Report of the Expert Workshop to Review the Japanese JARPA II Special Permit Research Programme

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The Workshop was held in the Toyomi Center Building, Tokyo from 24-28 February 2014.

1. INTRODUCTORY ITEMS

1.1 Chair's opening remarks

The Workshop was chaired by Palka, ex-Chair of the IWC Scientific Committee. She explained that normally the Chair of Special Permit Review Workshops was the present Scientific Committee Chair, who at this time is Kitakado. However, since Kitakado was a member of the proponents, the Scientific Committee agreed at their last Annual Meeting that the previous Committee Chair would be an appropriate chair for this Review Workshop. Palka then welcomed the Panel members, observers and Japanese proponents to Tokyo and thanked the Fisheries Agency of Japan for hosting the Workshop. Morishita, the IWC Commissioner for Japan, also welcomed the Panel and all participants.

The Chair recalled that the JARPA and JARPA II programmes have been reviewed three previous times: in May 1997 during an IWC sponsored mid-term review of the JARPA programme; in January 2005 during a non-IWC review of the results of JARPA for the period 1987/88-2003/04; and in December 2006 during an IWC final review of the JARPA programme.

Since that time, the Scientific Committee had developed the 'Annex P' process of reviewing special permit programmes (IWC, 2013b). The Committee had held two previous review Workshops for special permit programmes following this process. The first was a review of the ongoing JARPN II programme in the western North Pacific (IWC, 2010) and the second was the final review of the Icelandic programme (IWC, 2014a).

1.2 Terms of Reference

'Annex P' contains Terms of Reference for review of ongoing proposals and completed proposals. Those that are relevant to the JARPA II review can be summarised as:

(1) how well the original objectives were met;
(2) whether the programme made other contributions to important research needs;
(3) the relationship of the research to IWC resolutions and discussions;
(4) utility of lethal and non-lethal techniques; and
(5) provide advice on:
    (a) practical and analytical methods that can improve research relative to stated objectives;
    (b) appropriate sample sizes to meet the stated objectives;
    (c) effects on stocks; and
    (d) when a further review should occur.

1.3 Overview of the process for developing advice for the Commission

The first component of the process is the present small specialist Workshop (this has to be held at least 100 days before the SC meeting), with a limited number of invited experts chosen by a Standing Steering Group (SSG); a limited number of proponent scientists, primarily to present the proposal and answer points of clarification; and a limited number of observers. Based on the proponents paper on analytical methods used in JARPA II, which was submitted nine months prior the Annual Meeting (e.g. 3 August 2013) , in accordance with Annex P the SSG drew up a shortlist of potential Panel members. Final selection was governed by availability (many of the potential nominated members were unable to attend), the need for balance (including between Scientific Committee and non-Scientific Committee members) and the available funds. The final Panel is listed in Annex A and comprised of three scientists who had never participated in the Scientific Committee, two scientists who have infrequently and not recently participated in Scientific Committee meetings and three regular members of the Scientific Committee; this is in addition to the Workshop Chair and Head of Science. One member, Punt, was also an author of two 'O' papers. Those papers, on statistical catch at age analysis (SCAA) were developed under contract of the IWC and implemented work directed by the Scientific Committee and were thus not deemed to include any conflict of interest. His participation in the discussion of that item within the Panel discussions was to provide information as required.

Five members of the Scientific Committee attended as observers and their names are given in Annex A as are the proponent scientists who attended the open sessions.

The report of the Workshop is to be made available for proponents by 11 March 2014. They are able to comment on the Panel report and to revise documents for submission to the Scientific Committee in light of comments within the Panel's report. The final report, attached comments from proponents and any moderately revised workshop documents developed as a result of recommendations are to be made available to the Scientific Committee by 7 April 2014. Major revisions or completely new documents based on recommendations must meet usual Scientific Committee document deadlines.

The Scientific Committee may make additional comments and the report of the Workshop, comments by proponents and comments by the Committee itself will be sent to the September 2014 Commission meeting.

1.4 Meeting arrangements and work schedule

The Chair explained that she will follow the previous Workshop format, with two types of sessions:

(1) open sessions where a limited number of scientists associated with the JARPA II research present the programme results and answer questions from the Panel – this is also open to observers; and
(2) closed sessions where only the Panel members discuss the proposal and develop their report.

In particular, her general intention was that for the morning sessions on days 1-4, the Japanese scientists and observers would provide their PowerPoint presentations for each of Items 3-11, although she recognised that some flexibility would be required and presentations may run into the early afternoon. Day 5 was for the Panel to discuss its overall conclusions and develop its report.

In the afternoon, the Panel will hold a closed meeting for summarising conclusions and recommendations for

[1]Presented to the meeting as SC/65b/Rep02.

each agenda item. During the closed sessions, she noted that it was possible that the experts may want to ask further clarifications and questions to the proponent scientists. She therefore requested that where possible they remain near the venue in the afternoon; although in this review this was rarely necessary. The Panel may request working papers from the proponents on specific topics as was the case in previous special permit reviews.

She referred to the 'Annex P' guidelines which state that Scientific Committee observers will 'not normally participate in discussions unless invited to do so by the Chair under special circumstances'. She was pleased to note that eight papers from Committee members had been submitted to the Workshop and that most of the authors of these papers were present. Several of these papers were presented by the authors and they provided valuable input into the Panel's discussions.

1.5 Review of documents and data

SC/F14/J01-38 (papers from proponents), SC/F14/O01-O08 (papers from Scientific Committee members), and SC/F14/R01-R05 (papers from the proponents that were in response to a SC/F14/O paper) were made available to the Workshop in accordance with deadlines specified in 'Annex P'. The list of documents is given as Annex C. A number of background papers were also available and these are referred to where appropriate in the text. The proponents, observers and Scientific Committee members submitting documents prepared PowerPoint presentations on each of the major topics (sometimes these applied to individual papers and sometimes they incorporated the results of several papers). It was agreed that with permission of the authors, these presentations would be made available to observers as well as Panel members but would be treated in a confidential manner.

2. ADOPTION OF THE AGENDA

The adopted agenda is given as Annex B.

3. PROPONENTS' OVERVIEW OF THE RESEARCH OBJECTIVES AND RESULTS (SC/F14/J01-J02)

The overview of objectives and results below is based on SC/F14/J01 prepared by the proponents. This summary has not been edited or approved by the Panel but represents the views of the Proponents. The Panel's views of individual items can be found under Items 4 onwards. The Panel's conclusions and recommendations are found under Item 12.

3.1 Overview of Objectives

Objectives 1 and 2

The rationale and research needs of JARPA II were explained in the original research plan, which was presented and discussed at the IWC Scientific Committee (IWC SC) in 2005 (Government of Japan, 2005). The development of the research objectives of JARPA II took into consideration the findings of the JARPA. During the 18-year period, the JARPA research showed evidences of the recovery of some whale species such as the fin and humpback whales which had been depleted by commercial whaling in the past century. One example is the increase in the abundance of the humpback whale in Areas IV and V (Matsuoka *et al.*, 2011). On the other hand the Antarctic minke whales were broadly stable with at most a slight decline in the same Areas and period (Hakamada *et al.*, 2013). The increase in the abundance of some large whale species implied changes in whale composition and distribution. For example in Area IV the humpback whale was extending its distribution to the south, sharing habit with the Antarctic minke whale along the ice-edge (Murase *et al.*, 2002). Because whales are top predators of the Antarctic marine ecosystem, the changes could have substantial effects on the ecosystem as a whole. The changes in the ecosystem could also have significant implications to the IWC conservation and management of whales.

JARPA research showed that a major transition has been taking place in recent years, which would affect the krill availability in the ecosystem and the biology of krill predators such as the Antarctic minke whale (Fujise *et al.*, 2006). In fact some changes in the biology of the Antarctic minke whale were reported during the JARPA period e.g. stable or slight increase in the age at sexual maturity (Zenitani and Kato, 2006) and deterioration in nutritional condition as revealed by a decrease in blubber thickness, girth and fat weight (Konishi *et al.*, 2008).

The JARPA II research plan therefore emphasised the need to systematically monitor changes of the Antarctic marine ecosystem over the long-term as well as changes of biological parameters in krill predators, and changes in the abundance of cetaceans inhabiting the Antarctic Ocean. It is also emphasised the need to monitor how cetaceans adapt to global warming and the changes in the ecosystem structure caused by human activities so as to provide a scientific basis for the comprehensive management of whale stocks (Government of Japan, 2005).

It should be noted here that continuous monitoring programmes form the backbone of all scientific research programmes which have the aim of providing advice on sustainable levels of catch for marine or terrestrial living resources. The reason is that population dynamics, and hence the size of the sustainable yield, can change in a manner that may not be predictable. Factors indexing these dynamics must therefore be monitored so that changes can be detected and important scientific information can be provided to the IWC as the basis for their conservation and management decisions.

Objective 1 of JARPA II was therefore the **'Monitoring of the Antarctic ecosystem'**: (i) monitoring of whale abundance trends and biological parameters; (ii) monitoring krill abundance and the feeding ecology of whales; (iii) monitoring the effects of contaminants on cetaceans; and (iv) monitoring of cetacean habitat.

Some specific scientific questions to be addressed under this objective are the following.

Given the results of JARPA that indicated a recent change in the Antarctic ecosystem, the aim here is the monitoring of temporal trend of parameters considered as 'indicators' of changes in the ecosystem.

- Whale abundance based on sighting data:
  - is the abundance of blue, humpback and fin whales increasing in the JARPA/JARPA II period?
  - is the abundance of Antarctic minke whale still maintaining a stable trend in the JARPA/JARPA II period?
- Whale abundance based on SCAA (age and sighting data):
  - what is the historical and recent trends in recruitment and total abundance of Antarctic minke whale?
- Whale distribution based on sighting data:
  - how the increase in abundance of large whales is affecting the distribution of Antarctic minke whale?
- Body condition and stomach content weight:

  - are these indices of nutrition declining in the JARPA/JARPA II period?
- Biological parameters based on age and reproductive data:
  - what is the historical and current trends of age at sexual maturity?
  - has the age at sexual maturity increased recently?
  - has the pregnancy rate decreased in the JARPA/JARPA II period?
- Contaminant load based on mercury and organochlorine data:
  - what is the pattern of temporal trend of pollutant levels in Antarctic whale samples?
  - what is the accumulation mechanism of pollutants in the Antarctic ecosystem?
- Cetacean habitat based on oceanographic and marine debris data:
  - how have the oceanographic conditions changed through the JARPA/JARPA II period?
  - what is the temporal trend of marine debris in the JARPA/JARPA II period?

Model building is essential for understanding, interpreting, and predicting the possible change in the Antarctic ecosystem indicated under the Objective 1. Models would also contribute to the improvement of the IWC conservation and management measures, as presented under Objective 4 of JARPA II (see below).

Objective 2 of JARPA II therefore is **'Modelling competition among whale species (to inform) future management objectives'**: (i) constructing a model of competition among whale species; and (ii) new management objectives including the restoration of the cetacean ecosystem.

The key question for the first part of Objective 2 (i) above is the following:
- can the predators-prey interaction alone explain the observed population trends of whale species and changes in biological parameters of the Antarctic minke whale in recent decades, without the need for recourse to environmental change hypotheses?

Objectives 3 and 4

The IWC adopted the Revised Management Procedure (RMP), the procedure for the management of commercial whaling for baleen whales. There is a need for better estimation of Maximum Sustainable Yield Rate (MSYR) in order to respond to any concerns over the implementation of the RMP and to improve its likely deficiencies concerning utilisation of whale resources. In the past the RMP *Small Areas* for Antarctic minke whale in the Antarctic were established as longitudinal sectors of 10° because there was no reliable scientific information on its stock structure, but at the very least, there is a need to redefine appropriate *Small Areas* in accordance with research results. Also another of the deficiencies of the current RMP is the zero catch quotas that it turns out when carrying capacity declines due to competition among whale species. The decrease in abundance caused by the competition is misinterpreted by the current RMP as an over-exploitation so that catches are

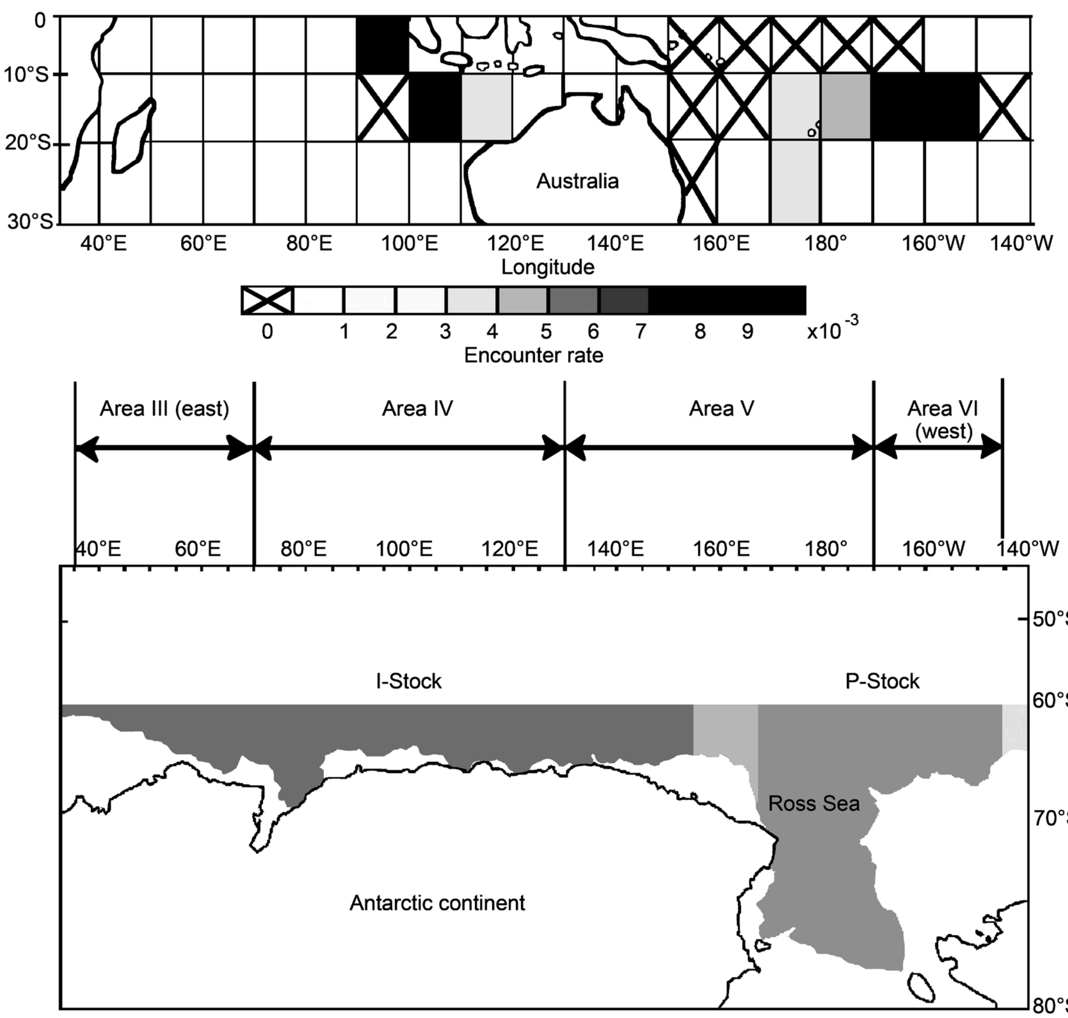

Fig. 1. Stock structure hypothesis of the Antarctic minke whale based on genetic and non-genetic data from JARPA (IWC, 2008). The upper figure shows the encounter rates of whales in 10° squares of latitude and longitude in waters 0°-30°S in October (Kasamatsu, 1995).

set unnecessarily low. That part needs also to be improved by the use of more realistic multi-species models.

Important information for the application of the current RMP process is stock structure, abundance and productivity (MSYR). JARPA research already provided some of the information.

For example the analyses of genetic and morphometric data obtained under the JARPA suggested the occurrence of at least two stocks in the JARPA research area, which for practical reasons are called 'Eastern Indian Ocean Stock' (I-Stock) and 'Western South Pacific Stock' (P-Stock). The data suggested an area of transition in the region around 150°-165°E (Fig. 1) across which there is an as yet undetermined level and range of mixing (IWC, 2008).

Abundance estimates in Areas IV and V were conducted based on the JARPA sighting surveys (Hakamada *et al.*, 2013). ADAPT-VPA analyses based on age and abundance data from the JARPA suggested $MSYR_{1+}$ values in the 4-6% range for Antarctic minke whale (Mori, 2006).

All this information, which is important for effective management under the RMP, is refined under the JARPA II in the context of the current RMP process as well in the context of the future improvement of the RMP.

Objective 3 of JARPA II is the **'Elucidation of temporal and spatial changes in stock structure'**: (i) Antarctic minke whale; and (ii) other baleen whale species.

Stock structure information is a basic requirement for the IWC conservation and management measures. It is essential for the implementation of the RMP. JARPA had indicated that the *Small Areas* used in the trial application of RMP to Antarctic minke whale in 1993 were not consistent with the stock structure of this species in the research area. Elucidation of the stock structure would also contribute to Objective 4.

Some specific scientific questions to be addressed under this objective are the following.

The aim of the JARPA II under Objective 3 is first to update the analyses on stock structure of Antarctic minke whale in the context of the suggested hypothesis, by using new genetics information obtained in the JARPA II, and then to estimate the mixing proportion of the I and P Stocks in the transition region, including possible yearly fluctuation in distribution and mixing proportion. The geographical overlap between the I and P Stocks under the JARPA II is examined in a wider sector than that suggested in the IWC JARPA Final Review (IWC, 2008): 130°-175°E. A different aim is to investigate the stock structure of fin, humpback and southern right whales in the feeding grounds.

- Are the additional genetics analyses based on JARPA II data consistent with the current stock structure hypothesis for Antarctic minke whale?
- How the distribution and mixing of the I and P Stocks changes annually?
- Are the fin, humpback and southern right whales genetically structured in the Antarctic feeding grounds?
- What is the biological validity of the IWC *Management Areas* for baleen whale species?

Objective 4 of JARPA II is **'Improving the management procedure for Antarctic minke whale stocks'**.

The goals under Objective 4 will be addressed with progress of the work under the other three Objectives. This objective is divided into two parts: (a) contribution to the implementation of the current RMP through the attainment of key information such as abundance, stock structure and MSYR (contribution from Objectives 1 and 3); and (b) contribution to the future improvement of the RMP through the incorporation of a more realistic (and possibly species-specific) MSYR range into the RMP algorithm, and the incorporation of the effects arising from the inter-species relationships among whale species (contributions from Objectives 1 and 2).

For (a) above, abundance and MSYR (through SCAA analyses) will be obtained under Objective 1 while the redefinition of Management Areas and mixing will follow results on stock structure under the Objective 3. For (b) above, MSYR (through VPA and SCAA analysis) will be obtained under Objective 1 and the incorporation of the effects arising from the inter-species relationships among whales species will be examined after the development of the ecosystem model has been completed under Objective 2.

Fig. 2 shows the interaction among the four Objectives of the JARPA II.

Overview of results

Objective 1 *'Monitoring the Antarctic ecosystem'*

ABUNDANCE AND DISTRIBUTION

Demographic parameters trends of Antarctic minke whale in 1940s-1970s were consistent with the pattern expected under the krill surplus hypothesis; the changes in the Antarctic ecosystem suggested under the JARPA research (e.g. whale species composition and distribution) was confirmed.

- SCAA analysis showed that Antarctic minke whale abundance increased from 1930 until the mid-1970s (SC/F14/O02).
- SCAA analyses showed that abundance trend in recent decades has been relatively flat in the I Stock and perhaps declining slowly in the P Stock (SC/F14/O02).
- The total abundance of Antarctic minke whales in Areas IIIE-VIW (Line Transect Method) has been roughly stable during the JARPA+JARPA II research period (SC/F14/J03).
- The abundance trend estimates of humpback whale Stocks D in Area IV (13.6% with 95% CI: 8.4%-18.7%) and E in Area V (14.5% with 95% CI: 7.6%-21.5%) were similar, and they showed a significant increasing trend during the JARPA+JARPA II period (SC/F14/J04).
- Spatial distribution of humpback whales in Area IV was expanded in the period 1989-2006 while the distribution of Antarctic minke whales remained stable in the same period (SC/F14/J18).
- The abundance of blue whales in Areas IIIE, IV, V and VIW combined showed a significant increasing trend during the JARPA+JARPA II period (8.2% with 95% CI: 3.9%-12.5%) (SC/F14/J05).
- The abundance of fin whales in Areas V and VIW combined showed a significant increasing trend during the JARPA+JARPA II period (12.0% with 95% CI: 2.6%-21.5%). The increasing trend was not statistically significant in Areas IIIE+IV (SC/F14/J05).
- The abundance of southern right whale in Area IV showed an increasing trend, which was not statistically significant (SC/F14/J05).

BIOLOGICAL PARAMETERS

Demographic parameters trends of Antarctic minke whale in 1940s-70s were consistent with the pattern expected under the krill surplus hypothesis; the change in the Antarctic ecosystem suggested under the JARPA research (e.g. whale species composition and distribution, biology of the Antarctic minke whale) was confirmed.

- Age at sexual maturity of Antarctic minke whale decreased between approximately 1940s and 1970s cohorts.

- The age at sexual maturity of Antarctic minke whale Stocks I and P has remained at between 7-8 years old from the 1970s cohorts. It showed a slight but statistically significant increasing trend from the 1970s cohorts (SC/F14/J08).
- The recruitment rate of Antarctic minke whale Stocks I and P increased between 1930s and 1970s and in recent decades it maintained a stable trend at a low level (in comparison with the level observed in the 1960s-1970s cohorts) (SC/F14/O02).
- The apparent pregnancy rate of Antarctic minke whale Stocks I and P maintained a stable trend at a high level during the JARPA+JARPA II period (SC/F14/J09).
- There is the possibility that fin whales are reaching sexual maturity at a younger age as compared with the period of commercial whaling (SC/F14/J10).

FEEDING ECOLOGY/ENERGETIC

The shift in the Antarctic ecosystem suggested under the JARPA research was confirmed. Deterioration in nutritional condition were found for the Antarctic minke whale. Less krill availability for Antarctic minke whale could explain the deterioration in nutritional conditions for this species. Less availability could be due to: (i) decrease in krill biomass because of global warming; or (ii) increase in the abundance of competing krill predators including baleen whales. The latter is better supported by the findings.

- The blubber thickness, girth and fat weight of Antarctic minke whales showed a significant decreasing trend throughout the JARPA period. There was no clear trend for the JARPA II period (Konishi *et al.*, 2008); SC/F14/J13). For both data sets combined the decreasing trend was less marked in comparison with that found for the JARPA period alone.
- The stomach content weight of Antarctic minke whales showed a significant decreasing trend throughout the JARPA+JARPA II period in offshore areas. No significant trend was found in the Ross Sea for females, where humpback whales are not distributed (Konishi and Butterworth, 2013); SC/F14/J14).
- The daily prey consumptions of Antarctic minke whales per capita during the feeding season based on two methods were 95.1-127.0 and 182.6-250.3kg for immature and mature male, and 125.8-138.7 and 268.1-325.5kg for immature and mature female, respectively. These values are equivalent to 2.65-4.02% of the body weight (SC/F14/J15).
- The total prey consumption by Antarctic minke whales in the research area was estimated in 3.51 and 3.98 million tons by each method, respectively. These values correspond to 7.6% and 8.6% of the estimated krill biomass in the research area (SC/F14/J15).
- The daily prey consumption per capita of Antarctic minke whales decreased between the JARPA and JARPA II periods for all sexual classes, based on the results of diurnal change in stomach content mass (SC/F14/J15).
- The daily prey consumption of fin whales per capita during the feeding season based on three methods ranged between 276 and 2,136kg. These values were equivalent to 0.50 and 3.84% of the body weight (SC/F14/J16).
- Antarctic minke and fin whales fed on krill of similar body size implying that fin whales and the Antarctic minke whales have similar feeding habit, and no prey size selectivity (SC/F14/J16).
- Body weight of fin whales in the JARPA II period is heavier than those previously reported for the Antarctic in the 1950s suggesting improved nutritional conditions in recent decades (SC/F14/J10).

POLLUTANTS

- Total Hg levels in krill sampled from the stomachs of Antarctic minke whales were similar between Areas IV (0.006-0.026 ppm dry wt) and V (0.003-0.052), and no yearly trend was observed for the period 2005-11 (SC/F14/J23).

