REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

(Busan, Republic of Korea, 11 to 22 July 2011)

CONTENTS

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INTRODUCTION

Opening of the meeting

1.1 The 2011 meeting of WG-EMM was held at the Lotte Hotel, Busan, Republic of Korea, from 11 to 22 July 2011. The meeting was convened by Dr G. Watters (USA) and local arrangements were coordinated by Mr J. Ahn, Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF) in association with staff from the National Fisheries Research and Development Institute (NFRDI).

1.2 The meeting opened in a joint session with WG-SAM to receive an opening welcome from Mr Youngman Kim (President of NFRDI). Mr Kim welcomed all participants and underlined the importance placed by the Republic of Korea on sustainable fisheries in the Antarctic. In thanking Mr Kim for his welcome, Mr A. Wright, CCAMLR Executive Secretary, recalled the commitment shown by Korea to research in the Antarctic and hoped that these meetings would provide a strong basis for continued Korean engagement in the scientific work of CCAMLR.

1.3 Dr Watters welcomed the participants (Appendix A) and thanked the Korean hosts for their work in preparing for meeting. Dr Watters recalled the tragic events surrounding the sinking of the Korean longline vessel *Insung No. 1* on 13 December 2010, noting that a Korean scientific observer was among the 22 people who lost their lives; the meeting observed a period of silence.

Adoption of the agenda and organisation of the meeting

1.4 The provisional agenda was adopted without change (Appendix B).

1.5 Documents submitted to the meeting are listed in Appendix C. While the report has few references to the contributions of individuals and co-authors, the Working Group thanked all authors of papers for their valuable contributions to the work presented to the meeting.

1.6 In this report, paragraphs that provide advice to the Scientific Committee and its working groups have been highlighted. A list of these paragraphs is provided in Item 4.

1.7 The report was prepared by various people: Drs A. Constable (Australia), L. Emmerson (Australia), H. Flores (EU), S. Hill (UK), S. Kasatkina (Russia), S. Kawaguchi (Australia), M. Kiyota (Japan), A. Makhado (South Africa), G. Milinevsky (Ukraine), K. Reid (Science Officer), B. Sharp (New Zealand), V. Siegel (Germany), C. Southwell (Australia), P. Trathan (UK) and X. Zhao (People's Republic of China).

Feedback from previous meetings of the Commission, the Scientific Committee and its working groups

1.8 Dr Watters outlined the background to the agenda for this year's meeting and provided an overview of each agenda item and the desired outcomes associated with providing advice to the Scientific Committee.

1.9 In particular, he emphasised the importance of Item 2 and the symposium on 'Feedback management approaches in the krill fishery' as this was an important opportunity to consider the views of Members on what constitutes feedback management and how it might be implemented in the krill fishery. He encouraged participants to engage in discussion and to seek clarification where required as there was a need to ensure a common understanding of terminology and concepts in the deliberations of the Working Group.

THE KRILL-CENTRIC ECOSYSTEM AND ISSUES RELATED TO MANAGEMENT OF THE KRILL FISHERY

Issues for the present

Krill fishing activity and CPUE

2009/10

2.1 Ten vessels from five Members fished for krill in Area 48 during 2009/10 and reported a total catch of 211 974 tonnes. The largest catch of krill was taken from the Antarctic Peninsula Bransfield Strait West (APBSW) SSMU in Subarea 48.1 (85 764 tonnes), followed by 37 650 tonnes from the Antarctic Peninsula Bransfield Straight East (APBSE) SSMU and 17 295 tonnes from the Antarctic Peninsula Drake Passage West (APDPW) SSMU. The remainder of the catch was taken predominantly in Subarea 48.2, notably 48 444 tonnes from the South Orkney West (SOW) SSMU. The catches of krill reported from the APBSE, APBSW and Antarctic Peninsula West (APW) SSMUs in 2009/10 were the highest catches reported from those SSMUs in the history of the fishery (WG-EMM-11/5, Table 5).

2.2 Three vessels used the continuous fishing system and accounted for approximately 50% of the total catch. Norway (119 401 tonnes) and the Republic of Korea (45 648 tonnes) reported the largest catches of krill respectively. Japan reported a catch of 29 919 tonnes, Russia reported 8 065 tonnes, Poland reported 6 995 tonnes and the People's Republic of China reported 1 946 tonnes.

2.3 Catches of krill in 2009/10 reached the apportioned limit for Subarea 48.1 (25% of the trigger level: 155 000 tonnes) and on 10 October 2010 the subarea was closed to krill fishing for the remainder of the season. At the time of the closure, the total catch reported in Subarea 48.1 from the in-season catch and effort reports was 154 736 tonnes (WG-EMM-11/5, Table 3). The final verified catch was 153 262 tonnes based on STATLANT data.

2010/11

2.4 Fifteen fishing vessels licensed by five Members (People's Republic of China, Japan, Republic of Korea, Norway and Poland) have fished in Area 48 up to May 2011. The total catch reported to May 2011 was 110 949 tonnes, most of which has been taken from Subarea 48.2 since February. Approximately 55% of the catch reported so far this season has been taken by two vessels using the continuous fishing system (*Saga Sea* and *Thorshøvdi*).

2.5 The cumulative trajectory of catch is similar to that from last year, however, the bulk of this was taken from Subarea 48.2 whereas in 2009/10, the bulk of the catch was taken from Subarea 48.1. The reported catch at the time of WG-EMM-11 was 129 533 tonnes.

2.6 Based on the catch of krill reported to May 2011, the equivalent catch reported to May in the previous five seasons and the total catches in those seasons, the forecast total catch of krill for the current season falls in the approximate range from 153 000 to 214 000 tonnes. Although the current trajectory of the cumulative catch in 2010/11 is similar to the trajectory observed in 2009/10, it is difficult to make an accurate prediction of the total catch for the current season due to the absence of knowledge on how the fishery might operate for the remainder of the season.

2.7 The Working Group noted that during 2010, Bransfield Strait was free of ice until late into the winter, allowing fishing operations in Subarea 48.1 to continue later into the winter compared to previous years. Furthermore, almost no catch was recorded in Subarea 48.3, suggesting that the dynamics of sea-ice may play a significant role in distribution of the fishery. In contrast, during 2011 there was early ice development in the Bransfield Strait, and so far the fishery has predominantly operated in Subarea 48.2.

2.8 The Working Group agreed that the effects of sea-ice on the fishery will include those arising from the changes in access to different areas, as well as the well-documented and potential changes in krill population dynamics associated with changing sea-ice distribution.

Notifications for 2011/12

2.9 Six Members submitted notifications for a total of 15 vessels intending to participate in krill fisheries during 2011/12. The notifications are for trawl fisheries for krill in Subareas 48.1, 48.2, 48.3 and 48.4. No notifications were submitted for exploratory krill fisheries in Subarea 48.6 or elsewhere. The total catch notified for 2011/12 was 391 000 tonnes, slightly less than the notified amount of 410 000 tonnes for 2010/11.

2.10 The Working Group noted a two-fold increase in the notified catch, compared to last year, by the People's Republic of China, which notified the second-largest amount (70 000 tonnes) following 175 000 tonnes of Norway. The Republic of Korea notified 67 000 tonnes.

2.11 The Working Group noted reports on details of methods for estimation of green weight that were provided in response to the new requirement under CM 21-03. The methods of estimation varied among vessels and included use of flow scales (continuous system), direct codend estimation and estimation using conversion factors. Direct codend estimation is based on volume estimated by the dimension of the codend when hauled up the deck and its density.

When conversion factors were used to estimate green weight, the conversion factors were derived using combined information from codend estimation, volume measurements in fishponds and actual product weights. The level of accuracy in estimated green weight may differ between these methods and seasons.

2.12 The Working Group acknowledged that the conversion factors to be used for the coming season will only be available once fishing begins and can only be estimated at sea. Therefore Members should report updates of this information every year.

2.13 The Working Group noted that the name of one vessel from Chile is yet to be advised. It was clarified that if the vessel is to participate in the fishery it will be advised by Chile at the annual meeting of the Scientific Committee in 2011. It was also clarified that configuration of the vessel is expected to be very similar to the other vessel notified by Chile (*Betanzos*).

Data reporting

Fine-scale catch and effort (C1) data

2.14 At its meeting in 2010, the Commission amended CM 23-06 so that the periodicity of reporting should apply to the subarea-specific trigger levels, and that once catches reach 80% of the catch limit (50% for all the subsequent years), a five-day reporting interval is required (CCAMLR-XXIX, paragraph 4.9). The Working Group noted that the Secretariat's forecasting of the closure in Subarea 48.1 was facilitated by the voluntary reporting of catches at five-day intervals by the vessels which were fishing in that subarea.

2.15 All vessels are submitting haul-by-haul catch and effort (C1) data in accordance with CM 23-06, and data have been received up to May 2011 for 2010/11.

Catching capacity

2.16 The daily catching capacity of vessels in the krill fishery has increased markedly since 2003/04 (Figure 1). Vessels using conventional trawls are now capable of catching and processing up to 450 tonnes of krill per day, with an average of 100 tonnes per day. Vessels using the continuous fishing system have, on recent occasions, exceeded catches of 900 tonnes of krill per day with an average in the region of 300 tonnes per day. Increased catching capacity is likely to have resulted from an increase in the catching power of vessels, with some vessels now using two nets simultaneously, and a greater efficiency in processing the catch.

Analysis of data from the krill fishery

2.17 WG-EMM-11/14 compared the size composition of krill caught by conventional and continuous trawling systems on the Russian krill trawler, *Maxim Starostin*, and did not find any significant differences in net selectivity. The authors suggested that difference in size composition arose as a function of variation in time and space rather than different selectivity between fishing techniques.

2.18 The Working Group recalled that variability in size composition of krill populations occurred between aggregations which makes comparison of size selectivity between fishing techniques difficult. The sampling must be well designed in time and space at an appropriate scale.

2.19 WG-EMM-11/28 reported on the spatial–temporal dynamics of standardised abundance indices of krill in Area 48 using GLMMs with Tweedie's distribution; a principal-components analysis was also undertaken. The results revealed considerable interannual variation in CPUE, with lesser degrees of variation contributed by such variables as country and month. The work demonstrated that CPUE has increased in recent years in Subareas 48.1 to 48.3.

2.20 WG-EMM-11/44 presented analyses of diagnostics from fitting GLMMs to standardise the CPUE series using C1 data reported between 1986 and 2008 in Area 48. The results revealed that the GLMM with Tweedie's distribution satisfactorily describes this set of fishery data. However, many hauls which might be interpreted as 'outliers' resulted from extremely high CPUE values resulting from converting high catch values obtained from short-duration hauls (5–10–15 minutes) into catches per hour.

2.21 Given that the analysis presented in WG-EMM-11/44 indicated that very high catches from short-duration tows leads to positively biased values of CPUE at an hourly timescale, the Working Group suggested it would be important to check the data and ensure the validity of extreme outliers.

2.22 In considering WG-EMM-11/28 and 11/44, the Working Group noted the importance of exploring the utility of CPUE in the krill fishery to improve understanding of trends and characteristics of krill stocks in space and time.

2.23 The Working Group noted implications of swarm structure and fishing strategy to CPUE analysis. For example, if a vessel targets a discrete high-density swarm, the CPUE is expected to be very high. On the other hand, if a vessel tows through a dispersed aggregation and must conduct longer-duration hauls, the CPUE is expected to be low. In either case, however, regional krill density itself could be the same.

2.24 CPUE may also be affected by other factors such as gear type, product type and factory processing capacity. There might also be alternative ways of incorporating fixed and random effects into mixed models. For example, year could be treated as a random effect and fishing area (subarea or SSMU) could be treated as a fixed effect. Further, different swarm structures may also have implications to analyses of CPUE. Workers undertaking further analyses of CPUE in the krill fishery were encouraged to take these points into account and submit the results to future meetings.

2.25 WG-EMM-11/P3 reported on a statistical method for discriminating environmental effects on krill fishery CPUE and indicates that atmospheric pressure may have significant effects on CPUE at a 12-month time lag.

2.26 The Working Group noted the relevance of this paper, however, since the paper was written in Spanish it was not possible for the Working Group to consider the contents in detail. The authors of the paper were encouraged to re-submit the paper in English for further consideration.

2.27 WG-EMM-11/39 reported on spatio–temporal variability in the size composition of krill and in fish by-catch (numbers) using an hierarchical Bayesian analysis of Japanese krill fishery data from 1995 to 2008. The paper showed that increased haul coverage ranging from 0 to 50% had marked effects in improving precision in estimates of mean krill size and numbers of fish in the by-catch.

2.28 The Working Group noted that analyses of krill fishery data, such as that provided in WG-EMM-11/39, is valuable for considering the sampling scheme of scientific observers. The Working Group encouraged further analysis using larger datasets that include wider seasonal and vessel variability.

Data from Soviet krill fishing expeditions

2.29 In 2009, Drs Milinevsky and L. Pshenichnov (Ukraine) initiated a project to digitise haul-by-haul catch and effort data from 54 Soviet krill fishing research, as well as exploratory and commercial expeditions, and the data were submitted to the Secretariat and uploaded to the CCAMLR database in 2011.

2.30 The second part of this project is to digitise the krill length-frequency data from these expeditions. This part of the project is currently under way and has received generous support from the Norwegian Krillsea Group. The Working Group looked forward to seeing the results that were expected to be submitted to the CCAMLR Secretariat by the end of 2011.

Scientific observer coverage

2.31 The Working Group noted the increasing observer coverage and the amount and quality of observer data being submitted to the Secretariat in recent years. This is a substantial achievement and greatly assists the Scientific Committee in understanding the status of this fishery and fishery operations. The Working Group thanked all scientific observers for their hard work and congratulated the Members involved for their great efforts in this regard. The Working Group looked forward to further achievement and success of the observer program.

2.32 The Working Group recalled that the purpose of the two-year experimental observer program (SC-CAMLR-XXIX, paragraphs 3.16 and 3.17) was the collection of high-quality data, especially on the priority areas that are required to understand the ecosystem effects of the krill fishery. In particular, understanding the overall impact of the fishery requires data on the mortality of krill and by-catch species and would require systematic spatial and temporal coverage by scientific observers (SC-CAMLR-XXVI, paragraphs 3.7 to 3.9).

2.33 The Working Group noted that the observed percentage of total hauls reported in Tables 1 and 2 in WG-EMM-11/11 was based on recorded entries in the 'Observed' field of the scientific observer logbook form K3. However, comparison of the 'number of hauls observed' with the 'number of hauls where information was collected' in Table 2 of WG-EMM-11/11 indicated that the 'Observed' field in the K3 form does not accurately capture the total number of hauls for which information was collected in all cases, particularly for vessels using the continuous fishing system. This meant that those vessels that actually had observers on board 100% of the time appeared to have the lowest level of observer coverage.

2.34 The Working Group requested that Tables 1 and 2 of WG-EMM-11/11 be resubmitted to the forthcoming meeting of the Scientific Committee, with the columns of the 'number of hauls observed' renamed 'number of hauls sampled' to be directly comparable to target observer coverage rates in CM 51-06, and calculated according to the definition in paragraph 2.36.

2.35 The Working Group noted the lack of clarity in the definition of a 'haul' and what constitutes an 'observed haul'. It was not clear whether 'observed' referred to a haul during which a specific type of observer data was collected (e.g. collection of length-frequency data), any types of observation were made or that there was an observer on board the vessel regardless of whether the data were collected or not. This definition is of particular importance since the target coverage rate in CM 51-06, paragraph 3(ii), is of '20% of observed hauls set by a vessel per fishing season being sampled'.

2.36 The Working Group therefore recommended that a sampled haul should be defined as a haul from which krill length-frequency data, fish by-catch or incidental mortality (*Scientific Observers Manual*, 2011) data were collected. The target sampling rate should be at least 20% of hauls set during the period that an observer is on board the vessel.

2.37 The sampling protocol for fish by-catch was revised in 2010 in order to collect quantitative by-catch data for fish of all size classes, to allow estimation of total fish by-catch. However, in its current configuration, the observer logbook form K12 does not allow the recording of length of individual fish caught. Therefore the Working Group recommended revision of the K12 form to include the collection of information on individual fish length.

2.38 The aim of the data collected through the 'fish sampling protocol' is to allow the Working Group to estimate rates of by-catch of fish of all size/age classes (and associated confidence interval) in the krill fishery. These estimates could then be reviewed by WG-FSA to assess the potential implication of the fish by-catch to the entire fish population at current and future levels of the krill fishery.

2.39 The Working Group agreed that sample collection for measurement of krill length frequency and fish by-catch must be taken before any other sorting of the catch has taken place (i.e. before any large fish are removed). As it is difficult to define the position on the vessel where sampling should occur, the Working Group specified the requirements of that sampling location (rather than the location itself) in order to provide advice that can be applied to a range of vessel configurations.

2.40 In considering the finfish by-catch, the Working Group recalled that the by-catch of fish is required to be reported by vessels in the haul-by-haul data submitted to CCAMLR, therefore this provides a means to highlight any biases in the sampling procedures used to quantify the by-catch of finfish in the krill fishery.

2.41 Data reporting from the krill fishery has increased during the last decade. As a result, information related to fishery operations is becoming increasingly available and there may no longer be a need to rely on scientific observations as the source of this information. For example, the reporting of haul-by-haul data in the krill fishery might provide a more appropriate source of data to examine fisheries dynamics than continuing to request observers to provide data from the krill fishing questionnaire.

2.42 The Working Group reviewed each logbook form used by observers on krill fishing vessels. The results of this review are summarised in Table 1, and the Working Group recommended that the forms K3, 4, 5, 6, 7, 9, 10, 11, 12 should be revised, noting the requests for advice from SCIC and WG-IMAF included in this table.

2.43 In reviewing the *Scientific Observers Manual* (2011), the Working Group agreed the importance of observer priorities being clearly articulated in Section 2, Part I of the manual so that observers can understand the current priorities identified by the Scientific Committee. It agreed that the paragraphs listing priorities for krill observers in Section 2 be revised as follows:

(i) Krill length measurement using 'Krill biological data form' to:

- understand the differences in gear selectivity between different fishing techniques and gear configurations
- collect length-frequency data from all regions.

(ii) Fish by-catch data collection using 'fish sampling protocol' to:

- determine the level of by-catch of fish, including fish larvae.

(iii) Incidental mortality data collection using 'Incidental mortality and warp strike forms' to:

- determine the level of warp strikes and incidental mortality of seabirds and seals.

2.44 The Working Group requested that all technical coordinators ensure that observers are made aware of these priorities rather than waiting until the next revision of the *Scientific Observers Manual*.

2.45 During the meeting, the Secretariat produced length-frequency distribution plots by subarea by month (Figure 2), as well as a table describing the number of all hauls undertaken for each specific observation, by subarea by month (Table 2), in order to assess the spatial and temporal coverage of observer data. The Working Group agreed that these plots and the table are helpful and should be provided in the future.

2.46 Table 2 describes the temporal and spatial coverage by scientific observers in 2009/10. Scientific observers were deployed for all subareas and months where fishing activities took place in Area 48. All three priority observations were undertaken in most combinations of month and subarea. The Working Group agreed that the table provides valuable information to understand the overall level of observer coverage achieved in the most recent season.

2.47 In order to clarify the difference between a haul on a conventional trawler and the two-hour period used to record catch on vessels using the continuous fishing system, the Working Group suggested that the two-hour catch reporting period be referred to as a haul-unit to clearly distinguish these periods from the conventional understanding of a haul.

2.48 In the continuous fishing system, there will be 12 haul-units in a day, and in the case when the vessel is towing two nets simultaneously, there will be 24. In conventional trawlers, the number of hauls per day could usually vary from 4–5 up to 18. Therefore, if the coverage requirement is based on the percentage of hauls or haul-units, large amounts of data may be collected from vessels undertaking continuous fishing operations or vessels with a conventional trawling system with a large number of hauls with significant consequence for observer workload, to the extent that it may not be possible to achieve the required minimum sampling rate. There will be less data being collected from vessels conducting a small number of hauls. However, the Working Group was not able to decide on a minimum requirement for sampling frequency that would apply to all vessels due to the unpredictable nature of the fishing operation in the Southern Ocean environment.

2.49 The Working Group recognised that the variability in achievable observer sampling rates discussed above, and the sampling flexibility allowed in the instructions in the *Scientific Observers Manual*, may be in conflict with the precise requirements of CM 51-06, and referred this matter to the Scientific Committee.

2.50 The Working Group requested the Secretariat to produce maps of where the fishery occurred, number of hauls, and coverage by quarterly period for krill biological sampling and fish sampling in 2009/10 and 2010/11, in order to visualise the spatial and temporal coverage of the observation, for use by the Scientific Committee at its next meeting.

2.51 The Working Group noted that it is unlikely that the fishery operation for the second year of the two-year experimental period would be completed in time for WG-EMM to review and analyse the results and to provide advice to the Scientific Committee in 2012. It further noted that observer data and reports are required to be submitted within one month after the observers return to their home port. The Working Group agreed that only those data for months where 80% of the observer logbooks have been submitted to the Secretariat should be included in the analysis. To achieve this, the Secretariat will need to know how many observers were active in the fishery in order to know the proportion of completed logbooks that had been submitted. Therefore, the Working Group recommended that the Members deploying national observers report the dates of deployments to the Secretariat prior to the deployment period.

2.52 The Working Group agreed that the following analyses need to be undertaken prior to WG-EMM-12 in order to make recommendations to the Scientific Committee on future requirements for observations in the krill fishery:

(i) analysis of observer coverage in time and space

(ii) trends and variations across fishing area in space, time and by vessel, for krill length composition, fish by-catch and interactions with birds and mammals

(iii) simulation studies to explore appropriate longer-term scientific observer plans to ensure data collection to achieve the CCAMLR objectives based on the data obtained through the two-year experimental period.

2.53 The Working Group also noted that there may be advantages to having a more dynamic/adaptive system for managing scientific observation in the krill fishery in the future. If there was real-time monitoring by the Secretariat of the data being collected, then it may be possible for vessels to consult the Secretariat as to what observation requirements are needed in areas they wish to fish in the near future. This could allow the observation requirements on a vessel to be flexible during a season. Such a sampling strategy could be investigated using the simulation approaches indicated in paragraph 2.52(iii).

Escape mortality and green weight

2.54 In 2010, the Scientific Committee encouraged pilot studies into escape mortality and that potential methods be trialled before being requested as routine activity by observers (SC-CAMLR-XXIX, paragraphs 3.12 and 3.13). Escape mortality is calculated as the amount of krill escaping through the trawl mesh multiplied by the proportion of animals that die as a result of this process.

2.55 Two papers presented pilot studies using alternative methods to estimate escape mortality. These included the use of patches (chafers) on the outside of nets to retain krill that pass through the mesh during towing (WG-EMM-11/15) and net-mounted video cameras (WG-EMM-11/36). Preliminary results from the patch trials, conducted when the catch rate was approximately 8.5 (tonnes per hour), suggested that the equivalent of 2 to 3% of the retained catch passed through the net and 60 to 70% of these were killed or non-viable. Chafers were placed on net sections with mesh sizes 100, 60 and 5 mm. No krill were found in the chafers attached to the 5 mm mesh. The chafer method would be time-consuming for an observer to deploy and analyse and requires knowledge of trawl construction and trawling technology. The Working Group noted that this method also requires an agreed process for extrapolating results from chafers to the whole net surface and to different net designs. Extrapolation is associated with uncertainty. The actual areas covered by the chafers and the actual area of the trawl net surface depend on the mesh opening angles which are affected by the trawling process. There is also the potential to overestimate damage to krill retained in chafers installed on the top panels of the trawl if they contact hard surfaces during lifting. The camera method is currently only feasible with natural illumination and is therefore restricted to a narrow part of the usual fishing depth range. Analysis of this method is also likely to be time consuming. The Working Group encouraged the submission of further results from both studies, noting that it would be valuable to both combine results from the two methods and standardise approaches.

2.56 The Scientific Committee recommended that standardisation of methods for estimating the green weight of the catch is urgently required to achieve more accurate estimates of actual catches (SC-CAMLR-XXIX, paragraph 3.9). WG-EMM-11/29 presented back-conversion factors from products to green weight and explained their derivation from operations on the FV *Fukuei-Maru*. Low-precision estimates of catch weight and volume are routinely obtained from net sensors and fish bins respectively. Several product lines (whole, meal, peeled, boiled) might be produced from a single catch. High-precision estimates of product weight are also routinely obtained. The Working Group welcomed this engagement from the fishing industry and requested variability estimates for the conversion factors and in the relative estimates from net sensors and fish bins.

