA and prior commercial operations, and which deserve further analysis without the need to collect new samples. Further use of available samples can be made by: (1) testing varying stock boundaries and time periods; (2) applying different molecular techniques and; (3) assessing potential biases from the non-random samples from commercial operations. Use of microsatellites, which are generally more sensitive markers for detecting population structure, will likely greatly reduce the number of samples needed. Second, the Scientific Committee recognised that sampling the breeding grounds (in lower latitudes) would greatly enhance the power of genetic analyses. It is important to note that non-lethal sampling is the only option in many of the suggested breeding grounds. Third, biopsy sampling techniques can and should be improved to apply specifically to minke whales. At present minke whales are easier to kill than to biopsy because killing technology has been developed for this species and for the weather conditions commonly encountered in the Southern Ocean. A similar effort in developing appropriate biopsy technology needs to take place. Fourth, molecular techniques are usually more powerful in identifying population structure than other techniques. The most efficient approach to analysing stock structure would be hierarchical, where molecular genetic techniques would be used first (both mitochondrial and nuclear). Only if no structure were detected would further techniques be initiated. In the case of JARPA non-genetic data, it was noted that it was difficult to evaluate its utility because analyses were incomplete. Therefore, it was not possible to evaluate whether these other data make a contribution beyond what has already been learned using molecular genetic techniques regarding stock structure. Finally, samples can also be collected from stranded whales and whales taken as by-catch.

2. A STATEMENT SUPPORTING THE NEED FOR LETHAL REMOVALS

Information required for stock identification cannot be obtained by non-lethal means alone. Rather, a variety of approaches should be used, many of which require lethal techniques. Genetic analyses using DNA can be conducted using biopsy sampling. However, the number of samples required in studies on stock identification in the case of the southern minke whale is large, and consideration of sampling collection should be taken into account. Regarding the collection of biopsy samples for DNA analyses, it should be noted that biopsy sampling techniques have not been successfully developed for use with minke whales. Considering the logistics of studying minke whales in the Southern Ocean, biopsy techniques that could be developed for use in low latitudes will likely not prove workable at high latitudes. Further, given the need for cost-effective sampling regimes due to the high operating costs of working in the Southern Ocean and the need for adequate sample size, it is unlikely that biopsy sampling would prove useful. Regarding non-genetic techniques for stock identification, it has been recognised that the age of individual whales is an indispensable piece of information in interpreting stock structure and that there are currently no non-lethal techniques that provide information on age. For example, many different sets of data that have been used to infer stock structure in other populations of large whales which require information on age (e.g. average age at sexual maturity, average age at recruitment, age specific reproductive rates and pollutant levels). Also, some kinds of genetic analyses for studies on stock structure, such as allozyme, require tissues other than skin or blubber, which can only be obtained using lethal techniques. Furthermore, studies that are based on morphometrics, parasites, conception dates, pollutant burdens, etc. are also useful for stock identification, and they cannot be undertaken using non-lethal techniques. In addition, while non-lethal techniques are the only option for rare or endangered stocks, lethal techniques when applied to healthy and relatively large populations typically produce research results more quickly than non-lethal techniques. Finally, the proceeds from the sale of post-study by-products of lethal studies, in accordance with Article 8 of the International Whaling Convention, can be used to offset some of the extreme costs of conducting research on minke whales in the Southern Ocean. The offsetting of costs is not possible using non-lethal techniques.