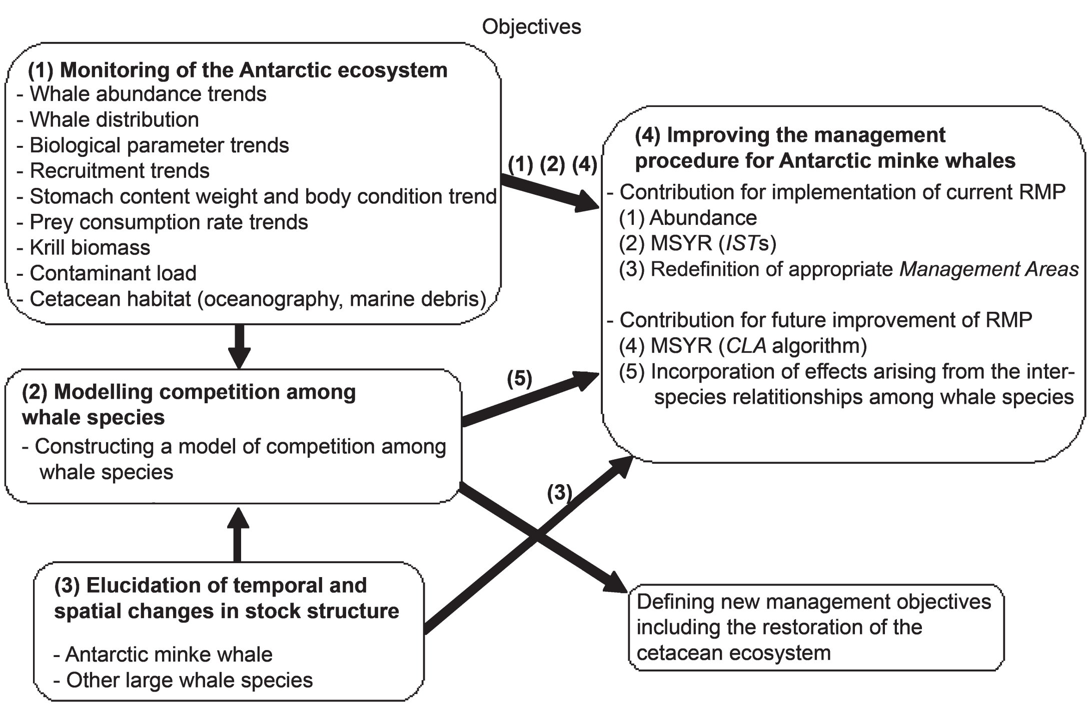

Fig. 2. Schema summarising the objectives of the JARPA II prepared by the proponents. Several parameters considered 'indicators' of change in the ecosystem are studied and monitored under **Objective 1**. The modelling exercise under **Objective 2** aims to provide interpretations to the pattern of changes observed under **Objective 1**: can these changes be explained only by the prey-predators interaction without the need for recourse to environmental change hypotheses? **Objective 4** depends on the results obtained under the other objectives: stock structure of Antarctic minke whale under **Objective 3**; abundance, MSYR and natural mortality of Antarctic minke whale under Objective 1.

- Total Hg levels in liver of Antarctic minke whale in Areas IV and V were 0.003-0.130 ppm wet wt and <0.001-0.250, respectively. These levels are considerably lower than those in other ocean basins. Hepatic Hg levels of all age groups of Antarctic minke whale in Area IV decreased significantly, and the age group 15-26 years old in Area V increased significantly during the JARPA and JARPA II period (SC/F14/J23).
- Mean concentration of organochlorine in 21-25 years old minke whale in Area V in 2010/11 were HCB (140 ng/g fat wt.), DDTs (100 ng/g fat wt.), PCBs (28 ng/g fat wt.), CHLs (25 ng/g fat wt.), and HCHs (0.8 ng/g fat wt.). Levels of DDTs, HCHs, HCB and CHLs in Area V decreased significantly with year, while the yearly trend of PCBs did not change significantly. The levels of HCHs in the Antarctic Ocean have varied from slightly decreasing to a steady state in the middle 1990s (SC/F14/J24).
- Mean concentrations of total Hg in livers and muscles of fin whale were 0.052 and 0.021 (ppm wet wt.), respectively. Mean concentrations of PCBs, DDTs, HCHs, HCB and CHLs were 6.5, 13, 0.65, 39 and 4.5 (ng/g fat wt.), respectively. Hg levels in liver and muscle were one order of magnitude lower than those of fin whales from the western North Atlantic Ocean. OCs levels were extremely lower than those in fin whales from the middle latitude of the northern hemisphere, and those in killer whales (top predator) from the Antarctic Ocean (SC/F14/J25).

OCEANOGRAPHY/MARINE DEBRIS

- The effect of the global warming was not detected in the research area (SC/F14/J20).
- Annual fluctuation on the locality of the southern boundary (SB) was observed in the research area during the JARPA and JARPA II periods. Southward shift of the SB generally coincided with a rapid increase of humpback whales in 1995/96 and 2001/02 suggesting that oceanographic conditions affect the distribution of whales (SC/F14/J21).
- A low incidence of marine debris and entanglements was observed in the JARPA/JARPA II period (SC/F14/J22).

Objective 2 *'Modelling competition among whale species'*

While developing ecosystem models requires a substantial data collection and analytical effort, initial progress was made toward this objective in JARPA II.

- Several input data for the models were collected by JARPA and JARPA II. Progress was made toward the development of two types of ecosystem models: multi-species production model and Ecopath with Ecosim. Several additional data and analyses were identified to progress further this work (SC/F14/J26).

Objective 3 *'Elucidation of temporal and spatial changes in stock structure'*

The stock structure hypothesis of Antarctic minke whales derived from JARPA research was confirmed and refined by JARPA II. Important stock structure information for assessment was also obtained for other large whale species in the Antarctic feeding ground.

ANTARCTIC MINKE WHALE

- Results of additional genetics (mtDNA sequencing; microsatellite DNA) analyses based on the JARPA II data were consistent with the previous stock structure hypothesis of at least two stocks in the JARPA II research area, which occupy the most western and eastern part of the JARPA II research area, respectively (I and P Stocks) (SC/F14/J28)
- Genetic analyses based on microsatellite showed significant yearly changes mainly within the stock in the most western side of the research area (I Stock). In general, results of the new microsatellite analyses suggested stronger fidelity to migration destination in females than in males (SC/F14/J28).
- The transition area where two stocks mix with each other is longitudinally wider than originally suggested under the JARPA. The spatial distribution of the two stocks has a soft boundary in Areas IVE and VW, which vary annually (SC/F14/J29).
- There are possible sex differences along the soft boundary (SC/F14/J29).

HUMPBACK WHALE

- Genetic pattern of variation based on mtDNA was consistent with the geographical locations of breeding and feeding grounds of Stocks D, E and F. Western Australia whales are strongly related to Area IV, Eastern Australia whales are related to Area VW and whales from New Caledonia and Tonga are related with feeding grounds east of 160°E. Whales from Cook Island and French Polynesia are not related genetically to whales in the feeding grounds covered by the JARPA II surveys (SC/F14/J30).
- Mixing proportion estimates of Stocks D, E and F in the feeding grounds were provided (SC/F14/J30).
- Results of microsatellite analyses showed that Areas IIIE, IV, V and VIW are occupied by different stocks, which is consistent with the mtDNA results (SC/F14/J31).

FIN WHALE

- Results of mtDNA and microsatellite analyses suggested genetic structuring in the JARPA II research area (SC/F14/J32).

SOUTHERN RIGHT WHALE

- Genetic analyses based on microsatellites suggested site fidelity of whales to Area IV. Results of the mtDNA analysis suggested longer distance feeding migration than previously thought, and the possibility that different stocks migrate into Area IV in summer (SC/F14/J33).

PHOTO-IDENTIFICATION

- 3,108 photo-ID images of the blue, humpback and southern right whales were digitised and incorporated into the ICR photo-ID catalogue (SC/F14/J34).
- Some 'matching' were found within the feeding ground and between feeding and breeding grounds, which are consistent with the results of the genetic analyses (SC/F14/J34).

IWC MANAGEMENT AREAS

- Results of the stock structure studies confirmed that the current Management Areas of the IWC are not supported by biological evidence in the case of the Antarctic minke whale.
- The IWC boundaries of the Areas III, IV, V and VI match better with the genetic results found for the humpback and fin whales.

Objective 4 *'Improving the management procedure for Antarctic minke whale stocks'*

- New information on stock structure and mixing and on abundance will be important for future RMP application to Antarctic minke whale, as such information is essential for the RMP's *pre-Implementation assessment* and *Implementation Simulation Trials.* JARPA II has shown that the previous trial specifications of the RMP to Antarctic minke whale in 1993 is no longer valid.

- The new information, particularly the stock structure information, is to render the RMP more efficient, i.e. providing extra catch without increasing conservation risk. For example the 10 degree longitude slices used previously as *Small Areas* are no longer supported by the JARPA II data.
- SCAA analyses based on JARPA II data showed that Antarctic minke whale can show growth rates that are appreciably larger than the lower bound for MSYR used in RMP trials.

Other results
- Alternative method for age determination in the Antarctic minke whale by way of aspartic acid enantiomers was developed (SC/F14/J12).
- New genetic method based on paternity analyses of foetuses to estimate the size of the mature male population of Antarctic minke whale was developed (SC/F14/J07).
- Novel information on physiology and reproductive biology of the Antarctic minke whale was provided (SC/F14/J35-J37 [published information]).

4. REVIEW OF RESULTS: MONITORING CETACEAN HABITAT

4.1 Proponents' summary of results
The comprehensive JARPA/JARPA II oceanographic survey has derived in a very unique set of temperature and salinity data profiles for almost half of the Antarctic area obtained systematically in more than 20 years of research. This data set enabled the oceanographic structure and dynamics in the research area to be investigated. Southward/northward movement of the Southern Boundary (SB) of the Antarctic Circumpolar Current (ACC) could play an important role in the distribution of whales in the research area. This should be further investigated using the comprehensive oceanographic and whale sighting data sets from JARPA and JARPA II. Additional results, important for the interpretation of other JARPA II results, is that the surveys provided no evidence of global warming in the research area unlike the case reported for the Antarctic Peninsula (Trivelpiece *et al.*, 2011).

JARPA/JARPA II surveys made possible the first comprehensive observations of marine debris on sea surface, stomachs of whales, and of entanglements of whales in the Antarctic. Given the low indices, the effect of marine debris on whales in the Antarctic is expected to be limited at the present time. Continued monitoring is desirable.

SC/F14/J20 analysed oceanographic observation data obtained by the JARPA and the JARPA II to clarify physical oceanographic conditions in the JARPA/JARPA II area as a basis for understanding the habitat environment of whales. About 2,500 profiles were obtained by XBT, XCTD and CTD observations from 1990 to 2009. Profile data were converted to the same format and utilised to describe the oceanographic features of the JARPA/JARPA II area. Based on this data set the averaged feature of the oceanographic structure in the research area for two decades was described. The Southern Boundary (SB) of the Antarctic Circumpolar Current (ACC), which is detected by a 0°C temperature contour line on the 27.6 isopycnal surface, characterised the research area. The position of the SB is controlled by major features of bottom topography such as the Kerguelen Plateau and the Pacific-Antarctic ridge. In the area east of the Kerguelen Plateau, the position of SB changes on a decadal timescale. The southward shift of SB in the region is observed in the early 2000s, and a northward shift is observed in the later 2000s. Although global warming is an important factor for the Southern Ocean, unlike the Antarctic Peninsula region, the JARPA and JARPA II temperature data shows no statistically significant warming in the JARPA/JARPA II research area for the two decades examined.

SC/F14/J21 examined information such as: (a) Kerguelen-Davis Oscillation Index (KDOI); (b) the extent of sea ice; (c) abundance estimates of humpback and Antarctic minke whales in Area IV from the 1989/90 to 2007/08 seasons collected by the JARPA and the JARPA II; and (d) zonal average of Southern Boundary of Antarctic Circumpolar Current (SB) in the Indian Ocean sector. Time-series of these data showed trends and relations as follows: First, KDOI indicated: (1) the effective data of Kerguelen had a limited number of years since 2006 while the Davis's data had 56 years since 1957, therefore, the analytical period of KDOI was limited to seven and half years at this stage; and (2) KDOI during 2006 and 2013 showed the variability of an upward trend with approximately 2-year periodicity. Second, sea ice extent in austral summer from 1979 to 2011 showed an upward trend with yearly variability suggesting some relationship with KDOI. In addition, the lower abundance estimate of Antarctic minke whale coincided with the larger sea ice extent such as 1997/98 and 2007/08, probably due to navigational limited surveys caused by sea ice. Third, the rapid southward shift of SB coincided with a rapid increase of humpback whales such as in 1995/96 and 2001/02, probably due to Antarctic Circumpolar Water southward shift.

SC/F14/J22 summarised the information on marine debris collected during the surveys of the JARPA and JARPA II for the period 1987/88 to 2010/11. Three kinds of observations were considered: marine debris on the sea surface, marine debris in the stomachs of whales caught (Antarctic minke, dwarf minke and fin whales), and entanglements. In the Antarctic research area, south of 60ºS, marine debris included metals (drum, can), petrochemical products (buoy, ball, bottle, container, fender, net, rope, styrofoma). Buoys were the most abundant debris (69% of all marine debris recorded). The highest density index (DI: number of marine debris observed per 100 n. miles) was recorded in Area V (DI: 0.15), followed by Area IV (DI: 0.12). DI of buoys in Area IV and V suddenly increased after the 2005/06 austral summer season. The increase of buoy debris coincides with an increase of long-line fishery operations in this area. The stomachs of a total of 10,041 Antarctic minke whales, 16 dwarf minke whales and 16 fin whales were examined for debris. A total of 70 marine debris and objects other than prey were found in the stomachs of the three species, including feather, stone, wood, plastic and others. The number of occurrence of marine debris and objects other than prey in the fore and main stomachs per 100 Antarctic minke whales examined was estimated at 0.35. Four cases of entanglement in a total of 10,041 Antarctic minke whales examined were found. Those involved fishing hook, monofilament fishing line, rope and packing band.

4.2 Panel's conclusions and recommendations
Monitoring the physical and biological habitat is an integral part of monitoring a whale's ecosystem, i.e. Objective 1 of JARPA II. The survey methods of the original proposal stated: 'Oceanographic and meteorological observations will be carried out while monitoring the environment, including sea ice, surface temperature, sea surface height and chlorophyll α concentration over the entire research area, using satellite data. JARPA II will investigate the relationships between oceanographic data and species distribution, including

cetaceans, by real-time or time series analysis. JARPA II also intends to actively cooperate with international organisations and projects on oceanographic surveys.'

The proposal was implemented during the first four years of JARPA II by collecting data via XBTs, CTDs, an Electric Particle Counting and Sizing System (EPCS), and an echo sounder at the same times and areas as the visual whale abundance survey was being conducted. Collection of such simultaneous data is an important component of being able to relate the physical and biological habitat with whale distribution and density and ultimately to assist in developing an understanding of the role of whales in the ecosystem.

Unfortunately, this was not done for the last two years (2009/10 and 2010/11) when only TDR data were collected.

SC/F14/J20 and SC/F14/J21 provided a good initial investigation into the broad spatial and temporal scale physical oceanographic characteristics within the JARPA study area. The authors conducted a variety of data checks using climatological worldwide data sources and thus re-calibrated some data. As stated in SC/F14/J20 this level of calibrations is sufficient to study broad scale features in the Southern Ocean. However, to investigate finer spatial and temporal characteristics, which is ideal when investigating the relationships between oceanographic data and species distributions, it is important to collect *in situ* water samples to calibrate and when necessary correct the instrument readings; as a minimum instruments should be calibrated at the factory once a year.

The Panel noted that in addition to the data collected by the JARPA and JARPA II programmes, there are a number of other sources of similar data (such as those found in world or Japanese databases) and also associated with other available habitat characteristics (such as bottom depth, sea ice extent, distance from sea ice, SST, chlorophyll, and sea surface height). Many of these databases are available online.

The Panel **recognises** the contribution of the long-term time series represented by the JARPA and JARPA II programmes, particularly in the context of simultaneous collection of whale and environmental data. However, the Panel is concerned that the necessary analytical work to fulfil the objectives of the programme has not received the attention and resources that it deserves. If the programme is to meet its objectives in the medium to long-term, the Panel makes the following **recommendations:**

(1) the collection of the full suite of oceanographic data be resumed in the coming season and the necessary calibration work be undertaken;
(2) the proponents investigate the availability and utility of other oceanographic and related data, including data on sea ice, archived in other Japanese or world databases and incorporate these with the data collected from the JARPA and JARPA II programmes to form a more comprehensive dataset (a useful catalogue of available data with links to many national Antarctic data centres is available from the Antarctic Master Directory at *www.gcmd.nasa.gov/portals/amd/*);
(3) the proponents consider make their oceanographic data available to other international programmes;
(4) the existing TDR and EPCS data are analysed to fully describe the datasets contents and review their usefulness in future habitat and whale analyses; and
(5) concerted efforts begin to analyse the oceanographic and other environmental data in the light of the obtained cetacean sightings survey and biological data (more details are provided under the relevant agenda items below).

Item (1) can begin immediately. Work on Items (2)-(5) should also begin as soon as possible and the initial results presented within the next two-three years. Items (2) and (3) will also fulfil the aim in the original proposal to actively cooperate with international organisations and projects on oceanographic surveys which to date has not been achieved. In these times of limited funds and resources, such cooperation is important to maximise efficiency and benefit.

The Panel **commends** the collection of debris data, both in the environment and in the stomachs of the whales that can provide valuable baseline data. Such information should regularly (the need to do this annually or less frequently should be evaluated) be analysed and presented to the IWC.

5. REVIEW OF RESULTS: ELUCIDATE TEMPORAL AND SPATIAL CHANGES IN STOCK STRUCTURE (SC/F14/J27-J34)

5.1 Proponents' summary of results

Significance of the stock structure analysis under the past JARPA is the occurrence of at least two stocks of Antarctic minke whales in the JARPA research area, which were called 'Eastern Indian Stock' (I-Stock) and 'Western Pacific Stock' (P-Stock), and the mixing of the two stocks in the region around 150°-165°E. In addition it was demonstrated that the current IWC Management Areas are not applicable to this species. Questions remaining were the detailed description of the mixing of the two Antarctic minke whale stocks in the transition area and the stock structure of other large whale species, such as humpback, fin and southern right whales in the research area.

The specific objectives of the stock structure studies presented are to: (1) examine the stock structure hypothesis for Antarctic minke whales proposed based on the JARPA data using only the JARPA II data (SC/F14/J28); (2) describe temporal and spatial mixing pattern of the I and P Stocks of Antarctic minke whales in the transition region (SC/F14/J29); and (3) understand genetic characteristics and stock structure of other large whale species, such as humpback (SC/F14/J30, SC/F14/J31), fin (SC/F14/J32), and southern right whales (SC/F14/J33) in the feeding ground.

SC/F14/J27 presented a brief summary of the genetic analysis protocols, including sampling, used at the Institute of Cetacean Research for the stock structure studies under the Objective 3 of the JARPA II. In general the protocols follow the IWC SC guidelines for DNA data quality control for genetic studies relevant to IWC management advice (IWC, 2009).

SC/F14/J28 tested the hypothesis on stock structure derived from the JARPA research by applying two different kinds of the genetic markers, 338bp of the mtDNA control region sequences (2,278 individuals) and 12 microsatellite DNA (mtDNA) markers (2,551 individuals) only to the JARPA II samples, making this study as an independent test. The areal and temporal pattern of the stock mixing, which is one of the objectives of the JARPA II, was examined in detail in a separate document (SC/F14/J29). The statistical analysis of heterogeneity followed a step-wise fashion: first, for each annual survey Areas IIIE, IVW and IVE were compared in the western sector, and Areas VE and VIW were compared in the eastern sector. Next the yearly variation in the western and eastern sectors was investigated. Finally a comparison between western and eastern sectors of the JARPA II research area was conducted. This was done for females only, males only, and both combined. While the mtDNA analysis detected statistically significant differences between the western and eastern sectors for females, males, and total samples, the microsatellite analysis did for females and total samples. Therefore genetic results based only on the JARPA II samples were consistent with the previous hypothesis of at least two stocks in the research area, one in the most western part (I Stock) and the other in the most eastern part (P Stock). Furthermore microsatellite analyses observed substantial yearly variation mainly within the I Stock, especially for females. These yearly differences could be explained either by the mixing of the I and P Stocks in different proportions in different years in part of the western sector (i.e. SC/F14/J29), or by the sporadic intrusion of an unknown third stock occurring in the western part of Area III. Unfortunately, despite the doubled number of the microsatellite loci from the previous JARPA study as recommended by the 2006 JARPA final review Workshop, the level of the stock differentiation was still too low (F_{ST} less than 0.001) to conduct genetic analysis at the individual level, that prevented us from conducting an analysis that could have distinguished the above two possibilities.

SC/F14/J29 took a mathematical approach that simultaneously incorporated two different sources of information, genetic and morphometric data, for estimating longitudinal segregation of two stocks. This study was in response to a recommendation made during the JARPA final review Workshop, and the model was originally presented to the IWC SC in 2012 using only the JARPA data (Kitakado *et al.*, 2012). This time the model was applied to the JARPA and JARPA II data collected between 1989/90 and 2010/11 in Areas IIIE-VIW. A soft boundary was allowed to vary by year and sex with assuming baseline stocks. A joint likelihood function derived from the two sources is defined for the estimation of mixing proportions. The mixing proportion was modelled by a linear logistic model with stock-specific, i.e. putative I-Stock in the western areas (Areas IIIE and IVW) and P-Stock in the eastern areas (Areas VE and VIW), parameters for the two sets of data. It was observed that the morphometric data were dominant to the genetic data and helped convergence in the optimisation. However, the inclusion of the morphometric data altered the estimation results and tended to give softer, i.e. more fluctuated, boundaries. On the whole, the result indicated that the spatial distribution of the two populations changed year by year in Areas IVE and VW, which was wider and more western than we previously proposed. It also suggested possible sex differences in the dynamics of the mixing pattern along the boundary.

SC/F14/J30 analysed mtDNA data from 575 humpback whales obtained in the Antarctic during surveys of the JARPA/JARPA II and the International Decade for Cetacean Research/Southern Ocean Whale and Ecosystem Research (IDCR/SOWER), and from 1,057 whales from low latitude localities of the South Pacific and eastern Indian Ocean to describe the distribution and mixing of breeding stocks D, E and F in the Antarctic feeding grounds. This study was conducted to respond to a recommendation from the JARPA review Workshop and to recommendations from the IWC SC in 2012 (IWC, 2013a). Such information is important to interpret abundance estimates as well as to allocate historical catches to stocks. This was one of the few studies that utilised samples from both low latitude and Antarctic areas. After the alignment of the sequences of the mtDNA control region from the two data sets, the consensus 329 bp was used. The low latitude samples were used as baselines representing ‘pure’ stocks to examine distribution and mixing of these ‘pure’ stocks in the Antarctic feeding area. The results were roughly consistent with north-south migration of Stocks D, E and F. Western Australia whales (D) are strongly related to Area IV, while Eastern Australia whales (E1) are related to Area VW and New Caledonia (E2) and Tonga (E3) whales were related to the feeding grounds east of 160°E. In contrast, Cook Island (F1) and French Polynesia (F2) whales were not related to the feeding grounds covered by the JARPA II surveys. This paper was presented and discussed at the IWC SC in 2013 (Pastene *et al.*, 2013).

SC/F14/J31 analysed biopsy samples from humpback whales obtained during surveys of the JARPA and JARPA II up to the 2010/11 season as well as IDCR/SOWER using 14 microsatellite DNA loci in order to describe their stock structure in the Antarctic feeding ground. The samples were divided into four groups based on the IWC *Management Areas*: III (n=93), IV (n=218), V (n=153) and VI (n=64). In three of 37 cases of duplicate sampling, the second samples were collected at least a day apart (1 day, 9 years, and 11 years). Heterogeneity tests were conducted for females only, males only, and both combined. Although a few cases of small temporal genetic differences were detected within the areas, major genetic differences were among the samples from the different Areas. In addition, stronger differentiation was seen in females than in males. Despite the increase in the number of the loci from six in the previous paper for the JARPA review Workshop to 14, the level of the stock differentiation (F_{ST}=0.003) was still too low to conduct genetic analysis at the individual level, so that further analysis would require using samples from their breeding areas to better understand the stock structure in the feeding grounds. Nevertheless, this microsatellite study confirmed that humpback whales from different stocks occupied the Areas with higher differentiation in females than in males.

SC/F14/J32 analysed samples of fin whales (biopsies and research takes) obtained during JARPA and JARPA II using mtDNA control region sequencing and microsatellite DNA to describe stock structure of this species in their feeding grounds. A total of 55 samples obtained from Area IIIE (n=6), IV (n=23), V (n=24) and VIW (n=2) was genotyped at 16 microsatellite DNA loci and was sequenced for 479 bp of the mtDNA control region. Although the haplotype distributions appeared to be quite different among the areas, almost all of the individuals had different haplotypes, reducing the statistical power. Statistical comparison was thus made by grouping the haplotypes into two categories: those specific to each of the Areas and those shared by more than one Area. Results of the mtDNA heterogeneity test showed statistically significant differences among Areas IIIE, IV and V. The microsatellite analysis also showed statistically significant differences between Areas IV and V. Results of the genetic analyses therefore suggested the possibility of genetic structuring of fin whale stocks in the JARPA II research area that corresponded to the IWC Management Areas. Their detailed mixing patterns should be explored with a larger sample size in the future.

SC/F14/J33 analysed biopsy samples from southern right whales obtained during the JARPA and JARPA II surveys up to the 2009/10 season using both microsatellite DNA and mtDNA markers in order to describe genetic characteristics of the species in the Antarctic feeding ground. A total of 70 samples obtained from Areas III to V was genotyped at 14 microsatellite DNA loci and was sequenced for 430bp of the mtDNA control region. In two cases of three duplicate sampling, the second samples were collected in a later year (4 and 8 years, respectively) in the same Area (IV), suggesting site fidelity to feeding ground. The levels of genetic diversity observed from both markers were comparable to those reported from other southern right whale genetic studies. A total of eight haplotypes was generated from 21 segregation sites and these haplotypes were phylogenetically separated into two clades. These eight haplotypes were then compared to the 37 haplotypes (273bp) reported in Patenaude *et al.* (2007) that were observed in the samples obtained from the Indo-Atlantic (Argentina and South Africa) and the Indo-Pacific (southern Australia and New Zealand) basins. The comparison revealed that our two clades were the same as their A and W clades, each of the eight haplotypes matched to one of their haplotypes, and three were same as their Indo-Atlantic specific haplotypes. These results suggest that some southern right whales undertake much longer-distance seasonal migration between their feeding and breeding grounds than we had previously thought and thus whales from multiple stocks migrate to our research area in the Antarctic feeding ground.