2.57 WG-EMM-11/29 also discussed the bucket phenomenon whereby trawl nets can generate leading pressure waves when water cannot efficiently pass through the mesh (e.g. when filled with catch or towed at higher than optimal speed for the net structure). The Working Group noted that interactions between the pressure wave and animals outside the net could be an additional source of mortality.

2.58 The Working Group noted that all green-weight estimation processes have associated uncertainty and that the absolute uncertainty in catch estimates increases in proportion to catch. It noted that this uncertainty is not accounted for in the current management process which uses a point estimate of total catch without an uncertainty estimate. It recommended that the Scientific Committee consider whether this uncertainty should be taken into account when comparing catch estimates with catch limits.

Recruitment variation, B_0 and precautionary yield

2.59 WG-EMM-11/20 provided details about the parameter values used in the reanalysis of the CCAMLR-2000 Survey data by SG-ASAM and presented transect- and stratum-specific krill density estimates. The Working Group noted that the relationship between krill length and target strength is not monotonic at 200 kHz. It noted that the implications of this had been considered by SG-ASAM, but it was still difficult for WG-EMM to understand these implications.

2.60 Dr Reid informed the Working Group that the background to the methods and technical details of the SG-ASAM reanalysis are documented in Calise and Skaret (2011).

2.61 Dr Kawaguchi informed the Working Group that Australia is making progress towards a revised B_0 estimate for Divisions 58.4.1 and 58.4.2 (SC-CAMLR-XXIX, Annex 6, paragraph 2.71), taking account of the approach recommended by SG-ASAM, and indicated that the revised estimate should be available in the next one to two years.

2.62 WG-EMM-11/17 used the GYM to estimate the fishing mortality (F:median = 0.0159) and the reduction in spawning stock biomass (median *SSB* trigger/SSB_0 = 97.7%) with an annual catch equal to the current trigger level, B_0 for Area 48 and a krill recruitment standard deviation (SD) of 0.126. A higher recruitment SD (0.164) resulted in a median F of 0.0163 and a median *SSB* trigger/SSB_0 of 97.1%. In response to the request from WG-EMM (SC-CAMLR-XXIX, Annex 6, paragraphs 2.76 and 2.77), the authors of WG-EMM-11/17 examined the reasons why the GYM terminates when recruitment SD is above 0.1764 with an average recruitment proportion of 0.557.

2.63 The Working Group noted that in the GYM the trial-specific average recruit proportion and its variability are used to parameterise a beta distribution from which a recruit proportion is drawn for each year of the trial. If the trial-specific average recruit proportion falls outside the range 0 to 1, the GYM re-samples from a normal distribution. However, the repeated use of this resampling can bias the realised average recruit proportion across trials, and the GYM is designed to terminate when this ‘fix’ has been used a critical number of times.

2.64 The Working Group recalled that the degree of recruitment variability presently used in the GYM could be an underestimate (SC-CAMLR-XXIX, Annex 6, paragraph 2.74) and that in stocks that experience high interannual variability in abundance arising from recruitment, the probability of biomass falling below 20% of the initial biomass might be greater than 0.1 even in the absence of fishing (SC-CAMLR-XXIX, Annex 6, paragraph 2.78). In these circumstances it would be impossible to satisfy the part of the decision rule designed to limit the probability of biomass falling below the 20% reference point to a maximum of 0.1.

2.65 The Working Group reiterated that the implications of krill recruitment variability, and how this might change as a result of climate change, on the specification of the current decision rule relating to the maintenance of stable recruitment should be investigated (SC-CAMLR-XXIX, Annex 6, paragraph 2.74).

Distribution of the trigger limit among statistical subareas

2.66 The Working Group recalled that CM 51-07 will expire this year and should be reviewed and revised in 2011 with the intent of ensuring the implementation of Article II of the Convention, and taking into account the resource requirements of land-based predators.

2.67 The Working Group noted that several papers contained information relevant to discussions on the subdivision of the trigger level among statistical subareas in Area 48 and to the revision of CM 51-07.

2.68 WG-EMM-11/5 reported that CM 51-07 came into effect in 2009/10 when the fishery was closed after being concentrated mostly in Subarea 48.1. In October 2010, the reported total catch of krill for that subarea was 153 262 tonnes, representing 98.9% of the subarea’s catch limit (155 000 tonnes), which triggered closure of the fishery in this subarea for the remainder of the fishing season.

2.69 WG-EMM-11/16 reported on the outcomes of the ‘Workshop on Antarctic Krill and Climate Change’, including the workshop’s conclusion that the precautionary management measures in CM 51-07 should be maintained until an agreement on the subdivision of the overall catch limit in Area 48 into SSMUs has been achieved.

2.70 WG-EMM-11/27 recommended that, in connection with the need to review CM 51-07, more scientific information is still required on the distribution, abundance and variability of krill and on land-based predator demands to provide future management advice on the spatial distribution of the precautionary catch limit amongst SSMUs.

2.71 As a result of the need for more scientific information, the authors of WG-EMM-11/27 further proposed that the interim subdivision of the trigger level in CM 51-07 be extended for two more fishing seasons. The authors also noted that, as the subdivision of the trigger level in CM 51-07 does not take into account that the krill fishery mostly concentrates in coastal areas and potentially can affect land-based predators, the trigger level should be further subdivided between coastal and pelagic areas to be suitably precautionary to take account of the needs of krill-dependent predators.

2.72 In considering the requirements for reviewing and revising the subdivision of the trigger level (CM 51-07, paragraph 2), the Working Group recalled its agreement in 2009 on the rationale that formed the foundation for the recommendation of the subdivision of the trigger level (SC-CAMLR-XXVIII, Annex 4, paragraph 3.127; see also SC-CAMLR-XXVIII, paragraphs 4.26 to 4.28).

2.73 The Working Group considered two main questions that would be pertinent to this review, and focused these questions on the situation in Subarea 48.1 where the interim catch limit of 155 000 tonnes was reached in 2009/10:

(i) Was the current subdivision effective in limiting the impact on predators in Subarea 48.1 in 2009/10?

(ii) Is the cap in Subarea 48.1 at an appropriate level if the fishery is going to be concentrated in Subarea 48.1, perhaps regularly, in the future?

2.74 The Working Group agreed that the answers to these questions need to be developed bearing in mind the statistical power of current monitoring to detect effects (see Figure 3) and the expectations of the effects of fishing on monitored parameters in years when concentrated fishing might arise. It noted that it would not be possible to have fishing continue and use CEMP to detect when a cap is needed before an effect occurs.

Evidence for effectiveness of current subdivision

2.75 The Working Group examined data from krill fishing and CEMP to see whether there was any evidence that the spatial subdivision of the trigger level between subareas did or did not provide suitable protection to krill predators in Subarea 48.1 in 2009/10.

2.76 Details of krill fishing activity and the application of CM 51-07 are given in WG-EMM-11/5. With respect to the distribution of the catches during 2009/10 and the part of the current season for which the Secretariat has data, the Working Group noted that:

(i) in 2009/10 and part of the current season, catches from SSMUs in Subarea 48.3 and around Elephant Island in Subarea 48.1 were lower than usual

(ii) in 2009/10, catches from SSMUs in the Bransfield Strait in Subarea 48.1 were about 20 times greater than the average historical catch in these SSMUs

(iii) in the current season, catch from the northeast coastal SSMU in Subarea 48.2 was approximately twice as much as in the previous 10 years, but not more than the long-term average.

2.77 The Working Group noted that the catch of krill in 2009/10 in two SSMUs in the Bransfield Strait (APBSW and APBSE) was 80% of the total catch in the whole of

Subarea 48.1. In the previous 10 years, 22% of the Subarea 48.1 catch has been taken in these two SSMUs, although there have recently been two years in which this proportion has been 40% (in 2005/06) and 60% (in 2008/09) (WG-EMM-11/5).

2.78 The Working Group agreed that it would be useful for the Convener to work with the Secretariat to provide, in its report on fishing activities to the Scientific Committee, maps of catches during both the 2009/10 and current season by fine-scale rectangle in Area 48 (similar to Figure 3 of WG-EMM-11/5), along with maps of the average annual catches in each fine-scale rectangle over the entire time series and of the average annual catches by fine-scale rectangle during the last 10 years. It would also be useful if the boundaries of the SSMUs could be overlaid on those maps.

2.79 The Working Group agreed that during 2009/10, the fishery did concentrate its operations in a manner that was not typical of the distribution of catches during either the previous 10 years or over the whole history of the fishery. Thus, it was further agreed that application of the subdivision of the trigger level in CM 51-07 had been successful, capping the catches in Subarea 48.1 during 2009/10, while maintaining flexibility in where vessels could fish up to that point. After the fishery in Subarea 48.1 was closed, flexibility was limited to the other subareas.

2.80 To consider possible ecosystem effects of the aggregation of the fishery in the Bransfield Strait during 2009/10, the Working Group examined the data submitted by Argentina and the USA on 23 CEMP parameters covering three CEMP sites and three species which forage in the Bransfield Strait during 2010/11 (WG-EMM-11/6). It noted that monitoring at CEMP sites in the Bransfield Strait did not substantially overlap in time with the fishery. The fishery in the Bransfield Strait occurred between April and October while CEMP monitoring started in October and continued through the 2010/11 austral summer. None of the CEMP monitoring included observations of arrival mass, which would be expected to reflect the conditions of animals whose foraging distributions would most likely overlap in time and space with fishing in the Bransfield Strait. As a result, the CEMP data are unlikely to reflect the immediate impact of the fishery, had such an impact occurred.

2.81 Furthermore, significant difficulties have previously been encountered in interpreting general ecosystem impacts from consideration of individual CEMP parameter trends which are often noisy and contain contradictory signals and may require more detailed statistical analysis to enable correct interpretation (Boyd and Murray, 2001; Reid et al., 2005).

2.82 Given the chronology of fishing and CEMP monitoring, and the difficulty of interpretation of raw CEMP data, the Working Group was unable to determine from the available data whether the aggregated fishing in the Bransfield Strait during 2009/10 had impacted the predators in that area.

2.83 The Working Group noted that the concentration of the fishery during 2009/10 occurred partly as a result of less sea-ice in the west Antarctic Peninsula (WG-EMM-11/5). The Working Group also noted that, in the future, concentrated fishing in Subarea 48.1 during winter is expected to occur more frequently due to the expected continuing decline in sea-ice in the region.

2.84 The Working Group also noted that in 2009/10 the fishery operated in Admiralty Bay, which is ASMA No. 1. After reviewing the Management Plan for that ASMA, the Working

Group was unsure if this fishing activity would be considered compatible with the Code of Conduct for that ASMA, as described in point 8.2 of its Management Plan. Accordingly, the Working Group suggested the Scientific Committee consider advising the Commission of this overlap of commercial fishing operations with the ASMA. Such information may need to be communicated to the ATCM, as it could indicate potential development of fishing activity within ASMA No. 1.

Futher consideration of the subdivision

2.85 The Working Group noted that no data were available to evaluate the likely impact of other catch levels for the Subarea 48.1 allocation of a subdivision of the trigger level. To do this effectively, the relative performance of monitored parameters would need to be measured under different catch conditions, expected to be around the levels of the current catch subdivisions. The development of such a relationship would require all relevant parameters to be monitored with high statistical power.

2.86 The Working Group agreed that to determine whether or not the performances of predators had significantly departed from their usual state due to the impacts of concentrated fishing in an area, a monitoring program would be required in the area of fishing and designed to have high statistical power (see Figure 3).

2.87 The Working Group agreed the following points would need to be addressed by the Scientific Committee to investigate whether the spatial subdivision of the trigger level is effective for protecting predators:

(i) advance notice of the areas in which the fishery will/could be concentrated so that monitoring can occur relative to those areas

(ii) an assessment of abundance of krill in the area before fishing begins and the flux of krill through the area

(iii) an assessment of the requirements of predators in the area to be fished

(iv) an assessment of whether the requirements of predators were affected by fishing.

2.88 It was also noted that consideration of the effects of fishing, and how to determine those effects with high confidence, is discussed in the symposium on feedback management procedures (paragraphs 2.149 to 2.152).

2.89 In the absence of knowing where fishing might become concentrated in future, the Working Group noted that advance warning would be needed to focus monitoring into relevant areas. The Working Group agreed that such a scenario is part of the consideration of a spatially structured feedback management procedure.

Other considerations

2.90 The Working Group noted that the trigger level is doing as intended and catches at this level are unlikely to have an effect on the krill population as a whole (across Area 48), while the spatial management strategy is being developed. However, it agreed that, should all the trigger level be taken from a concentrated area, then it may have effects on local predators.

2.91 Furthermore, it noted that the assessment of precautionary krill catch levels had assumed that the size of krill caught by the fishery would remain the same as in historical catches. The impact of the fishery on the krill population itself may be larger if the fishery targets younger krill than considered in the assessment of the catch limit.

2.92 The Working Group agreed that calculations of a subdivision can be improved by the use of acoustic biomass assessments of the distribution of krill, as well as estimates of consumption by krill predators in different areas. Available recalculations of krill abundance and predator requirements by subarea are given in Table 3.

2.93 The Working Group noted that a new synoptic survey of krill would be useful for revising the subdivision in the future.

2.94 Anticipating that there may be future similar concentration events in the Bransfield Strait, the Working Group recommended that the CEMP data relevant to the overlap of predator foraging and the Bransfield Strait fisheries be examined to determine the statistical power of available data and what field programs might be needed to detect the effects of fishing in the region in the future. It encouraged Members collecting relevant CEMP data to undertake this work. These analyses may be able to be supported by the Secretariat, depending on the priorities of the Scientific Committee and available resources in the Secretariat.

Advice

2.95 The Working Group recalled its advice of 2009 (SC-CAMLR-XXVIII, Annex 4, paragraphs 3.127 to 3.138) that, to be consistent with the precautionary approach and to avoid concentration of the catch as the trigger level is approached, a spatial allocation of the trigger level (620 000 tonnes) by subarea (CM 51-07) is required.

2.96 The Working Group was unable to determine, based on available scientific evidence, whether the subdivision between subareas according to CM 51-07 is precautionary enough or over-precautionary.

2.97 Therefore the Working Group could not advise the Scientific Committee on the adoption of any alternative allocation scheme. Accordingly, it advised the Scientific Committee that the precautionary subarea allocation scheme for the trigger level described in CM 51-07 should be retained until sufficient information is acquired for its revision.

Other issues related to spatial management of the krill fishery

2.98 WG-EMM has previously established an initial framework of SSMUs in Subareas 48.1 to 48.4 with a first-order division of the subareas into coastal and pelagic areas and a second-order division of coastal areas into smaller units (SC-CAMLR-XXI, Annex 4, Appendix D, paragraph 5.22). There was no corresponding subdivision of pelagic areas. However, pelagic areas are the location of the majority of the krill biomass, most of its consumption by predators, and 10% of the historical catch. WG-EMM-11/18 described a proposal to assess ecosystem structure as the basis for identifying finer-scale SSMUs for pelagic areas in Subareas 48.1 to 48.3. Finer-scale pelagic SSMUs would allow a greater range of options for the subdivision of catches, afford pelagic predators a greater level of protection from localised fishery impacts, and allow more realistic evaluation of management strategies for both the fishery and the ecosystem.

2.99 The Working Group suggested that, further to the information presented in WG-EMM-11/18, appropriate data for characterising the structure of pelagic areas includes observation and tracking data for seabirds and mammals, and continuous plankton recorder data.

2.100 WG-EMM-11/22 presented a GIS that has been developed to store and deliver data on CCAMLR's spatial management units and spatially resolved conservation measures. The GIS files are available at the British Antarctic Survey website (ftp://ftp.nerc-bas.ac.uk/pub/ptf/ccamlr) for evaluation by CCAMLR and its Members. The GIS facilitates easy mapping of CCAMLR's spatial management framework at any scale and by a variety of attributes, including catch limits for specific species. It allows rapid access to spatial data that may be useful in developing and implementing conservation measures, including seabed areas, distances between features and proportions of management units with particular characteristics.

2.101 The Working Group agreed that the GIS is a useful repository of conservation measures and mapping tool. It requested the provision of data files in ASCII format. The Working Group noted that the British Antarctic Survey's mapping expertise is a valuable resource which could potentially be used to assist the Secretariat. It encouraged the Secretariat to work with the UK Delegation to identify CCAMLR mapping requirements and potential delivery.

Views of the ecosystem

Other systems

2.102 Dr Makhado gave presentations describing the links between the population collapse of the African penguin (*Spheniscus demersus*) and commercially fished prey species in southern Africa (WG-EMM-11/P8) and on the results from ongoing seabird and seal monitoring conducted by South Africa at the Prince Edward Islands (WG-EMM-10/P1 to 10/P5, 10/P15 and 10/P16).

2.103 The Working Group thanked Dr Makhado for his excellent presentations and agreed that, even though the changes in the African penguin population were remote from the CCAMLR area, there were a number of potential synergies with the work of CCAMLR. In particular, the presentations showed that the effects on predators of changes in the abundance and distribution of commercially fished species is dependent on the availability of suitable alternative prey, recognising that the ability to utilise alternative prey sources will depend on species-specific aspects of foraging ecology. In some cases the reduction in the availability of the primary prey species may be reflected in a change in the population of a predator that cannot access alternative prey, whereas in other species it may be reflected in a change in dietary composition.

2.104 The results from monitoring on Prince Edward Islands highlight the value of multi-species monitoring, especially where contrasts in the response of different species may provide an enhanced understanding of the ecosystem response to change. The Working Group noted that this had important potential implications for CEMP monitoring and should be considered in the discussion of the future role of ecosystem monitoring in CCAMLR.

Krill predators

2.105 WG-EMM-11/6 summarised trends and anomalies in biological CEMP indices. The number of parameters reported has decreased since the mid-1990s but the number of sites has remained relatively stable over that period, with commencement of data collection at some new sites balancing cessation at other sites.

2.106 The Working Group noted that some aspects of CEMP data submission and reporting may need to change as CEMP is modified to meet the needs of feedback management. The need for additional data may place further demands on the Secretariat which will need to be reconciled in relation to other tasks and the resources available to the Secretariat.

2.107 A comprehensive survey of Adélie penguin (*Pygoscelis adeliae*) breeding site distribution and population abundance along 3 000 km of coastline of East Antarctica found 44 unreported breeding sites, increasing the number of known sites by 42%, and estimated that the population had approximately doubled over the past 30 years (WG-EMM-11/31, 11/32 and 11/34). The surveys provide data from sites and regions not currently covered by CEMP and suggest significant large-scale changes in the ecosystem in recent decades in these regions, but the causes are currently unclear.

2.108 WG-EMM-11/P1 examined long-term declines in krill, sea-ice and Adélie and chinstrap penguin (*P. antarctica*) populations in the West Antarctic Peninsula and updated previous work that suggested both Adélie and chinstrap penguins would show contrasting responses to changing environmental conditions. The authors proposed a mechanism for changes in penguin populations relating to changes in the abundance of their main prey, Antarctic krill (*Euphausia superba)*, that includes the effects of historical over-exploitation and the recovery of harvested species, as well as more recent effects on sea-ice extent from climate change.

2.109 The Working Group welcomed work such as WG-EMM-11/P1 that aims to synthesise data and provide advice on mechanisms for change in predator populations. It encouraged the authors and others interested in such studies to consider how the different datasets could be combined statistically to provide signals of change.

2.110 A 16-year Adélie penguin mark-recapture program at Béchervaise Island using implanted transponders indicated that penguin survival was associated with different aspects of sea-ice and its variability for penguins at different life-history stages (WG-EMM-11/P4). The Working Group recalled that long-term Adélie penguin survival data have now been collected at a number of sites around Antarctica, and agreed that a combined analysis of these data could provide insights into the factors affecting survival. Such an analysis would need to take into account different methods for marking birds, as published studies have shown that flipper banding can reduce penguin survival.

2.111 A survey of minke whales around the Antarctic Peninsula found that while Antarctic minke whales (*Balaenoptera bonaerensis*) were numerically dominant, the survey provided the first records of dwarf minke (*B. acutorostrata* subsp.) from the area (WG-EMM-11/P2). Furthermore, both species remain in the Antarctic during the austral winter, which may have significant implications for the estimation of krill consumption by predators. The Working Group agreed that information on the distribution and abundance of baleen whales in the Antarctic would be important in understanding potential demand for krill, especially in pelagic areas.

Krill and fish

2.112 WG-EMM-11/40 presented results on fish by-catch data collected by scientific observers on board Japanese commercial krill fishing vessels to the north of South Georgia during austral winters from 2002 to 2008. A total of 19 species were recorded from 1 173 net hauls, including icefish (*Champsocephalus gunnari*) and myctophid species. *Electrona antarctica* was not a major component of the recent mesopelagic ichthyofauna. In contrast, *Protomyctophum choriodon*, which is known as a south temperate species, dominated the recent samples. The authors argued that the unimodal size distribution of *P. choriodon* could indicate that the species probably migrated from northern warmer areas to South Georgia. They concluded that since the distribution patterns and biological peculiarity of fish are related to oceanographic conditions, the shifts in species and size composition may demonstrate oceanographic and climatic changes in the Antarctic Ocean. The authors, therefore, recommended a long-term monitoring of ichthyofauna through the scientific observer program.

2.113 The Working Group noted with interest the shift in species composition for myctophids with a sub-Antarctic species replacing a typical Antarctic species in the vicinity of South Georgia. It was also noted that at the same time the species *E. carlsbergi,* a species of the Polar Front and managed by a CCAMLR conservation measure in the past, was almost absent from the samples. Unfortunately, no observer data are available from the very warm 2009 season, because the krill fishery moved away from South Georgia due to very low krill abundance.

2.114 Dr T. Iwami (Japan) informed the Working Group that similar analyses of observer data are currently in progress for Subareas 48.1 and 48.2. The Working Group encouraged further long-term analyses by other Members who collect fish by-catch data from the commercial krill fishery to improve the knowledge about the impact of the fishery on fish stocks and detect potential changes in the fish species composition.

2.115 The Working Group noted that predator diet samples collected at South Georgia, especially from fur seals, showed a similar species composition and length-frequency distribution to those reported in WG-EMM-11/40, particularly with respect to the increased occurrence of *P. choriodon* in warmer years.

2.116 The Working Group encouraged additional studies on *C. gunnari* on size and age composition, and comparison of observer data from the krill fishery, with data obtained from UK bottom trawl surveys around South Georgia. This analysis could extend the database into the winter season and may result in additional information of icefish cohort strength.

2.117 WG-EMM recommended that WG-FSA consider WG-EMM-11/40 during its 2011 meeting in its deliberations about potential impacts of the fish by-catch in the krill fishery and its potential impacts on fish stocks. WG-EMM will review its work plan over the next two years and will discuss the possibilities of how the information of by-catch data from the observer program can be better used, and how to assess the by-catch rates and CV, as well as the total amount of fish taken by the krill fishery. It is planned to carry out such an assessment in the near future, and WG-EMM will inform WG-FSA about the outcomes of this assessment. The Working Group encouraged myctophid specialists to continue this work and to be involved in the assessment when it arises.

2.118 The Working Group acknowledged a presentation by Dr Iwami on the 'ICEFISH Exhibition Project' by the Tokyo Sea Life Park. The public aquarium exhibits polar fish (e.g. *Harpagifer* spp. and in future, e.g. icefish (*Chionodraco rastrospinosus*)) to make the public aware of the great polar fish diversity.

Krill biology and survey results

2.119 WG-EMM-11/P7 described for the first time the entire process of krill mating behaviour. The only reported observation of reproductive behaviour made in the wild was by Naito et al. (1986), who observed the mating behaviour of surface swarms of krill. Observations of the current study were conducted by using an autonomous submersible video camera lowered near the seafloor at depths of 400–700 m. The traditional view is that post-larval krill are typically confined to the top 150 m of the water column with reproduction occurring in surface waters. This study showed the existence of krill at 400–720 m depth where mating can take place. This confirms increasing evidence that krill are also present in summer time in water layers deeper than 200 m (Schmidt et al., 2011). The authors of WG-EMM-11/P7 argued that these observations are challenging the assumption that only an insignificant portion of the krill population lives below 200 m.

2.120 The Working Group noted the most recent results on krill vertical distribution and encouraged further studies on the vertical extent of krill distribution and the epibenthic habitat, as well as its significance on the overall population. It was noted that such studies require development of new sampling methods, because net sampling at these depths close to the bottom will be difficult, and ship-borne acoustic systems are limited due to the depth range of the used frequencies.

2.121 Dr Constable indicated that acoustic towed bodies could be a potential method to record data from deeper layers. He also noted that the autonomous submersible video camera used for the study presented in WG-EMM-11/P7 is relatively small and robust and can easily be used. Since krill was observed to be attracted by the light of the camera, the time to saturation might be a possible way to be used as an indicator of krill density in the vicinity of the camera.