SC/F14/J34 summarises the information on photo-identification of blue, southern right and humpback whales obtained during the JARPA/JARPA II surveys in Antarctic Areas IIIE, IV, V and VIW in the austral summer seasons. A total of 3,108 photo-identification pictures selected from all of the pictures obtained between 1989/90 and 2010/11 were deposited in the photo-identification catalogue administrated by the Institute of Cetacean Research. All of the deposited pictures were digitised to facilitate archiving. The JARPA pictures of blue whales were submitted to the IWC Secretariat to facilitate comparisons with other catalogues. Similarly, the JARPA pictures of humpback and southern right whales were provided to the IWC's Antarctic Humpback Whale Catalogue and to other international research organisations, respectively, under co-operation studies. A preliminary examination of the pictures within the feeding grounds as well as between the feeding grounds and lower latitude localities resulted in several matches. The JARPA and JARPA II photo-identification data have the potential to contribute to the better understanding of the movement, distribution and abundance, and in turn to the assessment and conservation of blue, southern right and humpback whales.

In summary, these studies demonstrated that the comprehensive large-scale JARPA II (as well as JARPA) survey effectively used a combination of lethal and non-lethal techniques to acquire valuable information for effective management of large whales in the Antarctic. The studies implied that different species require different management strategies on an area by area basis even within the same feeding grounds for their long-term persistence. The stock structure results are one of the key information for the RMP process. The JARPA results were refined under the JARPA II and this information can be used in the context of the current RMP process as well as in the context of the future improvement of the RMP. We believe that our studies properly addressed and answered all of the objectives we raised and the recommendations from previous reviews that required a response.

5.2 Panel's conclusions and recommendations

This section deals with Objective 3 of JARPA II: Elucidation of temporal and spatial changes in stock structure. In addition to a general paper describing genetic laboratory methodology (SC/F14/J27) and a summary overview paper (Pastene, 2006), the Proponents presented two genetic papers on minke whales (SC/F14/J28, SC/F14/J29, with the latter also including morphometric data), two genetic papers on humpback whales (SC/F14/J30, SC/F14/J31), one genetic paper each on fin whales (SC/F14/J32) and southern right whales (SC/F14/J33), and a summary of photo-ID information for blue, southern right, and humpback whales (SC/F14/J34).

The Panel noted that knowledge of stock structure is fundamentally important not only to this objective of the programme but to all of the objectives. The Panel **commends** the considerable field and laboratory effort that had gone into developing a comprehensive long-term dataset, particularly for the Antarctic minke whales. It also **commends** the efforts to develop analytical approaches to incorporate genetic and other markers in an integrated analysis (SC/F14/J29).

5.2.1 Scope of the studies

The Panel **agrees** that information resulting from the JARPA and JARPA II programmes has considerably increased our understanding of stock structure within the research area, which directly addresses Objective 3. However, the Panel noted that Antarctic minke whales and other baleen whale species are more-or-less continuously distributed around the Antarctic continent; in contrast, the JARPA II research area represents just under half of the circumpolar area. Given the stated objective, the lack of information provided for areas outside the programmes' research area presents some inherent difficulties in fully meeting the objective to elucidate spatial and temporal variations in stock structure, even though the information developed under JARPA II is probably sufficient for the purposes of developing trials to evaluate RMP variants within the area of sampling. This issue is discussed in more detail below with respect to Antarctic minke whales.

5.2.2 Genetic data

The Panel **welcomes** the fact that the authors of SC/F14/J27 referenced the IWC guidelines for DNA data quality control (IWC, 2009) as had also been recommended at the JARPN II review (IWC, 2010). However, the Panel **recommends** that a revised paper be submitted that explains in more detail how far the guidelines were able to be followed (the present paper did note why the proponents had not been able to follow one recommendation regarding sequencing of microsatellite loci).

5.2.3 Antarctic minke whales

SC/F14/J28 described new mtDNA and microsatellite genetic analyses of minke whales. The Panel **welcomes** the fact that, in response to comments from the JARPA review Workshop (IWC, 2008), the authors had doubled the number of microsatellite markers, sequenced a portion of the mtDNA molecule, and performed additional analyses, including use of the clustering program STRUCTURE (Pritchard *et al.*, 2000) to evaluate evidence for more than one gene pool. This paper excluded samples from the putative mixing area, which were considered in SC/F14/J29. The Panel **acknowledges** the extensive laboratory and analytical work behind the paper. However, there are a number of places where additional information is required to fully interpret the results. For example, if the authors' hypothesis is correct that different proportions of stocks I and P mix in part of Area IV, then the F_{IS} values for that area should on average be positive, reflecting a deficiency of heterozygotes. Furthermore, the loci showing the most positive F_{IS} values should be the loci having the highest F_{ST} values among the two putative stocks (Waples, 2011). If the two-Stocks-with-mixing hypothesis is true, then the analysis suggested above should also produce a positive correlation between F_{IS} and F_{ST} for samples taken from the area of putative mixing that were not considered in this analysis. Similarly, the magnitude of linkage disequilibrium at pairs of loci should be proportional to the product of F_{ST} at the two loci involved (Waples, 2011). The mean F_{ST} estimated between the two stocks in this case is quite small (<0.001), so these correlations might be hard to detect. If these analyses are conducted, it would be reasonable to start by evaluating only females, which show the strongest signal of differentiation.

The Panel makes the following detailed **recommendations** concerning SC/F14/J28:

(1) samples from the putative pure I and P Stocks have statistically significant differences in allele frequencies – a revised paper should provide the locus-specific F_{ST} or theta values for these comparisons to identify which loci are responsible for the differences;
(2) Table 4 presents evidence for overall deviations from Hardy-Weinberg (HW) expectations in both putative stocks – a revised paper should include F_{IS} values for each locus in each stock to provide information about the direction and magnitude of HW deviations and thus the biological importance of this result; and
(3) the discussion section should be expanded to consider the results of the analyses suggested above.

SC/F14/J29 provides an innovative approach to integrate multiple sources of data to distinguish stock structure and identify time-varying distribution patterns by maturity class. As noted below, the method could be extended to make use of other data sources such as stable isotope ratios of C, N and O, and hence provide a way to synthesise much of the information on stock structure collected during JARPA/JARPA II. Stable isotope ratios of these elements have been used to assess population structure and degree of mixing in other cetacean species with reasonable success (Born *et al.*, 2003; Giménez *et al.*, 2013; Vighi *et al.*, 2014) and, in addition, this method has the potential to assess the value of data collected using lethal methods (in this case, the morphometric data).

The Panel **welcomes** this effort to integrate genetic and non-genetic data, noting that this is in accord with the Scientific Committee's view that stock structure can best be addressed using a suite of techniques and data types. The Committee has recognised that developing a quantitative integrative approach is complex. In terms of developing a revised paper in time for the forthcoming Scientific Committee meeting, the Panel makes the following **recommendations:**

(1) notation in the paper should be improved to avoid using the same index for individual and stock;
(2) the estimates of the parameters and their standard errors should be reported – this information could be used to identify which of the morphometric measurements is most informative regarding stock mixing;
(3) diagnostic statistics for the fits to the morphometric data should be presented;
(4) the meaning of the statement: 'The variables *G* and *M* are further assumed independent within an individual, and also between individuals' should be clarified – it is not clear whether this means that matrix *G* is assumed independent of matrix *M*, or that the different elements of *M* are assumed to be independent (i.e. is the Σ diagonal?);
(5) the parameters for each model should be documented to clarify how many of the parameters of the mean function and variance-covariance matrix (morphometric data) as well as the baseline allele frequencies (genetic data) are estimated parameters; and
(6) the discussion should explore the fact that one of the main results of this study - that morphometric data had a stronger influence on results than the genetic data - differs from that found in many other such studies, and the authors should suggest a possible biological explanation for this result.

In the longer-term, the Panel **recommends** that:

(1) the model be formulated as a random effects model (Bayesian or maximum likelihood). This may eliminate some of the problems associated with lack of convergence for some of the more complicated models – this might also reduce some of the large inter-annual fluctuations in mixing proportions, which a plot produced during the Workshop (Fig. 3) shows are generally very imprecise;
(2) more flexible functions for the relationship between longitude and proportion should be considered; and
(3) the benefits of applying the integrated model to all data (i.e. data aggregated by sex and maturity state) should be re-evaluated since, for example, there are clear between-sex differences in some of the morphometric measurements such as V7 (fig. 3 of SC/F14/J29) - a model with sex-specific values for the mean and variance functions for the morphometric data, but sex-independent distribution proportions should be explored.

Management procedure considerations on stock structure focus on developing plausible interpretations of available data not simply the single 'best' interpretation when examining uncertainty. In this spirit, the Panel **recommends** that during the coming year, the authors of SC/F14/J28 and SC/F14/J29 consider the merits of an alternative to the two-Stocks-with-mixing hypothesis: a single stock that exhibits one-dimensional isolation by distance along a longitudinal gradient. This alternative is suggested by visual inspection of fig. 3 in SC/F14/J29, which shows how morphometric scores for individual whales vary by longitude. Morphology appears to vary more or less linearly along the zone of sampling, rather than being constant at the eastern and western extremes, with an area of mixing in between. Under isolation-by-distance, statistical comparisons of samples from the extreme eastern and western sampling regions could produce the types of results described in SC/F14/J28 (Schwartz and McKelvey, 2009).

The genetic analyses of isolation-by-distance could use the statistic (a) for comparing genotypes of individuals suggested by Rousset (2000). With isolation-by-distance, a linear relationship is expected between a and ln(distance), where distance is measured by longitude. It should be possible to modify the genetic/morphometric model in SC/F14/J29 to evaluate a scenario in which morphology varies along a cline. Conceptually, the study system could be considered to correspond to a narrow ribbon, either joined end to end or not. If samples were available from 360 degrees of longitude rather than just under half that, it would be possible to determine whether the opposite ends of the ribbon are joined (hence forming a type of flattened torus) or remain separate. Under the latter scenario, Antarctic minke whales would form a type of ring species (Irwin *et al.*, 2005), with extreme forms being reproductively isolated, but connected by gene flow along a gradient. These two scenarios might not imply that different RMP variants would be selected for the portion of the range that has been sampled, but they would have profoundly different implications for understanding of the biology of the species, and that seems to be broadly consistent with JARPA II Objective 3.

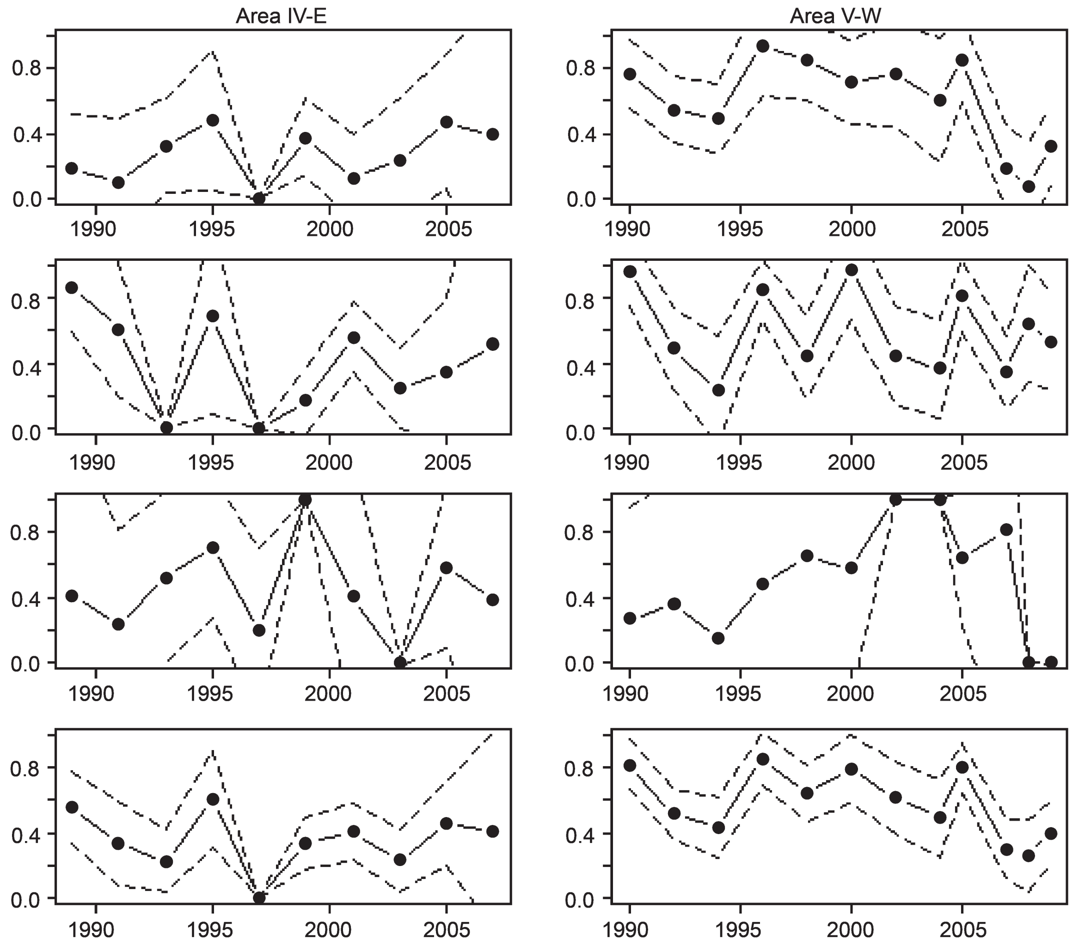

Fig. 3. Point estimate and approximate 90% confidence interval for the estimation of 'area-wise mixing proportion' based on 'genetic and morphometric data'.

Stock-structure Archetype III in IWC (2006) illustrates an isolation-by-distance scenario of the kind suggested here. In the present case, application and interpretation will be complicated by the fact that minke whales are migratory, and the genetic data are collected on the feeding grounds rather than the breeding grounds. Furthermore, the magnitude of genetic differentiation is small. Nevertheless, the Panel **agrees** that evaluating whether the empirical genetic and morphometric data are consistent with an isolation-by-distance model in the area of mixing would provide valuable information. One approach that might be able to distinguish between the two-Stocks-with-mixing and isolation-by-distance hypotheses is to evaluate how the inbreeding index (F_{IS}) changes with longitude. Under two-Stocks-with-mixing, F_{IS} should be zero (on average) in the pure-Stock areas (indicating agreement with Hardy-Weinberg equilibrium within stocks) and positive in the area of mixing (indicating a deficiency of heterozygotes due to the Wahlund effect). Under the isolation-by-distance hypothesis, the value of F_{IS} should be slightly positive and should not change with longitude.

Pastene (2006 provided a useful historical perspective and summary of hypotheses and results of studies regarding stock structure of Antarctic minke whales. This summary was particularly valuable as it included discussion of a number of potential stock-structure indicators in addition to genetics, including tagging data, pollution studies, ecological markers, morphometrics, size at physical maturity, and sighting and catch distributions. However, some types of information collected by JARPA II (such as oceanographic data) were not integrated into the analysis. The Panel **recommends** that the Proponents attempt to collect/incorporate other types of information that were not discussed but which potentially could be important to elucidate temporal and geographical changes in minke whale stock structure, including building upon recent developments in satellite tags (the Panel recognises the practical difficulties but believes that the gains could be important for a number of topics under the programme in addition to stock structure), stable isotopes of C, N and O, and fatty acids (IWC, 2014a).

5.2.4 Humpback whales

SC/F14/J30 examined mtDNA in samples (primarily from biopsies from JARPA, JARPA II, and SOWER surveys) of humpback whales from Antarctica and lower latitudes. This study was conducted to respond to a recommendation from the JARPA review (IWC, 2008) and to recommendations from the Scientific Committee to study distribution and calculate mixing proportions of breeding stocks D, E and F in the feeding grounds (IWC, 2013a). The Panel **welcomes** these results, first presented as Pastene *et al.* (2013) at the 2013 meeting of the Scientific Committee, which provide valuable information about distribution of humpback whales on the Antarctic feeding grounds.

SC/F14/J31 reported results for microsatellite DNA analysis of the Antarctic samples (but not the lower latitude samples) of humpback whales analysed for mtNDA in SC/F14/J30. The authors increased the number of loci from 6 to 14 in response to the recommendation of the JARPA review Workshop (IWC, 2008). Table 3 of SC/F14/J31 shows that each sample was in agreement with overall Hardy-Weinberg (HW) equilibrium, but no information was given in the text about the results of these tests or how they varied among loci. Other tables show p-values for heterogeneity tests comparing samples from different areas or times. The Panel **recommends** that an updated paper be submitted in which the tables also include the effect size (e.g. F_{ST} values).

5.2.5 Fin whales

SC/F14/J32 reported results of genetic analysis of fin whales using mtDNA and microsatellites. The total number of samples available across all years and sectors (n=52) was much fewer than planned, and this limits any conclusions about stock structure. The study incorporated biopsy samples from the JARPA programmes as well as captured animals. Standard tests of heterogeneity found no evidence for significant spatial differences in mtDNA, but the authors did find significant differences when they conducted an additional analysis that re-sorted the haplotypes into groups that are shared among regions and those that are not.

While welcoming the new information on fin whale stock structure - a subject that has not been examined by the Scientific Committee for many years (Donovan, 1991) - the Panel was concerned at some aspects of the analyses and interpretation. It therefore **recommends** that an updated paper be provided that:

(1) omits the analysis using *post-hoc* groupings unless the authors can provide a robust statistical justification for this approach;
(2) discusses in more detail the fact that three microsatellite loci showed significant departures from Hardy-Weinberg (HW) expectations after accounting for multiple testing before the data are used in other analyses;
(3) provides F_{IS} values for each locus in table 7 of SC/F14/J32, which would indicate whether the HW departures represent an excess or deficiency of heterozygotes; (that information is essential to understand the possible causes for the deviations);
(4) shows how the samples were arranged into Management Areas in fig.1; and
(5) recognises that conclusions about possible differences between Areas IV and V are provisional until the nature, cause, and influence of these HW deviations are resolved.

In the longer term, in order to increase sample sizes the proponents should examine the availability of historic tissues that may be used for genetic studies (e.g. from commercial whaling or biopsy samples from other research cruises).

5.2.6 Southern right whales

SC/F14/J33 reported results of genetic analysis of biopsy samples from 70 southern right whales, with most (n=63) being taken in Area IV reflecting their distribution within the research area as searching effort was made throughout the research area; mtDNA sequences were compared with those reported in previous studies to allow comparisons across studies. As expected, most haplotypes in the present study matched to those previously reported from the Indo-Pacific, but three haplotypes appear to be of Indo-Atlantic origin, which suggests that at least some southern right whales might make longer migrations than previously thought. Although the sampling design provided limited power to detect geographic variation throughout the whole of Antarctica, the Panel **welcomes** this study that represents the first attempt to genetically characterise southern right whales feeding in Antarctica.

5.2.7 Photo-identification data

SC/F14/J34 summarised photo-ID information contained in over 3,000 images of humpback, blue, and southern right whales taken during JARPA and JARPA II cruises. The photos were taken opportunistically and SC/F14/J34 reported some preliminary matches.

The Panel **welcomes** the effort that has been put into the collection of photographs for photo-ID. It also **welcomes** the submission of photographs to relevant international catalogues. It **recommends** that further effort is put into analysing these data in conjunction with these other Southern Hemisphere catalogues, recognising their potential to provide information on stock structure, mixing and movements. It expects that such work could be presented to the Scientific Committee within the next two years.

6. REVIEW OF RESULTS: MONITORING WHALE ABUNDANCE TRENDS (SC/F14/J03-J07, SC/F14/J17-J18; SC/F15/O01-O02)

6.1 Proponents' summary of results

Based on sighting data by JARPA and JARPA II, abundances of Antarctic minke, humpback, fin, blue, southern right, sperm, southern bottlenose and killer whales were estimated. There are good agreements between IDCR/SOWER abundance estimates and JARPA/JARPA II abundance estimates for Antarctic minke and humpback whales. Abundance trends obtained from JARPA and JARPA II are also generally consistent with biological and demographic information. This reconfirms the scientific value of the sighting data during JARPA and JARPA II.

6.1.1 Antarctic minke whales

SC/F14/J03 estimated abundance and abundance trend of Antarctic minke whale based on sighting data collected by JARPA and JARPA II (1989/90-2008/09 seasons). These analyses addressed most of the previous recommendations from the JARPA review Workshop in 2006 (see Annex 4 of SC/F14/J01). Abundance estimates were based on the standard line transect method using the program DISTANCE under the assumption of $g(0)=1$. The annual rates of increase were estimated using log-linear models. Model error was taken into consideration in the estimates. Results:

	Average	Minimum		Maximum	
Area	Estimate	Estimate	CV	Estimate	CV
IIIE	18,759	4,478	0.911	48,540	0.711
IV	32,714	15,088	0.645	63,794	0.509
V	101,106	67,661	0.308	151,072	0.326
VIW	15,486	8,434	0.601	27,790	0.507

Estimates of annual rates of increase were 1.1% (95% CI: -2.3, 4.5%) for Areas IIIE+IV and 0.6% (95% CI -2.2%, 3.3%) for Areas V+VIW. Adjustments to allow for $g(0)$ being less than 1 were made by the application of a regression model developed from the results of the Okamura-Kitakado (OK) method estimate of Antarctic minke whale abundance from IDCR-SOWER surveys, which provides estimates of $g(0)$ from the statistics of the minke whale school size distribution in a stratum. With this adjustment, abundance estimates increased by an average of 88.0% for Area IV and 109.0% for Area V. The annual rates of increase changed to 2.5% (95%CI-1.3, 6.3%) for Area IIIE+IV and -0.6% (95%CI-3.9, 2.6%) for Area V+VIW, which are not substantially different from the base case. It is suggested that there is good agreement between IDCR-SOWER abundance estimates and the abundance estimates with the $g(0)$ adjustment in Areas IV and V.

6.1.2 Humpback whales

SC/F14/J04 estimated abundance and abundance trend of humpback whale based on sighting data collected by the JARPA and the JARPA II (1989/90-2008-09 seasons). These analyses addressed most of the previous recommendations from the JARPA final review Workshop in 2006 (see Annex 4 of SC/F14/J01). Abundance estimates were based on the standard line transect method using the program DISTANCE under the assumption of $g(0)=1$. The annual rates of increase were estimated using log-linear models. Results:

	First year			Last year		
Area	Year	Estimate	CV	Year	Estimate	CV
IIIE	1995/96	1,378	0.190	2007/08	11,904	0.261
IV	1989/90	5,325	0.302	2007/08	29,067	0.255
V	1990/91	602	0.343	2008/09	13,894	0.338
VIW	1996/97	1,493	0.185	2008/09	3,609	0.322

Estimates of annual rates of increase in Areas IIIE, IV, V and VIW are 20.8% (95% CI:4.1, 37.6%), 13.6% (95% CI8.4, 18.7%), 14.5% (95% CI7.6, 21.5%) and 6.2% (95% CI-0.9, 13.4%), respectively. Except for Area VIW all the trend estimates were statistically significant. The JARPA+JARPA II results thus indicate that humpback whales in Area IV and Area V are definitely increasing rapidly. There is good agreement abundance estimates based on JARPA+JARPA II and those based on IDCR-SOWER in Areas IV and V.

6.1.3 Blue, fin and southern right whales

SC/F14/J05 estimated abundance and abundance trends of blue, fin and southern right whales based on sighting data collected by JARPA+JARPA II (1989/90-2008/09). The estimates are calculated by standard line transect analysis methods using the program DISTANCE under the assumption that $g(0)=1$. The annual rates of increase were estimated using regression model. Results:

Start – latest seasons	Start season		Latest season		Abundance trend	95% CILL	95% CIUL
	Abund.	CV	Abund.	CV			
Blue whale, Areas IIIE+IV+V+VIW							
1995/96-2008/09	300	0.308	1,223	0.345	0.082	0.039	0.125
Fin whale (Indian Ocean stock), Areas IIIE-IV							
1995/96-2007/08	3,087	0.191	2,610	0.285	0.089	-0.145	0.324
Fin whale (western S Pacific stock), Areas V+VIW							
1996/97-2008/09	1,879	0.226	14,981	0.298	0.120	0.026	0.215
Southern right whale, Area IV							
1989/90-2007/08	42	1.305	1,557	0.303	0.059	-0.164	0.281

The abundance trend estimate for blue whales was statistically significant. The abundance trend estimate for fin whales in Areas V+VIW was statistically significant. Changes in whale species composition were also confirmed in Area IV.

6.1.4 Odontocetes

SC/F14/J06 estimated abundance and abundance trends of sperm, southern bottlenose and killer whales based on sighting data collected by JARPA+JARPA II (1989/90-2008/09). The estimates are calculated by standard line transect analysis methods using the program DISTANCE under the assumption that $g(0)=1$. The annual rates of increase were estimated using regression model. Results:

	Minimum		Maximum		Abundance trend		
Area	Estimate	CV	Estimate	CV	Estimate	95%CILL	95%CIUL
Sperm whale							
IIIE	1,181	0.197	2,309	0.199	0.021	-0.041	0.082
IV	1,358	0.192	4,106	0.255	-0.024	-0.062	0.013
V	597	0.509	2,185	0.254	-0.039	-0.082	0.005
VIW	101	1.008	736	0.214	0.066	-0.090	0.223
Southern bottlenose							
IIIE	866	0.569	7,364	0.383	-0.018	-0.225	0.190
IV	1,082	0.266	11,828	0.266	0.104	0.030	0.179
V	893	0.447	6,729	0.269	0.077	0.013	0.142
VIW	908	0.396	2,681	0.233	0.009	-0.099	0.117
Killer whale							
IIIE	524	1.036	6,300	1.157	0.084	-0.096	0.264
IV	2,268	0.489	14,374	0.185	-0.021	-0.087	0.044
V	7,184	0.356	18,867	0.277	-0.011	-0.048	0.026
VIW	943	0.593	4,066	0.350	0.043	-0.120	0.206

Abundance trend are not statistically significant except those of southern bottlenose in Area IV and V. Abundance estimates for sperm, southern bottlenose whales are considered to be underestimated due to assumption that $g(0)=1$.

6.1.5 Paternity analysis

SC/F14/J07 used a mark-recapture method with paternity analysis based on microsatellite DNA data from the JARPA and JARPA II samples of Antarctic minke whales to estimate their stock size and movement pattern. Throughout the paternity analysis, genotypic data of maximum 12 microsatellite DNA loci examined from 137 foetuses that were collected from the pregnant females captured during the 2003/04 JARPA were used to look for their potential fathers among 1,779 males collected from the 2001/02 JARPA to 2010/11 JARPA II. One case of matching among the foetus-mother-father trio was found. The assigned father's body length was 8.66m and the estimated age was 12 years old, which did not necessarily, deny the match. This matching was used to conduct preliminary estimate the mature male abundance of the I Stock using Petersen mark-recapture method modified by Chapman.

6.1.6 Distribution

SC/F14/J17 examined the distribution pattern of the Density Index (DIW: number of whales sighted/100 n.miles) of blue, fin, sei, Antarctic minke, humpback, southern right, sperm, southern bottlenose, *Ziphiidae* and killer whales in the Antarctic based on the JARPA (1987/88-2004/05) and JARPA II (2005/06-2008/09) sighting data. A total of 353,134 n.miles was surveyed in Areas IIIE, IV, V and VIW, mainly south of 60°S. The following table summarises the sighting information:

Species	All Areas (IIIE, IV, V and VIW; south of 60°S, 35°E-145°W						Order of DIW
	Sch.	Ind.	Calf	Mss	DIS	DIW	
Blue whale	286	495	11	1.73	0.081	0.140	8
Fin whale	1,268	5,209	20	4.11	0.359	1.475	5
Sei whale	36	59	0	1.64	0.010	0.017	10
Ant. minke	25,507	69,076	1	2.71	7.223	19.561	1
Humpback	10,036	18,770	137	1.87	2.842	5.315	3
Southern right	235	298	6	1.27	0.067	0.084	9
Sperm whale	3,810	3,926	0	1.03	0.079	1.112	6
S bottlenose	1,666	3,045	3	1.83	0.472	0.862	7
Unid. beaked	3,175	5,457	3	1.72	0.899	1.545	4
Killer whale	1,472	20,569	59	13.97	0.417	5.825	2

Among 10 whale species, Antarctic minke whales were the most frequently sighted species, followed by the killer, humpback, unidentified beaked, fin, sperm, southern bottlenose, blue, southern right and sei whales in the DIW order. Maps of the DIW by 1° x 1° square are provided. These large amounts of data collected by JARPA and JARPA II including the current maps will contribute to investigating habitat utilisation of each species and provide more useful information for whale management in the Antarctic and Antarctic marine ecosystem.

SC/F14/J18 revealed that the spatial distribution of humpback whales was expanded in Area IV in the period of JARPA and JARPA II (1989/90-2005/06) while that of Antarctic minke whale remained stable. The results indicated that competition between humpback and Antarctic minke whales for habitat in Area IV during the period of JARPA and JARPA II was intensified as abundance of humpback whales increased (SC/F14/J04). The competition could be reflected in the decline of the energy storage and stomach contents weight of Antarctic minke whales (SC/F14/J13; SC/F14/J14). Data obtained in JARPA and JARPA II were used in SC/F14/J18 and were divided into three periods: early (1989/90, 1991/92 and 1993/94), middle (1995/96, 1997/98 and 1999/2000) and late (2001/02, 2003/04 and 2005/06). Spatial distribution was estimated using generalised additive models (GAM). The presence or absence of whales was used as a response variable while seafloor depth, distance from shelf break and longitude were used as explanatory variables.

Mean probabilities of the occurrence of Antarctic minke whales in the survey area in early, middle and late periods were 0.41, 0.46 and 0.41 while those of humpback whales were 0.14, 0.35 and 0.46. Occupied area indices (probabilities of the occurrence of Antarctic minke whales minus probabilities of the occurrence of humpback whales) were also calculated. If the index was 1, only Antarctic minke whales were present in a grid cell while only humpback whales were present if the index was -1. If the index was 0, probabilities of the presence of Antarctic minke whales and humpback whales in a grid cell were identical. Mean occupied area indices in early, middle and late periods were 0.28, 0.11 and -0.07, respectively.

6.1.7 Summary

In summary, the abundance trend for the Antarctic minke whales was broadly stable in both Areas IIIE+IV and V+VIW in the JARPA/JARPA II period. There was a good agreement between IDCR-SOWER and JARPA/JARPA II abundance estimates in Areas IV and V. Abundance of blue, humpback and fin whales are increasing in the JARPA/JARPA II period. The abundance of southern right whales is increasing but the trend is not significant. There was a good agreement between IDCR-SOWER and JARPA/JARPA II abundance estimates for humpback whales in Areas IV and V. A significant increasing trend was found for southern bottlenose whales in Areas IV and V.

It should be noted that the increasing trend of blue whale and fin (Areas V+VIW) whales was not significant by using JARPA data only. They became significant with the addition of new data from JARPA II.

Whale species composition was changing gradually, especially in Area IV. A temporal shift in species composition and spatial distribution of humpback whales was observed in Area IV, which was not observed in Area V (Area V includes the Ross Sea where humpback whales do not distribute).

6.2 Author's summary of the SCAA analysis

Punt has been undertaking work on statistical catch-at-age analysis (SCAA) on behalf of the Scientific Committee for many years as described in SC/F14/O01, using age data from commercial catches, JARPA and JARPA II as well as abundance estimates from IDCR/SOWER and the JARPA programmes.

SC/F14/O02 applied statistical catch-at-age analysis to data for Antarctic minke whales. The SCAA model is spatially-structured, can model multiple stocks of minke whales, and can utilise several data types for parameter estimation. The application to Antarctic minke whales considers two stocks (I and P) in five areas which cover Antarctic Areas III-E to IV-W. The parameters of the model (annual deviations about the stock-recruitment relationship, changes over time in carrying capacity, density-dependence parameters (productivity and carrying capacity), and the parameters which determine growth by stock, age-specific natural mortality by stock, and vulnerability by area and 'fleet') are estimated by fitting the model to data on catches, catch-at-length, conditional age-at-length, and estimates of absolute and relative abundance. A reference case analysis is selected, and sensitivity explored using retrospective analyses and by varying the assumptions on which the reference case analysis is based. The reference case analysis is able to mimic all of the data sources adequately. Most of the analyses (reference and sensitivity) indicate that Antarctic minke whales in the assessed area increased from 1930 until the mid-1970s and have declined thereafter, with the extent of the decline greater for minke whales in Antarctic Areas III-E to V-W than for those further east. Natural mortality is consistently estimated to be higher for younger and older individuals. Estimates of $MSYR_{1+}$ are presented, but are unreliable owing to the lack of contrast.

6.3 Panel's conclusions and recommendations

6.3.1 Abundance and trends from surveys

The Panel **welcomes** the presentation of results from the JARPA and JARPA II programmes. This represents a considerable expenditure of research time and a large dataset for long-term monitoring. It complements the work of the IDCR/SOWER programme that has now finished. The importance of monitoring trends in abundance for cetacean species is of general conservation and management interest as well as providing information relevant to the JARPA II programme objectives and especially as input to ecosystem models. It is particularly important in the context of documenting the recovery of species/populations that had been extensively depleted by commercial whaling, as well as investigating variation in species mix compared to the period prior to exploitation.

The JARPA review meeting (IWC, 2008) had examined the survey information available at that time and had identified a number of items that required further investigation before acceptable abundance estimates could be obtained. The Panel **agrees** that the papers on Antarctic minke whales (SC/F14/J03) and humpback whales (SC/F14/J04) had adequately addressed most of these concerns and had in some cases identified further work that would be undertaken - see the discussion in Matsuoka *et al.* (2011) and Hakamada *et al.* (2013). It requested clarification of the treatment of additional variance in the estimation of rate of increase and further consideration as to the approach used.

Given the importance of $g(0)$ estimation to the Antarctic minke whale abundance estimation (IWC, 2013a) and the necessarily *ad hoc* approach used in SC/F14/J03 to account for this in the JARPA and JARPA II programmes where the independent observer approach had not been implemented, the Panel **recommends** that consideration be given to using an independent observer approach in future surveys.

The papers on the other baleen whale species (SC/F14/J06) had been unable to follow the same analytical procedure for some aspects of the abundance estimation due to smaller sample sizes than were available for the minke and humpback whale cases, particularly in that they were unable to obtain separate estimates for sightings vessels only (as opposed to combined with sightings and sampling vessel data) only for part of the period.

It is important to remember that the estimates of abundance and trends presented in the papers to the Workshop represent numbers (and trends) of animals within particular geographic areas at particular times of the year. In some cases, such as Antarctic minke whales, humpback whales and blue whales, this probably covers the peak of their distribution in the austral summer. However, for others such as fin whales, this is not the case based on their past distributions. In perhaps the most extreme case of sperm whales, only large males penetrate south of 60°S. While the authors note these issues, the Panel **reiterates** that considerable care should be given to their interpretation. In all cases, *if* the results are intended to provide inferences of population trends, then careful consideration needs to be given to the questions of stock structure; this can be particularly complex for cases/areas where separate breeding stocks overlap on the feeding grounds. While this is covered briefly in the papers presented, these matters need to be considered more thoroughly by the authors in the discussion sections of their papers.

Recognising the value of these datasets and welcoming the analyses presented, the Panel **recommends** that a revised stand-alone paper for the 'other' baleen whale species (i.e. not the Antarctic minke and humpback whales – these have already been published) is developed (and submitted for publication) that:

(1) presents a more thorough description of methods and assumptions used (bringing in some of the information presented in other papers such as SC/F14/O02):
(2) highlights the issues related to small sample size and the recommendations made at the JARPA review meeting, including those relating to use of the SSV data and the treatment of non-surveyed areas);
(3) identifies more clearly the differences between ideal and realised tracklines by year including percentage achieved coverage;
(4) explains more fully the treatment of additional variance components in the estimation of rates of increase;
(5) includes more extensive discussion than at present of the results including interpretation of the results with respect to stock structure and proportion of range covered, the implications of the sensitivity results on the confidence intervals obtained within the 'base case', the merits of the inclusion or exclusion of abundance estimates that rely on considerable extrapolation within the trend estimation process; and
(6) includes an updated power analysis of the effects of survey interval and estimation of trend to inform consideration of levels of effort and survey design in the future.

With respect to the toothed whale estimates, there are some additional issues that arise in the context of $g(0)$, which is considerably more difficult to estimate for sperm and bottlenosed whales given their diving behaviour. The authors need to consider, given these issues and the lack of knowledge of the full distribution of these species, whether the production of absolute abundance estimates is feasible or valuable. The Panel also **recommends** the collection of data on the ecotype of killer whales to try to allow estimates of abundance to be developed for each. This information is of importance to ecosystem modelling given their different feeding habits and in particular to evaluate the consequences of predation on minke whales.

6.3.2 SCAA analyses

The Panel **welcomes** the updated SCAA analysis presented. It **agrees** that the SCAA model is both the best currently available model for examining stock dynamics for the Antarctic minke whales in the JARPA II area, and that the model performs well in this regard. There are however a number of recommendations for improvements and further work, which are discussed below. The Panel also noted that certain results from the SCAA model may not be consistent with inferences developed from other components of JARPA II or may suggest potential revisions to the design of JARPA II itself. These points are also outlined below, and should be considered by the proponents.

ABUNDANCE ESTIMATES

The model is currently tuned to the abundance estimates from JARPA/JARPA II that were available in late 2013. These should be replaced by the $g(0)$-corrected estimates in SC/F14/J03. Given the comparison of estimates from JARPA and IDCR in SC/F14/J03, model configurations in which the JARPA/JARPA II abundance estimates are treated as absolute measures of abundance should be explored further.

RANDOM EFFECTS MODEL

The model uses a random effects structure implemented as errors-in-variables to estimate year effects in recruitment and a number of other parameters (vulnerabilities, proportion of each stock in each area, growth rate and carrying capacity, SC/F14/O02, appendix E). The functional forms and standard deviations of these random effects are set externally to the model based on expert judgement. If these standard deviations are too small, there is a risk of overly smoothing the deviations between years, and hence underestimating the confidence limits. Following a request from the Panel, a test was run to re-estimate recruitments with an essentially unconstrained distribution (standard deviation of log recruitment deviations of 10). The recruitment estimates resulting from this run were plotted against those estimated with the standard deviation used in the base case (see Fig. 3). The linear nature of the scatterplot indicates that the estimation was not affected by the choice of standard deviation. The Panel **recommends** that similar tests should be performed for the other parameters with annual deviations to check that the specified standard deviations are not overly constraining.

MSYR

As the author noted, the variability in MSYR in the sensitivity tests (SC/F14/O02, table 8) indicates that the model is not able to reliably estimate MSYR. It appears that there is little contrast in the data required to estimate MSYR. Previous versions of the model had given MSYR estimates. However this may have been an artefact of the relatively inflexible nature of model structure. The Panel **recommends** that the ability to estimate MSYR should be revisited in the future in light of the availability of new data.

NATURAL MORTALITY MODEL

The piecewise model characterising the relationship between natural mortality and age is, in some respects, sub-optimal. The need to externally define the breakpoints raises the risk of introducing model mis-specification. Tests with the autoregressive function produce a similar mortality function, and it seems possible that the Siler model would also give similar results. If so, the Panel **recommends** using the Siler function as this will reduce the risk of model mis-specification and be more parsimonious than the autoregressive function. If the Siler function does not match the autoregressive function, then it would be preferable to adjust the breakpoints in the piecewise model so that the model gives a better (but still parsimonious) approximation to the autoregressive solution.

The Panel also **recommends** that sensitivity tests are conducted to examine the response of the modelled population to changes in the mean *M* for both stocks when these are assumed to be the same.

STOCK STRUCTURE

The Panel noted that the model is currently configured with two non-overlapping stocks. However, the model has the capability to incorporate a wide variety of different possible stock structures, and recent results from the JARPA programmes (see Item 5) suggest possible different stock structures. For example, two stocks may mix across Areas IVE and V-W with the proportional contribution of each stock to the total abundance in this mixing area varying over time. It would be possible to extend the SCAA model by fitting to a time series of mixing proportions (such as the proportions predicted by the model described in SC/F14/J29) or by fitting directly to genetic and morphometric data that may discriminate among the two stocks (e.g. by implementing an approach similar to that described in SC/F14/J29 directly in the SCAA model). Either approach gives the possibility that the model can, in the future, evaluate the impact of different stock-structure hypotheses on the stock dynamics. The Panel also noted that if further analysis of genetic and morphometric variations in minke whales from the JARPA II study area supports the alternative hypothesis of a single stock in which individuals are isolated by distance (see Item 5.2) rather than two stocks which mix, substantial revision to the SCAA model would be required.

CHANGES IN CARRYING CAPACITY THROUGH TIME

The base case model estimates that carrying capacity increased from the mid-1940s to the early 1960s and then decreased. The Panel **agrees** that care should be taken when interpreting trends in carrying capacity that may be estimated using the SCAA model. Estimated trends in carrying capacity would not necessarily index trends in the availability of krill. The SCAA model is parameterised such that carrying capacity may also index the annual survival of age-0 minke whales, which are born, nursed, and weaned at low latitudes. Thus, estimated trends in carrying capacity may index trends in conditions that have occurred outside the Antarctic, including trends in predation on minke whale calves.

CHANGES IN GROWTH RATES THROUGH TIME

The model produces estimates of rapid growth in the early time period and slower growth in more recent years, with a transition between the early 1980s and around 1990 (SC/F14/O02, fig. 5). The estimated growth rates are, however, largely determined by data on the smallest individuals, and few small individuals were caught during the commercial hunt. Therefore, estimated growth rates in the earliest period may be unreliable. This issue should be considered further because, at present, it is difficult to reconcile the age-at-maturity time series presented in SC/F14/J08 with the growth rates estimated by the SCAA model. The time series presented in SC/F14/J08 suggests that growth rates did not decline during the 1980s and were relatively constant for all cohorts born since about 1965. The Panel **recommends** that the proponents and developers of the SCAA work to resolve this apparent inconsistency.

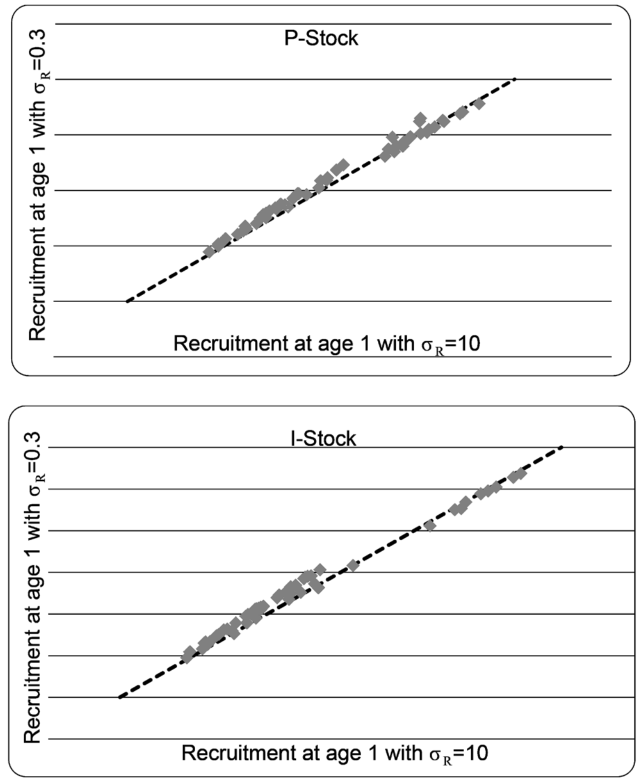

Fig. 4. Scatterplot of recruitment at age 1 and different SD assumptions (see text).

EFFECTS OF JARPA/JARPA II DATA

Results were presented indicating that removing JARPA/JARPA II abundance data (while retaining JARPA/JARPA II age-length data and the IDCR/SOWER abundance data) had little effect on the model results. This was interpreted to indicate that the abundance data are consistent with other data (including the age-length JARPA/JARPA II data) fitted in the model. To further evaluate the effect of the JARPA/JARPA II data, the Panel **recommends** that sensitivity tests removing all JARPA/JARPA II data except catches from the model (including removing the age-length data), or removing just the age-length data while retaining the abundance data. In either case, an assumption about selectivity pattern for the JARPA/JARPA II period would be needed.

The Panel **agrees** that sensitivity tests such as those undertaken to examine the effects of including (excluding) the JARPA/JARPA II abundance data from the SCAA are useful for considering the future design of JARPA II. For example, if the annual JARPA II abundance data have little effect on results from the SCAA, the proponents might be presented with an opportunity to spend less time conducting sightings surveys while spending more time addressing other issues. For example, if a sighting survey was not conducted one year, the time at sea could be used to conduct a process study focussed on field work that examines the possibility of competition between whale species (see Item 6.3.3 above).

6.3.3 Alternative approaches to abundance estimation

SC/F14/J07 reported results of a preliminary evaluation of use of paternity analysis to estimate abundance of Antarctic minke whales. This exercise genotyped 137 female-foetus pairs collected during 2003/04 JARPA cruises and searched for matches among the >1,700 males in the genetic dataset. One likely match to a male parent was found. The analytical procedures used and the caveats provided were generally appropriate. The Panel **welcomes** this general approach because it has considerable potential to provide useful information and had the following comments on this preliminary evaluation:

(1) a point estimate of abundance based on a single parent-offspring match is of questionable value, since: (a) the confidence intervals are so wide - Bravington *et al.* (2014) shows how to calculate the number of matches required to produce an estimate with a specified coefficient of variation; and (b) the point estimate is unstable in that the addition of even a single recapture dramatically reduces the point estimate; and

(2) although a brief mention is made of the importance of random sampling, this crucial topic merits a fuller treatment, given the fact that all samples are restricted to an area that represents less than half of the summer distribution of the species.

6.3.4 Distribution

This section addresses part of Objective 1 of JARPA II: Monitoring of the Antarctic ecosystem, with special reference to temporal changes in cetacean distribution based on sightings data and the specific consequences for the distribution of minke whales; and part of Objective 2: Modelling Competition among whale species. Proponents presented two papers on distribution including: a general mapping of species occurrence pooling all the observations from JARPA and JARPA II from 1987 to 2009 and using an uncorrected index of whale density with 1° x 1° resolution (SC/F14/J17); and a paper (SC/F14/J18) reporting an analysis of changes in the spatial distribution of minke and humpback whales in Area VI during the JARPA and JARPA II period using generalised additive models (GAMs). The Panel was **pleased** to see the effort of putting all the sightings data together, providing a retrospective view of the distribution of all cetacean species observed, and the use of spatially-explicit modelling of the humpback and minke whale sightings to address some of the proposed objectives.

The GAM analysis breaks down the JARPA and JARPA II period from 1987 to 2006 into an early, middle and late phase and reports large scale area occupancy for each species, and a derived area occupancy index to address the extent of overlap in spatial distribution between minke and humpback whales. The Panel identified two major issues: (1) the analysis of area occupancy should be more informative, which could be achieved by expressing the results in terms of whale density using line transect-based spatial modelling, as opposed to using simple GAMs, and where possible, the analysis should be carried out for other species; and (2) the index to compare occupancy between species in its current formulation cannot appropriately describe species overlap and segregation in distribution and their changes over time.

While welcoming the use of more quantitative approaches to examining distribution, the Panel **notes** the methods used are somewhat simplistic. The Panel therefore **recommends** that a more rigorous area occupancy analysis should be undertaken that incorporates recent advances in spatial modelling (Bravington and Hedley, 2012), accounting for whale detectability and the encounter rate process, including autocorrelation, and thus reflecting spatially-explicit differences in density. In addition, the choice of explanatory variables in spatial models should better reflect the environment that describes the distribution of each species, such as sea-ice, primary production and oceanography, incorporating a broader dataset than simply using JARPA and JARPA II data alone (and see Item 4). Recommended remote sensing resources, as used in other analyses (Beekmans *et al.*, 2010) are, *inter alia*, bathymetry databases (GEBCO or others) and related indices such as distance to shelf break and other contours; ocean colour for chlorophyll concentration (NASA Sea-viewing Wide Field-of-view Sensor, SeaWiFS) or related; sea ice concentration and related ice indices, including distance to the sea ice edge, maximum and minimum seasonal sea ice extent, and sea ice season duration; sea surface temperature (SST); frontal zone location positions of the Southern Antarctic Circumpolar Current Front (SACCF) and the Southern Boundary of the Antarctic Circumpolar Current (SBACC), and sea surface velocities (SSV).

The Panel **agrees** that the index of area occupancy to predict presence-absence also needs to be improved by re-formulating the analysis as a line-transect based spatial model. This will increase the accuracy of fine-scale prediction and will improve the analysis of segregation in distribution range between minke and humpback whales. In addition, the index used to investigate the extent of overlap in distribution ($z_i = p_{x,i} - p_{y,i}$ where i is a small scale prediction grid cell, $p_{x,i}$ is the probability of presence of minke whales, and $p_{y,i}$ of humpback whales) is not valid in its present form, as it is based on models and predictions independently derived for each species. Moreover, many different combinations of $p_{x,i}$ and $p_{y,i}$ yield identical z_i values, although the interpretation of those values could be very different. A proposed solution to this problem is modelling together the spatially-explicit probabilities of absence of both species ($p_{00,i}$), presence of minke whales ($p_{x0,i}$), presence of humpback whales ($p_{0y,i}$), and presence of both species ($p_{xy,i}$) in response to spatial covariates. The observed presence of each species in a grid cell can be treated as a sample from a multinomial distribution, and estimation in a GAM analysis context can be achieved as in Beare *et al.* (2003) using a binomial or Poisson regression approach, or alternative solutions.

As part of their discussion of distribution, the proponents note that a major motivation of the work presented is in response to Objective 2, and in particular inter-specific competition. Their main emphasis is on Antarctic minke and humpback whales, and the ecological consequences of their competition. However, the Panel **agrees** that despite the apparent changes in distribution and relative abundance of these two species, any firm conclusion is premature[2] and is but one of several possible hypotheses to explain existing data and for use in modelling. The Panel **notes** that at this stage the proponents have failed to develop a proposed underlying hypothesis for this competition, or the formulation of a conceptual model to develop an analytical framework. Studies on whale competition are rare, and mostly investigate the partition of resources utilised by different species on the feeding grounds (Friedlaender *et al.*, 2009; Santora *et al.*, 2010). This requires a characterisation of the spatial distribution of each whale species in relation with environmental variables, and the distribution, abundance and behaviour of their common prey.

[2]SC/F14/J18 stated that 'The results indicated that competition between humpback and Antarctic minke whales for habitat in Area IV during the period of JARPA and JARPA II was intensified as abundance of humpback whales increased'.

To this aim, the Panel **recommends** that the focus of future effort should include work that will enable specification of a hypothesis as to how the proposed competition in the Antarctic ecosystem is taking place as well as other alternative hypotheses. The Proponents should show that the attribution of correlational results to competition is not confounded by the consequences of oceanographic shifts and changes in carrying capacity leading to changes in prey and whale distribution and abundance. This requires conclusive evidence of foraging preferences, shared use of the same prey field by different whale species and information that the prey field is somehow unable to satisfy the demands of all predators that are sharing the resource. For this, the Panel **recommends** the use of dedicated methods such as TDRs linked to satellite telemetry to characterise species-specific diving ranges in relation with the size and distribution of krill aggregations; and use of indirect methods to compare prey preferences. The Panel **refers** to the full discussion of related matters in the context of the SOWER 2000 programme (IWC, 2000b). It **stresses** the importance of swarm size as well as average density with respect to studies of energetics and successful feeding of baleen whales. In order to develop plausible hypotheses for use in ecosystem modelling as part of JARPA II, the Panel **recommends** that the proponents invest effort in some and preferably all of the following:

(1) analysis of proximity of whale species in the sighting survey tracklines – this can be done with existing data and initial analyses should be possible within the next year;
(2) focused studies of prey swarming behaviour and density in relation with local whale distribution and abundance – this may require a change of fieldwork focus for one or more seasons and integrated data from focal follows, telemetry (radio and/or satellite), krill abundance and density estimates and biopsy sampling (for *inter alia* stable isotope analysis);
(3) comparison of prey in stomach contents in areas where both species overlap in distribution, and in areas where they segregate, including investigation of whether whale species and krill length-maturity classes exhibit distinct spatial segregation in their distribution patterns – this can begin with existing samples and it should be possible to present a progress report within the next two years; and
(4) analysis of stable isotope ratios of C, N and O from tissue samples – initial examination of the discriminatory power of such analyses can occur with existing samples preserved dry or frozen.