2.122 WG-EMM-11/24 presented data of 18 expeditions carried out by AtlantNIRO between 1970 and 2000 in the central and eastern part of the Area 48 (Subareas 48.4 and 48.6). Distribution of krill was analysed with reference to the structure and dynamics of the water masses in the area of the South Sandwich Islands, Bouvet Island, Maud Rise seamount in the southern part of the Lazarev Sea and up to the coastal zone of the continent. The hauls were made with a research Isaacs-Kidd trawl and different types of commercial midwater trawls.

2.123 According to their results, the authors of WG-EMM-11/24 concluded that:

(i) in the Atlantic sector of the Antarctic Ocean the main features of the water dynamics and structure are determined by interaction of the ACC and the Weddell Circulation (WC)

(ii) results from the surveys in Subareas 48.4 and 48.6 indicate high krill density in the Frontal Zone of the WC, the Antarctic near-shore current zone and near Bouvet Island

(iii) krill aggregations (above 1.0 tonne per 1 hour trawling) were recorded in the central part of the WC (South Sandwich Islands), near Bouvet Island, in the coastal area in Subarea 48.6 and at Maud seamount

(iv) the quasi-stationary pattern of circulations and eddies associated with these zones allows the development of potential krill fishing grounds in Subareas 48.4 and 48.6.

2.124 The Working Group welcomed the analysis of historic survey data from areas where little or no commercial fishing has occurred in the past. The Working Group noted that there are obviously pelagic areas in Subareas 48.1 to 48.3 (WG-EMM-11/18; paragraphs 2.122 and 2.123) outside the southwest Atlantic sector where potentially fishable areas exist, and which leave the option for the fishery to spread its fishing effort. The existence of such potential areas should certainly be considered in the development of a feedback management system.

2.125 The Working Group considered whether the areas currently fished for krill will always be the favourite fishing grounds for the commercial fishery, or whether the fishery is flexible in its strategy and decision process such that if it encounters poor krill conditions in Subareas 48.1 to 48.3 it would move into the pelagic areas such as the ones in the southeast Atlantic.

2.126 Dr Kiyota responded that in the past, the Japanese fishery acted as a fleet exchanging information on potential krill concentrations. With only a single vessel left in the krill fishery, there is little opportunity to search for new fishing grounds with high krill concentrations, but the fishery tends to rely on past experience and fish in areas with known and predictable concentrations.

2.127 It was noted that currently there is no ecosystem monitoring in place in Subareas 48.4 or 48.6 at the fishing ground proposed in WG-EMM-11/24. The need to establish appropriate monitoring of potential impacts on ecosystems was emphasised for the case of a developing fishery in Subarea 48.6. It was further noted that the pelagic krill in the Southeast Atlantic are partly located in regions with very long seasonal ice cover, or are remote and far from port facilities, as well as in areas with little shelter, which would limit the fishing season and increase the logistic difficulties at the same time. The Working Group concluded that a feedback management system will consequently also have to consider cost-benefit aspects and realise that moving into areas such as Subareas 48.4 and 48.6 could have an influence on the efficiency/viability of the fishery.

2.128 WG-EMM-11/26 reanalysed the US AMLR acoustic biomass time series from 1996 to 2011 using the recently (SG-ASAM-10) corrected SDWBA model. It also presented an updated, but simplified, proportional recruitment time series and net-based abundance time series for the Elephant Island region of the South Shetland Islands.

2.129 The Working Group noted:

(i) Proportional recruitment (the number of age-1 animals to the total number of animals in an area) is generally calculated using the CMIX software. For this paper, the authors have simply calculated the proportion of krill ≤ 35mm in an area for each survey. The authors stated that no significant differences in the proportional recruitment time series were evident. Proportional recruitment of *E. superba* in the Elephant Island region showed peaks in 1993, 1996, 2002/03, 2008 and 2011.

(ii) Net-based mean abundance of krill in the Elephant Island region fluctuated between <1 and ~10 krill m^{-2} between 1992 and 2011 during the January survey. Highest values were observed in 2003. Over the last three years, krill density has averaged around 1 m^{-2} suggesting rather lower abundance of krill over this time period.

(iii) Acoustic biomass of *E. superba* in the South Shetland Islands has varied by more than an order of magnitude since the mid-1990s. The highest biomass recorded was around Elephant Island in 1997. Krill biomass was high during the late 1990s and declined to lows in the early 2000s, before increasing again since 2006. These updates, corrected estimates of krill biomass, are weakly correlated with previous estimates. This result is especially important because the differences in acoustic biomass will influence the correlation between krill biomass, environmental drivers and other species.

2.130 The Working Group wished to recognise the great value of the long-term US AMLR dataset and especially the effort that is carried out to update the work and biomass estimates using the most recent accepted methods. The Working Group also recognised the great value of the UK time series from South Georgia, which is also up-to-date. Together, they form a very important set of data for understanding historical change in Area 48 and form an essential foundation for considering management of the krill fishery.

2.131 The Working Group suggested that an analysis of the combined data from the Antarctic Peninsula and South Georgia should be carried out, and possible correlations should be examined between areas across the Scotia Sea.

2.132 The Working Group noted the simplified recruitment index introduced by WG-EMM-11/26. Although the authors stated that no significant differences in the proportional recruitment time series were evident, the Working Group thought that applying the size range up to 35 mm would result in an inclusion of almost half the age group 2+, which usually has a mean size-at-age around 36 mm in summer. It was therefore suggested that this index should be renamed to avoid confusion with the R1 estimated according to the index established by de la Mare (1994). It was further suggested that, in case results are presented using the simplified index, these should be accompanied by the established R1 to allow comparison with results from the published time series and used by the CCAMLR GYM.

2.133 WG-EMM-11/13 presented results of a joint German–USA krill net sampling survey west of the Antarctic Peninsula in January 2011. The intention was to collect data on krill distribution, abundance, demography, spawning and recruitment success. The results represent the most complete survey of the krill stock on the western side of the Antarctic Peninsula conducted since the late 1980s.

2.134 The results of WG-EMM-11/13 indicated that:

(i) In the southern part the mean krill density was higher than in the northern area. Overall adult krill abundance was below the long-term average.

(ii) Hot spots of krill larvae concentrations occurred in the southwest (northern Bellingshausen Sea), and smaller spots north of Livingston Island. According to the distribution maps, it can be assumed that the distribution range of krill larvae extended well beyond to the north of the currently chosen station grid, whereas the adult krill population was well inside the station grid. In combination with the adult female maturity stage composition (mainly gravid and spent), there is indication for an early and successful spawning in 2011.

(iii) Salps (*Salpa thompsoni*) were studied as an important component of the Antarctic zooplankton because of their potential ability to outcompete other zooplankton grazers such as krill. In contrast to krill, salp abundance was substantially higher in the northern area compared to the south.

(iv) Overall krill length-frequency distribution was bimodal with a dominance of juvenile krill and a second peak for adult 50 mm large krill. Krill size and age composition showed a clear onshore–offshore distribution pattern, with juveniles inshore, and the spawning stock along the continental slope and in oceanic waters. Proportional krill recruitment was high in 2011, although absolute recruitment was still below the values observed during the 1990s.

(v) Near-surface temperature and salinity showed variability associated with the presence of ACC water and Weddell Sea water. The intrusion of relatively warm ACC water masses with unusually high SST north of the South Shetland

Islands was probably responsible for differences in distribution of large krill, in larvae abundance, and salp density between the southern and the northern part of the survey area.

2.135 The authors of WG-EMM-11/13 concluded that the example of the larger-scale 2011 survey demonstrates how the size of the survey area may affect the R1 index. Smaller/younger krill of age-class 1 in the coastal zone may be more affected by retention in the southern regions of the Peninsula and be responsible for a reduced recruitment index in the northern section of the Bransfield Strait–South Shetland Elephant Island region.

2.136 The Working Group welcomed the joint effort to collaboratively carry out two national surveys and combine the two datasets in WG-EMM-11/13 as this allows a much larger area to be covered, it also provides a better understanding of the spatial heterogeneity in krill distribution and abundance along the Antarctic Peninsula.

2.137 The Working Group advised the Scientific Committee to take note of the results that juvenile krill of age-class 1+ is predominately concentrated in near-shore areas along the entire Peninsula from Marguerite Bay (Adelaide Island) in the south up to, and including, Bransfield Strait in the north. Fishing in nursery areas will have a different impact on the stock than fishing on adults. Management of the krill fishery will need to account for this.

2.138 WG-EMM-11/16 presented the report of the workshop ‘Antarctic krill in a changing ocean’. The one-week workshop was co-sponsored by the EU and the Netherlands on Texel Island (NL) (EU–Netherlands Workshop) in April 2011. The intention was to bring together krill specialists from CCAMLR Members and countries usually not involved in CCAMLR meetings, to discuss krill biology under the scenario of climate change and the implications for management of krill stocks, including past and future trends in ocean warming, sea-ice decline and ocean acidification. The authors:

(i) concluded that climate change adds to uncertainties that surround krill fisheries management

(ii) urged, among other recommendations, maintenance of the current precautionary trigger in Area 48 (CM 51-07)

(iii) emphasised that the most rapid changes (e.g. ocean warming, sea-ice decline) have been occurring in the southwest Atlantic sector, where major parts of the *E. superba* population and the krill fishery concentrate and a decline of krill populations has been observed at least during the period from 1976 to 2003

(iv) noted that the impact of climate change is predicted to increase considerably throughout the Southern Ocean during the present century and that these environmental changes will act in concert to modify the abundance, distribution and life cycle of krill

(v) concluded that most of the anticipated changes are likely to negatively impact krill and that synergistic effects would also probably be negative

(vi) concluded that among the population parameters determining the distribution and biomass of krill, recruitment, driven by the winter survival of larval and juvenile krill, was considered to be most susceptible to climate change (see also WG-EMM-11/P6)

(vii) noted that changes in the distribution and population size of krill would probably have far-reaching ramifications in Antarctic ecosystems, and in addition, direct effects of climate change on other parts of the ecosystem will also be important

(viii) concluded that, because the assessment of catch limits using the GYM does not account for trends in the ecosystem resulting from climate change, management methods should be enhanced to account for such changes, such as recruitment variability, plasticity of habitat use, as well as top predator population consumption

(ix) made several recommendations with respect to CCAMLR's ecosystem-based management approach:

(a) the impact of climate change on krill demands an adaptive management approach

(b) controlling fisheries pressure is the only realistic way to mitigate effects of fisheries and climate change on ecosystems

(c) current precautionary management measures need to be continued

(d) effects of fisheries on krill and ecosystems need to be considered at appropriate spatial scales

(e) monitoring of key population parameters of krill needs to be intensified and improved

(f) there is an urgent need to integrate the plasticity of habitat use of krill in population estimates

(g) population sizes and food demand of krill predators must be better quantified

(h) CEMP needs to be expanded and intensified

(i) valuable data for management should be provided by the krill fishery itself

(j) scientific participation in SC-CAMLR working groups needs to be broadened.

2.139 The Working Group thanked the EU and the Netherlands for taking the initiative of this workshop. The workshop was considered a valuable contribution to WG-EMM and CCAMLR, and particularly the significant contribution by scientists outside the usual CCAMLR community was greatly appreciated.

2.140 The Working Group agreed that the recommendations listed by the specialist workshop (WG-EMM-11/16) reflect key issues of the work in progress of WG-EMM, and recommended that the Scientific Committee consider the report of the workshop.

2.141 With regard to the recommendation of the EU–Netherlands Workshop regarding scientific participation in SC-CAMLR working groups, the Working Group highlighted efforts to build scientific capacity in SC-CAMLR (e.g. SC-CAMLR-XXIX, paragraphs 15.10 to 15.12) and encouraged continued involvement of scientists from krill fishing nations.

2.142 With respect to future impacts of climate change, the Working Group agreed to develop approaches suitable for distinguishing between climate change-induced and fisheries-induced effects on krill populations. The Working Group acknowledged the value of CEMP for monitoring ecosystem changes and potential perturbations caused by the fishery and emphasised that issues of the sensitivity of CEMP to distinguishing these effects would be considered in the development of feedback management procedures. The 2003 review of CEMP indicated that it was unable to distinguish between these effects at the low levels of fishing at that time. To be successful, monitoring was likely to be needed across all areas where fishing was occurring.

2.143 WG-EMM-11/19 reported on recent progresses with updating the KRILLBASE analysis. The original KRILLBASE database (including records from 1926 to 2003) was expanded with extensive recent data covering mainly the 2003–2009 period in the southwest Atlantic sector. Provisional analysis of potential artefacts (e.g. net mouth area, proportion of day and night hauls, sampling depth) showed no obvious directional change in sampling method that could have influenced the results observed. A more rigorous analysis of long-term trends based on a fully updated KRILLBASE is expected in the near future and will be reported to CCAMLR.

2.144 WG-EMM-11/41 presented a preliminary analysis of possible inter-connections between decadal variability of winter air temperatures and *E. superba* density variations. Temperature anomaly showed oscillations with an 8-year period. Highest krill densities were observed during transition periods from negative to positive temperature anomalies. Krill densities were significantly correlated with temperature anomalies in the preceding year. The 8-year periodicity in krill and air temperatures probably reflected ENSO effects and sea-ice change.

2.145 The Working Group emphasised the value of this study and encouraged similar investigations to help understand the large interannual variability of krill abundance in the Southern Ocean.

2.146 WG-EMM-11/P5 analysed the structure of marine ecosystems in the Argentine Islands Archipelago with a focus on pollution effects. During a multi-year study, high concentrations of cadmium and other hazardous heavy metals found in sediments were mirrored in both benthic and pelagic biota. The authors concluded that the effect of pollution may explain observed low zooplankton abundances and the absence of krill larvae, indicating in particular the susceptibility of krill recruitment to local environmental contamination.

2.147 WG-EMM-11/P6 reported on an experimental study of the effect of increasing pCO_2 on krill embryos and larvae. The study demonstrated that krill embryos developed normally under up to 1 000 µatm pCO_2, but their development was almost totally inhibited at

2 000 µatm. Model-projected pCO_2 within the wide depth range in which krill occur is likely to range in between these two values by the year 2100. These results emphasised the urgent need for understanding the response of different ontogenetic stages of krill to increasing pCO_2. In order to predict the possible fate of krill in a changing Southern Ocean, interactive effects with other agents of climate change (e.g. warming, sea-ice decline) should be explored, and a mechanistic understanding of the effect of increased pCO_2 on krill should be developed.

2.148 The Working Group noted that in future scenarios of ocean acidification local extreme pCO_2 values may impact krill before mean values reach critical levels.

Issues for the future

Symposium on Feedback Management of Krill

2.149 Dr Watters introduced the Symposium on Feedback Management of Krill by recalling that the Scientific Committee had identified this as a priority area of work (SC-CAMLR-XXIX, paragraph 15.1 and Table 7). He emphasised that the symposium should facilitate the development of a broad understanding of what feedback management means and the identification of components that it might include. Dr Watters indicated that the current focus of work for developing the feedback management approach should be the existing krill fishery in Area 48; however, he emphasised that the concepts developed during the symposium should be applicable to other areas, as the krill fishery expands in future years. Dr Watters noted that the symposium would allow the Working Group to produce a plan of work for the future, which included defined components, with clear time scales for delivery.

2.150 The Working Group noted that work on feedback management had a long history in CCAMLR with many aspects considered at WG-EMM since its inception in 1995. Particular discussions of direct relevance include:

(i) feedbacks in approaches to the conservation of Antarctic marine living resources (CCAMLR-VII, paragraphs 136 to 150)

(ii) the Commission determining that feedback management is to be preferred as a long-term strategy (CCAMLR-X, paragraphs 6.13 to 6.17)

(iii) development of methods to combine CEMP indices for use in management and to analyse time series of CEMP data to detect anomalies (SC-CAMLR-XVI, Annex 4, paragraphs 6.6 to 6.11, 6.58 to 6.79, 7.10 and 7.11)

(iv) consideration of further approaches to ecosystem assessments (SC-CAMLR-XIX, Annex 4, paragraphs 4.86 to 4.137)

(v) requirements for considering management approaches for the krill fishery (SC-CAMLR-XX, Annex 4, paragraphs 5.1 to 5.36)

(vi) designation of SSMUs (SC-CAMLR-XXI, Annex 4, Appendix D)

(vii) review of CEMP (SC-CAMLR-XXII, Annex 4, Appendix D)

(viii) plausible ecosystem models for testing approaches to krill management, including discussion on what is required in an evaluation (SC-CAMLR-XXIII, Annex 4, Appendix D)

(ix) evaluation of approaches to subdivide the catch limit amongst SSMUs, including the development of modelling tools (SC-CAMLR-XXIV, Annex 4, Appendix D; SC-CAMLR-XXV, Annex 4, Appendix D; SC-CAMLR-XXVI, Annex 7, paragraphs 5.7 to 5.51)

(x) risk assessment for Stage 1 subdivision of the precautionary catch limit among SSMUs in Area 48, including further development of ecosystem assessment methods (SC-CAMLR-XXVII, Annex 4, paragraphs 2.1 to 2.102)

(xi) consideration of the requirements in developing feedback management strategies (SC-CAMLR-XXVIII, Annex 4, paragraphs 3.139 to 3.155).

2.151 Dr Watters indicated that he had invited a number of individuals to prepare presentations that would help facilitate discussion and understanding about the necessary components of feedback management. Presentations were given by Drs Constable, Kasatkina, Kiyota, Milinevsky, Trathan and Watters; copies are available in the Members area of the CCAMLR website.

2.152 Individual abstracts, together with a summary describing the six presentations, are given in Appendix D. The presentations gave different perspectives on feedback management, each providing specific details and objectives. The presentations highlighted many areas of broad agreement. The presenters agreed that feedback management includes monitoring, assessment and decision-making, and that a feedback management approach should use decision rules to adjust activities in response to the state of indicators to achieve the objectives of Article II of the CAMLR Convention. Presenters agreed that there are a wide range of potential indicators of ecosystem state; that uncertainties in understanding the ecosystem and its state must be addressed in the use of these indicators; and that the range of activities that could be adjusted include research activities as well as the distribution and intensity of fishing effort and catch.

2.153 During subsequent discussion of the six presentations, the Working Group identified a number of fundamental principles, together with an associated set of defined components. The following fundamental principles were agreed:

(i) The objectives of Article II must be achieved in the context of a changing ecosystem.

(ii) There is a need to maintain the precautionary approach in managing the krill fishery.

(iii) A feedback management approach should be developed collaboratively amongst Members of CCAMLR, making efficient use of the available skills and resources, but drawing on appropriate expertise outside CCAMLR where necessary.

(iv) A feedback management approach for krill will use decision rules to adjust selected activities (distribution and level of krill catch and/or research) in response to the state of monitored indicators.

(v) Indicators will typically be derived from multiple approaches and platforms (including fishing vessels, research vessels and land-based monitoring), and analysed and assessed by the Scientific Committee to provide advice to the Commission.

(vi) Monitoring and management should reflect the spatial scale of the fishery and should take account of spatial ecosystem structure.

(vii) Candidate feedback management systems should be robustly evaluated by the Scientific Committee in order to provide advice on the efficacy of the procedure to the Commission before implementation.

2.154 The Working Group agreed that at all stages during the development and implementation of any feedback management approach, it would be necessary to provide regular advice to the Scientific Committee (and the Commission), as well as seeking their guidance whenever appropriate. The Working Group also recognised that consultation with fishery practitioners and other stakeholders would be beneficial to a successful outcome.

2.155 The Working Group agreed the following components as the basis for future work:

1. Development of a list of candidate feedback management approaches, including consideration of any operational implications for the fishery and for monitoring.

2. Identification of an agreed suite of indicators appropriate to candidate feedback management approaches.

3. Review of spatial and temporal structure in the ecosystem in which the current Area 48 fishery operates and consideration of the implications for monitoring and management.

4. Development of agreed decision-making mechanisms for the candidate feedback management approaches, including decision rules which identify how fishing strategies and/or monitoring are to be adjusted on the basis of the indicators.

5. Provision of advice on operationalising the objectives of Article II in the context of a changing ecosystem.

6. Evaluation of candidate feedback management approaches.

2.156 The Working Group noted that each of the components must be considered in the context of the whole process of developing a candidate feedback management approach, as development of any particular component may be dependent on the trade-offs with other components. As a result, the process may be iterative.

2.157 The Working Group agreed that the six components should be considered over the next three years, with focus on components 1 to 3 in 2012, components 4 and 5 in 2013 and component 6 in 2014. The Working Group also agreed that fully developed candidate feedback management approaches should be evaluated earlier than 2014 if they were available.

2.158 The Working Group reviewed a number of issues in relation to each of the six components.

Component 1: Development of a list of candidate feedback management approaches, including consideration of any operational implications for the fishery and for monitoring

2.159 The Working Group recognised that there were different candidate feedback management approaches that could be used for managing the krill fishery. Four classes of candidate approaches are shown in Table 4 as illustrations of what might be done, showing some of the consequences for decision-making and the importance of trade-offs; other approaches are also possible. The implications for the fishery differ, principally because each approach relies on different indicators; thus, the type of indicators needed, and their geographic coverage, will depend on the future flexibility required for the fishery by the Commission.

2.160 Some feedback management approaches could be implemented relatively quickly, while others may take longer. For example, CCAMLR may be able to develop a feedback management system almost immediately using the existing CEMP monitoring available in Area 48. Such an approach may require a highly precautionary catch and/or a spatially restricted catch, focused in those areas where existing monitoring occurs. Alternatively, if the fishery wished to operate over a much wider spatial scale, including areas where no CEMP monitoring was available, harvesting might need to be extremely precautionary, particularly until such factors as flux were understood more completely. The Working Group therefore noted that the catch and distribution of the fishery would need to match CCAMLR's ability to detect change.

2.161 The Working Group noted that it will be important to develop a framework for comparing different feedback management approaches. This would need to include developing a common set of performance measures, diagnostic outputs or plots that may be examined and evaluated for each candidate approach. Outputs may include empirical analyses, simulation outputs, or even behavioural metrics describing fishing activity or ecosystem actions.

Component 2: Identification of an agreed suite of indicators appropriate to candidate feedback management approaches

2.162 The Working Group agreed that it would be necessary to undertake a gap analysis of appropriate indicators for each candidate feedback management approach in order to identify which indicators are needed, which are available and which are missing. Potential indicators include fishery-based indices, fishery-independent krill indices, land-based predator indices, pelagic predator indices and environmental indices. It will be necessary to determine which indicators to monitor, how to monitor them and where to monitor them.

2.163 The Working Group recognised that some indicators were expensive to collect, placing financial burdens and responsibilities on either fishing companies or national programs. It therefore agreed that a cost-benefit analysis of candidate indicators would be necessary; some indicators may provide only marginal ecological or management information, others may be critical to the successful implementation of a particular candidate feedback management approach. A proper analysis of costs and benefits will therefore be necessary in order to determine realistic trade-offs amongst parts of the management procedure.

2.164 The Working Group recalled that at current harvesting levels, it is unlikely that the existing design of CEMP, with the data available to it, will be sufficient to distinguish between ecosystem changes due to harvesting of commercial species and changes due to environmental variability, whether physical or biological (SC-CAMLR-XXII, paragraph 3.12i). The Working Group recognised that as the fishery increased, it may eventually become possible to detect the impacts of fishing with existing data series, but it would be essential to ensure the fishery operated in areas in which the effects could be detected. It may also be necessary to increase the types of indicators available for feedback management if changes were to be detected more rapidly. The Working Group recognised that, in particular, an increased range of indicators from the fishery would be valuable. For example, it considered that acoustic information collected systematically by fishing vessels would be of great value.

2.165 The Working Group further agreed that a review of CEMP in the context of feedback management would be valuable as it would almost certainly be appropriate to employ a number of new methods for monitoring dependent predators. For example, it may be useful to use remote cameras, aerial surveys, satellite remote sensing, or opportunistic visits to penguin breeding colonies using ships of opportunity, to provide broad-scale geographic information on regional predator population trends.

2.166 The Working Group noted that one important consideration was that existing datasets may form the future basis of important indicators for monitoring. Such data require careful cost-benefit evaluation as they may carry with them a number of important caveats, but with appropriate decision-making mechanisms and decision rules, they may still be feasible to use. Thus, there is a potential trade-off between a small number of precise indicators versus a diverse range of less precise indicators. Part of the cost-benefit analysis may also need to consider the opportunity cost if some datasets were ended because they were not considered important for candidate feedback management approaches.