7. REVIEW OF RESULTS: MONITORING KRILL ABUNDANCE AND FEEDING ECOLOGY OF WHALE STOCKS (SC/F14/J13-J16, SC/F14/J19, SC/F14/O03, SC/F14/O05-O07)

7.1 Proponents' summary of results

JARPA II includes a research component of krill biomass estimation based on quantitative echo sounder data. Along with this data, feeding ecology (e.g. energy storage, stomach content, and feeding habit) of Antarctic minke and fin whales was investigated. Analysis of those data would contribute to answering such scientific questions as; whether the total availability of krill to whales in the Antarctic marine ecosystem has changed or not, and whether the shift in the whale species composition has affected prey availability to different species of whales. This analysis would also contribute to building ecosystem models for the Antarctic marine ecosystem.

SC/F14/J15 investigated the feeding habits of Antarctic minke whales based on samples obtained during the surveys of the JARPA and JARPA II for the period 1987/88-2010/11. Some of the analyses considered recommendations offered during the 2006 JARPA final review meeting, e.g. those related to the duration of the feeding period, digestion rate and examination at smaller scales. The Antarctic minke whales fed mostly on Antarctic krill in offshore area, and on ice krill in coastal (shallow) area on the continental shelf of the Ross Sea and Prydz Bay. The whales fed mainly before 05:00am suggesting that feeding activity decreases early in the day. The daily prey consumption was estimated using two independent methods, one based on theoretical energy requirements and the other on diurnal changes of stomach contents mass. The daily prey consumptions per capita during the feeding season based on the two methods were 95.1kg, 127.0kg and 182.6kg, 250.3kg for immature and mature males, and 125.8kg, 138.7kg and 268.1kg, 325.5kg for immature and mature females, respectively. This is equivalent to 2.65-4.02% of the body weight. The daily prey consumption per capita decreased between the JARPA and JARPA II periods based on the results of the method on diurnal change in stomach content mass, for all sexual classes. The seasonal prey consumption by all Antarctic minke whales in the research area was 3.51-3.98 million tons, and this figure was equivalent to 7.6-8.6% of the krill biomass estimated by acoustic survey in the total research area. Further research on feeding ecology will focus on the 'uncertainties in the prey consumption estimates of whales'.

SC/F14/J16 examined the feeding habits of fin whales sampled during the surveys of the JARPA II for the period 2005/06-2010/11 (n=16). The fin whales fed mostly on Antarctic krill in the research area. The daily prey consumptions of fin whales per capita estimated by three methods ranged from 276 to 2,136kg. These values were equivalent to 0.50 and 3.84% of the body weight. The seasonal prey consumptions for all fin whales in the total research area based on three methods were 0.54-0.78 million tons, 3.38-4.51 million tons and 2.19-2.93 million tons, respectively. There was coincidence in the frequency of body length of the Antarctic krill, *E. superba* consumed by fin and Antarctic minke whales. It seems that fin and Antarctic minke whales have similar feeding habits with no prey size selectivity. SC/F14/J10 showed evidences that fin whales taken by JARPA II are heavier than those taken by commercial whaling in the 1950s.

SC/F14/J19 presented results of krill biomass estimations based on quantitative echo sounder data. Estimations were made based on data obtained in Areas IIIE/IV in the 2007/08 JARPA II survey and in Areas V/VIW in the 2008/09 JARPA II survey. The biomass estimates obtained in Areas IIIE and IV were 6.6 and 12.5 million tons, respectively while those in Areas V and VIW were 24.0 and 3.4 million tons, respectively. The information on krill biomass for Area IV was used as input parameters in the ecosystem modelling work. It should be noted here that comprehensive data for krill biomass abundance were obtained only for two JARPA II seasons due to security problems.

In summary SC/F14/J13 and SC/F14/J14 showed consistent results on deteriorating nutritional conditions of Antarctic minke whales in the research period. SC/F14/J15 showed that the daily prey consumption per capita of Antarctic minke whales decreased between the JARPA and JARPA II periods for all sexual classes, providing additional support to the results of SC/F14/J13 and J14 (see Item 8 below). These results suggested that less krill is available for Antarctic minke whales in recent years (JARPA+JARPA II period). Direct estimation of krill biomass, however, was obtained only for two JARPA II surveys due to security problems.

7.2 Panel's conclusions and recommendations

7.2.1 Krill abundance

The estimation of krill abundance represents a fundamental component of JARPA II and is central to its ability to meet its ecosystem-related objectives. As described in Item 10.2.1.1, a reliable time series of krill abundance is required in order to quantify possible competition between whale species. SC/F14/J19 presented the results of two directed surveys for krill. While welcoming the work to estimate krill abundance the Panel had concerns over the interpretation of results in the paper. In particular, the size compositions used for classifying acoustic targets as Antarctic krill, *E. superba*, appear to be contaminated by data on other euphausiid species. For example, fig. 3a of that document indicates that no Antarctic krill were included in the size-frequency distribution of animals collected from stratum IV-NW during 2007/08. The Panel **recommends** that the biomass estimates reported in SC/F14/J19 be recomputed using size compositions that, in northern strata, are representative of *E. superba* only since this is the primary species of krill that minke whales consume in these strata. For strata IV-SW and V-SE, which respectively include Prydz Bay and the Ross Sea, the Panel **recommends** that separate size-frequency distributions and biomass estimates be made for *E. superba* and *E. crystallorophias*[3].

The Panel **recommends** that the recomputed biomass estimates reported in SC/F14/J19 be compared to biomass estimates made from acoustic data collected during JARPA as soon as possible. As the authors themselves have noted, to make this comparison, the acoustic data from both JARPA and JARPA II must be processed in the same way. Such comparisons have the potential to provide the first direct evidence as to whether there have been changes in the biomass of krill in the JARPA II study area. However, the Panel also highlighted the fact that the data from the JARPA and JARPA II programmes alone are limited. It therefore **recommends** that any such comparisons also include biomass estimates from the BROKE (Nicol *et al.*, 2000) and BROKE-WEST (Nicol, 2010) surveys. It is important to note that during the BROKE survey, acoustic data were collected at only two frequencies. To compare JARPA and JARPA II acoustic biomass estimates to that from BROKE, it might be necessary to reprocess the existing JARPA and JARPA II data using only the frequencies used in BROKE. The Panel **stresses** that limiting processing of acoustic data collected during future surveys to two frequencies is **not** recommended.

The understanding of krill biomass (and any trends in it) is fundamental to future work under JARPA II if it is to meet its objectives. Whilst recognising issues associated with outside disturbance, the Panel is **concerned** that not enough effort has thus far been made in JARPA II to address this issue. The Panel **notes** that the IKMT net used during JARPA II is appropriate for the objective of observing the species and size compositions of euphausiids in the JARPA II study area, but **agrees** that an insufficient number of IKMT tows were made during the two krill surveys reported in SC/F14/J19. The relatively few tows that were made during surveys conducted in 2007/08 and 2008/09 were not likely to have provided representative data on the species composition of euphausiids nor on the size composition of *E. superba* in the study area. For example, only two tows were made in the IV NW stratum during 2007/08, and *E. superba* were not caught in either tow.

The Panel **welcomes** the fact that a substantial number of random krill samples (about 200g per sample) were collected from the stomachs of whales sampled during JARPA and JARPA II and archived at the ICR (Table 1). Some of the krill samples have already been processed to provide size-frequency distributions (using about 50-150 krill per sample). A smaller number of samples have also been processed to provide maturity-stage distributions of the krill. All krill samples archived from collections made prior to 1996/97 have been processed, but a substantial number of the samples archived from collections made since 1996/97 have yet to be processed. Size and maturity distributions are extremely valuable for understanding the dynamics of the krill stock in the JARPA II study area and the Panel **recommends** that the archived krill samples be processed to characterise size-frequency and maturity-stage distributions as a matter of priority. The Panel also **recommends** that the proponents collaborate with members of SC-CCAMLR to use data collected from the archived samples in an effort to study the population dynamics of krill.

The Panel **recommends** that future krill surveys conducted during JARPA II employ survey design standards, including the spacing between net-tow stations along the acoustic transect lines, similar to those developed and implemented for the CCAMLR 2000 (Trathan *et al.*, 2001), BROKE (Nicol *et al.*, 2000) and BROKE-WEST surveys (Nicol, 2010). It would also be useful for the proponents to discuss survey design issues with scientists outside the JARPA II programme that have experience in conducting krill surveys.

The Panel **notes** that the backscattering strength threshold (log $S_v \leq$ -80dB) used thus far during JARPA II is potentially biasing low the acoustic krill biomass estimates. The proponents indicated that the threshold values were selected to accommodate the excessive noise of the research vessel, recognising that this would affect the detection of small krill. The depths over which backscattering data were integrated to estimate krill biomass (15-150m) were also limited by vessel noise (more typically, backscattering data on krill are integrated down to 250m). The Panel **recommends** that future krill surveys be conducted using a more appropriate vessel since krill biomass estimates are required to meet the objectives of JARPA II. Noise standards for conducting acoustic surveys have been discussed by ICES (1995).

Future krill surveys should be frequent because the density of krill in any given stratum may vary significantly from year to year, and the objectives of JARPA II require a time-series view of how the prey field is changing over time. The JARPA II study area is very large, and it is probably not possible to survey the entire study area every year with a single survey vessel. Thus, the Panel **recommends** either using multiple survey vessels to synoptically cover the JARPA II study area every 1-3 years or using one vessel to survey alternating halves of the study area every year (similar to the approach taken for sighting surveys).

[3]In cases where data from the IKMT tows do not provide sufficient data to characterise the size compositions of *E. superba* (or *E. crystallorophias*), it may be possible to use data on the size compositions of these species from the fresh (F) component of the diets of whales sampled in any given stratum if the spatial distribution of sampled whales was random with respect to the distributions of these two euphausiids and there is some confidence that the whales did not select for certain sizes of prey.

7.2.2 Feeding ecology, consumption rates and inputs to ecosystem modelling

The Panel considered papers SC/F14/J15, SC/F14/O03 and SC/F14/R01 under this item. The Panel welcomes the considerable amount of field and laboratory work undertaken on this subject and analysed in SC/F14/J15. However, it **agrees** that a major shortcoming of the work originally presented in SC/F14/J15 was that the results presented did not quantify uncertainties in the various estimates of consumption. This shortcoming was identified in SC/F14/O03; in SC/F14/R01, the proponents proposed the use of a Monte Carlo approach to address this shortcoming.

The Panel **agreed** that the approach proposed in SC/F14/R01 is both a positive development and a useful way forward. However this work is at its beginnings only; without the results of a thorough analysis, the Panel is unable to determine whether JARPA II has provided or will provide consumption estimates within a sufficiently narrow range. The Panel **recommends** that work proposed in SC/F14/R1 be further developed and allocated high priority. Ideally a new paper should be submitted to the next meeting of the Scientific Committee. As a minimum, this should advance the outlined work plan by including in the Monte Carlo simulations, uncertainty in:

(1) *r* (the ratio of low/high feeding intake) and the length of the feeding season for Method 1; and
(2) the extent of night feeding for Method 2.

The Panel also **recommends** that the work is extended by computing a time series of Monte Carlo results for the total potential consumption of krill using abundance estimates of Antarctic minke whales (preferably those estimated by the SCAA model) and the uncertainties around these estimates.

These analyses are an essential consideration as to the extent to which the JARPA II programme in its present form is able to meet its objectives. The Panel therefore **recommends** that the results of the Monte Carlo work be used to re-evaluate the future research and sampling in JARPA II. This should include an exploration of the sensitivity of the Monte Carlo distributions of consumption estimates (for both individuals and for the total stock(s) of whales) to a reduction in the uncertainty of each parameter and to the choice of allometric relationship between body mass and metabolic rate. Future research should be targeted to reduce uncertainties in the parameters to which the Monte Carlo distributions of consumption estimates are most sensitive. This approach could also be used both to aid determination of future sample sizes by estimating how many samples would be needed to reduce uncertainties in consumption estimates by a desired level and to assess whether lethal or non-lethal sampling or a combined approach represents best way of reducing such uncertainties.

The Panel **agrees** that results presented in SC/F14/J16 (figs 4-6) indicate substantial overlap in the sizes of krill that are consumed by Antarctic minke whales and fin whales when sampled near the same locations and times, noting also that the sample size for fin whales is small, restricted to smaller individuals and outside the species main distribution area. As elsewhere in this report, however, the Panel **cautions** the proponents over any over-interpretation that this proves that there is 'inter specific interaction' or competition between these species in any limiting sense (e.g. see SC/F14/J18), rather than it being one of several potential hypotheses. SC/F14/J16 suggests that differences in the size composition of krill consumed by both species will be determined by the size-specific distribution of krill.

Table 1

Numbers of krill samples that were collected from whale stomachs and have been archived at the ICR, including the numbers of these archived krill samples that have already been processed to characterise size-frequency distributions of krill eaten by whales.

JARPA	Sample no.	BL data	JARPA II	Sample no.	BL data
1989/90	55	55	2005/06	62	8
1990/91	33	33	2006/07	80	4
1991/92	45	45	2007/08	46	0
1992/93	140	140	2008/09	73	1
1993/94	164	164	2009/10	49	2
1994/95	161	161	2010/11	22	2
1995/96	201	201			
1996/97	243	27			
1997/98	264	32			
1998/99	180	22			
1999/2000	288	23			
2000/01	151	24			
2001/02	107	0			
2002/03	94	0			
2003/04	113	0			
2004/05	116	35			
Total	**2,355**	**962**	**Total**	**332**	**17**

The Panel notes that while the distributions of minke and fin whales overlap, minke whales are most abundant farther south and fin whales are most abundant farther north; the size compositions of krill in the areas where these whales are most abundant may differ, and, if so, that would tend to lessen the strength of interactions between them. The Panel also noted that when the best available point estimate of krill biomass in Area IV during 2007/08 (12.5 million tonnes, SC/F14/J19) is compared with the best available point estimates of krill consumption by minke whales (0.37 million tonnes using Method 1 and 0.33 million tonnes using Method 2, SC/F14/J15) and fin whales (0.05-0.42 million tonne using three different allometric relationships between body mass and metabolic rate, SC/F14/J16), the hypothesis that minke whales and fin whales are competing for krill in a limiting sense does not seem well supported. These point estimates suggest that together both species of whales might have consumed about 6% annually of the standing biomass of krill and thus that krill biomass was not limiting.

The Panel's conclusions and recommendations regarding the nutritive condition of Antarctic minke whales (blubber thickness and energy storage – SC/F14/J13; and stomach contents – SC/F14/J14) are further described in Item 8.3.2.

8. REVIEW OF RESULTS: MONITORING WHALE BIOLOGICAL PARAMETERS (SC/F14/J08-J12, SC/F14/J35-J37)

8.1 Proponents' summary of results

The general objective of this component of the programme was to monitor the changes over years in Antarctic ecosystem from viewpoint of biological parameters. Recruitment, pregnancy rate, age at sexual maturity and other biological parameters were selected as target parameters. Biological parameters of Antarctic minke whales were estimated by using JARPA and JARPA II samples and yearly trend was examined for I-Stock and P-Stock.

8.1.1 Age at sexual maturity

SC/F14/J08 examined yearly trend of age at sexual maturity in the Antarctic minke whale based on Transition Phase (TP) in earplugs collected by the JARPA (1987/88-2004/05) and the JARPA II (2005/06-2010/11). Analysis was conducted for both sexes and for two stocks (I and P) separated at 165°E. TP of the JARPA samples were read by two readers (reader-K and reader-Z) and by a new reader (reader-B) in the case of the JARPA II samples. Truncation bias was corrected by standard procedures. Yearly trend of mean age at sexual maturity derived from two reader groups were consistent. The results confirmed that the age at sexual maturity of both stocks declined from the mid 1940s cohorts at around 10-12 years old to the early 1970s cohorts at around 7-8 years old, presumably as response to improved nutritional conditions at that time. Age at sexual maturity remained constant at 7-8 years old till the 1990s cohorts. Statistical analysis to investigate trend from the 1970s cohorts showed slight but statistically significant increasing trend for the I Stock (both sexes) and P Stock (females). Although slight trend was detected, the level of current changes is much smaller than the decreasing trend level observed from the 1940s cohorts in response to improved nutritional conditions at that time.

8.1.2 Ageing errors

During the JARPA final review Workshop a recommendation was made that the comparability of commercial and JARPA age data be investigated by re-reading a sub-set of the commercial samples in an appropriately designed blind test. Based on the results of the studies responding the recommendation, the IWC SC agreed in 2010 that no further experiments or analyses on age reading errors were needed to resolve ageing related problems raised at the JARPA review Workshop. SC/F14/J11 presented a statistical method for quantifying age-reading error, i.e. the extent of bias and inter-reader variability among readers, which use the data produced in the blind test. The method in SC/F14/J11 assumes the availability of an independent control reader who produces reference ages for ageing structures which are also read by the subject readers. This reader is assumed to provide unbiased age estimates. Linear structures in bias and variance are incorporated in a conditional probability matrix representing the stochastic nature of age-determination for each reader. A joint likelihood function for the parameters related to ageing bias, variance and nuisance parameters is defined based on observed ageing outcomes from both the control and subject readers. The method is applied to data for Antarctic minke whales taken during Japanese commercial whaling (1971/72-1985/86) and JARPA (1986/87-2004/05). A total of 250 earplugs selected according to a predetermined protocol were used in the analyses to estimate the inter-reader variation for four Japanese readers. One of the authors acted the control reader. The Japanese readers and the control reader differed in terms of both the expected age given the true age, and variance in age-estimates. The expected age and random uncertainty in age-estimates differed among the Japanese readers, although the two readers in charge of age-reading for samples taken during JARPA and JARPA II provided quite similar ageing outcomes. These results contribute to analyses using catch-at-age data for this species. It should also be noted that the model and approach in this paper can be applied to populations other than the Antarctic minke whales, if a control reader is available, even retrospectively. An original version of this paper was presented to the IWC SC meeting in 2013 as Kitakado *et al.* (2013). After discussion, the IWC SC agreed that the approach and results of the study provide useable inputs data for SCAA analysis.

8.1.3 Alternative ageing techniques

SC/F14/J12 measured the eye lenses of 18 Antarctic minke whales and of 20 foetuses to examine the approach of age estimation in Antarctic minke whales by ratio of aspartic acid enantiomers. In the age estimation equation, the specific coefficient of hydrolysis effect in preparation and the constant conversion of aspartic enantiomers (*Kasp*) were estimated. The study found that the D/L ratio of aspartic acid in the lenses of minke whales had increased by 0.0102 in the hydrolysis process (7hr at 108°C), and estimated that the *Kasp* was 1.96×10-3 (/year) calculated from the earplug age and the age index with the D/L ratio of aspartic acid in minke whales. Consequently, formulae Age (year) = 511×Ln ((1+D/L)/(1-D/L)) -13.2 was obtained. In the future, this method would be applied to other species and individuals with unreadable earplugs.

8.1.4 Pregnancy rate

SC/F14/J09 examined yearly trend of the proportion of pregnant whales in the matured female population (PPF) of Antarctic minke whales based on samples collected by the JARPA (1987/88-2010/11) and the JARPA II (2005/06-2010/11) surveys. Linear and logistic regression analyses were conducted to estimate yearly trend in this biological parameter for I-Stock and P-Stock, separated at 165°E. The PPF of both stocks appeared stable at around 0.9 and when data from all years were combined, the PPF was 0.932 for I-Stock and 0.904 for P-Stock. No significant yearly trend was detected in either stock during the JARPA II period. A significant increasing trend was detected in the JARPA and JARPA+JARPA II period analyses for the P Stock by the logistic regression analysis. The latter result was influenced by just two lower values in the 1990/91 and 1994/95 seasons. Although continuation of the high PPF was observed during the JARPA II period, monitoring of the PPF is important to detect possible change in nutritional condition and reproduction which affect sustainable management of this whale stock.

8.1.5 Nutritive condition

SC/F14/J13 showed the results of the annual trend in energy storage in sexually mature Antarctic minke whales based on catch data from all 24 surveys of the JARPA and JARPA II. These analyses addressed most of the previous recommendations from the JARPA final review Workshop in 2006 (see recommendations Marine Ecosystem 4-6 in Annex 4), as well as more recent recommendations from the IWC SC, e.g. analyses included survey track line in random effects as recommended in IWC (2013a). Five variables which are, or could be, indices of storage of energy, were examined: total fat weight in the whale body, blubber thickness at two lateral measurement points and girth measured at two specified positions. Three of these variables were available from almost all whales sampled, but girth at axilla was measured over 20 years and fat weight was only measured over 17 years of the JARPA programme, and only for the first whale sampled on each day. A number of covariates were also recorded. A large number of linear mixed-effects statistical models were investigated for each of the dependent variables, and the Bayesian Information Criterion (BIC) was used to select the best model. All models examined had ‘year’ as a possible explanatory variable. The results show that all five measures of energy storage declined substantially over time during the JARPA period, with a more than 10% decline in total fat weight. For all five dependent variables the values for energy stores are higher for females than for males. The values increase during the feeding season and are higher for higher body coverage of diatoms. This is assumed to be a measure of how long the animal has spent in Antarctic waters. The results are similar when each sex is analysed separately, but the decrease in energy stores was somewhat larger in females than in males.

The results from the JARPA II period were very different from the JARPA period. There is no clear trend towards increase, or further decrease, in any of the four measures of energy storage. The results suggest that fundamental changes have taken place in the eastern part of the Antarctic marine ecosystem during the 1990s. These changes have resulted in less optimal feeding conditions for Antarctic minke whales.

SC/F14/J14 reported the results of an analysis of temporal trend in stomach content weight in the Antarctic minke whale, one of the major krill predators in Antarctic waters. These analyses addressed most of the previous recommendations from the JARPA final review Workshop in 2006 (see recommendation Marine Ecosystem 3 in Annex 4), as well as more recent recommendations from the IWC SC e.g. analyses are now based on survey transects as recommended by IWC (2013a). A reported decline in energy storage over almost two decades indicates that food availability for the whales may also have declined until recently. To test this hypothesis, catch data from 21 survey years in the JARPA and JARPA II (1990/91-2010/11) was used to investigate whether there was any annual trend in the weight of stomach contents of Antarctic minke whales. Linear mixed-effects analysis showed a decreasing trend in the weight of stomach contents over the 21 years since 1990/91, which was statistically significant. A similar pattern of decrease was found in both males and females, except in the case of females sampled at higher latitude in the Ross Sea. These results suggest a decrease in the availability of krill for Antarctic minke whales in the lower latitudinal range of the research area. The results are consistent with the previously reported decline in energy storage (SC/F14/J13). The decrease in krill availability could be due to environmental changes or to an increase in the abundance of other krill-feeding predators. The latter appears more likely, given the recent rapid recovery of the humpback whale. Furthermore, humpback whales are not found in the Ross Sea, where both Antarctic krill and ice krill are available, and where no change in prey availability has been suggested for Antarctic minke whales.

8.1.6 Summary

In summary the analysis of biological parameters of Antarctic minke whale showed a small but significant increase in the age at sexual maturity after the 1970s cohorts suggesting that nutritional conditions could be deteriorating for this species. However the age at sexual maturity has remained low at between 7-8 years old. Furthermore a constant and high pregnancy rate was observed during the JARPA/JARPA II period. Therefore in this period high reproductive rates can be postulated however the recruitment rate has not increased in the same period. On the other hand there is the possibility that the age at sexual maturity of fin whale (see below) could have decreased suggesting improved nutritional for this species. The changes in age at sexual maturity in the Antarctic and fin whales are consistent with the change in the ecosystem suggested by JARPA results.

With respect to nutritive condition, SC/F14/J13 and SC/F14/J14 showed consistent results on deteriorating nutritional conditions of Antarctic minke whales in the research period.

8.1.7 Fin whales

SC/F14/J10 presented new biological information of 16 Antarctic fin whales collected from JARPA II biological research. New information on body proportion, reproductive status, age/length relationship, body length/body weight relationship as well ecological markers (external parasites), is presented. For age/body length relationship and age/maturity parameters were compared with data of the commercial whaling period in the Antarctic which stopped some 36 years ago. The main results were that body weight of whales in the JARPA II period is heavier than those previously reported for the Antarctic in the 1950s. Further, results suggested the possibility that whales are reaching sexual maturity at younger ages.

8.1.8 Other information on the biology of Antarctic minke whales

SC/F14/J35 (Nagai *et al.*, 2007) used follicular oocytes, follicular fluid, and umbilical serum from seven female Antarctic minke whales in JARPA II to investigate whale reproductive physiology, especially for improvement of in vitro oocyte maturation and related technologies for whales. Main results were the following: (i) the mean diameter of the oocytes from the large follicles was significantly greater than those from the small and medium follicles; (ii) the osmolarity of the follicular fluid from the small follicles was significantly lower than that of the medium follicles; (iii) the concentrations of the total-protein, glucose, albumin and chlorine concentrations of the follicular fluid from the three groups of follicles were significantly lower than that of the umbilical serum; (iv) for steroid hormones, the progesterone concentrations were not significantly different among the fluid from the three groups of follicles and the umbilical serum, but the estradiol 17-β concentrations of the follicular fluid increased with the size of the follicle (14.3 and 34.6 ng/ml for small and large follicles, respectively).

SC/F14/J36 (Ono *et al.*, 2009) used heart samples of Antarctic minke whale collected during the 2005/06 JARPA II surveys for comparison of Purkinje fibres in different mammalian species by light and electron microscopy. From light microscopy of silver impregnated tissues in the cytoarchitecture of a network of Purkinje fibers revealed the reticular fibres ensheathing individual Purkinje strands consisting of 2-8 cells in both the ungulates (i.e. sheep and goats) and cetaceans (whales and dolphins) while they encircled each Purkinje cell in the primates (humans and monkeys), carnivores (dogs and seals), and rodents (rats). By scanning electron microscopy of NaOH digested tissues findings, the ungulates were found to have a Purkinje fiber network composed of Purkinje strands; the cells in the strands were oval and made side-to-side and/or end-to-end connections while in primates and carnivores it was delicate and complicated; the Purkinje cells were usually cylindrical and connected end-to-end, the exception being their polygonal or stellate shapes at the bifurcations. Purkinje cells in the rodents resembled ventricular cardiac myocytes in cytoarchitecture. From the comparative observations, this study showed that the whales and seals respectively had Purkinje cells similar to that of the ungulates, and the primates and carnivores. These findings indicated that the structural variety of the Purkinje fiber network may reflect the conducting function and be related to the phylogeny of the mammalian species.

SC/F14/J37 (Sasaki *et al.*, 2013) studied the morphological and immuno-histochemical nature of the structure and function of placenta in the Antarctic minke whale using the samples of the placenta and non-pregnant uterus obtained during the 2001/02, 2002/03 and 2004/05 seasons of the JARPA as well during the 2005/06 JARPA II season. From the hematoxylin and eosin stain and immuno-histochemically stained samples using the avidin-biotin peroxidase complex (ABC) method or scanning electron microscopy findings, they revealed morphological changes of placenta through the gestation period and the localisation of steroidogenic enzyme in the Antarctic minke whale placenta. From the findings the placentation and morphological function typical of cetaceans may become apparent.

8.2 Observer summary of SC/F14/O06-O08

The authors of SC/F14/O06 and O07 summarised the conclusions of their analyses of minke whale body condition that used the JARPA/JARPA II data. The biology of the Antarctic minke whale and the highly variable Antarctic environment are likely to generate within season spatial and temporal heterogeneity in the distribution of individuals by sex, age, maturity and condition. Consequently attempting to monitor subtle trends in biological parameters of Antarctic minke whales such as blubber thickness and stomach contents requires a carefully considered and consistent sampling strategy. They showed that JARPA and JARPA II have not followed such a strategy and consequently the data are confounded and biased. Even after complex statistical modelling, any long-term trends inferred from these data are likely to be imprecise and unreliable. Standard linear and linear mixed effects models were applied to attempt to correct for heterogeneity in the manner in which the data were collected and these confirmed that interaction terms were significant. The results of these analyses indicated that spatial and temporal heterogeneity requires complicated statistical modelling and that statistical inferences from these models are weak and ambiguous. While some models suggest statistically significant trends in some body condition parameters others do not, with the conclusion that the data collected during JARPA and JARPA II are insufficient for determining whether there have been trends in Antarctic minke whale body condition or otherwise.

The authors of SC/F14/O08 also noted that the methods used to calculate sample sizes had assumed that sampling was the only source of variability and consequently had failed to take into account spatial and temporal variability. A bootstrap analysis demonstrated that the original method of calculation substantially over-stated the ability of JARPA II to detect changes in body condition and were therefore invalid.

The authors pointed out that backwards model selection using BIC in the nutritive condition analyses leads to the illogical consequence that a valid *a priori* hypothesis for spatial and yearly interaction terms is accepted, but would then subsequently be discarded even though it is highly statistically significant. Furthermore the models using interaction terms have the lowest AICs.

8.3 Panel's conclusions and recommendations

The Panel **recognises** the considerable field and laboratory effort that lay behind the papers on biological parameters. Discussion of biological parameters is part of the proponents' objective of monitoring the ecosystem. The work is also directly dependent upon and relevant to consideration of stock structure (Item 5). It is also dependent on the broad consideration of the representativeness of the sampling design (see the JARPA review [IWC, 2008] and Item 12). The Panel **notes** that the analyses presented on biological parameters assume: (a) that the sampling scheme is broadly representative of the population; and (b) related to the stock structure hypotheses agreed at the JARPA review rather than those that were subsequently presented to this meeting (Item 5). With respect to sampling design in JARPA II, the Panel **notes** the disruption caused to the proposed sample size and design due to outside interference in the Antarctic and refers to the discussions on sample size and design at the JARPA review meeting (IWC, 2008) and in SC/F14/O05-O07. The Panel's overall comments on sampling design/size within JARPA II are given under Item 12.1.2.

8.3.1 Biological parameters

8.3.1.1 AGE AT ATTAINMENT OF SEXUAL MATURITY

SC/J14/J08 examined the changes in the age at attainment of sexual maturity (t_m) as reflected in the identification of the 'transition phase' in the earplugs of Antarctic minke whales. The authors identified a decline from the mid-1940s cohorts (around 10-12 years) to the early 1970s (7-8 years), remaining largely constant since then but with possibly a slight recent increase in the I-Stock and P-Stock (females).

The Panel **agrees** that the analyses presented in SC/J14/J08 require further refinement in addition to updating with respect to stock structure, as the authors' themselves note. In particular, it **recommends** that a revised paper should:

(1) use the approach of Thomson *et al.* (1999) to better account for truncation bias (which is considered in SC/F14/J08) as well as the fringe effect, which relates to the low proportion of animals with ages slightly higher than the age-at-maturity, an issue likely related to the need for contrast to detect a transition phase in an earplug;
(2) incorporate the effects of age reading errors presented in SC/F14/J11;
(3) take into account the problems of the representativeness of samples in recent years due to disruption of the programme discussed under Item 12.1.2;
(4) compare analyses of t_m from the transition phase with those using corpora counts and, if available, histological studies of testes;
(5) compare the results of the revised study with those, re-analysed to the extent possible following Thomson *et al.* (1999) for fin and sei whales from the Antarctic to examine whether any observed trends are synchronous, which may provide information on whether there is a cross-specific (e.g. outside environmental) cause to the trends;
(6) evaluate alternative models (e.g. where trends are shared across sex, stock or both); and
(7) include a more detailed description of the models evaluated and a more detailed discussion of the results that considers all plausible explanations for observed trends.

The Panel **recognises** that incorporating all of these suggestions will probably not be possible for the next Scientific Committee meeting. However, it believes that an updated paper that at least includes an improved discussion and a workplan and timetable should be presented.

The Panel noted that SC/F14/J11 had already been discussed and approved by the Scientific Committee (IWC, 2013a) and is 'in press'. It **endorses** the positive conclusions of the Scientific Committee and **welcomes** this work.

8.3.1.2 PREGNANCY RATES

SC/F14/J09 examined pregnancy rate data from JARPA and JARPA II. The Panel **notes** that 'pregnancy rates' identified in the paper are more appropriately called 'apparent pregnancy rates'. The Panel **stresses** that pregnancy rate (or apparent pregnancy rate) data should not be over-interpreted. In terms of effects at the population level the ultimate parameters of interest are successful births and calf survival rather than pregnancy rates *per se*. The Panel **agrees** that the analyses presented in SC/J14/J09 require further refinement in addition to updating with respect to stock structure, as the authors' themselves note. It **recommends** a number of improvements that should be incorporated into a revised version of the paper:

(1) further discussion of the limitations of the criteria used to identify a pregnant female – in particular, better account should be taken of the fact that small foetuses may be missed by scientists and that foetuses may be lost due to abortion[4] during the hunt or loss during towing leading to an underestimate of true pregnancy rate; and
(2) to assist with (1), the authors should consider examination of other criteria for pregnancy (in some cases this may be possible from existing data or tissue samples) including diameter of the largest uterine horn, histology of the uterine mucosa, examination of the mammary glands and examination of hormone levels in blubber.

With respect to (2), the Panel **recognises** that identification of lactating females is more difficult in Antarctic minke whales because births occur in winter and lactation lasts only about three months, while harvesting takes place in the summer i.e. some months after weaning. The Panel **recommends** that the feasibility of using histological examination of mammary glands to assess recent lactation is examined. If this is possible, the proportions of recently lactated to [apparently] pregnant females and to mature females would be a more appropriate index of reproductive success that would likely be more sensitive to environmental fluctuations than crude pregnancy rates because perinatal mortality or abandonments of newborns by females in low nutritive condition is known to occur in many mammal species. The possibility of undertaking a feasibility study using existing samples should be examined and the results reported to the Scientific Committee.

The Panel **notes** that while age at attainment of sexual maturity is the result of conditions affecting the individual over a period of several years, pregnancy/lactation is more directly linked to the conditions prevailing in the season when the whale had been caught or in the immediately previous one. Given the proponents' primary objective of studying biological parameters in order to monitor changes in the ecosystem, the Panel **recommends** that the relationship between reproductive parameters and the information available on body condition, krill consumption and environmental covariates such sea surface temperature (SST), location, and other factors be examined on an annual basis. This may help to explain anomalous years like the 1990-91 or the 1994-95 seasons, when low apparent pregnancy rate values were observed.

The Panel also **recommends** that:

(1) existing sampling protocols be examined to ensure that uterine horn and mammary gland measurements are recorded and mammary gland tissue and uterine mucosa are collected for histological analysis; and
(2) the programme takes the opportunity to examine the efficacy of approaches to examine pregnancy using blubber analyses and faecal samples found for some other mysticetes (Kellar *et al.*, 2013; Mansour *et al.*, 2002) – and see Item 12.4.

8.3.1.3 AGE ESTIMATION

The use of the Aspartic Acid Racemisation (AAR) age estimation method, adapted for mammals by Bada *et al.* (1980), has recently regained interest for use with cetaceans. It is useful for species where standard methods are not applicable (e.g. species lacking teeth or readable earplugs) as well as comparison with standard methods. SC/J14/J15 offers some new approaches to the AAR technique including a correction for the effect of acid-hydrolysis extractions and a correction for 'foetus age' in the DL_o estimate. The authors were able to measure differences in the *DL* ratios of developing foetuses (*n*=20), which suggests good precision in their *DL* measurements. One of the usual challenges of this method is obtaining a sufficient sample of 'age 0' animals which is not a problem for the present study.

The Panel **welcomes** this work and makes the following **recommendations** for an updated paper:

(1) improve the estimates of SE which were artificially optimistic in that: (a) they did not incorporate all sources of error, such as error in K_{asp} (the time-temperature change constant of aspartic acid), the DL_o measurement, and the *DL* measurements for each individual; and (b) were applied incorrectly to calculate the SE of the age estimates (in fact they estimate the mean SE of the regression as a function of age);
(2) with respect to (1) a more appropriate method is the bootstrapping as in Rosa *et al.* (2012) or the Delta method as in George *et al.* (1999);
(3) better specification of how the correction for a hydrolysis effect on the DL measurements was developed and applied;
(4) a fuller explanation in the methods sections as to how the lens nucleus was dissected without contaminating it with 'modern' tissue from the exterior of the lens or with blood or fluids;
(5) present the earplug estimates side-by-side with the AAR estimates;
(6) for ovaries collected from mature females, include the total number of corpora for both ovaries in the analysis to determine ovulation rates and age relationships (George *et al.*, 2011); corpora data should be collected as part of future age studies; and
(7) correct the labels in fig. 3 and carefully check the use of K_{asp} *vs* 2 K_{asp} in the manuscript.

In the longer term, the sample size should be increased.

8.3.2 Nutritive condition

The factors considered in the models on which the analyses in SC/F14/J13 and SC/F14/J14 are based are not derived from biological hypotheses, but rather arise primarily from discussions within the Scientific Committee. The Panel **recognises** that this is a consequence of the nature of the discussions within the Scientific Committee rather than a failure by the authors. The Panel **recommends** that the authors of SC/F14/J13 and SC/F14/J14 first develop a conceptual model of the system under consideration and use that to identify a set of covariates to consider in the modelling. Model selection should always be guided by underlying knowledge of the system. It is therefore inappropriate to automatically select the 'best model' because such a model can lead to covariates being selected for which there is no reason that there are related to response variable. Following the selection of which factors to consider in the modelling, the following steps should be undertaken[5]:

(1) identify whether any of the covariates are highly correlated and either: (a) exclude a subset of the covariates so that the remaining covariates are uncorrelated; or (b) develop new covariates which represent independent aspects of the current covariates (using for example PCA);
(2) select a 'full model' (this may be difficult if the data set is unbalanced) and base selection of which factors and

[4]Of course, it is also possible that abortion may have occurred naturally at a more advanced stage if the whale had not been caught.

[5]These steps are provided for the analysis of environmental and geographic factors on measures of condition but pertain to analysis of any data.

their interactions to treat as random effects - the models should be fitted using REML and a model selection approach such AIC, BIC or standard hypothesis testing approach applied; and
(3) select the fixed effects structure given the random effects structure selected at step (2), where the models are fitted using maximum likelihood; and
(4) use REML to fit the best model identified in (3) above.

SC/F14/J13 and SC/F14/J14 do not report many fit diagnostics. The Panel **recommends** that any revised papers provide at least plots of the residuals versus the predictor variables (including year and stratum), histograms of residuals and random effects, plots of residuals spatially, and Q-Q plots for the 'best model' (although there may be more appropriate diagnostic statistics for these analyses given the unbalanced nature of the data set).

The Panel **notes** too that the original estimates of the power to detect changes in blubber thickness only accounted for sampling error. It **recommends** as a more appropriate way to assess power, use of the results of existing data analyses to characterise both sampling error and other sources of error and to use all error when simulating data as the basis for power calculations.

The Panel also **recommends** that future analyses of the data on the condition of Antarctic minke whales include: (a) consideration of a model in which year is a categorical variable and is treated as a random effect if a plot of residuals against year show there are residual patterns by year; and (b) examination of how robust the results in SC/F14/J14 are to basing model selection on BIC rather than AIC.

Given the discussion in a number of papers presented by both proponents and observers, the Panel offers the following summary of the merits or otherwise of AIC and BIC, both commonly used metrics for model selection. The two metrics, while mathematically similar (twice the negative log-likelihood plus a penalty term), arise from different underlying arguments (Kass and Raftery, 1995). BIC will tend to select simpler models than AIC if the number of data points exceeds 7, all things being equal (because the penalty term for additional parameters is larger than for AIC). Simulations have shown that AIC often selects a more complex (wrong) model over the simpler (and correct) model (Kass and Raftery, 1995). Whether this necessarily means that BIC is always better than AIC is not clear because AIC attempts to find the best approximating model rather than true model (which would be rarely in the set of candidate models). BIC is, however, generally preferred to AIC for 'large' data sets. However, what constitutes 'large' in any particular case depends *inter alia* on the set of models under consideration. Thus, for any one problem the selection between AIC and BIC is seldom definitive. Many practicing statisticians consequently often apply both AIC and BIC, examine the sensitivity to the different models selected and apply expert judgement.

Despite the complexity of the analyses and the protracted discussion of appropriate statistical techniques, the Panel **expresses the opinion** that the 'weight of evidence' that the different measures consistently indicated that there was an overall decline in body condition of minke whales through the JARPA period, as well as the implications of such a result, warrants careful consideration and further investigation in terms of possible causes.

The Panel **notes** that the recommendation from the previous review of the JARPA programme (IWC, 2008) to improve analyses of body condition by using more accurate proxies, such as the lipid content of the blubber has, for the most part, not been followed by the proponents, although this may partly be due to the text not being as clear as it might have been. Although blubber thickness has an overall correlation with blubber lipid content, the relation between the two variables is poor and tends to fit an asymptotic relationship where lipid contents fall precipitously in individuals with thin blubber; moreover, blubber would tend to thicken when body girth decreases (Aguilar *et al.*, 2007, pp.6-7) and fig.2). As a consequence of both processes, blubber thickness would tend to underestimate lower body condition stages. The Panel thanked the proponents for some preliminary analyses of a small number of samples during the Workshop but **recommends** that further studies should incorporate blubber lipid content analyses for all samples, and that the collection of current measurements also continues to ensure comparability with past and future data.

The Panel further **notes** that several cetacean research programmes include the collection of faeces from wild populations to assess diet and food habits. The JARPA II programme is in position to assess the efficacy and accuracy of this non-lethal approach. In that regard, the Panel **recommends** that faecal samples (from the colon) be compared with stomach samples for species composition (and see Item 12.4).

8.3.3 Other studies of reproduction not directly relevant to the objectives of JARPA II

The Panel **welcomes** papers that make maximum use of the samples obtained even when not directly relevant to the objectives of the programme. It made comments on two of these.

SC/F15/J35 is a published paper which describes some new information on aspects of minke whale reproductive physiology and endocrinology. It appears that it is intended as a general addition to literature about cetacean reproductive biology; however, the Panel noted that the *in vitro* maturation of whale ova a technique that is of uncertain application and the authors do not explain how or where such technologies could be used. The Panel had some editorial suggestions that might have improved the paper but recognise that is no longer appropriate.

SC/F14/J37 describes the structure and function of the placenta of the Antarctic minke whale. The Panel **notes** that similar literature is rare and that this paper is among the most thorough descriptions available. Since morphology is a direct expression of a species' adaptation to the environment, it provides a fundamental expression of how the animal interacts with (and depends upon) that environment to achieve homeostasis. Sudden disruptions of environmental factors can rapidly have negative consequences on survival of individuals and on population demographic rates. Since function follows form, ecologically-driven dysfunctions are best understood once the normal morphology has been described. In a changing environment, such an understanding can inform conservation policy and management. For example, with regard to paper SC/F14/J35, the transmission of contaminants across the placenta from mother to foetus is determined by the type of placentation.

The Panel **recommends** further anatomical work on the Antarctic minke whale for structures that have not been fully investigated in minke or other species.

9. REVIEW OF RESULTS: MONITORING EFFECTS OF CONTAMINANTS ON CETACEANS

9.1 Proponents' summary of results
JARPA II has been collecting and analysing data on contaminants in the body of whales and whale's prey. This component provides unique scientific information on the effects on the contaminants on the health of whales and movements of the contaminants in the Antarctic marine ecosystem. The data has been utilised by the scientists outside of the JARPA/JARPA II programmes as a valuable source of information to the environmental analysis.

SC/F14/J23 measured total Hg levels in samples from Antarctic krill, and Antarctic minke whales to examine the features of accumulation and yearly changes of total Hg in Antarctic Areas IV and V. Total Hg levels in Antarctic krill from Areas IV and V were in the range 0.006-0.026 and 0.003-0.052ppm dry wt., respectively. There were no significant differences between Areas. No yearly changes of total Hg levels in Antarctic krill were observed in samples from both Areas in the period from 2005 to 2011. Hg levels in liver of Antarctic minke whales from Areas IV and V were in the range 0.003-0.13 and <0.001-0.25ppm wet wt., respectively. Hepatic Hg levels of minke whales of all age groups in Area IV decreased significantly with research years and that of 15-26 year old whales in Area V increased significantly.

SC/F14/J24 determined the concentrations of persistent organochlorines in the blubber of five mature male (21-25 years old) Antarctic minke whales from Antarctic Area V sampled by the JARPA II in 2010/11. For comparison, blubber from 40 whales sampled by the JARPA surveys in the period from 1988/89 to 2004/05, were used. In 2010/11 mean concentrations of HCB (140ng/g fat wt.) were the highest followed by DDTs (100ng/g fat wt.), PCBs (28ng/g fat wt.), CHLs (25ng/g fat wt.), and HCHs (0.8ng/g fat wt.). Levels of DDTs, HCHs, HCB and CHLs in Area V decreased significantly with year, while the yearly trend of PCBs did not change significantly. HCHs levels in minke whales in 2010/2011 were similar to those in the JARPA period from 1996/97 to 2004/05 however they were lower than those in the JARPA period from 1988/89 to 1996/97. These results suggested that levels of HCHs in the Antarctic Ocean have varied from slightly decreasing to a steady state in the middle 1990s.

SC/F14/J25 determined total mercury (Hg) in 10 livers and 16 muscle samples of fin whales sampled by the JARPA II in 2005/06-2010/11. In addition PCBs, DDTs, HCHs, HCB and CHLs were determined in two blubber samples of fin whales sampled in 2010/11. Mean concentrations of total Hg in livers and muscles were 0.052 and 0.021 (ppm wet wt.), respectively. Mean concentrations of PCBs, DDTs, HCHs, HCB and CHLs were 6.5, 13, 0.65, 39 and 4.5 (ng/g fat wt.), respectively. Hg levels in liver and muscle of fin and Antarctic minke whales from the Antarctic Ocean were similar, and these were one order of magnitude lower than those of fin whales from the western North Atlantic Ocean. Geographical differences of Hg levels within a species could be caused by food, habitat and/or age. Levels of OCs, except for HCB, in fin whales from the Antarctic Ocean were similar to those in the Antarctic minke whales. These levels were extremely lower than those in fin whales from the middle latitude of the northern hemisphere nearby human activity, and those in killer whales from the Antarctic Ocean. These results suggest that the OCs levels in whales could mainly be affected by the position of their food in the food chain and area. OCs levels in fin and Antarctic minke whales in the Antarctic Ocean could be the lowest among whale species in the world. HCB levels in large whales would be affected by trophic levels of its preys rather than by spatial differences.

Firstly, it should be noted that the pollutant analyses summarised above were based on a limited number of samples from JARPA II. This was due to the fact that most of the samples collected for this purpose were lost after the tsunami that affected Japan in 2011. The analysis of the remaining samples however, provided interesting results. For example they confirmed the Antarctic Ocean as the cleanest area. The data on pollutant accumulation in whale tissues and prey species in the Antarctic is an important baseline for comparison with future research in the same or different research areas.

The first examination of pollutants in the fin whale in the Antarctic showed very low levels of mercury and organochlorines. Again the data set can be used as a baseline for future comparisons with fin whales from other areas.

9.2 Panel's conclusions and recommendations
The Panel **welcomes** the papers presenting the results on organochlorine and heavy metal analysis in tissues of Antarctic minke whales and the krill consumed while recognising that, especially for organochlorine studies, the loss of samples due to the tsunami severely limited the scope of the studies. It **concurs** with SC/F14/J23 and SC/F14/J24 that the results indicating very low tissue levels for both groups of pollutants pointed towards the lack of effects on whale populations.

Given the low pollutant levels traditionally observed in Antarctic minke whales based on the previous JARPA analyses, the Panel **recommends** that if the programme continues, pollution studies should be given lower priority and the resources used to address other higher priority issues. While sampling and appropriately storing of tissue and krill samples should continue for reference purposes in case of evidence for a new pollutant in the region or the occurrence of a shift in trends, the Panel **agrees** that it would be sufficient to undertake analyses on a suitably chosen subsample at periodic intervals (say 3-5 years).

The Panel also **welcomes** the research on marine debris, a type of pollution on which little information is available for the Antarctic Ocean. It **notes** that information on this had also been collected by the now discontinued SOWER programme. This topic has also been recently identified as a priority by the IWC (2014b). The Panel also **notes** the low incidence of both ingested debris and occurrence of debris in the sea surface. It **recommends** continuation of these observations and that the data be shared with other international efforts.

10. REVIEW OF RESULTS: MODEL OF COMPETITION AMONG WHALE SPECIES

While developing ecosystem models requires a substantial data collection and analytical effort, initial progress was made toward this objective in JARPA II by: (a) providing several data sets from JARPA/JARPA II as input data; (b) starting developing of two models; and (c) identifying new data and analyses to progress further this work.

10.1 Proponents' summary of results
SC/F14/J26 showed the progress made in the development of ecosystem modelling for species in Area IV. Two types of modelling approaches were employed; one is a multi-species production model, and the other is the EwE, a comprehensive

(whole-of-ecosystem) model. There are differences in the component species between them, but the baleen whales and krill play key roles in both. For the statistical estimation in the multi-species production model, a functional response function was proposed to link the dynamics of predators (four baleen whale species and crabeater seal) and prey (Antarctic krill) to both between and within-species competitions. The model was applied to the data on time series of the four baleen whale species, crabeater seal and krill, and then a likelihood function was defined based on the data with some additional assumptions on inestimable parameters. However, at this stage the estimated population trends for the component species did not fit well to the data, which might be attributed partly to lack of spatial structure in the model and partly to lack of representativeness of assumed parameters and information on prey abundance. For the EwE approach, the construction of a mass-balancing for Ecopath for 27 functional groups was attempted, which could be the basis for the next stage of analysis for projection forward using the Ecosim framework. Several suggestions were made to progress the modelling work.

10.2 Panel's conclusions and recommendations

10.2.1 Ecosystem modelling

The Panel **notes**, as did the proponents, that the modelling work is at a preliminary stage. However, the Panel **stresses** that this work is an integral part of assessing whether the proponents can meet JARPA II Objectives 1, 2 and 4. Furthermore, the modelling work forms a key platform for integrating the various aspects of the overall JARPA II programme into a coherent understanding of the ecological role of studied whale species in the ecosystem. The Panel therefore **recommends** that considerably more effort and resources are allocated to this aspect of JARPA II (and see other recommendations such as those detailed under Items 6.3.4 and 7.2.2). Without this, it is not possible to state whether the programme can meet its objectives. Such work will also be of importance in reviewing future priorities for field work.