Component 3: Review of spatial and temporal structure in the ecosystem in which the current Area 48 fishery operates and consideration of the implications for monitoring and management

2.167 The Working Group recognised that in developing a feedback management approach, it would be valuable to create a spatial subdivision of the fishery. This would allow approaches to be used whereby some areas would be closed to fishing (reference areas) while others would be open to area-specific levels of fishing intensity. Such a spatial subdivision could have the potential to allow the effects of harvesting to be clearly identified, particularly if reference and fished areas were used in a way that response to harvesting in the fished areas could be easily identified. Reference and fished areas would not have to be ecologically identical, but they would need to maintain the same set of relative ecological relationships across sites, even if some ecological factors were to change in absolute terms.

2.168 The Working Group noted that there were a number of alternative approaches that could be employed with regard to spatial subdivision of the fishery. It also noted that fishing effort could be focused spatially or temporally and/or in a structured manner in order to determine the impacts of harvesting on predators and other ecosystem components, or to learn about ecosystem processes that may be critical for management procedures (SC-CAMLR-XXVI, Annex 7, paragraphs 5.12 to 5.14).

2.169 The Working Group noted that the candidate feedback management approaches described in Table 4 used the terms 'reference area monitoring' and 'structured fishing'. Reference area monitoring is defined as the use of monitored reference areas (in which no fishing occurs) to provide the basis for understanding effects in fished areas. Structured fishing is defined as the manipulation of fishing effort (distribution and/or intensity) to help achieve management objectives and/or for providing information about ecological responses. The Working Group noted that these two forms of spatial subdivision might allow revisions to overall management as understanding of the ecosystem increases.

2.170 The Working Group noted that spatial subdivision of the fishery would also have the potential to provide information about the operation of important components of the ecosystem, including oceanographic connection and krill flux between areas. It would also allow management on the basis of area-specific catch limits, which would provide more options for balancing fishery and ecosystem objectives, than would the use of large-scale catch limits alone.

2.171 The Working Group recognised that subdivision of the fishery would provide a great deal of management information about the ecosystem effects of fishing. However, it also noted that there would be a number of other factors that would need to be considered. For example, natural spatial and temporal variability in krill distribution and abundance could mean that focused fishing activity in a particular area was not possible in a particular season. Recognition of such variability in the design of structured fishing trials might help to increase understanding of the ecosystem. However, such variability may have economic implications for the fishery, as well as management implications for interpreting the results of reference area monitoring or structured fishing.

2.172 Although the Working Group noted that spatial subdivision of the fishery may impact on the flexibility of fishing operations as well as having economic implications, it recognised that it was not yet possible to evaluate the magnitude of any such impacts, including on the future development of the krill fishery. The Working Group also noted that determining such impacts would require a fully detailed cost-benefit analysis, including possible trade-offs, of specific candidate feedback management approaches, including implications for specific monitoring requirements.

2.173 The Working Group noted that reference area monitoring or structured fishing could take place close to existing CEMP sites. However, it agreed that these sites were scientifically important for a variety of research priorities, including climate change research; further, any spatial subdivision of fishing effort close to such a site might confound the use of the site in relation to these other priorities. Consequently, the Working Group recognised that alternative monitoring programs should be established in areas likely to be fished in order to provide baseline monitoring before reference area monitoring or structured fishing began. The experience at existing sites shows that developing baseline information on land-based predators could require monitoring for a number of years and this may mean that it could take more than 10 years to provide clear results from a fishing trial.

2.174 The Working Group agreed that the design of any feedback management procedure would need detailed consideration of the statistical power of the monitoring for interpreting results, or for extrapolating results to the wider Antarctic ecosystem.

Component 4: Development of agreed decision-making mechanisms for the feedback management approaches, including decision rules which identify how fishing strategies and/or monitoring are to be adjusted on the basis of the indicators

2.175 The Working Group noted that there were different ways to implement decision-making mechanisms for different candidate feedback management approaches; some might depend on projection models based on a general theoretical understanding, while others might be focused on empirical observations and comparisons.

2.176 The Working Group noted that the level of accuracy and precision reflected in ecological monitoring methods would have important implications for management decisions. However, it recognised that detection and measurement of any impacts from fishing may be better facilitated by using a spatially structured feedback management approach, using either reference area monitoring or structured fishing.

2.177 The Working Group noted that there may be benefits in producing a risk management framework to evaluate different feedback management approaches. It noted that any decision-making mechanism should maintain the precautionary approach by not only protecting against Type I errors (an incorrect conclusion that the effects of fishing are greater than the actual effect, i.e. reduce the fishery when not necessary) but also by reducing Type II errors (an incorrect conclusion that the effects of fishing are less than the actual effect, i.e. not reduce the fishery when necessary) so that the risks of each are balanced.

2.178 The Working Group noted that the interaction of spatial and temporal scales was important in the Southern Ocean and that this will result in lags in indicators. It recognised that dealing with such lags was critical to the successful implementation of any feedback management approach. The Working Group also noted that there was potential to cause adverse reactions in the ecosystem if management actions were not implemented in a timely manner.

2.179 The Working Group noted that a staged implementation of the feedback management approach would offer many benefits as it would allow the management procedure to be tested in a controlled way and changed if necessary before the fishery becomes fully developed. Decision rules could be used to facilitate this process by setting catches, spatially distributing catches, adjusting the monitoring program and/or setting limits on the fishery.

2.180 The Working Group noted that use of reference area monitoring and/or structured fishing would increase understanding about fishery impacts which could allow an increased rate of fishery development in the future. Approaches that incorporate reference area monitoring could potentially facilitate gradual increases in catch limits in monitored open areas as these methods are designed to identify fishery effects. Advances in understanding structured fishing could facilitate stepwise increases in catch limits. Without the use of reference area monitoring and/or structured fishing, progress beyond the existing catch trigger level could be more restricted.

2.181 The Working Group noted that the time scales and the magnitude of adjustments made by a feedback management approach (from minor tactical adjustment to major strategic revision) depend on the details of the approach and the information required.

2.182 Possible decision rules include models that scale management actions (for instance, adjusting catch limits) in response to indicator values (for instance, predator performance or krill density). In designs using reference area monitoring, the indicator could represent the effect that the fishery is having on the system since the reference area could allow this to be determined (i.e. the indicator is a function of the difference between the state of the fished and reference areas). In monitoring designs which do not facilitate attribution of state changes to fishing effects, a general indicator of ecosystem state (e.g. krill stock biomass) would be used.

2.183 WG-EMM-11/25 suggested a class of indicator for use in feedback management based on trends in the difference between the observed state of predator populations in fished areas and contrasting reference areas where fishing is not permitted. This approach detects deviations from a baseline empirical relationship between the temporal patterns of abundance in the two areas. The magnitude of such deviations or the degree of confidence that they constitute real changes could be used as input variables in a decision model.

2.184 The additional uncertainty associated with less specific indicators implies a need for greater precaution (paragraphs 2.80 to 2.82) and is likely to lead to a slower development of understanding of the effects of fishing and whether these are compatible with Article II. This is illustrated in Figure 4. At present, our knowledge of the system is limited. As a result, the catch trigger level of 620 000 tonnes has been set to avoid substantial impacts on predators while appropriate management approaches are developed. There is also little knowledge about the likely limits of impacts that the ecosystem can sustain. In the situation where neither reference areas nor structured fishing is used, it may be possible to obtain sufficient information about the system to allow catches to increase beyond the trigger level, but the impacts of the fishery and the resilience of the ecosystem to these impacts are likely to remain poorly understood. Where a design includes monitoring of structured fishing, reference areas, or both, the management system is likely to be able to improve knowledge on the impacts of the fishery and the resilience of the ecosystem more quickly, allowing the catch to rise further and faster whilst maintaining a precautionary approach that ensures that the impact is sustainable.

2.185 Structured fishing approaches, designed to increase the understanding of ecosystem responses, may lead to a revised understanding of management needs which might also require revision of the overall management strategy. This level of decision would require the active involvement of the Scientific Committee and the Commission.

Component 5: Provision of advice on operationalising the objectives of Article II in the context of a changing ecosystem

2.186 The Working Group agreed that when operationalising Article II in the context of feedback management, it would be necessary to consider trends in the Southern Ocean ecosystem resulting from climate change, particularly when formulating decision rules. The Working Group also agreed that other directional drivers of ecosystem change that result in trends in ecosystem signals will need to be considered, these include changes in predator populations following ecosystem recovery after historical harvesting (WG-EMM-11/P1).

2.187 The Working Group recognised that analyses and decision rules could use the 'current' system as a reference point (e.g. productivity levels for a given year in the absence of fishing), rather than using a historical reference point (i.e. productivity levels prior to the commencement of historical harvesting), noting that this would provide valuable insight into how the ecosystem operates. Similarly, the Working Group noted that simulation results comparing outcomes in the presence and absence of fishing would provide additional insight into ecosystem operation.

Component 6: Evaluation of candidate feedback management approaches

2.188 The Working Group recommended that the Scientific Committee should evaluate candidate feedback management approaches in order to provide robust advice on the potential performance of candidate approaches to the Commission before implementation.

2.189 The Working Group noted that a simulation environment may prove helpful for this, for example, by using a management strategy evaluation framework (i.e. testing the candidate approach in a model representation of the ecosystem which includes appropriate levels of uncertainty). Such a framework could lead to iterative improvements in the design of candidate approaches, through examination of the robustness of the approach and reference points to different assumptions of system state and response. The Working Group noted that ecosystem models can be difficult to develop but agreed that even simple models may significantly inform the Scientific Committee about the robustness of a particular approach.

2.190 The Working Group agreed that a complete candidate feedback management approach would have to incorporate the outcomes of various cost-benefit analyses, including possible trade-offs for the monitoring indicators, as well as the outcomes of a cost-benefit analysis of how resources were allocated between monitoring, assessment and decision-making.

2.191 The Working Group recognised that development of a feedback management system may require investment in new methods of monitoring, assessment and decision-making. Historically, costs for such activities have been met by fishing companies and/or by national programs. The Working Group noted that the options for feedback management may be limited by the resources available to monitoring. The Working Group noted that, in order to implement some desirable management procedures, it may be necessary in the future to explore burden-sharing options, both within existing funding sources, but also by considering new sources of funds. The Working Group therefore advised the Scientific Committee that one important trade-off would be detailed consideration of the value of the fishery, against the infrastructure needed to manage it.

2.192 WG-EMM-11/21 noted that the concept of Ecosystem Services, which is widely used to articulate the objectives of natural resource management, particularly when there are multiple objectives (such as conservation and rational use), might be a useful tool for communicating CCAMLR's objectives and achievements to the wider international community.

CEMP and STAPP

2.193 WG-EMM-11/42 used a simulation approach in a GIS to explore a number of sample survey design options for undertaking a regional-scale survey of Adélie penguin breeding populations in the Mawson region of East Antarctica, with the aim of optimising the trade-off between bias, efficiency and disturbance. The Working Group noted this important study that could guide the design of large-scale penguin population surveys, and that should be considered for its potential input into the CEMP standard methods in relation to minimising disturbance.

2.194 WG-EMM-11/37 explored the utility of an automated camera system for cost-effective land-based predator monitoring in Antarctica. Camera images are used to attain measurements of breeding success and phenology events, or proxies for them, and a preliminary assessment for this purpose was very successful. The cameras are being used to expand the spatial extent of Adélie penguin monitoring in East Antarctica at less accessible sites, and to extend monitoring to other above-ground nesting seabird species. The cameras are being trialled at lower latitudes in Antarctica by the US and UK in 2011/12. The Working Group welcomed the development of the camera system for monitoring and helping to meet the recommendations of WG-EMM-11/16, which include the need to increase coverage of CEMP. The Working Group also noted that the CEMP standard methods may need to be revised in the future to incorporate new monitoring technologies such as cameras, and that new technologies could feed into monitoring programs such as CEMP, SOOS and Sentinel. The Working Group encouraged future consideration of using camera images to monitor late-season activities when chicks become mobile and move out of the field of view, to assess bird condition, and to download images remotely to allow timely data retrieval. The Working Group encouraged researchers using cameras as monitoring tools to link with other researchers who have expertise in image analysis to develop methods of efficiently processing the broad suite of images that can be obtained from cameras.

2.195 WG-EMM-11/38 is a response to a request from the Working Group in 2009 to consider incorporation of the photographic method in WG-EMM-09/38 into CEMP Standard Method A3 (penguin breeding population size). The paper reviewed CEMP Standard Methods A3a, A3b and A9 (penguin breeding chronology) and outlined some difficulties in the application of these methods, particularly with regard to a lack of flexibility in the timing of A3 counts and the amount of effort required to collect A9 data. These difficulties may be restricting the amount of A3 data that are being submitted to CEMP. The paper outlined some specific modifications that could be made to A3.

2.196 The Working Group noted that modifications to Method A3 would be required if the penguin count database developed by WG-EMM-STAPP were to be incorporated into CEMP. It supported the proposal to draft modifications to Methods A3 and A9 for consideration by the Working Group at WG-EMM-12.

2.197 WG-EMM-11/12 presented a simulation study to determine how frequently data on penguin attendance at their breeding sites need to be collected to adequately represent attendance functions. The study showed that sampling at intervals of six days did not adequately recover simulated attendance data and was not recommended. For intervals less than six days, higher frequency in data collection improved the precision of estimated attendance ratios.

2.198 WG-EMM-11/33 reviewed the potential underlying drivers for phenological change for Adélie penguins, described shifts in Adélie penguin breeding phenology reported at different locations around Antarctica, and presented results from long-term monitoring at the Béchervaise Island CEMP site. Explanations for contrasting shifts in phenology highlight difficulties in distinguishing between direct responses to changes in the environment compared with indirect responses through changes in the underlying food web. The paper recommended that phenology data collected under Method A9 be used for monitoring purposes as well as adjustment purposes, and provided a description of factors which can influence data collected by the methodology in WG-EMM-11/37 and 11/38. The Working Group noted that because phenological changes can be a response to changes in krill abundance, further understanding of the factors driving phenology and their demographic consequences would be useful. In this context, a comparison of all available datasets is important to better understand long-term changes in different regions of Antarctica.

2.199 WG-EMM-11/30 provided a summary of progress of WG-EMM-STAPP to estimate abundance and consumption of krill by pack-ice seals, fur seals, penguins and flying seabirds in Area 48, and to partition the overall foraging effort by these predator groups into SSMUs. Work has been completed for pack-ice seals, and work on estimating overall abundance and krill consumption for fur seals and penguins is expected to be completed within the next few years. The remaining components of the work plan, which involve estimating overall abundance and consumption for flying seabirds, and partitioning the foraging effort by fur seals, penguins and flying seabirds across SSMUs, is expected to take at least another five years. The work on partitioning foraging effort will require strategic collection of foraging tracking data across species, sites and seasons to add to existing data, and the development of predictive foraging-environment distribution models, which together comprises a substantial body of work. The work on estimating flying seabird abundance will require further collation and analysis of at-sea survey data, which is also a substantial body of work.

2.200 The Working Group thanked Dr Southwell for convening WG-EMM-STAPP and guiding its progress to this point, and noted that, with the exception of flying seabirds, the initial phase of work in estimating overall abundance and krill consumption is nearing completion and a second phase focused on foraging distribution is now required (Table 5). The Working Group also noted that products and outcomes of WG-EMM-STAPP in regard to estimates of penguin population size and trends will be very useful to CCAMLR in providing a larger-scale context for the detailed measurements made locally at CEMP sites.

2.201 The Working Group recommended that WG-EMM-STAPP liaise with the Secretariat during the coming year to develop a plan for consideration by the Scientific Committee on how these products may be submitted to, and managed by, the Secretariat in a similar way that CEMP data are currently submitted and managed.

2.202 Given the potential importance of flying seabirds in overall krill consumption, the Working Group discussed ways in which the work on estimating their abundance and consumption could progress. While SCAR has previously provided CCAMLR with information on the status and trends of bird populations through SCAR-GEB, this information was mainly focused on penguin abundance due to the scarcity of data on flying seabird abundance at the large scales required by CCAMLR. As SCAR-GEB has recently been integrated into a predator group, the Expert Group on Birds and Marine Mammals (SCAR-EGBAMM) focusing on foraging distribution, any collaboration with SCAR on flying seabird abundance data is unlikely in the medium-term future.

2.203 The Working Group recognised there is a significant knowledge gap for flying seabird status and trend information for birds in the CAMLR Convention Area, and considered that CCAMLR, through the Scientific Committee, needs to find a means of engaging with the broader community of scientists working on flying seabirds to fill this gap.

2.204 Progressing the work on foraging distribution models may also require engagement with the broader scientific community. In particular, developing links with SCAR-EGBAMM, which is focused on foraging distribution data, and with organisations such as BirdLife International, will be important. It may also be necessary to engage a new, or broader, group of CCAMLR scientists to work on this issue.

2.205 The Working Group recommended that WG-EMM-STAPP maintain its focus over the next few years on completing its work on estimating abundance and krill consumption by fur seals and penguins, but also recognised that it is important to progress work on foraging distribution as quickly as possible.

2.206 As an initial step, Dr Trathan agreed to liaise with scientists within SCAR and BirdLife International who are working on predator foraging distribution to assess areas of common interest and expertise that may help expedite CCAMLR's work. The Working Group also considered the formation of a subgroup within WG-EMM, specifically focused on modelling foraging distribution, could help maintain progress.

2.207 The Working Group noted the increasing evidence that krill consumption by fish and benthic organisms might exceed that by land-based predators, and recognised that fish and benthic organisms are important dependent and related species. It recognised the important contribution that both CEMP and WG-EMM-STAPP have made to understanding interactions between krill and land-based predators and that similar concerted efforts might help to clarify the role of fish and benthic organisms.

2.208 The Working Group discussed the implications of recent work on new methods and technologies for CEMP. There was agreement that approaches developed in WG-EMM-STAPP in relation to regional-scale estimation of status and trends in penguin populations could be transferred to CEMP after consideration of how these data could be used in a monitoring program. This would provide a hierarchy of Method A3 data collection within CEMP, with frequent monitoring at a small number of sites set within less-frequent surveillance monitoring across a larger number of sites. This hierarchical approach may also be appropriate for some other parameters. Such a tiered structure of data collection would allow different questions to be addressed.

2.209 Some consideration would need to be given to how data collected at different spatial scales might be made available to the Secretariat. Method A3 data collected at the scale of the breeding site is in a suitable format to be directly included in the CEMP database, while the format of data collected at a regional scale may not be suitable and some other means of submission may be necessary. The VME registry may be a useful model for developing a submission or archiving process of regional-scale A3 data. The Working Group noted that these arrangements were unlikely to be appropriate for regional-scale population survey data with other taxa, such as pack-ice seals, because of the fundamentally different nature of data.

2.210 The Working Group agreed that CEMP Standard Methods A3 and A9 should be modified to facilitate future submission of A3 data collected at sub-optimal times of the breeding season and A3 data collected at both local and regional scales (paragraph 2.196). Given that a variety of methods are involved, this would require methods to be described in terms of general principles or as 'best-practice' guidelines rather than in a case-specific manner as is currently done in the CEMP standard methods. The Working Group noted that deviation from the standard methods was not a recommended practice unless data quality and standardisation were maintained, as was achieved in the recommended modification to Method A3.

2.211 The development of the automated camera system described in WG-EMM-11/37 provided the potential to collect data on some CEMP parameters at new sites in a cost-effective way. The Working Group encouraged further evaluation of the utility of this and possibly other technologies as a means of expanding the spatial extent of monitoring in the future. These developments enhance the feasibility of CEMP being designed specifically to the requirements of a future feedback monitoring and management system and more broadly for contributing to an assessment of the state of the ecosystem. The Working Group emphasised the importance of maintaining standardisation and comparability where new methods and technologies are used for collecting data as part of CEMP in the future. As such, proposed new methods and approaches, including those for Method A3, will need to be reviewed by the Working Group and adopted before inclusion in CEMP.

2.212 The Working Group also recalled that the value of time-series data collected under prescribed CEMP methodologies increases as the time series grows, and that reducing or stopping existing CEMP programs will severely compromise the ability to monitor change in the ecosystem. However, rising costs and funding restrictions are making it increasingly difficult for Members to continue long-term work as individual national programs. The Working Group therefore encouraged the development of multi-national CEMP programs wherever possible. The Working Group also considered that fishers could make a valuable contribution to CEMP through activities such as routine acoustic sampling.

2.213 The Working Group recognised that CEMP needs to focus on information required by the Commission to make management decisions. The development of a feedback monitoring and management system may require CEMP to change or evolve from its present form to include greater spatial coverage, to monitor at different spatial and temporal scales, and to include more or different parameters and revised methods for existing parameters.

2.214 The Working Group also noted that any changes to CEMP need to take into account the implications for the work of the Secretariat, and therefore agreed that any decisions to expand the scope of CEMP should be made judiciously and be prioritised to the needs of the Commission.

Integrated assessments for krill

2.215 The Working Group welcomed the development of an integrated assessment model for krill as presented in WG-EMM-11/43 Rev. 1 and noted that the model uses the combined time series of net-derived length-frequency data and acoustic biomass estimates from the US AMLR Program in Subarea 48.1. Currently the model can be fitted to either the biomass series or to the net data but does not provide a consistent link between the two series.

2.216 The Working Group considered the structural assumptions underlying the integrated model construction, in particular:

(i) the model provides a means to identify those parameters that can be estimated and those that may need to be measured directly. For example, the exploration of krill movement scenarios may help to highlight areas of future research

(ii) recognising the importance of krill recruitment dynamics, it may be important to ensure that the choice of stock–recruit relationship does not mask important underlying dynamics and prevent these dynamics from being fully explored

(iii) given the difficulty in determining the age of krill, the developers could consider the potential for using a length-based, rather than an age-based, approach.

2.217 The development of an integrated assessment model for krill is an important part of the work required to manage the krill fishery in the future and would also provide an opportunity to explore some of the structural assumptions about krill dynamics in Subarea 48.1 and in other areas.

Fishing vessel research

2.218 The Working Group considered the research undertaken in Subarea 48.2 in 2011 by the *Saga Sea* (WG-EMM-11/23), the proposal for integrated land- and ship-based research in Subarea 48.2 to be undertaken by Norway, UK and the USA (WG-EMM-11/4 Rev. 1) and the proposal from Japan for a pilot study to collect acoustic data from the *Fukuei-Maru* during fishing operations (WG-EMM-11/35).

2.219 The *Saga Sea* survey (WG-EMM-11/23) was carried out by two scientists from 4 to 8 February according to the design agreed by WG-EMM-10. Acoustic data for krill distribution and biomass estimation was collected with a calibrated two-frequency (38 kHz and 120 kHz) Simrad EK60 scientific echosounder along six transects around the South Orkney Islands; biological samples and hydrographical data were also collected and preliminary results presented. In addition, systematic observation on the occurrence of apex predators (marine mammals and penguin) was also documented. This is the first of the planned five-year surveys, which represents the first effort of this kind from the krill fishing industry in the Convention Area.

2.220 In considering the recommendations in WG-EMM-11/23, the Working Group noted the proposal to change the transect layout for next year's survey and recommended to Norway that it was desirable to optimise the survey design as quickly as possible in order that changes in the spatial coverage do not compromise subsequent data analysis. In noting the desire of Norway to extend the northern section of the transects to fully cover a major topographical feature, the Working Group agreed that this was an improvement, but cautioned that discontinuing the westernmost transect could limit linkages to ongoing and proposed surveys in Subareas 48.1 and 48.2.

2.221 The potential value of collecting data from vessels operating in the krill fishery has long been recognised by CCAMLR and therefore the developments described in WG-EMM-11/4 Rev. 1, 11/23 and 11/35 were warmly welcomed by the Working Group. It is important to recognise the position CCAMLR is in by having this level of engagement from fishing vessels, and there is a need to maximise this opportunity to learn about the fishery and krill dynamics in areas and times where other sources of data are often very limited.

2.222 WG-EMM-11/4 Rev. 1 reported the outcomes of a fruitful workshop convened at the Institute of Marine Research (IMR), Bergen, Norway, in April 2011, to investigate the basis for integrated investigations and evaluation of krill resources in Subarea 48.2. The workshop was attended by 11 participants from Norway, UK and the USA. It is noted that a Norwegian research survey with RV *G.O. Sars* in 2013/14 is under consideration with an aim to repeat part of the CCAMLR-2000 Survey, and wider international involvement is called for to repeat that entire survey. The feasibility of collecting acoustic data from commercial krill vessels was also discussed during the workshop, and the acoustic data sampling strategies outlined in the *ICES Cooperative Research Report*, No. 287 (Collection of acoustic data from fishing vessels) was put forward for consideration by CCAMLR.