10.2.1.1 KRILL BIOMASS TIME SERIES (AND SEE ITEM 7.2.1)

It is important to calculate the fraction of the krill stock consumed by each species to model potential competition between the different whale species. Trends in food availability to a given predator are a function of both trends in competing predators and the available prey biomass; it is difficult to draw conclusions on possible competition effects without also knowing trends in prey availability. The Panel therefore **recommends** that future high priority be given to obtaining new estimates to allow an area-based time-series of krill biomass estimates, if JARPA II is to meet Objectives 1 and 2. The Panel also **agrees** with the proponents that the time series can be extended into the past by reanalysing the JARPA krill data with revised target strength values to make past data compatible with more recent observations. This is discussed under Item 7.2 but is mentioned again here given the importance of krill biomass trends as a critical component of modelling whale consumption and competition.

10.2.1.2 ECOPATH MODEL

Further development of the Ecopath model may prove useful given the limited data and biological knowledge on the functioning of the Antarctic ecosystem. Parameterisation should be improved, fitting to the available data where possible. Development of an Ecopath model has the potential to not only give an overall picture of ecosystem links, it may prove useful to form the basis of sensitivity analyses to highlight where uncertainty in the biological understanding and data has a high impact on the ecosystem models; quantifying uncertainty and examining sensitivity is valuable in its own right because it can provide input into defining future research needs, and informing the design of the minimum realistic models. The Panel therefore **recommends** that the Monte Carlo approach developed by Gaichas *et al.* (2011 to characterise uncertainty in Ecopath results be applied. The Panel also **recommends** that, to account for observed trends in the abundance of whales in the JARPA II study area, 'biomass accumulation' terms be included in the development of a revised Ecopath.

10.2.1.3 MINIMUM REALISTIC MULTISPECIES MODELLING

The multispecies production model described in SC/F14/J26 has the potential to model the interactions among various whale species. However the model is currently at an early stage in development. The Panel **strongly encourages** continued development of this approach and increased allocation of effort. The model is rather ambitious for a first stage in model development, with four whale species and one seal species. The level of data availability is much greater for minke and humpback whales than for the other species, and the Panel **suggests** that it may be useful to start the modelling work by constructing a model containing only these two whale species. Adding additional predator species would be justified if such a model can be constructed and successfully fitted to data. A stated aim of the modelling is to compare model results including and excluding competition among species. However, all versions of the proposed multi-species model will include some degree of 'competition' because all of the predator species in the models outlined in SC/F14/J26 are feeding on the same finite krill resource. Consequently, the current model structure cannot be used to test the hypotheses that competition is impacting Antarctic minke whales. In principle, this hypothesis can be tested by comparing the fits of the current model with that of a series of single-predator models. However, the Panel **notes** that fitting the production model using ADMB may be difficult for technical reasons. One possible partial solution to this is to reduce the step length within the model (e.g. from an annual to a monthly time step).

10.2.1.4 GENERAL

The Panel **recommends** that simulation be used to determine the data needed to reliably distinguish among competing hypotheses to explain the available data, including the proponents' preferred option, competition among species. Artificial datasets of known properties allow for testing of model behaviour, including identifying whether the model is able to respond in predictable ways to known signals in the data. This process can also be used to identify the required level of precision in the data to parameterise the model.

The whale species of interest spend only a fraction of their lives within the JARPA II area. Whale dynamics will also be impacted by factors when they are outside this area, although in many cases there is unlikely to be data to parameterise such effects. The Panel also **notes** that there is a time lag in the biomass dynamics (due to generational effects), which is poorly modelled in the current production model. This could be addressed by using a multispecies version of the SCAA model developed for minke whales, or by introducing the lags explicitly into the production model.

The Panel **emphasises** that producing ecosystem models is a long-term exercise, which requires the integration of a large amount of data as well as ecological and biological knowledge of the system. The work conducted to date represents a useful start. However, the Panel **recommends** increased collaboration with other researchers from outside the JARPA II area to improve the modelling. This should be in the form of incorporating data from adjacent areas where possible, and by sharing expertise and knowledge with other ecosystem and multispecies modelling experts. Furthermore, model development should not only draw on data from the existing elements of the JARPA II project, but should also inform the development of the project (and future projects) to address data deficiencies identified during the model development process.

The stated main aim of producing the ecosystem models is to provide tools to test competing hypotheses about ecosystem functions (for example 'that there is a competition-driven inverse relationship between minke and humpback whales'). The models developed must fit to available data to have sufficient realism to produce reliable results. The models must also be sufficiently flexible to incorporate a range of different competing hypotheses and should do so in a clear and explicit manner.

11. REVIEW OF RESULTS: IMPROVE MANAGEMENT PROCEDURE FOR ANTARCTIC MINKE WHALES

11.1 Proponents' summary of results

In the short term, the results of the Revised Management Procedure (RMP) *Implementation* can be substantially improved when such information as stock structure, abundance and a range of possible MSYR become available and more accurate (contributions from Objectives 1 and 3). Knowledge of the Antarctic marine ecosystem and its dynamics (Objectives 1 and 2) would also improve the IWC conservation and management system, including the application of the ecosystem approach.

New information on stock structure and mixing and on abundance from JARPA II will be important for any future RMP application to Antarctic minke whales, as such information is essential for the RMP's *pre-Implementation assessment* and *Implementation Simulation Trials.* JARPA II has shown that the previous trial application of the RMP to Antarctic minke whale in 1993 is no longer valid.

For example, the new information, particularly the stock structure information, will render the RMP more efficient, i.e. providing extra catch without increasing conservation risk. The 10 degree longitude slices used previously as *Small Areas* are no longer supported by the JARPA II data. JARPA II has provided new information on stock structure enabling a better definition of *Small Areas*.

Furthermore SCAA analyses based on JARPA II data showed that the Antarctic minke whale can show growth rates that are appreciably larger than the lower bound for MSYR used in RMP trials.

The results above are consistent with the view expressed by the IWC Scientific Committee at the 1997 IWC JARPA Mid-term Review (IWC, 1998b) which was also confirmed by the IWC JARPA Final Review Workshop (IWC, 2008):

> 'Finally, the results of the JARPA programme while not required for management under the RMP, have the potential to improve management of minke whales in the Southern Hemisphere in the following ways: (1) reductions in the current set of plausible scenarios considered in *Implementation Simulation Trials*; and (2) identification of new scenarios to which future *Implementation Trials* will have to be developed (e.g. the temporal component of stock structure). The results of analysis 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 about the level indicated by the existing *Implementation Simulation Trials* of the RMP for those minke whales' (IWC, 1998b; 2008).

11.2 Panel's conclusions and recommendations

The trials used to select the current *Implementation* of the RMP for the Southern Hemisphere minke whales (IWC, 1993) were based on the assumption that there are six stocks of minke whales in the Antarctic. The boundary between half-Areas I-E and II-W (i.e. 60°W) was assumed to be the boundary between the 'core' areas for two stocks, with the boundaries of the 'core' areas for the remaining stocks set by selecting five additional core area boundaries at random from the remaining 11 half-Area boundaries, subject to the constraint that the 'core' areas may not be more than four half-Areas wide. The trials considered two assumptions regarding mixing of stocks.

(1) The 'concentration' hypothesis in which a stock (the concentration stock) is selected at random from the six. This stock occupies its core area only. Each of its neighbours occupies its own core area plus the adjacent half-Area within the first concentration stock. The stock 'opposite' the first stock is the second concentration stock. It also occupies its core area only. Each of its neighbours occupies its own core area plus the adjacent half-Area with the second concentration stocks' core area.
(2) The 'overlap' hypothesis assumes that in each year each of the six stocks feeds in the nearest half-Area of the two core areas immediately adjacent to own core area.

The trials considered MSYR values of 1% and 4%, and set historical abundance based on estimates from abundance from IDCR for 1979-90. No *Implementation Reviews* have been conducted for the Southern Hemisphere minke whales. Moreover, the trials used to select the current *Implementation* were not developed using the protocol which has been used when conducting the *Implementations* for the western North Pacific minke whales and the North Atlantic fin whales (IWC, 2012). No trial specifications based on the results from the JARPA/JARPA II were presented to the Workshop.

The stock structure hypotheses on which the original trials were based were very broad, with the aim to encompass most likely actual situations. The information from JARPA and JARPA II, along with other information obtained since the original trials were developed, would be very useful if the current protocol were to be applied, as they should refine the set of hypotheses on which trials would be based. In particular, the information on stock structure collected during JARPA/JARPA II could be used to develop stock structure hypotheses for Areas III-E to IV-W which are conditioned on data, while the revised estimates of abundance would be used for conditioning. The information from the SCAA and similar analyses could be used to develop hypotheses related to changes in carrying capacity, natural mortality, and variation in birth rates.

The operating models on which *Implementation Simulation Trials* have been based have considered multiple stocks but have not explicitly allowed for hypotheses related to competition and ecosystem change[6]. In principle, the work on ecosystem modelling could be used to develop a set of operating models which allow for competition. However, the ecosystem models need to be developed with sufficient resolution (e.g. age- and sex-structure for minke whales).

[6]Single-stock trials and some *Implementation Simulation Trials* in which carrying capacity, natural mortality and MSYR changed over time have been conducted to examine the qualitative features of these factors on the performance of the RMP.

12. SUMMARY AND CONCLUSIONS

Before considering the individual components and papers presented in terms of objectives, the Panel made a number of general comments that are applicable to all aspects of the programme.

12.1 General issues

12.1.1 General statement on specification of objectives

The Panel noted several times in its discussions that the general and extremely broad nature of the objectives of the original proposal and its ongoing nature made it difficult to fully review how well the programme could be said to be meeting its own objectives:

(1) 'monitoring of the Antarctic ecosystem';
(2) 'modelling competition among whale species (to inform) future management objectives';
(3) 'elucidation of temporal and spatial changes in stock structure'; and
(4) 'improving the management procedure for Antarctic minke whale stocks'.

The Panel **welcomes** the clarification of the objectives and their inter-relationships provided by the proponents in SC/F14/J01, but **notes** that within such broad and long-term overall objectives as (1) and (2), almost any information can be said to be contributing to them in some way; this made the task of the Panel to assess how well the programme was meeting its own stated objectives, somewhat difficult. It also **notes** that previous Panels have encountered similar difficulties.

The Panel therefore **recommends** that for the benefit of any future Panel reviews as well as for the proponents' own internal review and evaluation process, the proponents read the guidelines for proposed permits developed by the Scientific Committee (IWC, 2013b) after JARPA II was developed, and consider developing refined objectives and sub-objectives with timelines for progress. This will allow performance to be more easily assessed in future and will better enable the timing of the next ongoing review (normally, this is every six years).

The Panel also **notes** that the original special permit programme also covered fin and humpback whales. It **believes** that the proponents should have considered the fact that their original sampling design was not carried out more carefully and provided information on any implications for future sampling and the overall multi-species modelling objective.

12.1.2 Sampling design and protocols

There are separate survey designs for the sampling and the survey vessels. Several of the analyses such as the statistical catch-at-age analyses rely on the assumption that the sampled animals are reflective of the survey estimates of abundance. In addition, analyses of data on, for example, blubber thickness, are more straightforward to conduct and interpret if the sampling scheme is balanced (and see SC/F14/O05). The Panel examined in detail the planned and realised tracklines for some of the surveys (SC/F14/J02). The latter tracklines often deviate from the planned tracklines due to disruption due to weather, ice conditions and increasingly to sabotage activities by protestors. The survey protocol states that the vessel continues along the trackline when surveying and sampling is disrupted by weather; surveying and sampling resumes when weather becomes conducive to scientific study. In contrast, the response to protestors appears often to have been to restrict the area where sampling takes place primarily to locations close to the ice-edge, effectively changing the sampling design and affecting the representativeness of the sample and thus the value of the long-term time series and the ability to meet objectives.

The Panel **is concerned** that the inability to realise the designed sampling scheme will severely compromise the ability of the programme's objectives to be met (some examples of this can be seen in SC/F14/O05). While the Panel **recognises** that the disruption by protestors is outside the proponents' control, it is clear that under these difficult circumstances, considerable effort must be made to ensure that the sampling remains representative rather than only focusing on sample size (the Panel noted that the size restrictions with respect to fin whales compromise the representativeness of that dataset within the research area). The Panel **recommends** that an explicit protocol is developed to specify *a priori* how the design is modified if disruption by protestors occurs; simulation studies based on existing data should assist in this. The aim of this protocol should be to: (a) maximise the extent to which sampled animals are representative of the survey estimates of abundance; and (b) ensure that the data remain compatible with the past datasets. If disruption continues, consideration should be given to not starting the survey at the same longitude in each study area so that it is reasonable to expect that all of the study area is covered over time. Development of protocols to account for disruptions should be undertaken by analysts as well as by those who conduct the surveys.

12.1.3 Integration of results from within each component of the programme and from outside the programme

The Panel **recognises** that this is the first period of the JARPA II programme but **notes** that the programme arose out of the long JARPA programme and that many of the papers analysed data from both programmes. It **agrees** that the analyses presented on the different objectives would have benefitted considerably from better integration of all aspects of the programme with the modelling work, in order to have allowed better identification of key parameters and the degree of accuracy and precision that would allow for robust conclusions to be drawn. The Panel **notes** that this was recognised in several of the proponents' presentations. It **recommends** that this should be undertaken as a matter of priority and a more complete evaluation of uncertainty undertaken in terms of model inputs to allow an updated evaluation of sampling design, size, research methods and priorities.

The Panel **welcomes** the considerable work that was put into field and laboratory work and the development of papers. However, as is apparent from a number of its recommendations, it is **essential** that further analytical work integrating the information available from the various aspects of the programme is undertaken. In particular, given the objectives of 'monitoring changes' and understanding the ecosystem, the Panel **stresses** the importance of trying to obtain as much information as possible on the environment (oceanographic, prey related, etc.) at appropriate geographical and temporal scales, and to integrate the analyses of such data in a coherent manner. Without such efforts, meeting stated objectives will not be possible. In this context, the Panel **notes** that the analyses of the extensive data collected was in many cases overly simplistic and isolated from other aspects of the programme. It **strongly recommends** that considerably more effort and resources be put into the analytical side of the programme, both via more thorough analyses of individual datasets where indicated in this report and especially through better integration amongst the datasets. As noted earlier this will also assist greatly in re-examining field priorities and strategy. It is already clear that the estimation of krill abundance (within or outside the programme) is **essential** to meeting ecosystem-related objectives.

12.1.4 Archiving and use of past samples

The Panel **notes** the recommendation from the JARPN II review that if whales are killed for scientific purposes, then every effort must be made to maximise the information from them. Whilst the JARPA II programme has undertaken considerable laboratory work, the Panel has identified a number of additional studies that will be valuable both for the programme itself and the wider scientific community (see recommendations). In addition, an important component of such a programme relates to archiving. It is essential that a proper tissue archiving system is in place that will allow:

(1) analytical sample sizes to be increased for studies that were carried out on only a subset of the animals killed; and/or
(2) new analyses to be carried out as techniques improve.

Similarly, it is important to compile a relational database that links all components and results of analyses for each animal with the tissue archive.

The Panel **agrees** that a number of questions potentially could be addressed with material that may have been preserved from the historical commercial catch. Examples include genetics on minke whales from outside the JARPA/JARPA II study area, genetics on fin and other whale species, stable isotopes on any species and area, or retrospective pollution studies on Antarctic minke whales and other species to better assess occurrence of temporal trends. While reports from JARPA and JARPA II detail the availability of tissue samples from these programmes, no similar information is available from the historical catch. The Panel **recommends** that a detailed list of available historical samples be produced, specifying details on species, date of sampling, associated biological data, and preservation method (e.g. formaldehyde, alcohol, frozen, dry, etc.).

12.1.5 Effect of catches on stocks

The effect of future JARPA II catches on the population of minke whales in Antarctic Areas III-E to VI-W was explored using HITTER analyses (SC/F14/J38). SC/F14/J38 suggests that catches of up to 850 animals per annum will not substantially reduce population sizes. While the Panel **agrees** broadly with the conclusion that such catches will not adversely affect Antarctic minke whales in the research area, it also notes that the most appropriate way to assess the impact of future Special Permit catches on stocks is within the framework of an RMP-type process; that approach explicitly accounts for uncertainty in a more appropriate way than a simple HITTER approach with sensitivity tests. The Panel **notes** that the IWC Scientific Committee has not undertaken a full *Implementation* of Antarctic minke whales under the current Requirements and Guidelines, as a result of the instruction of the Commission after the establishment of an IWC Sanctuary in the Southern Ocean.

The actual catches of fin whales were small given the estimated abundance within the research area (which does not cover the major distribution of fin whales based on past catches). Given this, and the abundance estimates available for the research area, the Panel **agrees** that the catches would not have affected the stock(s). No humpback whales were taken in the first phase of the programme. Again it notes that an RMP-type process is required to fully address questions concerning the effect of ongoing catches on stocks.

12.2 Achievement of objectives

The Panel draws attention to its comments above (see Item 12.1.1) concerning the specification of the objectives and the difficulties it faced in reaching conclusions on the first phase of the long-term programme. In particular, it refers to the need for additional work to assist in future reviews. In reviewing the components of the programme, the Panel **notes** the interactions between objectives and components of work provided in Fig. 2 above. It has therefore structured its summary based upon agenda Items 4-11, recognising that some of the topics address more than one of the objectives.

12.2.1 Monitoring cetacean habitat (see Item 4.2)

The monitoring of the physical and biological habitat is relevant to all of the objectives and central to Objective 1.

The Panel **notes** that thus far, JARPA II has built upon some of the work undertaken on collecting oceanographic information but that unfortunately this work has been limited in the most recent two years.

The Panel **recognises** the contribution of the long-term time series represented by the JARPA and JARPA II programmes, particularly in the context of simultaneous collection of whale and environmental data. However, the Panel is **concerned** that the necessary analytical work to fulfil the objectives of the programme has not received the attention and resources that it deserves. If the programme is to meet its own objectives in the medium to long-term, the Panel makes the following **recommendations:**

(1) the collection of the full suite of oceanographic data be resumed in the coming season and the necessary calibration work be undertaken;
(2) the proponents investigate the availability of other oceanographic and related data and incorporate these with the data collected from the JARPA and JARPA II programmes to form a more comprehensive dataset;
(3) the proponents develop a method to make their data available to other international programmes;
(4) the existing TDR and EPCS data are analysed to fully describe the datasets contain and review their usefulness in future habitat and whale analyses; and
(5) concerted efforts begin to analyse the oceanographic and other environmental data in the light of the obtained cetacean sightings survey and biological data (more details are provided under the relevant agenda Items below).

The Panel **welcomes** the work being undertaken on marine debris and encourages its continuation and the regular presentation of the results to the IWC.

12.2.2 Temporal and spatial changes in stock structure (see Item 5.2)

The work presented relates directly to Objective 3 of the programme but is fundamental to the other objectives as well. The Panel **commends** the considerable field and laboratory effort that had gone into developing a comprehensive long-term dataset, particularly for the Antarctic minke whales, as well as the efforts to develop analytical approaches to incorporate genetic and other markers in an integrated analysis.

The Panel **agrees** that considerable progress has been made in understanding stock structure within the research area (just under half of the circumpolar region) in accord with Objective 3. However, it **draws** attention to the fact that the programme has incorporated little information from outside the research area.

12.2.2.1 ANTARCTIC MINKE WHALES (SEE ITEM 5.2.3)
The Panel **welcomes** the work represented in SC/F14/J28 and SC/F14/J29; the latter representing the innovative integrative approach, incorporating genetic and non-genetic data. It made a number of detailed short-term recommendations for revised papers, highlighting additional analyses that will assist in interpretation of the data.

The Panel made a number of medium-term **recommendations** to develop further the approach of SC/F14/J29. It also **recommends** consideration of other potential hypotheses (e.g. isolation-by-distance along a longitudinal gradient), recognising that management procedure (Objective 4) considerations on stock structure focus on developing plausible interpretations of available data, not simply the 'best' when examining uncertainty.

Finally, the Panel **recommends** incorporation of additional types of data in consideration of stock structure (and any temporal trends).

12.2.2.2 HUMPBACK WHALES (SEE ITEM 5.2.4)
The Panel **welcomes** the examination of humpback stock structure on the feeding grounds (SC/F14/J30) by integrating data from biopsy samples collected during JARPA and JARPA II with other data collected within the Antarctic and higher latitudes. This work was undertaken in response to a recommendation from the JARPA review and makes a valuable contribution to the in-depth assessments of Southern Hemisphere humpback whales.

The Panel made some detailed recommendations for a revised paper.

12.2.2.3 FIN WHALES (SEE ITEM 5.2.5)
The Panel **welcomes** the genetic analyses presented in SC/F14/J32 on fin whales, although the sample size was small. The study incorporated samples from the catch as well as biopsy samples collected during JARPA and JARPA II. However, the Panel has some concerns about some aspects of the analyses and interpretation. The Panel made some detailed recommendations for a revised paper. In the longer term, it **suggests** increasing the sample size from existing data by using biopsy samples collected by other programmes (e.g. SOWER) and from earlier commercial whaling.

12.2.2.4 SOUTHERN RIGHT WHALES (SEE ITEM 5.2.6)
The Panel **welcomes** the genetic analyses presented in SC/F14/J33 with biopsy samples primarily collected in Area IV. The study provided the first attempt to genetically characterise southern right whales on the feeding grounds and provided indications that at least some southern right whales may travel further than previously thought. This information will contribute to future in-depth assessments of this species.

12.2.3 Monitoring abundance, trends and distribution (see Item 6.3)

12.2.3.1 ABUNDANCE AND TRENDS FROM SURVEY DATA (SEE ITEM 6.3.1)
This information is related to Objectives 1, 2 and 4 and is to a considerable degree dependent upon information obtained under Objective 3.

There were two primary analytical approaches: sightings data analyses and statistical catch-at-age analyses (SCAA).

The Panel **welcomes** the presentation of survey results from the JARPA and JARPA II programmes. It **agrees** that this information is contributing significantly to the objectives of the programme. The survey work represents a considerable expenditure of research time and a large dataset for long-term monitoring. It complements the work of the IDCR/SOWER programme that has now finished. The importance of monitoring trends in abundance in cetacean species is of general conservation and management importance especially in the context of documenting the recovery of species/populations that had been extensively depleted by commercial whaling, as well as investigating variation in species mix compared to the period prior to exploitation.

The JARPA review meeting (IWC, 2008) had examined the survey information available at that time and had identified a number of items that required further investigation before acceptable abundance estimates could be obtained. The Panel **agrees** that the papers on Antarctic minke whales (SC/F14/J03) and humpback whales (SC/F14/J04) had adequately addressed most of these concerns and had in some cases identified further work that would be undertaken - e.g. see the discussion in Matsuoka *et al.* (2011) and Hakamada *et al.* (2013).

The Panel made a number of detailed recommendations (Item 6.3.1) to develop a revised stand-alone paper for the 'other' baleen whale papers. In terms of future field work, the Panel **recommends:** (1) consideration of the use of Independent Observer mode in future surveys to address the issue of $g(0)$; and (2) the collection of killer whale ecotype data.

12.2.3.2 SCAA ANALYSES (SEE ITEM 6.3.2)
The Panel **notes** that the SCAA analyses, whilst using data from JARPA and JARPA II, have been directed by the Scientific Committee and undertaken by non-proponent scientists (primarily Punt) over many years. The Panel **welcomes** the updated SCAA analysis presented. It **agrees** that the SCAA model is both the best currently available model for examining stock dynamics for the minke whales in the JARPA II area, and that the model performs well in this regard. The Panel made a number of detailed **recommendations** for improvements and further work. The Panel also **notes** that certain results from the SCAA model may not be consistent with inferences developed from other components of JARPA II or may suggest potential revisions to the design of JARPA II itself. These points concerned *inter alia* MSYR, stock structure and growth rate changes. They should be considered by the proponents once the revised SCAA analyses have been undertaken.

12.2.3.3 ALTERNATIVE APPROACHES TO ESTIMATING ABUNDANCE (SEE ITEM 6.3.3)
The Panel **welcomes** the preliminary evaluation of the use of paternity analysis to estimate abundance of Antarctic minke whales (SC/F14/J07). It made two suggestions regarding further work on this matter.

12.2.3.4 DISTRIBUTION (SEE ITEM 6.3.4)
Examining and understanding the distribution of whale species and the reasons for any changes in distribution is central to Objectives 1 and 2. The Panel **welcomes** the work undertaken in this regard, primarily based upon the sightings survey data and recognises the attempts to quantify changes in distribution (primarily of minke whales and humpback whales) over time within the research area. That being said, the Panel **recommends** that more robust and comprehensive analyses of the existing data be undertaken that incorporate many more potential explanatory variables. In particular, a more rigorous area occupancy analysis should be undertaken that incorporates recent advances in spatial modelling. The Panel **agrees** that much greater emphasis be placed upon this analysis in the short-term (1-2 years) in order to determine the extent to which objectives are being met and to determine whether improvements are required.

The distributional information has been used by the proponents to formulate their 'competition' hypotheses (Objective 2). The Panel **agrees** that considerably more work is needed to develop a conceptual model for such competition. This requires additional field effort to that currently being undertaken in order to develop plausible hypotheses for use in ecosystem modelling that are essential to meet Objective 2. The Panel **recommends** that the proponents invest effort in some and preferably all of the following:

(1) analysis of proximity of whale species in the sighting survey tracklines – this can be done with existing data and initial analyses should be possible within the next year;
(2) focused studies of prey swarming behaviour and density in relation with local whale distribution and abundance – this may require a change of fieldwork focus for one or more seasons and integrated data from focal follows, telemetry (radio and/or satellite), krill abundance and density estimates and biopsy sampling (for *inter alia* stable isotope analysis);
(3) comparison of prey in stomach contents in areas where both species overlap in distribution, and in areas where they segregate, including investigation of whether whale species and krill length-maturity classes exhibit distinct spatial segregation in their distribution patterns – this can begin with existing samples and it should be possible to present a progress report within the next two years; and
(4) stable isotope analysis from tissue samples – initial examination of the discriminatory power of such analyses can occur with existing samples.

12.2.4 Monitoring krill abundance and feeding ecology

12.2.4.1 KRILL ABUNDANCE (AND SEE ITEMS 4.2 AND 7.2.1)

Monitoring krill abundance is fundamental to Objectives 1 and 2 of the programme. While welcoming the work that has been done in JARPA and at the beginning of JARPA II (see Item 4.2), the Panel is **concerned** that insufficient recent effort has been placed upon this component of the work. The Panel has made a number of recommendations both with respect to the analysis of existing data and the collection of future data. In particular, the Panel **recommends** that future krill surveys should be frequent because the density of krill in any given stratum may vary significantly from year to year, and the objectives of JARPA II require a time-series view of how the prey field is changing over time. The JARPA II study area is very large, and it is probably not possible to survey the entire study area every year with a single survey vessel. Thus, the Panel **recommends** either using multiple survey vessels to synoptically cover the JARPA II study area every 1-3 years or using one vessel to survey alternating halves of the study area every year (similar to the approach taken for sighting surveys).

12.2.4.2 FEEDING ECOLOGY (AND SEE ITEM 7.2.2)

Understanding feeding ecology is central to achieving Objective 2 and is relevant to Objective 1.

The Panel **welcomes** the considerable amount of field and laboratory work undertaken on this subject and analysed in SC/F14/J15. However, it identified a number of important shortcomings in the work originally presented, in particular related to quantification of uncertainty. The Panel **agrees** that the approach developed by the proponents during the Workshop to address these shortcomings (SC/F14/R01) is both a positive development and a useful way forward; however, without the results of a thorough analysis, the Panel is unable to determine whether JARPA II has provided or will provide consumption estimates within a sufficiently narrow range. The Panel **recommends** that work proposed in SC/F14/R01 be further developed and allocated high priority. Ideally a new paper should be submitted to the next meeting of the Scientific Committee. As a minimum, this should advance the outlined work plan by including in the Monte Carlo simulations, uncertainty in:

(1) *r* (the ratio of low/high feeding intake) and the length of the feeding season for Method 1; and
(2) the extent of night feeding for Method 2.

The Panel also **recommends** that the work is extended by computing a time series of Monte Carlo results for the total potential consumption of krill using abundance estimates of minke whales (preferably those estimated by the SCAA model) and the uncertainties around these estimates.

These analyses are an essential consideration as to the extent to which the JARPA II programme in its present form is able to meet its objectives. The Panel therefore **recommends** that the results of the Monte Carlo work be used to re-evaluate the future research and sampling in JARPA II. Details are provided under Item 7.2.3. This approach could also be used both to aid determination of future sample sizes by estimating how many samples would be needed to reduce uncertainties in consumption estimates by a desired level and to assess whether lethal or non-lethal sampling or a combined approach represents best way of reducing such uncertainties.

The Panel **agrees** that results presented in SC/F14/J16 (figs 4-6) indicate substantial overlap in the sizes of krill that are consumed by minke whales and fin whales when sampled near the same locations and times, noting also that the sample size for fin whales is small, restricted to smaller animals and outside the species main distribution area. However, the Panel **cautions** the proponents over any over-interpretation that this proves that there is 'interspecific interaction' or competition between these species in any limiting sense. The information provided in SC/F14/J16 suggests that together, minke and fin whales might have consumed about 6% of the standing biomass of krill and thus that total krill biomass *per se* was not limiting.

The Panel **reiterates** that additional field work is needed (see Item 12.2.3.4) to develop plausible hypotheses in order to meet Objective 2.

12.2.5 Monitoring whale biological parameters (and see Item 8.3)

The Panel **recognises** the considerable field and laboratory effort involved in the papers on biological parameters. This work is relevant to Objective 1 and to Objective 4 and is dependent upon consideration of stock structure (Item 5). It is also dependent on the representativeness of the sampling design (see the JARPA review (IWC, 2008) and Item 12). The Panel **notes** that the analyses presented on biological parameters assume: (a) that the sampling scheme is broadly representative of the population; and (b) related to the stock structure hypotheses agreed at the JARPA review rather than those that were subsequently presented to this meeting (Item 5). With respect to sampling design in JARPA II, the Panel **notes** the disruption caused to the proposed sample size and design due to outside interference in the Antarctic and refers to the discussions on sample size and sampling design at the JARPA review meeting (IWC, 2008) and in the papers by de la Mare and colleagues at this meeting (see Item 8.2). The Panel's overall comments on sampling design/size within JARPA II are given under Item 12.1.2.

12.2.5.1 AGE AT ATTAINMENT OF SEXUAL MATURITY/ PREGNANCY RATES (AND SEE ITEMS 8.3.1.1 AND 8.3.1.2)
The Panel **welcomes** the information provided on these important topics, recognising the amount of field and laboratory work involved and the analytical work in estimating ageing errors. However, it cautions the proponents against over-interpretation of the data at this stage. It **recommends** additional analytical work to be undertaken before conclusions can be drawn as detailed under Items 8.3.1.1 and 8.3.1.2.

Recommendations for future field and laboratory work are made under Item 8.3.1.2.

12.2.5.2 AGE ESTIMATION (AND SEE ITEM 8.3.1.3)
The Panel **welcomes** the work presented on the evaluation of the use of aspartic acid racemisation as an alternative approach to estimating age and made a number of **recommendations** for an updated paper and future work.

12.2.5.3 NUTRITIVE CONDITION (AND SEE ITEM 8.3.2)
The Panel **recognises** that the factors considered in the models on which the analyses in SC/F14/J13 and SC/F14/J14 are based are not derived from biological hypotheses, but rather arise primarily from discussions within the Scientific Committee. The Panel **recommends** that the authors of SC/F14/J13 and SC/F14/J14 first develop a conceptual model of the system under consideration and use that to identify a set of covariates to consider in the modelling. Model selection should always be guided by underlying knowledge of the system. It is therefore inappropriate to automatically select the 'best model' because such a model can lead to covariates being selected for which there is no reason that there are related to response variable. The Panel made a series of suggestions and recommendations as how best to take this work forward.

Despite the complexity of the analyses and the protracted discussion of appropriate statistical techniques, the Panel **expresses the opinion** that the 'weight of evidence' (i.e. the different measures consistently indicated that there was an overall decline in body condition of minke whales through the JARPA period), as well as the implications of such a result, warrant careful consideration in terms of cause.

Following the discussion at the JARPA review meeting (IWC, 2008) and the advantages of considering lipid content of the blubber as well as thickness, the Panel **recommends** that any further studies should incorporate blubber lipid content analyses for all samples, and that the collection of current measurements also continues to ensure comparability with past and future data. The Panel also **recommends** that faecal samples (from the colon) be compared with stomach samples for species composition.

12.2.6 Monitoring the effects of contaminants (see Item 9.2)
The Panel **welcomes** the papers presenting the results on organochlorine and heavy metal analysis in tissues of Antarctic minke whales and the krill consumed while recognising that, especially for organochlorine studies, the loss of samples due to the tsunami severely limited the scope of the studies. It **concurs** with SC/F14/J23 and SC/F14/J24 that the results indicating very low tissue levels for both groups of pollutants pointed towards the lack of effects on whale populations. Given the low levels observed, the Panel **recommends** lower priority for pollutant studies in the future and **agrees** that it would be sufficient to undertake pollutant analyses on a suitably chosen subsample at periodic intervals (say 3-5 years).

The Panel also **welcomes** the research on marine debris, a type of pollution on which little information is available for the Antarctic Ocean. It **notes** that information on this had also been collected by the now discontinued SOWER programme. This topic has also been recently identified as a priority by the IWC (IWC, 2014b). The Panel also **notes** the low incidence of both ingested debris and occurrence of debris in the sea surface. It **recommends** continuation of these observations and that the data be shared with other international efforts.

12.2.7 Model of competition among whale species (see Item 10.2)

12.2.7.1 ECOSYSTEM MODELLING (AND SEE ITEM 10.2.1)
The Panel **recognises** that the modelling work is at a preliminary stage. The Panel **stresses** the fundamental importance of this work to most of the objectives of JARPA II and an understanding of the role of the studies species in the ecosystem. The Panel therefore **recommends** that considerably more effort is allocated to this aspect of JARPA II (and see other recommendations such as those detailed under Items 6.3.4 and 7.2.2). Without this, it is not possible for the Panel to state whether the programme can meet its objectives. Such work is also of importance in reviewing future priorities for field work.

12.2.7.2 KRILL BIOMASS TIME SERIES (AND SEE ITEM 10.2.1.1)
Knowledge of krill biomass (and trends thereof) are central to the JARPA II programme. Recognising the difficulties posed due to outside disruption, the Panel **recommends** that future high priority be given to obtaining new estimates to allow an area-based time-series of estimates of krill biomass, if JARPA II is to meet Objectives 1 and 2. The Panel also **agrees** with the proponents that the time series can be extended into the past by reanalysing the JARPA krill data with revised target strength values to make past data compatible with more recent observations (and see Item 7.2).

12.2.7.3 ECOPATH MODEL (AND SEE ITEM 10.2.1.2)
The Panel **notes** that further development of the Ecopath may prove useful given the limited data and biological knowledge of the Antarctic ecosystem and made **recommendations** to improve the approach.

12.2.7.4 MINIMUM REALISTIC MULTISPECIES MODELLING (AND SEE ITEM 10.2.1.3)
The Panel **welcomes** the preliminary work undertaken and **strongly recommends** further development of the approach with increased allocation of effort. The Panel made a number of suggestions to further this approach.

12.2.7.5 GENERAL (AND SEE ITEM 10.2.1.4)
The Panel **recommends** that simulation be used to determine the data needed to reliably distinguish among competing hypotheses to explain the available data, including the proponents' preferred option, competition among species. This may be used to identify: (1) whether models are able to respond in predictable ways to known signals in the data; and (2) the required level of precision in the data to parameterise them.

The Panel **emphasises** that producing ecosystem models is a long-term exercise, which requires the integration of a large amount of data as well as ecological and biological knowledge of the system. The work conducted to date represents a useful start. However, the Panel **recommends** increased collaboration with other researchers from outside the JARPA II area to improve the modelling exercise.

The stated main aim of producing the ecosystem models is to provide tools to test competing hypotheses about ecosystem functions (for example 'that there is a competition-driven inverse relationship between minke and humpback whales'). The models developed must fit to available data to have sufficient realism to produce reliable results. The models must also be sufficiently flexible to incorporate a range of different competing hypotheses and should do so in a clear and explicit manner.

The Panel made a number of suggestions to further the modelling work.

12.2.8 Improved management procedure for Antarctic minke whales (see Item 11.2)

The Panel **agrees** that the information from JARPA and JARPA II, particularly with respect to stock structure and abundance will greatly improve any future *Implementation Simulation Trials,* should these ever be requested by the Commission. Similarly, SCAA and related analyses could be used to develop hypotheses related to carrying capacity, natural mortality and variation in birth rates. In principle, the work on ecosystem modelling could be used to develop a set of operating models which allow for competition. However, the ecosystem models need to be developed with sufficient resolution (e.g. age- and sex-structure for minke whales).

12.3 The relationship of the research to IWC Resolutions and discussions

The Panel briefly considered this item. The Commission has passed a number of Resolutions on matters related to ecosystem research and climate change. Resolution 1994-13 (IWC, 1995) encouraged Contracting Governments and the Scientific Committee to study environmental changes and impact on cetaceans. Resolution 1995-10 (IWC, 1996) encouraged Contracting Governments to study the effects of pollutants on cetaceans as recommended by the Scientific Committee's Workshop on the topic. Resolution 1997-7 (IWC, 1998a) encouraged Contracting Governments to continue to provide information on environmental changes and potential effects on cetaceans. Resolution 1999-4 (IWC, 2000a) requested Contracting Governments to provide the Scientific Committee with data on contaminants in cetaceans.

The Panel **agrees** that a number of aspects of the JARPA II programme are relevant to these Resolutions. The submission of the present Workshop papers fulfils the request that these types of analyses be submitted to the IWC. Submitting revised or new papers that incorporate the Panel recommendations will provide better information related to the Resolutions and discussions.

In addition to the work related to ecosystems and environmental change discussed above, the Panel **agrees** that the work on stock structure and abundance, in addition to information from photo-identification studies is directly relevant to the Scientific Committee's work on the in-depth assessments of the Antarctic minke whale, humpback, blue and right whales.

12.4 Utility of lethal and non-lethal techniques

The Panel **stresses** that its primary task at this meeting was to provide an objective scientific review of results of the JARPA II programme thus far including consideration of lethal and non-lethal methods; its task was not to provide either general condemnation or approval of lethal sampling research under scientific permit in general - consideration of this would require discussion of a number of issues well beyond the purview of a scientific panel - e.g. see the approach identified in Waples and Plummer (2009).

The Panel noted the more extensive discussion of this issue at the Workshops to review the JARPN II programme (IWC, 2010) and Icelandic programme (IWC, 2014a), including a table summarising the actual and potential contributions of various lethal and non-lethal techniques as applied to North Atlantic minke whales. These reports provided a good review of the strengths and weaknesses of the then available non-lethal techniques for studies on the following topics that are also relevant to the JARPA II Research Programme: feeding ecology; pollutant studies; and stock structure including genetic studies. The Panel also noted the more recent review undertaken as part of the SORP (Southern Ocean Research Partnership) programme. The Panel has not repeated the information from those reviews again here but took them into account during its deliberations.

Although a comparison of the utility of lethal and non-lethal sampling is not an objective of the JARPA II programme, the samples and data already collected to achieve the objectives can be analysed to investigate this general research question. This would also be consistent with the approach of JARPA II to use both lethal and non-lethal techniques; review of the effectiveness of both lethal and non-lethal methods in a quantitative manner will certainly benefit periodic review of the long-term programme.

Therefore, the Panel **recommends** that the proponents examine the approaches for comparison used in the Icelandic programme be conducted and develop an approach to formally and objectively compare the results from different approaches in the light of the programme's objectives. More specifically, conclusions about diet and nutritional status based on analysis of stomach contents could be compared to conclusions drawn from analysis of fatty acids or stable isotope ratios based on internal tissues and organs and tissue derived from mimicked biopsies (skin and outermost blubber). This can then be used by the proponents and future Panels to better address this issue in a quantitative way.

Under Item 8.3.2, the Panel recommended collecting faeces to conduct DNA and diet composition analyses. These samples could also be used in the comparison study of lethal and non-lethal techniques.

13. ADOPTION OF REPORT

The Panel completed the primary work on its report and recommendations at the Workshop and subsequently by email prior to its submission to the proponents on 11 April 2014. Final editing took place in the period following 11 April by email. The final edited report was adopted later in April 2014.

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Annex A

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Annex B

Agenda

1. Introductory items
   1.1. Chair's opening remarks
   1.2 Meeting arrangements and work schedule
   1.3 Review of documents and data (SC/F14/J01-J38, SC/F14/O01-O08)
2. Adoption of the Agenda
3. Proponents' overview of the research objectives and results (SC/F14/J01-J02)
4. Review of results: monitoring cetacean habitat (SC/F14/J20-J22)
   4.1 Proponents' summary of results
   4.2 Panel's conclusions and recommendations
5. Review of results: elucidate temporal and spatial changes in stock structure (SC/F14/J27-J34)
   5.1 Proponents' summary of results
   5.2 Panel's conclusions and recommendations
6. Review of results: monitoring whale abundance trends (SC/F14/J03-J07, SC/F14/J17-J18; SC/F14/O01-O02)
   6.1 Proponents' summary of results
   6.2 Panel's conclusions and recommendations
7. Review of results: monitoring krill abundance and feeding ecology of whale stocks (SC/F14/J13-J16, SC/F14/J19, SC/F14/O03, SC/F14/O05-O07)
   7.1 Proponents' summary of results
   7.2 Panel's conclusions and recommendations
8. Review of results: monitoring whale biological parameters (SC/F14/J08-J12, SC/F14/J35-J37)
   8.1 Proponents' summary of results
   8.2 Panel's conclusions and recommendations
9. Review of results: monitoring effects of contaminants on cetaceans (SC/F14/J23-J25)
   9.1 Proponents' summary of results
   9.2 Panel's conclusions and recommendations
10. Review of results: model of competition among whale species (SC/F14/J26)
    10.1 Proponents' summary of results
    10.2 Panel's conclusions and recommendations
11. Review of results: improve management procedure for Antarctic minke whales
    11.1 Proponents' summary of results
    11.2 Panel's conclusions and recommendations
12. Summary and conclusions (SC/F14/J01, SC/F14/J38, SC/F14/O04, SC/F14/O08)
    12.1 Achievement of the objectives
    12.2 Other contributions to important research needs
    12.3 The relationship of the research to IWC Resolutions and discussions
    12.4 Utility of lethal and non-lethal techniques
13. Adoption of Report

Annex C

List of Documents

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SC/F14/J

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02. Konishi, K., Hakamada, T. and Pastene, L. Response to document SC/F14/O05 ‘JARPA and JARPA II cannot monitor trends in the Antarctic ecosystem due to flawed sampling strategies’ by S. Wotherspoon *et al.*
03. Hakamada, T. and Konishi, K. Response to Document SC/F14/O07 ‘JARPA II sample size calculations ignore spatial and temporal variability’ by W. K. de la Mare *et al.*
04. Pastene, L. A response to Australia’s observers’ statement (SC/F14/O08) to the JARPA II Special Permit Expert Panel Review Workshop
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Annex D

Data Produced by JARPA II that were Available for the Review Workshop

Abundance estimate several species[1]

	Seasons	Sample size
1. Angle and distance experiments	2005/06-2010/11	2,617 tests
2. Ice edge line	2005/06-2010/11	4,234 points
3. Effort data	2005/06-2010/11	43,161 activities
4. Weather data	2005/06-2010/11	34,694 records
5. Sighting Antarctic minke whale	2005/06-2010/11	7,344 sch.
6. Sighting fin whale	2005/06-2010/11	605 sch.
7. Sighting humpback whale	2005/06-2010/11	4,570 sch.
8. Sighting blue whale	2005/06-2010/11	146 sch.
9. Sighting southern right whale	2005/06-2010/11	150 sch.
10. Sighting sperm whale	2005/06-2010/11	894 sch.
11. Sighting S bottlenose whale	2005/06-2010/11	310 sch.
12. Sighting killer whale	2005/06-2010/11	352 sch.

Ecological data (oceanographic, marine debris, krill)

	Seasons	Sample size
13. Temperature (XBT)	2005/06-2010/11	18 stations
14. Temp. salin. (XCTD)	2005/06-2010/11	347 stations
15. Temp. salin. (CTD)	2005/06-2010/11	361 stations
16. Temp. salin. (EPCS)	2005/06-2010/11	482 days
17. Marine debris (stomach)[2]	2005/06-2010/11	3,280 whales
18. Marine debris (sea surface)	2005/06-2010/11	88 cases of debris obs.
19. Echo sound (krill abund./dist.)	2007/08, 2008/09	326 days
20. IKMT net	2007/08, 2008/09	68 stations
21. Body length krill	2007/08-2008/09	68 stations

Antarctic minke whale (biological, feeding ecology, pollutants, stock structure data)

	Seasons	Sample size
Biological data		
22. Catching date	2005/06-2010/11	3,264 whales
23. Catching location	2005/06-2010/11	3,264 whales
24. Sex	2005/06-2010/11	3,264 whales
25. Body length	2005/06-2010/11	3,264 whales
26. Age (earplug)[3]	2005/06-2010/11	3,264 whales
27. Age (racemization)[4]	2005/06-2010/11	38 whales
28. Transition phase[5]	2005/06-2010/11	3,264 whales
29. Presence/absence of corpora[6]	2005/06-2010/11	1,701 whales
30. Testis weight[7]	2005/06-2010/11	1,563 whales
31. Fetus length	2005/06-2010/11	1,127 whales
32. Fetus weight	2005/06-2010/11	1,127 whales
33. Fetus number[8]	2005/06-2010/11	1,701 whales
34. Fetus sex	2005/06-2010/11	1,127 whales
35. Lactation condition	2005/06-2010/11	1,701 whales
Feeding ecology/energetics		
36. Blubber thickness (two points)	2005/06-2010/11	3,264 whales
37. Body weight	2005/06-2010/11	1,597 whales
38. Freshness stom. contents	2005/06-2010/11	1,925 whales
39. Main prey	2005/06-2010/11	332 whales
40. Organ weight incl. fat weight	2005/06-2010/11	82 whales
41. Girth (two points)	2005/06-2010/11	3,264 whales
42. Stom. content (IWS)	2005/06-2010/11	3,264 whales
43. Stom. content weight	2005/06-2010/11	2,953 whales
44. Lipid content in blubber	2005/06-2010/11	20 whales
Pollutants/health[9]		
45. Heavy metals (whale)	2005/06-2010/11	212 whales
46. Organochlorine (whale)	2005/06-2010/11	5 whales
47. Heavy metal (prey)	2005/06-2010/11	30 prey
48. Gross pathological observations of internal organs[10]	2005/06-2010/11	3,264 whales
Stock structure		
49. Body proportion (8 measurements)	2005/06-2010/11	3,264 whales
50. mtDNA (sequences) (from catches)	2005/06-2010/11	2,278 whales
51. mtDNA (RFLP) (from catches)	2005/06	764 whales
52. Microsatellite DNA (from catches)	2005/06-2010/11	2,551 whales

Antarctic fin whale (biological, feeding ecology, pollutants, stock structure data)

	Seasons	Sample size
Biological data		
53. Catching date	2005/06-2010/11	17 whales
54. Catching location	2005/06-2010/11	17 whales
55. Sex	2005/06-2010/11	17 whales
56. Body length	2005/06-2010/11	16 whales
57. Age (earplug)[3]	2005/06-2010/11	16 whales
58. Transition phase[5]	2005/06-2010/11	0 whales
59. Presence/absence of corpora[6]	2005/06-2010/11	8 whales
60. Testis weight[7]	2005/06-2010/11	8 whales
61. Foetus length	2005/06-2010/11	3 whales
62. Foetus weight	2005/06-2010/11	3 whales
63. Foetus number[8]	2005/06-2010/11	8 whales
64. Foetus sex	2005/06-2010/11	3 whales
65. Lactation condition	2005/06-2010/11	8 whales
Feeding ecology/energetics		
66. Blubber thickness (14 points)	2005/06-2010/11	16 whales
67. Body weight	2005/06-2010/11	15 whales
68. Freshness stom. contents	2005/06-2010/11	14 whales
69. Main prey	2005/06-2010/11	15 whales
70. Organ weight including fat weight	2005/06-2010/11	15 whales
71. Girth (three points)	2005/06-2010/11	16 whales
72. Stomach content (IWS)	2005/06-2010/11	16 whales
73. Stomach content weight	2005/06-2010/11	15 whales
74. Lipid content in blubber	2005/06-2010/11	10 whales
Pollutants/health[9]		
75. Heavy metals (whale)	2005/06-2010/11	16 whales
76. Organochlorine (whale)	2005/06-2010/11	2 whales
77. Gross pathological observations of internal organs[10]	2005/06-2010/11	16 whales
Stock structure		
78. External measurements (41)	2005/06-2010/11	16 whales
79. mtDNA (sequences) (catches/biopsy)	2005/06-2010/11	C:17; B:13
80. Microsatellite DNA (catches/biopsy)	2005/06-2010/11	C:17; B:13

Stock structure other species

	Seasons	Sample size
Humpback whale		
81. mtDNA (sequences) (biopsy)	2005/06-2009/10	121 whales
82. Microsatellite DNA (biopsy)	2005/06-2009/10	127 whales
83. Photo-identification data	2005/06-2010/11	1,201 pictures
Blue whale		
84. mtDNA (sequences) (biopsy)	2005/06-2010/11	11 whales
85. Photo-identification data	2005/06-2010/11	376 pictures
Southern right whale		
86. mtDNA (sequences) (biopsy)	2005/06-2010/11	33 whales
87. Microsatellite DNA (biopsy)	2005/06-2010/11	33 whales
88. Photo-identification data	2005/06-2010/11	671 pictures

Annotations

[1]Standard Line Transect data. It should be noted that in some JARPA II surveys some areas could not be covered due to external interferences and sabotages from anti-whaling groups, and that some kind of extrapolation will be necessary.

[2]The figure given corresponds to the total number of stomachs examined.

[3]JARPA II age data of Antarctic minke whale were obtained by a new reader with expertise and training enough for this kind of work. The figure given here are the total number of earplugs examined. Age information could be obtained for 81.8% of the total samples. An ageing calibration exercise was carried out (Kitakado *et al.*, 2013). In the case of the fin whales age information could be obtained for 100% of the samples.

[4]This sample size corresponds to the results of a pilot study to investigate the feasibility of the racemization method for ageing purposes. At this stage these data were not produced for the purpose of biological parameters estimates but for examining the feasibility of the technique.

[5]The figure given corresponds to the total earplugs examined. Transition Phase information in the Antarctic minke whales could be obtained for approximately 42.1% of the total samples (mature+immature).

[6]Ovary samples were lost as an effect of the 2011 earthquake and tsunami so information on the number of corpora is not available. Information on the presence/absence of corpora (information necessary for determining sexual maturity in females) is based on examination of the ovaries conducted at the field.

[7]While in JARPA both testis weight and histological approaches were used for determining sexual maturity in males, in JARPA II maturity of males was determined only by the testis weight criterion (due to 'man-power' limitation and economical considerations).

[8]The figure given corresponds to the total females examined.

[9]The 2011 earthquake and tsunami affected heavily the samples collected for pollutant studies. This explains the particular smaller samples size for this item.

[10]This figure corresponds to the total number of whales examined for abnormal tissues or organs in gross pathology.

The data listed here do not necessarily match the numbers for those items indicated in the cruise reports of the JARPA II for the period 2005/06-2010/11. This is due to the fact that a substantial number of samples for some items were lost due to the earthquake and tsunami that affected Japan on 11 March 2011 (IWC, 2012). These tables shows the actual number of data by each item. Data for those items obtained during the JARPA surveys were also available for the review Workshop.

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