2.223 In recognising the importance of the opportunity to use fishing vessels to collect acoustic data on krill, the Working Group agreed that it was important to provide clear guidance on the process for collecting such data under an appropriate design framework in order that the data can be used in the work of CCAMLR. In particular, it will be important to recognise that data would need to be collected in a directed manner in order to ensure the maximum utility of the data collected.

2.224 The Working Group noted that, while in the proposed pilot study in WG-EMM-11/35, data would only be collected at 38 kHz, the addition of data from 120 kHz would greatly improve the utility of the research. There would be need to specify the sampling methods to collect length-frequency data during the acoustic survey (noting the potential different selectivity of research versus commercial trawls) and that there may be advantages in repeating existing acoustic transects in Subareas 48.1, 48.2 and 48.3, but that the implications of the choice of survey design would have implications for estimation of variance in acoustic estimates.

2.225 Recognising that the use of acoustics on fishing vessels was primarily designed to provide qualitative information on krill biomass and distribution to locate fishable aggregations, whereas acoustic systems on scientific research vessels are designed to provide quantitative information, the Working Group agreed that, in order to ensure that CCAMLR is able to obtain the maximum benefit from fishing-vessel-based acoustic data on krill, SG-ASAM would need to provide advice on how best to collect and evaluate the data collected using different methods. In particular, SG-ASAM is requested to provide advice on:

(i) Survey design –

The implications of directed and undirected survey design, including the location and timing of transects, and the desirability of using existing acoustic transects in Subareas 48.1, 48.2 and 48.3 (including those used in the CCAMLR-2000 Survey). The potential for collection of acoustic data between and at trawl stations during fishing operations. The collection of biological data required to interpret acoustic data and assist in target identification.

(ii) Acoustic data collection –

Define the minimum requirements for acoustic data collection that could provide quantifiable estimates of krill biomass/distribution from fishing vessels, recognising that the vessels may not be configured to collect acoustic data at 38, 120 and 200 kHz as per the CCAMLR protocol (assuming appropriate survey design). This should include details of calibration, vessel sound characteristics and acoustic frequencies available on the vessel and whether the data are to be collected in a supervised (e.g. by scientists or suitably qualified observers on the vessel) or unsupervised (by vessel crew) manner. Where data are to be collected in an unsupervised manner, SG-ASAM should be requested to provide a detailed set of instructions to ensure that acoustic data are properly collected and stored.

(iii) Acoustic data processing –

Provide advice on the most appropriate way to process the acoustic data arising from fishing vessels, including target identification, biomass estimation and associated uncertainty. This should include advice on the most appropriate data formats and data management implications of collection of acoustic data.

2.226 The Working Group noted that in seeking advice from SG-ASAM, while it was important to provide clear guidance on the issues to be addressed, it recognised that the experts within SG-ASAM could provide advice on other relevant issues not identified in paragraph 2.225.

VULNERABLE MARINE ECOSYSTEMS

3.1 The Working Group considered WG-EMM-11/7 which summarised VME notifications received by the Secretariat under CMs 22-06 and 22-07. The Working Group recognised that assessing notifications made under CM 22-06 was the responsibility of WG-EMM, whereas notifications made under CM 22-07 would be considered by WG-FSA. To date (excluding new notifications in 2011, see WG-EMM-11/10) there have been 32 notifications in three subareas under CM 22-06, all of which were in areas where bottom fishing activities were already restricted. Under CM 22-07, there have been 112 notifications, with 46 VME Risk Areas identified, and six fine-scale rectangles within which most of the notifications are contained. The Working Group recommended that in the course of updating this paper for resubmission to the Scientific Committee, the Secretariat should characterise these fine-scale rectangles in greater detail, for example, reporting what VME taxa have been observed and the number of observations in each.

3.2 WG-EMM-11/17 also described the level of reporting of VME by-catch data at the scale of individual line segments, as required 'to the extent possible' under CM 22-07. Segment-level reporting has increased in recent years but there are substantial differences in the level of VME data reporting provided from different vessels.

3.3 The Working Group considered WG-EMM-11/10 which described a proposal to designate two VMEs to protect areas of dense stalked crinoid communities observed on isolated knolls in the vicinity of Admiralty Seamount (in SSRU 881G) using towed camera deployments as part of the New Zealand IPY survey in 2008. Stalked crinoids are identified as a VME taxon on the basis of rarity/uniqueness, fragility, lack of adult motility and longevity (SC-CAMLR-XXVIII, Annex 10, Table 1). The paper included supplemental information in the form of a peer-reviewed publication (Bowden et al., 2011) describing the extreme uniqueness of these assemblages (similarly dense communities of stalked crinoids have never before been observed) and their potential high significance for scientific understanding of the evolutionary and biogeographic history of Southern Ocean benthic invertebrate fauna (i.e. these areas are thought to be persistent remnants of a formerly widespread archaic benthic assemblage, with indications of great age). The observed communities bear closer resemblance to fossil strata from the later Paleocene and Eocene eras than to any observed extant community.

3.4 The Working Group agreed that WG-EMM-11/10 described what appear to be extraordinarily rare or unique benthic communities of high scientific significance. The Working Group recalled the advice of WG-EMM-10 regarding appropriate spatial scales and sampling designs on which characterisation of anomalously high abundance/importance/rarity should be based when evaluating VME proposals (SC-CAMLR-XXIX, Annex 6, paragraphs 3.46 to 3.48), and agreed that the area surveyed in the IPY and previous surveys was sufficiently large and sufficiently well stratified to draw meaningful conclusions as to the rarity of the observed communities. The Working Group recommended that the areas proposed be approved by the Scientific Committee for inclusion on the VME registry.

ADVICE TO THE SCIENTIFIC COMMITTEE AND ITS WORKING GROUPS

4.1 The Working Group provided advice to the Scientific Committee and other working groups on the following topics:

(i) Scientific observer coverage –

(a) increasing observer coverage and amount and quality of observer data (paragraph 2.31)

(b) clarification of target coverage rate for sampled hauls in CM 51-06 (paragraphs 2.35 and 2.36)

(c) specification for the requirements of sampling locations on krill vessels (paragraph 2.39)

(d) recommendation for observer logbook form updates and requests for advice from SCIC and WG-IMAF (paragraph 2.42)

(e) technical coordinators to ensure that observers are aware of priorities for krill observers (paragraphs 2.43 and 2.44)

(f) potential conflict between sampling flexibility allowed in the instructions in the *Scientific Observers Manual* and precise requirements of CM 51-06 (paragraph 2.49)

(g) Members deploying national observers report the dates of deployments to the Secretariat prior to the deployment period (paragraph 2.51).

(ii) Escape mortality and green weight –

(a) consider whether uncertainty in catch estimates should be taken into account when comparing catch estimates with catch limits (paragraph 2.58).

(iii) Recruitment variation, B_0 and precautionary yield –

(a) implications of variability in krill recruitment on the decision rules for setting catch limits (paragraphs 2.64 and 2.65).

(iv) Distribution of the trigger limit among statistical subareas –

(a) krill fishing operations in ASMA No. 1 (paragraph 2.84)

(b) factors to be investigated to determine whether the spatial subdivision for protecting predators is effective (paragraph 2.87)

(c) spatial allocation of the trigger level (620 000 tonnes) by subarea in CM 51-07 should be retained until sufficient information is acquired for its revision (paragraphs 2.95 to 2.97).

(v) Krill and fish –

(a) assessment of fish by-catch rates and CV including informing WG-FSA about the outcomes of this assessment (paragraph 2.117)

(b) management of the krill fishery will need to account for spatial concentration of age-class 1+ which is predominately concentrated in near-shore areas (paragraph 2.137)

(c) recommendations from the EU–Netherlands krill workshop reflect key issues of the work in progress of WG-EMM (paragraph 2.140).

(vi) Symposium on Feedback Management of Krill –

(a) schedule to address components for future work to deliver feedback management approaches by 2014 (paragraphs 2.155 and 2.157)

(b) time scales of implementation of feedback management approaches require the catch and distribution of the fishery to match CCAMLR's ability to detect change (paragraph 2.160)

(c) a feedback management approach with some areas closed to fishing (reference areas) and others open to area-specific levels of fishing intensity would allow clearer identification of effects of harvesting (paragraph 2.167)

(d) need for cost-benefit analysis, including possible trade-offs, of specific candidate feedback management approaches, including implications for specific monitoring requirements (paragraphs 2.163 and 2.172)

(e) developing baseline monitoring data with sufficient statistical power from new sites could take more than 10 years to provide clear results from a fishing trial (paragraphs 2.173 and 2.174)

(f) benefits of a staged implementation of the feedback management approach, including choice of indicators and the need to consider long-term changes in the ecosystem (paragraphs 2.179, 2.182 and 2.186).

(vii) CEMP and STAPP –

(a) draft modifications to Methods A3 and A9 for consideration at WG-EMM-12 (paragraph 2.196)

(b) progress of WG-EMM-STAPP to estimate abundance and consumption of krill by pack-ice seals, fur seals, penguins and flying seabirds in Area 48 (paragraph 2.199)

(c) need to find a means of engaging with the broader community of scientists on status and trend flying seabirds (paragraph 2.203)

(d) the value of time-series data collected in CEMP programs and encouragement for new approaches to funding to develop new programs (paragraphs 2.212 and 2.213).

(viii) Fishing vessel research –

(a) need to ensure that CCAMLR is able to obtain the maximum benefit from fishing-vessel-based acoustic data on krill, including request for advice from SG-ASAM (paragraphs 2.225 and 2.226).

(ix) Vulnerable marine ecosystems –

(a) the areas proposed in WG-EMM-11/10 be approved by the Scientific Committee for inclusion on the VME registry (paragraph 3.4).

(x) Secretariat's Strategic Plan –

(a) revised Strategic Plan is very useful in clarifying the roles in providing science support from the Secretariat across all working groups and the Scientific Committee (paragraph 6.3).

(xi) Observers at working group meetings –

(a) issues considered in discussion by the Working Group that the Scientific Committee might include in its consideration of this subject (paragraphs 6.5 and 6.6)

(b) benefit of a non-technical summary of the outcomes of working group meetings and the discussions in the Scientific Committee (paragraph 6.7).

(xii) WG-EMM Convener

(a) new Convener to be found to co-convene WG-EMM-12 with Dr Watters (paragraph 6.11).

FUTURE WORK

5.1 The Working Group noted that it had embarked on an ambitious plan of work and that the developments to build science capacity in the Secretariat, along with the opportunities available from the CCAMLR General Science Capacity Special Fund, could provide important support in progressing this work subject to the priorities agreed by the Scientific Committee.

5.2 Dr D. Agnew (Scientific Committee Chair) reminded the Working Group of the CCAMLR Scientific Scholarship Scheme and encouraged participants to review the priorities for future work and relay these to prospective applicants to the scheme.

5.3 The Working Group agreed that advice from SG-ASAM on the potential costs and logistical support required for processing of acoustic data collected from fishing vessels would be helpful in determining if this could be a suitable area of work to be supported by the General Science Capacity Special Fund.

5.4 The following items of future work were identified during the course of the meeting:

(i) Notifications for 2011/12 –

(a) Members to report each year updates on conversion factors to be used for the coming season (paragraph 2.12)

(b) Chile to advise the Scientific Committee in 2011 of the name of the vessel notified for krill fishing in 2012 (paragraph 2.13).

(ii) Analysis of data from the krill fishery –

(a) CPUE analysis, including checking validity of extreme outliers and choice of fixed and random effects (paragraphs 2.20, 2.22 and 2.24)

(b) authors of WG-EMM-11/P3 encouraged to re-submit the paper in English for further consideration (paragraph 2.26)

(c) wider seasonal and vessel coverage analysis of krill length and fish by-catch (paragraph 2.28).

(iii) Scientific observer coverage –

(a) provide observer coverage data in format directly comparable to target observer coverage rates in CM 51-06 (paragraph 2.33)

(b) revisions to observer logbook forms (paragraphs 2.37 and 2.42)

(c) production of maps of fishery and observation coverage distribution for use by the Scientific Committee in 2011 (paragraph 2.50)

(d) analyses prior to WG-EMM-12 on future requirements for observations in the krill fishery (paragraph 2.52).

(iv) Distribution of the trigger limit among statistical subareas –

(a) production of maps of fishery by fine-scale rectangle in Area 48 (paragraph 2.78)

(b) examination of CEMP data relevant to the overlap of predator foraging and fisheries in the Bransfield Strait (paragraph 2.94).

(v) Other issues related to spatial management of the krill fishery –

(a) Secretariat to work with the UK Delegation to identify CCAMLR mapping requirements and potential delivery (paragraph 2.101).

(vi) Views of the ecosystem –

(a) Krill predators:

- combined analysis Adélie penguin survival data taking into account different methods for marking birds (paragraph 2.110)

(b) Krill and fish:

- comparison of size and age composition of *C. gunnari* in krill by-catch and bottom trawl surveys around South Georgia (paragraph 2.116)

(c) Krill biology and survey results:

- examination of correlations in monitoring data from the Antarctic Peninsula and South Georgia (paragraph 2.131)
- comparison of the use of different recruitment indices (paragraph 2.132).

(vii) Symposium on feedback management of krill –

(a) schedule for considering components to fully developed candidate feedback management approaches by 2014 (paragraph 2.157).

(viii) CEMP and STAPP –

(a) draft modifications to Methods A3 and A9 for consideration at WG-EMM-12 (paragraph 2.196)

(b) liaise with scientists within SCAR and Birdlife International on predator foraging distribution to assess areas of common interest (paragraph 2.206).

(ix) Integrated assessments for krill –

(a) development of an integrated assessment model for krill (paragraph 2.217).

(x) Fishing vessel research –

(a) addition of data from 120 kHz and choice of survey design in pilot study to use krill fishing vessel to collect acoustic data (paragraph 2.224)

(b) request for advice from SG-ASAM in 2012 (paragraph 2.225).

5.5 The Working Group recalled its decision last year (SC-CAMLR-XXIX, Annex 6, paragraph 5.11) to consider the following items at WG-EMM-12:

(i) MPAs – by 2012, submit proposals on an RSMPA to the Commission

(ii) krill and krill predators –
(a) integrated assessment
(b) feedback and spatial management
(c) decision rules and climate change.

It also recalled that consideration of these issues would be contingent on the progress made on other items during 2011 and the priorities of the Scientific Committee.

OTHER BUSINESS

Secretariat's Strategic Plan

6.1 Mr Wright introduced WG-EMM-11/9 which provided an update on the development of a revised Strategic Plan for the CCAMLR Secretariat. He noted that the process to revise the Strategic Plan had been informed by the Independent Review of the Secretariat's Data Management Systems which was approved by the Commission last year (CCAMLR-XXIX, paragraphs 3.5 and 3.10). He outlined the key outcomes of the review which was completed in early 2011 (CCAMLR-XXX/5). The outcomes of the two reviews included proposals to enhance science and data management support from the Secretariat to address priority areas in the work of the Scientific Committee.

6.2 The Working Group noted the

- proposal to change the job titles of the Science Officer to the 'Science Manager' and Scientific Observer Data Analyst to the 'Scientific Observer Program Coordinator' to better reflect the roles and responsibilities of these positions

- terms of reference for an Analytical Support Officer position within Science Services

- restructuring and revised administrative processes for the Data Centre.

6.3 The Working Group agreed that the revised Strategic Plan provided a clear and concise description of the structure and function of the Secretariat and was very useful in clarifying the roles in providing science support from the Secretariat across all working groups and the Scientific Committee. It agreed that the Analytical Support Officer would be very useful to the work of the Working Group.

Participation of Observers in working group meetings

6.4 Following the request of the Scientific Committee (SC-CAMLR-XXIX, paragraph 15.19), Dr Watters presented a potential mechanism to facilitate the engagement of Observers (e.g. NGOs) in working group meetings. This mechanism would provide for a single representative of those international organisations that are invited to attend the Scientific Committee to attend working group meetings. That representative would contribute to discussion only at the direct request of a Member and would not provide written statements for the report of the meeting. The submission of papers to working group meetings would be subject to the agreement of the Convener and the Chair of the Scientific Committee that the paper is scientifically relevant. All Observers would be bound by a confidentiality agreement and any breach of that agreement would result in permanent disbarment of that Observer organisation from all working group meetings.

6.5 The Working Group thanked Dr Watters for this presentation that provided a good basis for discussing this issue. In the subsequent discussion the Working Group considered:

(i) the inclusion of fishing industry representatives in some delegations had brought important insights into the operation of fisheries that provided important context for scientific discussions

(ii) the potential positive contribution that the presence of Observers might bring to the work of the working groups, including increasing transparency and awareness of processes in those groups

(iii) the long history of positive engagement by Observers at the Scientific Committee has demonstrated interest in, and knowledge of, CCAMLR

(iv) an acknowledgement that understanding the discussion of science issues at the Scientific Committee in the absence of participation in the working groups is challenging

(v) whether there should be any requirement for academic qualification for the Observer representatives attending working group meetings

(vi) increasing the understanding of meetings by Observers that have a genuine interest in CCAMLR would be beneficial

(vii) while the science used by CCAMLR is robust to external review, there were sometimes sensitive issues under discussion (including both data and analyses) that require confidentiality and discretion and the involvement of Observers at those times would need to be carefully considered.

6.6 In the discussion of these issues, the Working Group did not seek to find consensus on each issue but simply highlighted them as items that the Scientific Committee might include in their consideration of this subject.

6.7 The Working Group agreed that providing a non-technical summary of the outcomes of working group meetings would be useful in informing a wider audience of the scientific discussions undertaken in the subsidiary bodies of the Scientific Committee and asked the Scientific Committee to consider a mechanism to produce such a summary.

ICED and SCAR

6.8 Dr Constable provided an update to the Working Group on work being undertaken in the IMBER program on Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED). Three main projects of interest to CCAMLR include the development of ecosystem models, consideration of regional differences in food webs and the development of monitoring climate change impacts on the Southern Ocean ecosystems. In the case of the latter, the ICED project on the Southern Ocean Sentinel aims to develop a program of multinational assessments of current and future ecosystem change in the region arising from climate change. A second workshop is to be held in Hobart, Australia, from 7 to 13 May 2012, to further discuss a collective approach to the Southern Ocean Sentinel, including optimal locations for routine monitoring and places where integrated studies might be useful for this task. The expectation is that these discussions will further add to the development of the biological monitoring envisaged for the SOOS.

6.9 The Working Group noted that the work of CEMP could be an important contributor of integrated studies and time series to any programs to monitor and measure change in the Southern Ocean.

6.10 Dr Reid provided an update to the Working Group on the establishment of a SCAR–CCAMLR Action Group, including an enhancement of the role of SCAR in providing advice to CCAMLR on climate change through the SCAR ACCE report and the proposed annual updates (SC-CAMLR-XXIX, paragraph 10.5). The SCAR Open Science Conference will be held from 13 to 25 July 2012, Portland, Oregon, USA, and CCAMLR has been invited to provide input into planning of a plenary session on science and policy.

Succession planning

6.11 Dr Watters reiterated his position as stated last year (SC-CAMLR-XXIX, Annex 6, paragraph 6.14) that 2012 would be his final year as the Convener of WG-EMM. He offered to co-convene the meeting next year with a potential successor should anyone wish to engage in this process. At the time of the meeting there was no indication of a potential successor.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

7.1 The report of the meeting of WG-EMM was adopted.

7.2 In closing the meeting, Dr Watters thanked all participants for their contributions to the meeting that had set in place the exciting prospect of making tangible progress towards a feedback management procedure for the krill fishery. He also extended the gratitude of all participants to the local organisers, to NFRDI and MIFAFF, and thanked them for their efficiency and generosity leading up to and during the meeting. He thanked the Secretariat for its support and, in particular, thanked those Secretariat staff who provided remote support for the meeting.

7.3 Dr Constable, on behalf of the participants, thanked Dr Watters for the amount of thought and preparation that he put into the meeting and how this had allowed some challenging issues to be addressed in a manner that successfully engaged all participants.

7.4 The meeting was closed.

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Table 1: Comments and actions recommended to be taken on the krill observer data e-forms.

Form	Comments	Action taken, or to be taken
K1		Retain as is.
K2	This information duplicates the information provided through the krill fishery notification process.	Retain the format. Observers still need to collect the details on board.
K3	Use of term 'Haul Number' is unclear for continuous trawlers. Haul number required here is number of 2-hour segments for observation and C1 data reporting. Sequence of fishing detail to be entered is not consistent with C1 form. Clarify why horizontal opening of nets is required here as it is already in K2. Necessity of K3(ii) form given the application of fish by-catch sampling protocol, however, we need to somehow record invertebrate by-catch.	Introduce a new term 'Haul ID Number'. One haul ID Number would be allocated to a haul for conventional haul, and one 2-hour reporting period (haul unit) for continuous fishing system. Revise the sequence of data entry on the form consistent with the C1 form.
K4	Weighing individual krill at sea is difficult to deliver reliable data. The term sample number is unclear. The term 'Krill colouration' is not an accurate description of this specific observation, and has been translated incorrectly into other languages.	Weighing individual krill should not be required. Use new term 'Haul ID Number' and 'Sample ID Number'. Translation of 'Krill colouration' to other languages needs to be checked. Insert pictures of krill with green stomach and clear stomach. Remove species code column. A new flow chart for maturity/stage identification in the *Scientific Observers Manual*.
K5	Does not allow collection of quantitative data.	Remove this form.
K6	Information on fleet dynamics can be obtained from other means (VMS, fishing operators).	Remove
K7	Could be combined with K11.	Request WG-IMAF's advice how K7 and K11 can be combined to give an IMAF form.
K8	Many of the descriptions are not relevant to krill fishery.	Retain as is. This format needs to be consistent with other fisheries.
K9	Is it important to retain this form? Should the observer register all vessels or only IUU vessels? Is it necessary to report the vessel more than once per day (it may be time consuming)?	Request advice from SCIC on the specific information that it needs to be reported by observers, as well as advice on how the observers show/determine if a vessel is an IUU vessel?
K10	What is the utility of this form?	Analysis of K10 data to review its utility.
K11	Could be combined with K7.	Request WG-IMAF's advice how K7 and K11 can be combined to give an IMAF form.
K12	Information on length of individual by-catch fish needs to be included.	Add length column to each of the sub-sampling rows.

Table 2: Number of hauls undertaken for each specific observation by subarea and by month during 2009/10. Percentage coverage is based on number of hauls for conventional, or numbers of 2-hour reporting periods used in the continuous fishing system, and is presented in brackets. Explanation for the column headers: Total number of hauls – number of hauls or 2-hour reporting periods for continuous fishing system; Hauls with observer on board vessel – number of hauls for both conventional and continuous fishing system; Number of hauls where observers collected data – number of hauls or 2-hour reporting periods for continuous fishing system that were sampled by observers; Hauls with krill length measured – number of hauls or 2-hour reporting periods for continuous fishing system sampled for krill length-frequency data; Hauls with IMAF data – number of hauls or 2-hour reporting periods for continuous fishing system sampled for seabird/marine mammal mortality; Hauls with warp strike data – number of hauls or 2-hour reporting periods for continuous fishing system sampled for warp strike; K5 finfish by-catch – number of hauls or 2-hour reporting periods for continuous fishing system observed for finfish by-catch using K5 form; Fish sampling form 2009 or 2010 – number of hauls or 2-hour reporting periods for continuous fishing system observed for fish using fish sampling form 2009 or 2010.

Season	Subarea	Month	Total number of hauls	Hauls with observer on board vessel	Number of hauls where observer collected data	Hauls with krill length measured	Hauls with IMAF data	Hauls with warp strike data	K5 finfish by-catch	Fish sampling form 2009 or 2010
2010	48.1	12	37	37	36 (97)	5 (14)	37(100)	36 (97)	8 (22)	0 (0)
		1	26	28	21 (75)	18 (64)	18 (64)	13 (46)	3 (11)	0 (0)
		2	141	114	71 (62)	2 (2)	57 (50)	13 (11)	0 (0)	2 (18)
		3	807	555	308 (55)	63 (11)	228 (41)	41 (7)	42 (8)	66 (12)
		4	1716	1224	436 (36)	149 (12)	165 (13)	127 (10)	57 (5)	109 (9)
		5	1535	530	219 (41)	88 (17)	38 (7)	54 (10)	39 (7)	65 (12)
		6	1945	761	255 (34)	64 (8)	82 (11)	119 (16)	74 (10)	136 (18)
		7	1746	855	152 (18)	50 (6)	72 (8)	127 (15)	84 (10)	142 (17)
		8	868	661	7 (1)	24 (4)		44 (7)	9 (1)	59 (9)
		9	908	833	23 (3)	38 (5)	18 (2)	65 (8)	14 (2)	74 (9)
		10	145	145	17 (12)	7 (5)	16 (11)	22 (15)	2 (1)	17 (12)
	48.2	1	508	502	36 (7)	28 (6)	35 (7)	105 (21)	32 (6)	33 (7)
		2	1152	855	156 (18)	77 (9)	95 (11)	231 (27)	44 (5)	58 (7)
		3	1130	886	217 (24)	59 (7)	72 (8)	203 (23)	40 (5)	85 (10)
		4	220	220	2 (1)	4 (2)	0 (0)	37 (17)	7 (3)	16 (7)
		10	176	175	1 (1)	20 (11)	0 (0)	25 (14)	7 (4)	17 (10)
	48.3	5	293	293	28 (10)	11 (4)	0 (0)	56 (19)	6 (2)	35 (12)
		6	122	121	3 (2)	4 (3)	0 (0)	10 (8)	2 (2)	11 (9)
Percent coverage	Average				(27.6)	(10.5)	(18.6)	(20.7)	(5.7)	(9.8)
	Median				(18.0)	(6.3)	(8.3)	(15.0)	(4.6)	(9.3)
	Minimum				(0.6)	(1.8)	(0.0)	(6.7)	(0.0)	(0.0)
	Maximum				(97.3)	(64.3)	(100.0)	(97.3)	(21.6)	(17.9)

Table 3: Illustrative estimates of SSMU- and subarea-specific krill consumption by fish, whales, penguins and fur seals, and krill biomass calculated from listed source papers. SSMU-specific krill biomass is calculated as the relevant stratum density from WG-EMM-11/20 multiplied by SSMU area following Hewitt et al. (2004).

Subarea	SSMU		Krill consumption (10^6 t.y^{-1})			Krill biomass (10^6 t)		
	No.	Name	SSMU	Subarea	Subarea (coastal only)	SSMU	Subarea	Subarea (coastal only)
			Hill et al. (2007)			WG-EMM-11/20		
48.1	1	APPA	8.04			8.27		
48.1	2	APW	1.48			4.77		
48.1	3	APDPW	0.49			2.05		
48.1	4	APDPE	0.96			2.12		
48.1	5	APBSW	1.17			2.86		
48.1	6	APBSE	1.00			3.73		
48.1	7	APEI	1.37			4.80		
48.1	8	APE	3.10	17.61	9.57	7.98	36.58	28.31
48.2	9	SOPA	10.06			25.46		
48.2	10	SOW	0.27			4.97		
48.2	11	SONE	0.56			3.27		
48.2	12	SOSE	1.61	12.51	11.34	4.78	38.49	13.02
48.3	13	SGPA	11.06			28.94		
48.3	14	SGW	5.40			1.43		
48.3	15	SGE	1.24	17.70	14.60	1.82	32.18	3.24

Table 4: Four possible classes of candidate feedback management approaches for the krill fishery in Area 48.

The table gives a preliminary assessment of some of the costs and benefits associated with these classes of feedback management but this assessment might change as more information becomes available.

The four classes of feedback management approach identified in the table are the four possible combinations of two ways of managing fishing effort and catches in a management procedure and for gaining insight into ecosystem responses. These are:

(i) STRUCTURED FISHING: the manipulation of fishing effort (distribution, catch and/or intensity) for learning about ecological responses and/or to achieve management objectives.

(ii) REFERENCE AREA MONITORING: the use of monitored *reference* areas in which no fishing is permitted as the basis for understanding effects in contrasting *fished* areas.

<table>
<tr><th></th><th></th><th>FULLY FLEXIBLE FISHING</th><th>STRUCTURED FISHING</th><th>REFERENCE AREA MONITORING</th><th>REFERENCE AREA MONITORING with STRUCTURED FISHING</th></tr>
<tr><td>1</td><td>REFERENCE AREA MONITORING</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td>2</td><td>STRUCTURED FISHING</td><td>No</td><td>Yes</td><td>No</td><td>Yes</td></tr>
<tr><td>3</td><td>Attribution of change to likely causes</td><td>Attribution impossible</td><td>Attribution possible but less likely</td><td>Attribution possible and likely</td><td>Attribution possible and most likely</td></tr>
<tr><td colspan="6">The potential for evidence-based attribution of observed changes in ecosystem state to fishery impacts depends on the indicators, the field monitoring design and analytical methods used. It is most likely to increase with the use of either structured fishing or reference area monitoring but would be highest when both methods are used. The power of attribution is likely to increase with replication of the reference areas.</td></tr>
<tr><td>4</td><td>Allows krill assessment</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="6">Each of the classes allow assessment of the krill stock if they incorporate suitable data collection and analyses.</td></tr>
<tr><td>5</td><td>Areas that could potentially provide fishery-dependent indicators</td><td>All areas</td><td>All areas</td><td>Fished areas</td><td>Fished areas</td></tr>
<tr><td colspan="6">Fishery-dependent indicators (e.g. CPUE) are derived from commercial fishing activities and, as such, can only be obtained from areas where fishing is permitted. This excludes reference areas and may also exclude other areas subject to short- to medium-term restrictions under some structured fishing designs.</td></tr>
<tr><td>6</td><td>Areas that could potentially provide fishery-independent indicators and assessments</td><td>All areas</td><td>All areas</td><td>All areas</td><td>All areas</td></tr>
<tr><td colspan="6">Fishery-independent indicators can be obtained from all areas, including those subject to restrictions on fishing. These data might be collected using fishing vessels as platforms.</td></tr>
</table>

(continued)

Table 4 continued

<table>
<tr><th></th><th></th><th>FULLY FLEXIBLE FISHING</th><th>STRUCTURED FISHING</th><th>REFERENCE AREA MONITORING</th><th>REFERENCE AREA MONITORING with STRUCTURED FISHING</th></tr>
<tr><td>7</td><td>Basis for diagnosis of effects of fishing</td><td>Model expectation – fished area comparisons</td><td>Model expectation – fished area comparisons</td><td>Model expectation – fished area and fished area to reference area comparisons</td><td>Model expectation – fished area and fished area to reference area comparisons</td></tr>
<tr><td colspan="6">Comparisons between model projections of the ecosystem state and observations of the actual state might be used to indicate fishing impacts in each class. Those classes that incorporate reference areas allow comparisons of the actual state in fished and contrasting reference (unfished) areas. Reference areas can also be used to test model predictions.</td></tr>
<tr><td>8</td><td>Can detect long-term change in krill productivity relative to what it would be without fishing</td><td>No</td><td>No</td><td>Maybe
(if some krill is isolated from the effects of fishing)</td><td>Maybe
(if some krill is isolated from the effects of fishing)</td></tr>
<tr><td colspan="6">Empirical measurements of long-term change in krill productivity must be obtained from areas that are mostly unaffected by fishing. Reference areas can provide these conditions only if they are not influenced over time by fishing elsewhere in the system.</td></tr>
<tr><td>9</td><td>Environmental indicators for estimating krill productivity relative to what it would be without fishing</td><td>Yes
(proxies would need to be estimated from pre-fishing baseline)</td><td>Yes
(proxies would need to be estimated from pre-fishing baseline)</td><td>Yes
(proxies from pre-fishing baseline and possible direct estimates using comparisons between fished and reference areas)</td><td>Yes
(proxies from pre-fishing baseline and possible direct estimates using comparisons between fished and reference areas)</td></tr>
<tr><td colspan="6">Indicators of environmental conditions (e.g. temperature, pH) could be obtained in each of the classes. These indicators could be used as proxies to judge whether the ecosystem has changed independently of fishing. Models of the relationship between environmental indicators and krill and/or its predators will be needed to establish the significance of such changes. Those relationships could be identified through comparison with data from the pre-fishing reference period (i.e. from the 'current' system, paragraph 2.187). However, reference area monitoring would be needed to determine if the identified relationships have changed over time.</td></tr>
<tr><td>10</td><td>Potential basis for decision rules</td><td>Cumulative changes</td><td>Cumulative changes</td><td>Cumulative plus attributed changes</td><td>Cumulative plus attributed changes</td></tr>
<tr><td colspan="6">The different classes have the potential to provide different levels of information for use in decision-making. Reference area monitoring facilitates observation-based comparisons between fished and unfished ecosystem states. It therefore has the potential to attribute change to fishing impacts and potentially allows decision rules that use the 'current' unfished state as a reference point, depending on the degree of connectivity among areas. Without reference area monitoring it is not possible to attribute change to fishery impacts, but it is still possible to detect the cumulative change in the system due to all drivers. In this case, an appropriate reference point may be the 'expected' state of the unfished system from model projections. Structured fishing could help to reduce uncertainty in these reference points.</td></tr>
</table>

(continued)

Table 4 continued

<table>
<tr><th></th><th></th><th>FULLY FLEXIBLE FISHING</th><th>STRUCTURED FISHING</th><th>REFERENCE AREA MONITORING</th><th>REFERENCE AREA MONITORING with STRUCTURED FISHING</th></tr>
<tr><td>11</td><td>Potential impact on fishery flexibility</td><td>Low</td><td>Moderate: requirement to participate in structured fishing</td><td>Moderate: long-term closed areas</td><td>High: long-term closed areas, requirement to participate in structured fishing</td></tr>
<tr><td colspan="6">Feedback management implies trade-offs between the flexibility of the fishery to operate anywhere in the managed area versus objectives relating to conservation, orderly development and the costs of monitoring. The use of structured fishing and restricted area monitoring limits this flexibility. However this trade-off must be balanced against other potential costs of fully flexible fishing associated with the continuing uncertainty in the indicators that this class can provide.</td></tr>
</table>

Table 5: Projected progress in work by WG-EMM-STAPP towards estimation of krill consumption by predator groups in SSMUs.

	Pack-ice seals	Fur seals	Penguins	Flying seabirds
Breeding population	2009	2012	2012	2016
Non-breeding population	2009	2012	2013	2016
Diet	2009	2012	2011	2016
Energetics	2009	2012	2013	2016
Total krill consumption	2009	2012	2013	2016
Foraging distribution	2009	2016	2016	2016

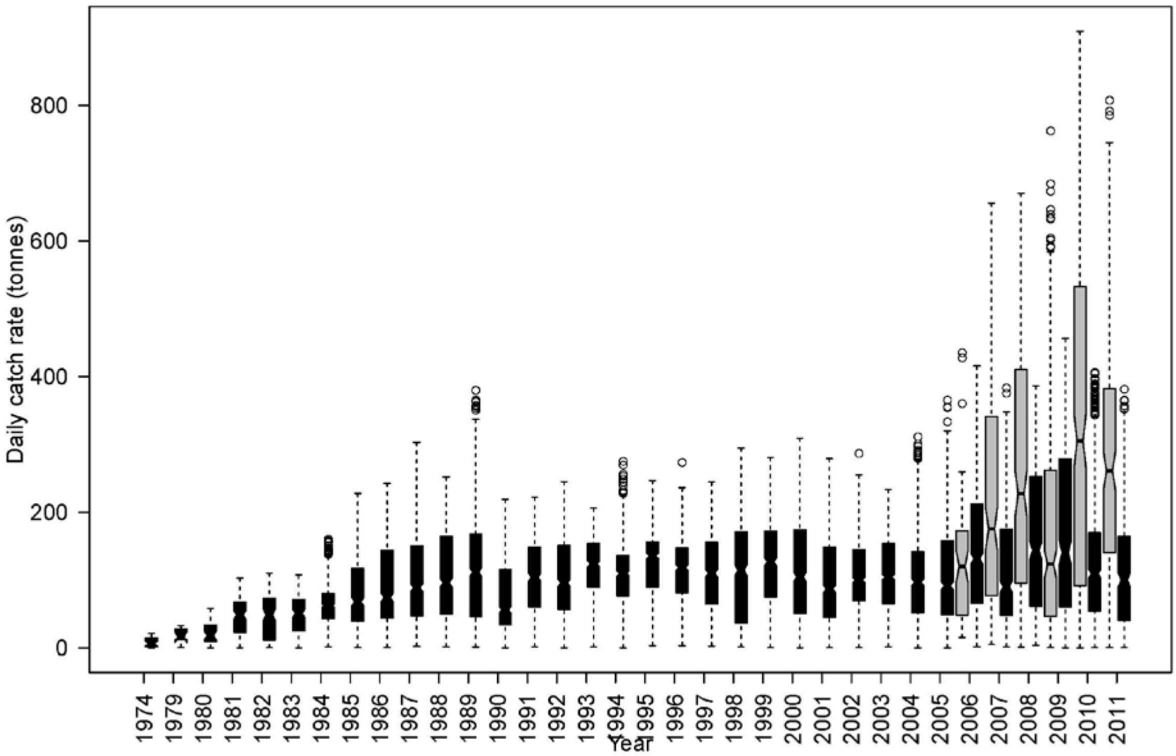


Figure 1: Daily catch of krill (tonnes per vessel) reported from Area 48 since 1980/81. Source: C1 data. Box plot – 75 percentile, solid dot – mean, vertical dotted line – 95 percentile, open circles – data points outside 95 percentiles. Black – conventional trawl, grey – continuous fishing system.

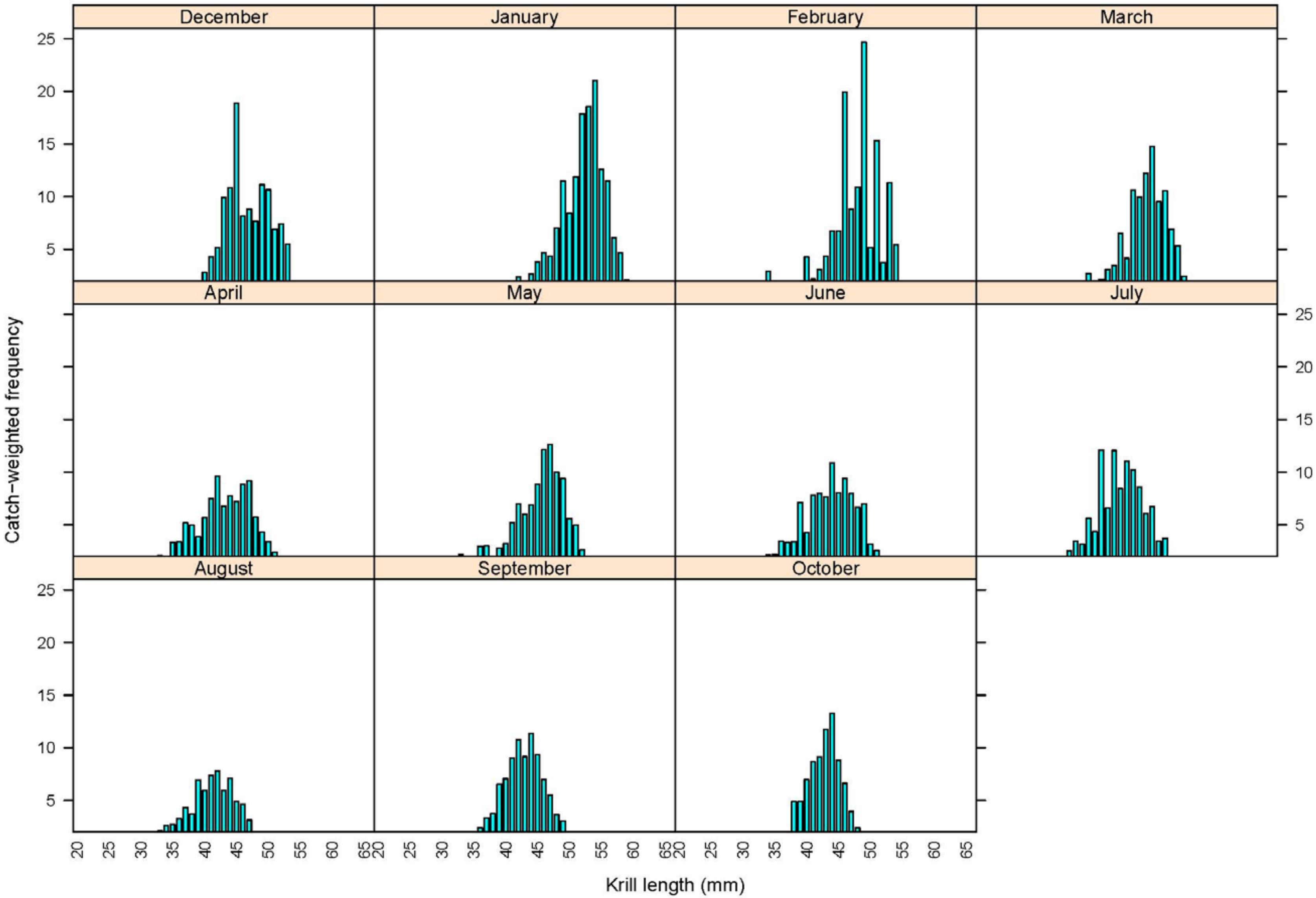


Figure 2(a): Length-frequency distribution by month in Subarea 48.1 for 2009/10.

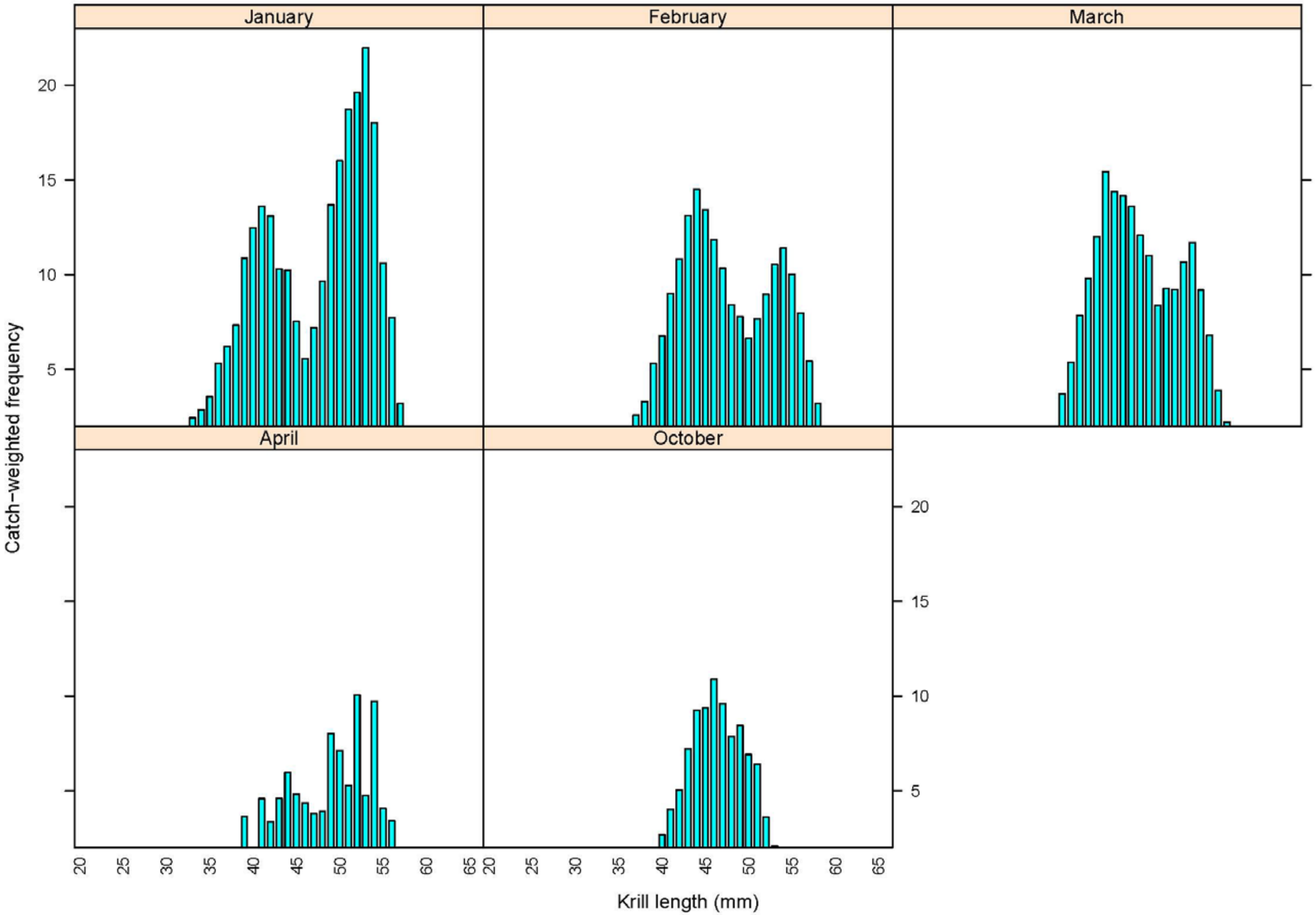


Figure 2(b): Length-frequency distribution by month in Subarea 48.2 for 2009/10.

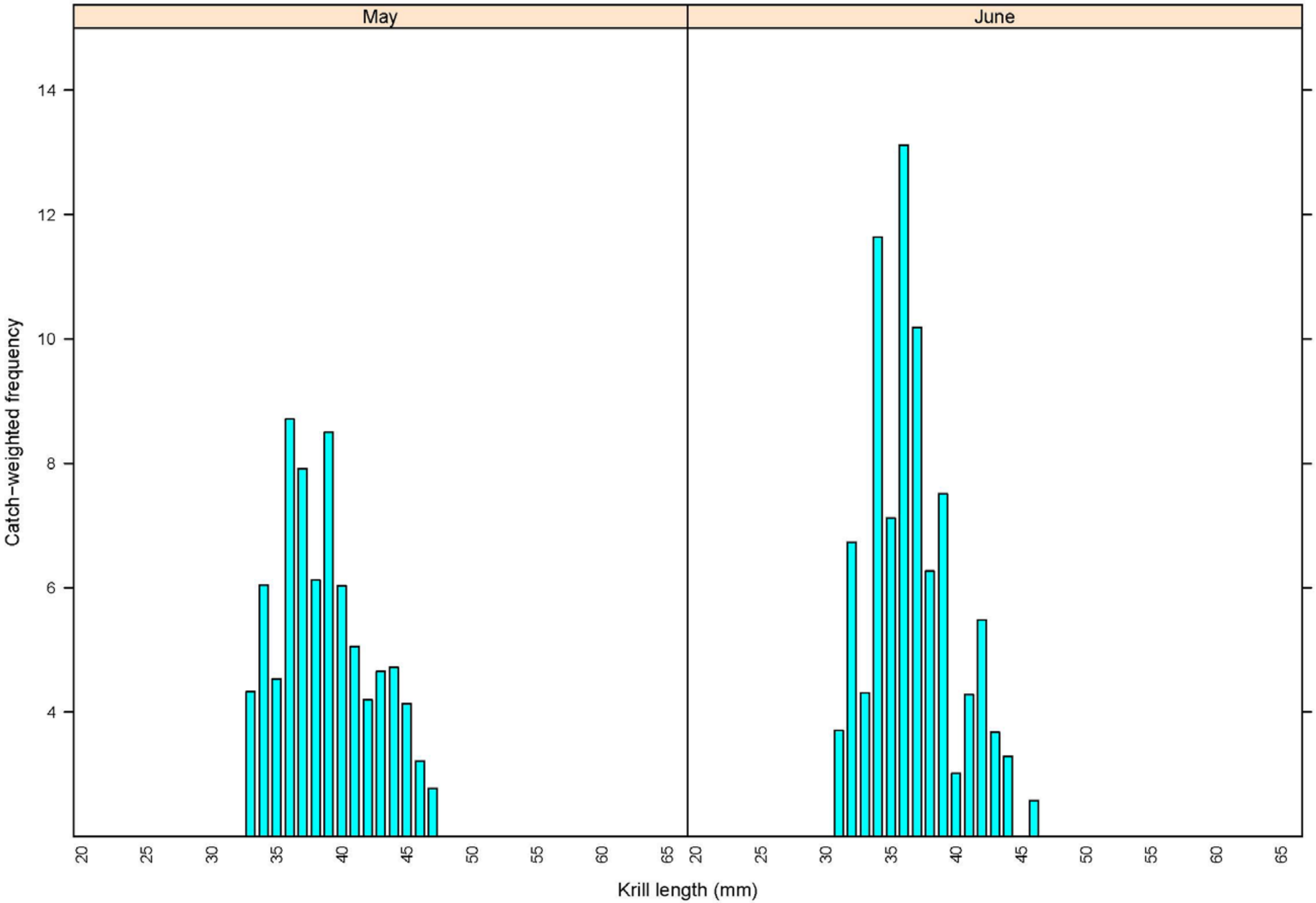


Figure 2(c): Length-frequency distribution by month in Subarea 48.3 for 2009/10.

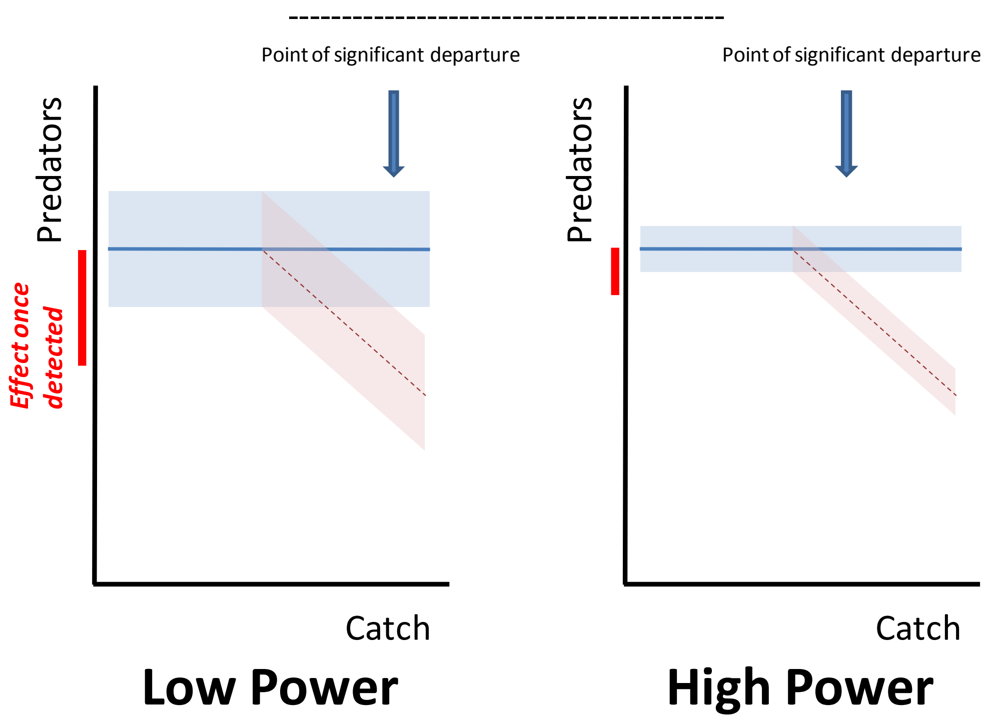
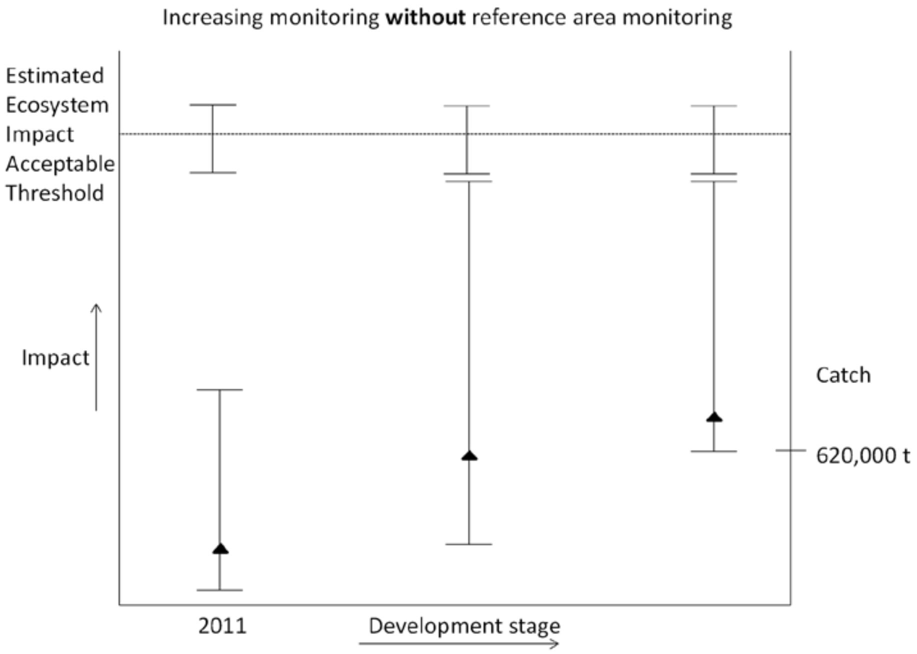


Figure 3*: Illustration of the effects of statistical power on detecting a significant change in a predator parameter given a level of catch and the error in estimating the predator parameter. Solid blue line indicates a scenario of no effect of catch. Solid red line indicates an effect of catch after a threshold is reached. The blue and red shading reflects the confidence intervals surrounding estimates of the predator parameter. The arrow indicating the point of significant departure is where a significant effect of the catch is likely to be detected. The red bars indicate the effect of the catch once detected. Statistical power for correctly determining that no effect has occurred increases as confidence intervals are reduced. This is illustrated by comparing the left and right plots.

* This figure is available in colour on the CCAMLR website.



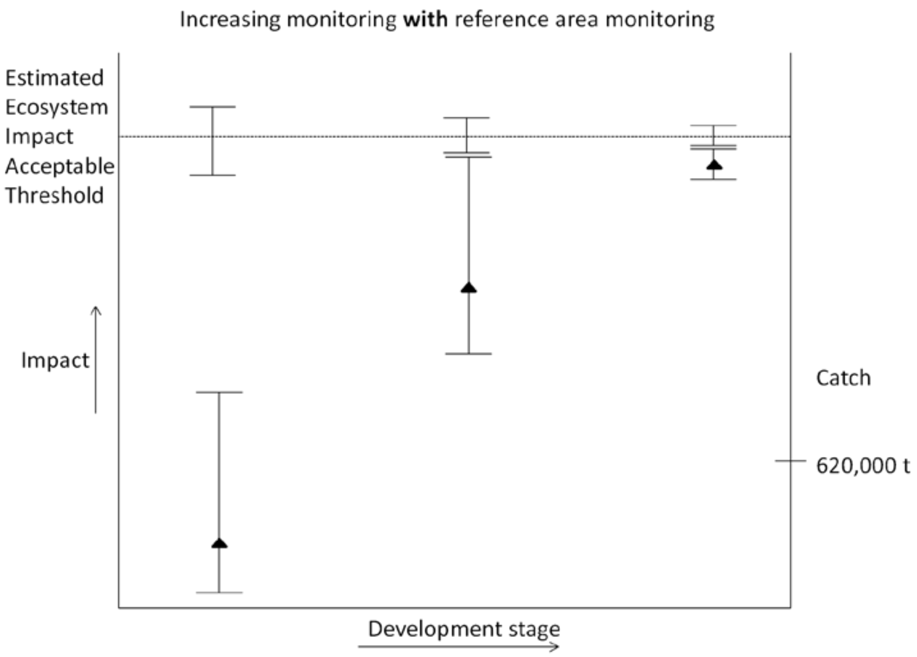


Figure 4: Potential revisions to catch limits and uncertainty under feedback management. The x-axis characterises possible stages in the development of a feedback management approach. The left axis shows the level of impact of a stage in the fishery, which also corresponds to a catch limit (right axis)*. Triangles show the estimate of impact with error bars. The horizontal line shows a putative limit of acceptable impacts. The error bars reflect the degree of understanding as to what this might be and how well it is estimated. Learning more about the system could allow revision of catch limits over time as our understanding increases. Reference area monitoring could allow attribution of ecosystem change to fishery versus other effects. This could reduce the uncertainty in assessments of fishery impacts, potentially allowing the catch to rise further and faster while maintaining a precautionary approach.

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* The relationship between impact and catch limit may not be a simple linear relationship as indicated here.

APPENDIX A

LIST OF PARTICIPANTS

Working Group on Ecosystem Monitoring and Management
(Busan, Republic of Korea, 11 to 22 July 2011)

ABE, Koki (Dr)	National Research Institute of Fisheries Engineering 7620-7, Hasaki, Kamisu Ibaraki 314-0408 Japan abec@fra.affrc.go.jp
AGNEW, David (Dr) (Scientitific Committee Chair)	MRAG 18 Queen Street London W1J 5PN United Kingdom d.agnew@mrag.co.uk
AHN, Jongkwan (Mr)	International Fishery Organization Division Ministry for Food, Agriculture, Forestry and Fisheries Gwacheon, Gyeonggi-do Seoul Republic of Korea ahnjk90@korea.kr
ARANA, Patricio (Prof.)	Pontificia Universidad Catolica de Valparaíso Escuela de Ciencias del Mar Casilla 1020 Valparaíso Chile parana@ucv.cl
ARATA, Javier (Dr)	Jefe Departamento Proyectos INACH Plaza Muñoz Gamero 1055 Punta Arenas Chile jarata@inach.cl

CHOI, Hyun Joong (Mr)	Sunwoo Corporation Sungji Bldg 935-2 Bangbae 1-dong Seocho-gu, Seoul Republic of Korea hjchoi@swfishery.com
CHOI, Jae Hoon (Mr)	Dongwon Industries Co. Ltd Dongwon Bldg 275 Yanjae-dong Seocho-gu, Seoul Republic of Korea jordan2233@dongwon.com
CONSTABLE, Andrew (Dr) (WG-SAM Co-Convener)	Antarctic Climate and Ecosystems Cooperative Research Centre Australian Antarctic Division Department of Sustainability, Environment, Water, Population and Communities 203 Channel Highway Kingston Tasmania 7050 Australia andrew.constable@aad.gov.au
EMMERSON, Louise (Dr)	Australian Antarctic Division Department of Sustainability, Environment, Water, Population and Communities 203 Channel Highway Kingston Tasmania 7050 Australia louise.emmerson@aad.gov.au
FLORES, Hauke (Dr) (representing the EU)	IMARES PO Box 167 1790 AD Den Burg (Texel) The Netherlands hauke.flores@wur.nl
FUJITA, Kaoru (Mr)	National Research Institute of Fisheries Engineering 7620-7, Hasaki, Kamisu Ibaraki 314-0408 Japan duke@fra.affrc.go.jp

HILL, Simeon (Dr) | British Antarctic Survey
Natural Environment Research Council
High Cross, Madingley Road
Cambridge CB3 0ET
United Kingdom
sih@bas.ac.uk

IWAMI, Tetsuo (Dr) | Tokyo Kasei Gakuin University
2600, Aihara-machi
Machida-shi, Tokyo
194-0292 Japan
iwami@kasei-gakuin.ac.jp

JONES, Christopher (Dr)
(WG-FSA Convener)
(WG-SAM Co-Covener) | US AMLR Program
Southwest Fisheries Science Center
National Marine Fisheries Service
3333 Torrey Pines Court
La Jolla, CA 92037
USA
chris.d.jones@noaa.gov

JUNG, Tae Bin (Mr) | Sunwoo Corporation
Sungji Bldg
935-2 Bangbae 1-dong
Seocho-gu, Seoul
Republic of Korea
tbjung@swfishery.com

KASATKINA, Svetlana (Dr) | AtlantNIRO
5 Dmitry Donskoy Street
Kaliningrad 236000
Russia
ks@atlant.baltnet.ru

KAWAGUCHI, So (Dr) | Australian Antarctic Division
Department of Sustainability, Environment,
Water, Population and Communities
203 Channel Highway
Kingston Tasmania 7050
Australia
so.kawaguchi@aad.gov.au

KIM, Doonam (Dr)	Fisheries Resources Management Division National Fisheries Research and Development Institute 408-1 Sirang-ri Gijang-eup, Gijang-kun Busan Republic of Korea dnkim@nfrdi.go.kr
KIYOTA, Masashi (Dr)	National Research Institute of Far Seas Fisheries 2-12-4, Fukuura, Kanazawa-ku Yokohama, Kanagawa 236-8648 Japan kiyo@affrc.go.jp
KRAFFT, Bjørn (Dr)	Institute of Marine Research Nordnesgaten 50 PO Box 1870 Nordnes N-5817 Bergen Norway bjorn.krafft@imr.no
KWON, Hyun Wook (Ms)	Ministry for Food, Agriculture, Forestry and Fisheries Seoul Republic of Korea 6103kwon@naver.com
MAKHADO, Azwianewi (Dr)	Department of Environmental Affairs PO Box 52126 Waterfront 8002 Cape Town South Africa amakhado@environment.gov.za
MILINEVSKYI, Gennadi (Dr)	National Taras Shevchenko University of Kyiv Volodymirska, 64 01601 Kyiv Ukraine genmilinevsky@gmail.com

MOON, Dae Yeon (Dr)
Fisheries Resources Management Division
National Fisheries Research
and Development Institute
408-1 Sirang-ri
Gijang-eup, Gijang-kun
Busan
Republic of Korea
dymoon@nfrdi.go.kr

OKUDA, Takehiro (Dr)
National Research Institute of Far Seas Fisheries
2-12-4, Fukuura, Kanazawa-ku
Yokohama, Kanagawa
236-8648 Japan
okudy@affrc.go.jp

PARK, Jason Won Mo (Mr)
Insung Corporation
Insung Bldg
113-2 Hannam-dong
Yongsan-gu, Seoul
Republic of Korea
jaypark@insungnet.co.kr

PARK, Woo Sung (Mr)
Dongwon Industries Co. Ltd
Dongwon Bldg
275 Yanjae-dong
Seocho-gu, Seoul
Republic of Korea
longtrawl@dongwon.com

PEATMAN, Tom (Mr)
MRAG
18 Queen Street
London W1J 5PN
United Kingdom
t.peatman@mrag.co.uk

PSHENICHNOV, Leonid (Dr)
YugNIRO
Sverdlov Street, 2
Kerch
98300 Crimea
Ukraine
lkpbikentnet@rambler.ru

SAMAAI, Toufiek (Dr)
Oceans and Coasts Branch
Department of Environment Affairs
Private Bag x2
Rogge Bay 8012
Cape Town
South Africa
tsamaai@environment.gov.za

SEOK, Kyujin (Dr)
National Fisheries Research
and Development Institute
408-1 Sirang-ri
Gijang-eup, Gijang-kun
Busan
Republic of Korea
pisces@nfrdi.go.kr

SHARP, Ben (Dr)
Ministry of Fisheries
PO Box 1020
Wellington
New Zealand
ben.sharp@fish.govt.nz

SIEGEL, Volker (Dr)
Institute of Sea Fisheries
Johann Heinrich von Thünen-Institute
Federal Research Institute for Rural Areas,
Forestry and Fisheries
Palmaille 9
22767 Hamburg
Germany
volker.siegel@vti.bund.de

SOUTHWELL, Colin (Dr)
Australian Antarctic Division
Department of Sustainability, Environment,
Water, Population and Communities
203 Channel Highway
Kingston Tasmania 7050
Australia
colin.southwell@aad.gov.au

SUITO, Motoyoshi (Mr)
Nippon Suisan Kaisha Ltd
Nippon Bldg
6-2 Otemachi 2-chome, Chiyoda-ku
Tokyo
100-8686 Japan
motsuito@nissui.co.jp

TATARNIKOV, Vyacheslav (Dr)
VNIRO
17a V. Krasnoselskaya
Moscow 107140
Russia
vtat@mail.ru

TRATHAN, Phil (Dr)
British Antarctic Survey
High Cross, Madingley Road
Cambridge CB3 0ET
United Kingdom
pnt@bas.ac.uk

VAN FRANEKER, Jan Andries (Dr)
(representing the EU)
IMARES
PO Box 167
1790 AD Den Burg (Texel)
The Netherlands
jan.vanfraneker@wur.nl

WATTERS, George (Dr)
(WG-EMM Convener)
US AMLR Program
Southwest Fisheries Science Center
National Marine Fisheries Service
3333 Torrey Pines Court
La Jolla, CA 92037
USA
george.watters@noaa.gov

WELSFORD, Dirk (Dr)
Australian Antarctic Division
Department of Sustainability, Environment,
Water, Population and Communities
203 Channel Highway
Kingston Tasmania 7050
Australia
dirk.welsford@aad.gov.au

YOON, Chang In (Dr)
Korea Institute for International
Economic Policy
Seoul
Republic of Korea
ciyoon@kiep.go.kr

ZHAO, Xianyong (Dr)
Yellow Sea Fisheries Research Institute
Chinese Academy of Fishery Sciences
106 Nanjing Road
Qingdao 266071
People’s Republic of China
zhaoxy@ysfri.ac.cn

ZIEGLER, Philippe (Dr)	Australian Antarctic Division Department of Sustainability, Environment, Water, Population and Communities 203 Channel Highway Kingston Tasmania 7050 Australia philippe.ziegler@aad.gov.au
ZUO, Tao (Dr)	Yellow Sea Fisheries Research Institute Chinese Academy of Fishery Sciences 106 Nanjing Road Qingdao 266071 People's Republic of China zuotalinch@yahoo.com.cn
Meeting Assistant: KIM, Ji Hyun (Ms)	Fisheries Resources Management Division National Fisheries Research and Development Institute 408-1 Sirang-ri Gijang-eup, Gijang-kun Busan Republic of Korea siren84@naver.com

Secretariat:

Andrew WRIGHT (Executive Secretary) David RAMM (Data Manager) Keith REID (Science Officer) Genevieve TANNER (Communications Officer)	CCAMLR PO Box 213 North Hobart 7002 Tasmania Australia ccamlr@ccamlr.org

APPENDIX B

AGENDA

Working Group on Ecosystem Monitoring and Management
(Busan, Republic of Korea, 11 to 22 July 2011)

1. Introduction
   1.1 Opening of the meeting
   1.2 Adoption of the agenda and appointment of rapporteurs
   1.3 Review of requirements for advice and interactions with other working groups

2. The krill-centric ecosystem and issues related to management of the krill fishery
   2.1 Issues for the present: recruitment variation, B_0, and precautionary yield; data from the fishery and scientific observer system; escape mortality; green weight; distribution of the trigger limit among statistical subareas; 'Views of the Ecosystem'
   2.2 Issues for the future: Symposium on Feedback Management, CEMP and STAPP; integrated assessment; 'fishing vessel science and surveys'

3. Vulnerable marine ecosystems – review of notifications made under Conservation Measure 22-06

4. Advice to the Scientific Committee and its working groups

5. Future work

6. Other business

7. Adoption of the report and close of the meeting.

APPENDIX C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Busan, Republic of Korea, 11 to 22 July 2011)

WG-EMM-11/1	Draft Preliminary Agenda for the 2011 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-11/2	List of participants
WG-EMM-11/3	List of documents
WG-EMM-11/4 Rev. 1	Report from the WS: integrated krill monitoring in the CCAMLR Subarea 48.2
WG-EMM-11/5	Krill fishery report: 2011 update Secretariat
WG-EMM-11/6	CEMP indices: 2011 update Secretariat
WG-EMM-11/7	Summary of VME notifications made under Conservation Measures 22-06 and 22-07 Secretariat
WG-EMM-11/8	Summary of krill notifications for krill fisheries 2011/12 Secretariat
WG-EMM-11/9	The Secretariat review of the Strategic Plan, associated activities and outcomes Secretariat
WG-EMM-11/10	Dense stalked crinoid dominated assemblages on admiralty seamount in the northern Ross Sea (SSRU 881G): two potential VMEs C.D. Jones (USA), D.A. Bowden (New Zealand) and S. Schiaparelli (Italy)
WG-EMM-11/11	Summary of observations aboard krill trawlers operating in the Convention Area Secretariat
WG-EMM-11/12	A simulation study to determine the relationship between sampling intensity and precision when estimating availability functions for breeding Adélie penguin colonies J. McKinlay and C. Southwell (Australia)

WG-EMM-11/13	Antarctic krill demography and population dynamics west of the Antarctic Peninsula in 2010/11 V. Siegel (Germany), C. Reiss (USA), K. Dietrich (USA), M. Haraldsson (Sweden) and G. Rohardt (Germany)
WG-EMM-11/14	Selectivity of conventional and continuous techniques of krill fishery D. Sologub (Russia)
WG-EMM-11/15	Preliminary results of the experiment on definition of Antarctic krill mortality rate in fishery L. Pshenichnov and K. Vyshniakova (Ukraine)
WG-EMM-11/16	Antarctic krill and climate change H. Flores (Netherlands), A.S. Atkinson (UK), E. Bravo Rebolledo (Netherlands), V. Cirelli (Argentina), J. Cuzin-Roudy (France), S. Fielding (UK), J.A. van Franeker (Netherlands), J.J. Groeneveld (Netherlands), M. Haraldsson (Sweden), S. Kawaguchi (Australia), B.A. Krafft (Norway), A. Lombana (USA), E. Marschoff (Argentina), B. Meyer (Germany), G. Milinevsky (Ukraine), S. Nicol (Australia), E.A. Pakhomov (Canada), A.P. Van de Putte (Belgium), C. Reiss (USA), E. Rombolá (Argentina), K. Schmidt (UK), V. Siegel (Germany), G.A. Tarling (UK), M. Teschke (Germany), H. Tonkes (Netherlands), J.-Y. Toullec (France), P.N. Trathan (UK), N. Tremblay (Germany), R. Werner (AKCP) and T. Werner (Germany)
WG-EMM-11/17	Estimation of management reference points consistent with the catch trigger level for the Antarctic krill fishery in Area 48 T. Peatman, J. Moir Clark and D.J. Agnew (UK)
WG-EMM-11/18	Using ecosystem structure to identify finer-scale SSMUs for oceanic areas in Subareas 48.1 to 48.3 S.L. Hill and J. Silk (UK)
WG-EMM-11/19	Progress with updating of the KRILLBASE analysis A. Atkinson (UK)
WG-EMM-11/20	The ASAM 2010 assessment of krill biomass for Area 48 from the Scotia Sea CCAMLR 2000 Synoptic Survey S. Fielding and J. Watkins (UK) and ASAM participants: A. Cossio, C. Reiss and G. Watters (USA), L. Calise and G. Skaret (Norway), Y. Takao (Japan), X. Zhao (People's Republic of China), D. Agnew (UK) and D. Ramm and K. Reid (CCAMLR Secretariat)
WG-EMM-11/21	Ecosystem services of the Southern Ocean S.M. Grant, S.L. Hill and P.N. Trathan (UK)

WG-EMM-11/22	A GIS of CCAMLR spatial management areas and conservation measures P. Fretwell, S.M. Grant and S.L. Hill (UK) and S. Parker (New Zealand)
WG-EMM-11/23	Preliminary results from the first survey season of Antarctic krill and apex predators with the commercial fishing vessel *Saga Sea* in the South Orkney Islands area 2011 B.A. Krafft, G. Skaret and L. Calise (Norway)
WG-EMM-11/24	Structure of the water masses and krill distribution in the central and eastern parts of the Atlantic Antarctic Area V.N. Shnar and S.M. Kasatkina (Russia)
WG-EMM-11/25	Comparing CEMP indices to inform feedback management of the Antarctic krill fishery J.T. Hinke and G.M. Watters (USA)
WG-EMM-11/26	A re-analysis and update of the Antarctic krill biomass in the South Shetland Islands, through 2011 A. Cossio, C. Reiss and R. Driscoll (USA)
WG-EMM-11/27	Revision of the Conservation Measure 51-07 (2009) interim distribution of the trigger level in krill fishery in Statistical Subareas 48.1, 48.2, 48.3 and 48.4 L. Pshenichnov and G. Milinevsky (Ukraine)
WG-EMM-11/28	Assessment of spatial–temporal dynamics of standardised CPUE for krill fishery in the Area 48 S.M. Kasatkina and P.S. Gasyukov (Russia)
WG-EMM-11/29	Operation pattern of a Japanese commercial krill fishing vessel in the Antarctic Ocean F. Matsumoto and M. Suito (Japan)
WG-EMM-11/30	Update on intersessional work by the Subgroup on Status and Trends Assessment of Predator Populations (WG-EMM-STAPP) C. Southwell, L. Emmerson (Australia), J. Forcada (UK), M. Goebel, J. Hinke, H. Lynch (USA), P. Lyver (New Zealand), J. McKinlay (Australia), N. Ratcliffe (UK), D. Ramm, K. Reid (CCAMLR Secretariat), C. Reiss, W. Trivelpiece, S. Trivelpiece (USA) and P. Trathan (UK)
WG-EMM-11/31	Current abundance of Adélie penguin breeding populations along the Kemp and Mac.Robertson Land coasts, East Antarctica: application of new survey and estimation methods for broad-scale population assessment C. Southwell, J. McKinlay, K. Newbery, L. Emmerson, M. Low, R. Pike, D. Wilson, D. Southwell and L. Einoder (Australia)

WG-EMM-11/32	New regional-scale surveys of the Adélie penguin breeding population in Prydz Bay: a step towards improved estimation of krill consumption in East Antarctica C. Southwell, J. McKinlay, K. Newbery, L. Emmerson and J. Lieser (Australia)
WG-EMM-11/33	Potential phenological responses to environmental variability and change for Adélie penguins L. Emmerson and C. Southwell (Australia)
WG-EMM-11/34	A large-scale survey of Adélie penguin breeding distribution in East Antarctica C. Southwell and L. Emmerson (Australia)
WG-EMM-11/35	Proposal of acoustic survey of Antarctic krill using fishing vessel K. Abe, M. Kiyota, F. Matsumoto and Y. Takao (Japan)
WG-EMM-11/36	Research plan and results of preliminary observation about the possibility of Antarctic krill escapement from a trawl net K. Fujita and S. Hasegawa (Japan)
WG-EMM-11/37	Using automated cameras as a cost-effective means of extending land-based predator monitoring C. Southwell, L. Emmerson and K. Newbery (Australia)
WG-EMM-11/38	Some possible modifications to CEMP Standard Methods A3a, A3b and A9 to allow greater flexibility in the collection and interpretation of breeding population count data C. Southwell (Australia)
WG-EMM-11/39	Analysis of variability of krill size and fish by-catch in Japanese krill fishery based on scientific observer data T. Okuda and M. Kiyota (Japan)
WG-EMM-11/40	Annual changes in species composition and abundance of by-catch fish collected by Japanese krill scientific observers in the north of South Georgia (CCAMLR Subarea 48.3), during austral winter from 2002 to 2008 T. Iwami, K. Taki and M. Kiyota (Japan)
WG-EMM-11/41	Antarctic Peninsula decadal winter temperature anomalies and Antarctic krill variability in the South Atlantic region: preliminary results G.P. Milinevsky, A.V. Grytsai and L.K. Pshenichnov (Ukraine)
WG-EMM-11/42	Optimising the design of large-scale ground surveys of Adélie penguin abundance using virtual simulation in a geographic information system C. Southwell, R. Driessen and S. Candy (Australia)

WG-EMM-11/43 Rev. 1	Modelling Antarctic krill: scale, movement and age-structure D. Kinzey, G. Watters and C. Reiss (USA)
WG-EMM-11/44	Some properties of diagnostics of GLMM model tuning for standardising CPUE indices in the Area 48 using the CCAMLR fishery statistics database P. Gasyukov and S. Kasatkina (Russia)

Other documents

WG-EMM-11/P1	Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica W.Z. Trivelpiece, J.T. Hinke, A.K. Miller, C.S. Reiss, S.G. Trivelpiece and G.M. Watters (*Proceedings of the National Academy of Sciences of the United States*, 108 (18) (2011): 7625–7628; published ahead of print 11 April 2011, doi:10.1073/pnas.1016560108)
WG-EMM-11/P2	Occurrence of dwarf minke whales (*Balaenoptera acutorostrata* subsp) around the Antarctic Peninsula J. Acevedo, C. Olavarría, J. Plana, A. Aguayo-Lobo, A. Larrea and L.A. Pastene (*Polar Biol.*, 34 (2011): 313–318, doi: 10.1007/s00300-010-0884-y)
WG-EMM-11/P3	Discrimination of environmental variables that influence the catch per unit effort: the case of the Antarctic krill fishery J.C. Quiroz, R. Wiff, M.A. Barrientos and F. Contreras (*Lat. Am. J. Aquat. Res.*, 39 (1) (2011): 71–81, doi: 10.3856/vol39-issue1-fulltext-7)
WG-EMM-11/P4	Adélie penguin survival: age structure, temporal variability and environmental influences L. Emmerson and C. Southwell (*Oecologia*, in press)
WG-EMM-11/P5	The structure and functioning of marine ecosystem in Argentine Islands waters E.Z. Samyshev (*J. Mar. Ecol.*, 10 (2) (2011): 5–25)
WG-EMM-11/P6	Will krill fare well under Southern Ocean acidification? S. Kawaguchi, H. Kurihara, R. King, L. Hale, T. Berli, J.P. Robinson, A. Ishida, M. Wakita, P. Virtue, S. Nicol and A. Ishimatsu (*Biol. Lett.*, 7 (2) (2011): 288–291, doi:10.1098/rsbl.2010.0777)

WG-EMM-11/P7	Ocean-bottom krill sex S. Kawaguchi, R. Kilpatrick, L. Roberts, R.A. King and S. Nicol (*J. Plankton Res.*, 33 (7) (2011): 1134–1138, doi:10.1093/plankt/fbr006)
WG-EMM-11/P8	Collapse of South Africa's penguins in the early 21st century R.J.M. Crawford, R. Altwegg, B.J. Barham, P.J. Barham, J.M. Durant, B.M. Dyer, D. Geldenhuys, A.B. Makhado, L. Pichegru, P.G. Ryan, L.G. Underhill, L. Upfold, J. Visagie, L.J. Waller and P.A. Whittington (*Afr. J. Mar. Sci.*, 33 (1) (2011): 139–156)
CCAMLR-XXX/5	Report on the independent review of CCAMLR's data management systems Secretariat
WG-SAM-10/10	Factors to consider in designing a systematic observer program for the krill fishery S. Kawaguchi and A. Constable (Australia)
WG-EMM-10/P1	Recent trends in numbers of four species of penguins at the Prince Edward Islands R.J.M. Crawford, P.A. Whittington, L. Upfold, P.G. Ryan, S.L. Petersen, B.M. Dyer and J. Cooper (*Afr. J. Mar. Sci.*, 31 (3) (2009): 419–426)
WG-EMM-10/P2	Recent trends in numbers of Crozet shags breeding at the Prince Edward Islands R.J.M. Crawford, P.G. Ryan, B.M. Dyer and L. Upfold (*Afr. J. Mar. Sci.*, 31 (3) (2009): 427–430)
WG-EMM-10/P3	A tale of two islands: contrasting fortunes for sub-Antarctic skuas at the Prince Edward Islands P.G. Ryan, P.A. Whittington and R.J.M. Crawford (*Afr. J. Mar. Sci.*, 31 (3) (2009): 431–437)
WG-EMM-10/P4	Recent population estimates and trends in numbers of albatrosses and giant petrels breeding at the sub-Antarctic Prince Edward Islands P.G. Ryan, M.G.W. Jones, B.M. Dyer, L. Upfold and R.J.M. Crawford (*Afr. J. Mar. Sci.*, 31 (3) (2009): 409–417)
WG-EMM-10/P5	Estimates of numbers of kelp gulls and Kerguelen and Antarctic terns breeding at the Prince Edward Islands, 1996/97–2008/09 P.A. Whittington, R.J.M. Crawford, B.M. Dyer and P.G. Ryan (*Afr. J. Mar. Sci.*, 31 (3) (2009): 439–444)

WG-EMM-10/P15	Summer survey of fur seals at Prince Edward Island, southern Indian Ocean M.N. Bester, P.G. Ryan and J. Visagie (*Afr. J. Mar. Sci*., 31 (3) (2009): 451–455)
WG-EMM-10/P16	Intra-archipelago moult dispersion of southern elephant seals at the Prince Edward Islands, southern Indian Ocean W.C. Oosthuizen, M.N. Bester, P.J.N. de Bruyn and G.J.G. Hofmeyr (*Afr. J. Mar. Sci*., 31 (3) (2009): 457–462)

APPENDIX D

SUMMARY OF PRESENTATIONS GIVEN AS PART OF THE WG-EMM SYMPOSIUM ON FEEDBACK MANAGEMENT APPROACHES

SUMMARY

1. Six participants gave presentations that provided various perspectives on feedback management with some specific details and objectives. The presentations highlighted that there were many areas of broad agreement between these perspectives. The presenters agreed that feedback management includes monitoring, assessment and decision-making, and that a feedback management approach should use decision rules to adjust activities in response to the state of indicators to achieve the objectives of Article II of the CAMLR Convention. They agreed that there are a wide range of potential indicators of ecosystem state, that uncertainties in understanding of the ecosystem and its state must be addressed in the use of these indicators, and that the range of activities that could be adjusted include research activities as well as the distribution and intensity of fishing effort. The presenters also agreed that feedback management is a valid goal and focus for the Working Group's efforts over the next few years.

INTRODUCTION

2. At the Convener's, Dr G. Watters, request, presentations on feedback management were given by Drs A. Constable (Australia), S. Kasatkina (Russia), M. Kiyota (Japan), G. Milinevsky (Ukraine), P. Trathan (UK) and Watters (USA). Copies of the presentations are available in the Members area of the CCAMLR website (www.ccamlr.org/prm/sc/emm11/emm11info.htm) and the details are summarised below.

PRESENTATION SUMMARIES

3. Dr Constable presented views on feedback management in a risk management system on behalf of himself and Drs S. Kawaguchi, C. Southwell, L. Emmerson, D. Welsford and S. Doust and Prof. S. Nicol from the Australian Antarctic Division. Previous work presented to WG-EMM was summarised, covering requirements (objectives) for feedbacks in managing the krill fishery, progress towards a risk management system in CCAMLR, including work over the last 10 years, points to consider in formulating decision rules for explicit management of Type I and II statistical errors, the need to identify and deal with critical sources of bias in feedback indices, factors to consider in designing field programs to address bias in feedbacks and the value of a staged approach to development of the fishery and the risk management system in order to resolve critical uncertainties in the structure and function of the ecosystem and to test the possible effects of fishing prior to a fully developed fishery. The authors emphasised that there are a number of trade-offs in developing a feedback management procedure to achieve the objectives in Article II. These trade-offs involve choices about the flexibility of the fishery, spatially distributed catch limits, ability to monitor the effects of fishing and the costs of management and fishing versus the value of the fishery.

Prospective evaluation of candidate procedures is needed so that the costs and benefits of different options can be understood and appropriate choices made for achieving the objectives of CCAMLR.

4. Dr Kasatkina compared krill fishing activity with available data on krill-dependent predator requirements. She noted that the annual catch in each year of the fishery has been significantly less than the uncertainty in B_0 estimates from the CCAMLR-2000 Survey and predator demands for krill; the total abundance of predators and their krill consumption are currently not known and it may never be possible to completely specify krill consumption by predators; it may never be possible to correctly describe the krill-centric ecosystem and the variability of ecosystem components influenced by the krill fishery. Given these issues, an appropriate way to develop a feedback management approach might be to identify critical processes and their indicators, and then develop decision rules based on monitoring these indicators. There are important uncertainties in understanding the overlap of fishing activities with krill-dependent predator requirements. It is important to address the following questions:

(i) Is the overlap between krill-dependent predators spatial, functional, or both?

(ii) Do predators and the fishery have distinct krill density requirements?

(iii) Is it possible to manage the fishery based on the critical density for predators?

(iv) Is it possible to avoid fleet localisation in small areas taking into account the spatial–temporal distributions of krill fishable biomass?

(v) Does spatial segregation of fishing grounds and predator foraging areas exist for most fishing and breeding seasons?

Feedback management procedures would require consideration of the spatial–temporal variability of krill biomass distribution and investigation of fishable biomass characteristics, including threshold density, the relationships between fishable biomass and total biomass, relationships between krill aggregation characteristics and fishery performance, and flux effects on krill distribution. Acoustic surveys may provide important information and the presenter discussed how to maximise the utility of research and fishing vessel acoustic data to support developing feedback management procedures.

5. Dr Kiyota gave a presentation pointing out several of the key elements of feedback management and demonstrated possible roles for the commercial fishery in developing the feedback process. His presentation showed that the application of negative feedback control to the management of krill-centred Antarctic ecosystems was challenging, due in part to difficulties related to data collection and the complexity of the system, but also because of our limited ability to control the state of the system, our only control being through fishery manipulation. He also noted that a delay in applying a control signal might pose a risk of making the system unstable. In this context, expanded monitoring is the key element for feedback management, and the fishery can play an important role in this through 'learning by doing' and by 'learning from the past', both of which are key components of systematic

conservation planning. He proposed that reducing uncertainty around fishing operations, timely data collection, and better use of long-term fisheries data, would help in monitoring the impacts of both fishing and of environmental change on krill-based ecosystems.

6. Dr Milinevsky gave a presentation on behalf of himself and Dr L. Pshenichnov (Ukraine). He noted that ecosystem changes are produced by climate variability and sometimes by fishery impacts. Exploitation of the ecosystem can result in negative changes. This is why precautionary management is needed, which is usually applied in the absence of information about the state of krill-dependent predators. In general terms, a system exhibits negative feedback when it acts to reduce the level of a perturbation. Management of the krill-based ecosystem should use negative feedback. We can provide scientifically based advice if we see a negative impact of the krill fishery on ecosystem state (species populations) but one of the key questions is how to separate natural variations from fishery impact. A feedback management scheme includes the following steps: (i) a change is detected in the state of an ecosystem indicator; (ii) we reduce impact on that indicator; and (iii) the ecosystem returns to a previous (undisturbed) state. To provide such a scheme, we need indicators of spatial and temporal differences in ecosystem state, indicators of environmental changes, and methods for diagnosing fishery impacts. The difficult issue of separating natural variations from changes produced by the fishery could be addressed using contrasting areas with different levels of fishing pressure, including reference areas without. A system of reference (unfished) areas and harvest (fished) areas (e.g. based on the current system of SSMUs) would help to distinguish natural impacts from fishery impacts and allow determination (or prediction) of predator population responses to harvesting. Comprehensive information would include: (i) CEMP; (ii) full coverage of the krill fishery by international scientific observers; (iii) data on krill escape mortality; (iv) reliable green-weight measurements. Items (iii) and (iv) provide necessary information about how much krill is removed from the ecosystem. One of the important sources of information, in addition to research surveys, is data from fishing vessels. Until enough scientific information is available, we need to be precautionary enough to protect the krill population as whole.

7. Dr Trathan gave a presentation on behalf of himself and Dr S. Hill (UK). This presentation gave an overview of uncertainties in current understanding of the ecosystem in Subareas 48.1 to 48.4 and suggested monitoring approaches that could provide appropriate indicators in the face of such uncertainty. In particular, it identified fishing vessels as appropriate platforms for fine-scale and meso-scale monitoring of krill stocks and their response to localised fishing impacts. It also suggested that CEMP data, in conjunction with an understanding of predator foraging distributions, is a useful basis for understanding ecosystem response. It discussed evaluation frameworks, including simulation, and noted that there are multiple trade-offs between the costs and benefits of various processes and objectives. It considered the roles and capabilities of the different institutional components of CCAMLR, concluding that feedback management is a complex process and that engagement and cooperation from all of these institutional components is necessary for successful development and implementation. It also emphasised the need to engage with the community of stakeholders, together with scientific linkages to a number of international scientific programs, and it noted that timely demonstration of the benefits of investment in data collection would help reinforce collaboration across CCAMLR.

8. Dr Watters presented various concepts related to feedback management and related these concepts to several practical choices and approaches that could be used to implement a management strategy for the krill fishery. The presentation was co-authored by Mr J. Hinke

(USA), and both authors benefitted from many previous discussions with other scientists within CCAMLR and the US AMLR Program. Dr Watters argued that a feedback strategy should be founded on CEMP, which already provides decades-long baseline time series (thus characterising trends and covariations that already exist in the ecosystem) and useful contrasts across areas and species. Several CEMP indicators are both relevant to the potential for competition between krill-dependent predators and the fishery and are sensitive to changes in the marine ecosystem (e.g. series that indicate predator abundance and condition). It is feasible to expand CEMP (e.g. to include regional estimates of predator abundance) and thereby lessen assumptions that trends at CEMP sites are representative at larger scales. A feedback strategy can use CEMP indicators to adjust the catch limit of krill and the spatial distribution of fishing activity. 'Hockey-stick' models that define decision rules for such adjustments can be parameterised from globally accepted standards (e.g. IUCN criteria for assessing population status) and empirical observations collected at CEMP sites (e.g. relationships between animal condition and subsequent survival). If a feedback strategy for the krill fishery includes no-fishing areas, these decision rules can help the Commission respond to changes that are attributable to fishing. If fishing occurs everywhere, these decision rules can facilitate responses to cumulative changes in the ecosystem.

9. There was broad agreement amongst presenters on the following points:

(i) The components of a feedback management approach are monitoring, assessment and decision-making.

(ii) A feedback management approach should use decision rules to adjust activities in response to the state of indicators to achieve the objectives of Article II of the CAMLR Convention.

(iii) The objectives of Article II must be achieved in the context of a changing ecosystem.

(iv) Management and monitoring should be spatially structured.

(v) A candidate feedback management strategy should be robustly evaluated before implementation.

CONCEPTS

10. The presentations identified a number of key concepts relevant to the development of a feedback management approach, including:

(i) Feedback occurs when the current state of a system influences its future state. Feedback can be negative if it opposes inputs that contributed to the current state, or positive if it reinforces them.

(ii) Indicators are characteristics of the system which give information about the state of a part of the system of interest in the management procedure. They should be able to be repeatedly measured using standardised methods. Some indicators must be analysed in conjunction with others to provide this information.

(iii) Bias and error – measurements of indicators have associated sampling error. The relationship between the indicators and the state of the ecosystem will also have associated uncertainty, including the potential for giving a biased view of the state of the ecosystem.

(iv) Risk management is the coordinated and economical use of resources to minimise, monitor and control the likelihood of undesirable events.

(v) Before-after-control-impact (BACI) is a standard environmental impact assessment design in which the site of a putative impact, and that of an impact-independent control site are monitored before and after the impacting event.

(vi) Learning – there was broad agreement that a feedback management approach includes learning about the ecosystem and its response to change.

FEEDBACK MANAGEMENT

11. The presenters identified a range of views about what constitutes feedback management. There was broad agreement that feedback management includes monitoring, assessment and decision-making, and that a feedback management approach should use decision rules to adjust activities in response to the state of indicators to achieve the objectives of Article II of the CAMLR Convention. Candidate feedback systems included those which restrict fishing in response to indications of a negative impact, those which also relax fishing restrictions in response to indications of positive conditions, and those which control research activities based on the state of the system. It was suggested that a passive feedback system lacks a pre-defined relationship between the state of indicators and the management response whereas an active feedback system incorporates a decision model that provides this relationship. Also, that the current krill management system is a possible feedback system which determines a catch limit based on a synoptic survey of the krill stock. The current assessment model does not include means for (i) taking account of previous states of the krill stock, or (ii) incorporating information about the state of the wider ecosystem into the decision-making process. Most presenters agreed that autonomous decision-making based on pre-defined rules would be extended in a future feedback management system.

INDICATORS

12. One of the main requirements of a feedback management system is a set of indicators of the status of the krill stock. Such indicators do not necessarily need to be direct measurements of the krill stock itself. Some presenters noted the low correspondence between acoustic, survey net-based and CPUE-based estimates of krill density. They identified the krill fishery as a major potential source of information, especially acoustic survey data. They proposed several potential acoustic survey designs to complement existing monitoring programs. These include latitudinal transects and meso-scale grids in the main shelf and shelf-break areas currently used by the fishery. Presenters noted that between-transect variability is not a complete estimate of uncertainty in krill biomass estimates, and that this uncertainty can arise from various sources, including the target identification

approach, the target strength model and the spatial interpolation method. It was suggested that feedback management will require a more detailed assessment of uncertainty in krill biomass.

13. Several presenters identified CEMP as a valuable source of potential indicators. They noted that CEMP has limited spatial coverage and does not currently provide information about the state of some major groups of krill predators, including fish and many flying seabirds. Nonetheless, CEMP time-series might provide appropriate baseline data for a feedback management approach. One presenter suggested that land-based predator abundance and foraging area were important candidate indicators.

14. The presenters discussed possible ways of selecting indicators for a feedback management approach. They noted the importance of existing monitoring data and suggested that the final suite of indicators should be an extension of existing time series, including long-term fishery data. They identified various potentially useful sources of additional information, including science programs such as SOOS, Oceanites and the Southern Ocean Sentinel component of ICED, which include a monitoring component but are not currently linked to CCAMLR. They also discussed the use of recent technologies, including satellite imagery and autonomous/remote control aircraft for collecting data on the abundance of land-based predators.

15. It was suggested that indicators could be selected on their ability to match the following criteria: relevance to making decisions, relationship to the area expected to be impacted, precision, length of existing time series and ease of implementation.

16. Identifying an appropriate suite of indicators will involve trade-offs between the scale versus resolution of monitoring (e.g. the precision of predator abundance estimates is likely to decline as the spatial scale increases), the cost of monitoring and analysis versus the value of the fishery, the utility value of innovation versus that of maintaining time series and the degree to which the indicators are needed in the management procedure.

STATE

17. Presenters noted the dynamic nature of the ecosystem, including the effects of climate variability and change and the recovery of species from over-exploitation. They also noted the uncertainty in many potential indicators. They agreed that these issues would need to be accounted for in developing a feedback management procedure and that some work is needed to interpret Article II in relation to the dynamics of the ecosystem.

18. The presenters recognised that a feedback management system must remain precautionary to minimise the risk of undesirable impacts of the fishery on the krill stock and the ecosystem. It was suggested that decision rules should minimise both Type I (reducing fishing activities based on false identification of an impact) and Type II (not reducing fishing activities due to failure to detect a real impact) errors.

19. The presenters recognised that response times can affect feedback management in a number of ways. Leading indicators are those which respond before more pertinent but slower indicators of ecosystem state (e.g. changes in reproductive output might precede changes in population size). There might be some advantage in using such indicators

although there might be a trade-off between response time and relevance to required ecosystem state. Relying on indicators with slower response times might limit the range of available management options. There is also a risk that delays which are not adequately accounted for might result in ineffectual or counterproductive management responses.

SPATIAL DESIGN

20. The presenters suggested that the spatial structure of the ecosystem and of fishing operations would be key influences on the design of a feedback management approach. It would be appropriate to limit an initial approach to Subareas 48.1 to 48.3 (or 48.4) to match the spatial scale of the current fishery and the main ecological datasets. However, an appropriate objective is to develop an approach that can be expanded to other areas as required. Some subdivision of the overall area into management units (such as the existing SSMUs) is necessary. A spatially structured approach would use indicators of the local state of the system and could allow spatial fishing restrictions. It could also be used to coordinate the spatial distribution of fishing and research effort to study ecosystem response to fishing pressure. Presenters discussed several designs based around contrasting fished and reference areas which are respectively open or closed to fishing. These are variations on the BACI design and require baseline data from both fished and reference areas to detect an impact occurring after the baseline period. The pattern of fished and reference areas could be fixed so that spatial contrasts in ecosystem state provide an indication of fisheries impacts. The pattern could also be manipulated over shorter time-periods, and could incorporate pulse fishing, to actively investigate the system's response to fishing.

21. Some presenters highlighted flux as a major issue, which either must be addressed in the design phase of a feedback management approach or which could be investigated through the use of a feedback management approach.

22. It was suggested that a system of spatial contrasts will limit the spatial flexibility of the fishery and that the cost of maintaining a flexible fishery is a monitoring system which is less able to detect fishing effects and must therefore be more precautionary. However, it was suggested that a contrast-based system requires at least one indicator per area and is therefore sensitive to the loss of indicators, whereas a precautionary system without contrasts could theoretically operate with just one appropriate indicator.

DESIGN QUESTIONS

23. Some presenters considered the form of decision models (the relationship between ecosystem state and management response). Suggestions included an approach based on measuring trends in the difference between the observed state of predator populations in fished and reference areas. This approach detects deviations from a baseline empirical relationship between the temporal patterns of abundance in the two areas. The degree of confidence that a deviation constitutes a real change could be used as one of the input variables in a decision model. While decision models might include a linear region where permitted fishing activity is proportional to ecosystem state, they should also include an asymptote representing a cap on permitted activity. They might also include thresholds below which no activity is permitted.

24. It was suggested that the implementation of feedback management could be staged to ensure that the fishery expansion does not proceed faster than the development of understanding of the ecosystem.

25. Presenters recognised the need to evaluate candidate feedback management systems before implementation. One potentially useful approach is simulation in a management strategy evaluation framework (i.e. testing the approach in a model representing the ecosystem, with appropriate accounting for uncertainty). It is likely that any evaluation framework could lead to iterative improvements in the design of candidate feedback management frameworks, including the collection and use of data. It was suggested that management strategy evaluation can be useful for demonstrating the value of data to data providers such as the fishing industry.

26. Presenters recognised that some of the proposed forms of feedback management require substantial investment of resource and the development of new capabilities by many parts of the CCAMLR community, including the national programs, the fishing industry, the Scientific Committee and its working groups, and the Commission. It was suggested that a concerted community effort, including engagement with appropriate organisations outside CCAMLR, is the most appropriate way to achieve a coordinated and economical use of resources to develop a feedback management approach.