Annex 6

Report of the Working Group on Ecosystem Monitoring and Management
(Santa Cruz de Tenerife, Spain, 2 to 13 July 2012)

CONTENTS

REPORT OF THE WORKING GROUP ON ECOSYSTEM MONITORING AND MANAGEMENT

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INTRODUCTION

Opening of the meeting

1.1 The 2012 meeting of WG-EMM was held at the Centro Oceanográfico de Canarias (COC), Instituto Español de Oceanografía, Santa Cruz de Tenerife, Spain, from 2 to 13 July 2012. The meeting was co-convened by Drs S. Kawaguchi (Australia) and G. Watters (USA) and local arrangements were coordinated by Mr L. López Abellán (COC).

1.2 Drs Kawaguchi and Watters welcomed the participants (Appendix A) and outlined the work plan agreed by the Scientific Committee (SC-CAMLR-XXX, Table 6). The agenda focused on the krill-centric ecosystem and management of the krill fishery and MPAs, including the outcomes from two technical workshops held earlier in 2012.

1.3 The pre-release version of the new CCAMLR website was available during the meeting. The new website features:

- modern design with expandable menus, quick links and related pages
- fully indexed search engine consistent with access security rules
- delegated access control using individual email addresses
- online meeting registration
- internal framework and work flow for authoring, review and translation
- comprehensive document archive, including listing of meeting papers by agenda items.

1.4 The Working Group congratulated the Secretariat for the extensive redevelopment of this online resource, and looked forward to the launch and continued development of the new website.

Adoption of the agenda and organisation of the meeting

1.5 The Working Group discussed the provisional agenda and agreed to expand Item 3 to include consideration of VMEs, and add an item on other ecosystem consideration, including fish-based interactions. The revised agenda was adopted (Appendix B).

1.6 Ten subgroups addressed detailed aspects of the agenda:

- Fishing activities (coordinator: Dr J. Arata, Chile)
- Scientific observations (coordinator: Dr G. Milinevskyi, Ukraine)
- Krill biology, ecology and management (coordinator: Dr A. Constable, Australia)
- Feedback management strategy (coordinator: Dr P. Trathan, UK)
- CEMP and WG-EMM-STAPP (coordinator: Dr C. Southwell, Australia)
- Integrated assessment model (coordinator: Dr Trathan)

- Fishing vessel surveys (coordinator: Dr J. Watkins, UK)
- MPAs (coordinator: Dr S. Grant, UK)
- VMEs (coordinator: Dr B. Sharp, New Zealand)
- Other ecosystem consideration (coordinator: Dr S. Hill, UK).

1.7 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.

1.8 In this report, paragraphs that provide advice to the Scientific Committee and its working groups have been highlighted; these paragraphs are listed in Item 5.

1.9 The report was prepared by Drs L. Emmerson (Australia), Hill, J. Hinke (USA), T. Ichii (Japan), Prof. P. Koubbi (France), Drs P. Penhale (USA), D. Ramm (Data Manager), K. Reid (Science Officer), Sharp, G. Skaret (Norway), V. Siegel (EU), Southwell and Prof. M. Vacchi (Italy).

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

Issues for the present

Fishing activities

Summary report on the fishery

2010/11

2.1 Thirteen vessels from six Members fished for krill in Area 48 during the 2010/11 fishing season and the total catch of krill was 180 992[1] tonnes. The largest catch of krill was taken off the South Orkney Islands in Subarea 48.2 where a total of 111 472 tonnes of krill was taken from the SOW SSMU; this was the highest catch reported from that SSMU since 1990/91. The other main area fished during the season was South Georgia, where 53 112 tonnes were taken from the SGE SSMU. The remainder of the catch was taken predominantly at the Antarctic Peninsula in Subarea 48.1, including 7 970 tonnes from the APDPE SSMU (WG-EMM-12/05, Table 5).

2.2 Two vessels used the continuous fishing system (*Saga Sea* and *Thorshøvdi*, now renamed *Antarctic Sea*) and accounted for approximately 49% of the total catch. Norway reported the largest catches of krill with a total of 102 460 tonnes, the Republic of Korea reported 30 642 tonnes, Japan reported a catch of 26 390 tonnes, the People's Republic of China reported 16 020[1] tonnes, Poland reported 3 044 tonnes and Chile reported 2 436 tonnes.

2.3 The catches of krill in 2010/11 did not trigger any closures in the fishery.

[1] Revised by the Secretariat during the meeting

2011/12

2.4 Nine vessels licensed from five Members (Chile, People's Republic of China, Japan, Republic of Korea and Norway) have fished for krill in Area 48 up to May 2012. The total catch reported to May 2012 was 78 468 tonnes, mostly taken from Subarea 48.1 in December, April and May. Approximately 60% of the catch reported so far this season has been taken by a single vessel (*Saga Sea*) using the continuous fishing system and pelagic beam trawls.

2.5 Based on the catch reported to May 2012, the equivalent catch reported to May in the previous five seasons, and the total catches in those seasons, forecast of the total catch for the current season falls within the approximate range of 108 000 to 151 000 tonnes. The trajectory of the cumulative catch in 2011/12 is currently in the lower range of the catch trajectories observed in the past five seasons.

2.6 The Working Group noted that the forecasted total catch of krill should be interpreted cautiously since the trajectory pattern of monthly cumulative catch in 2011/12 indicated a linear monthly increase in catches and is very different to the sigmoidal increase in catches from the previous five seasons. In addition, the sea-ice coverage in winter 2012 was unusually low in Subarea 48.1 (see also SC-CAMLR-XXX, Annex 4, paragraph 2.6).

Notifications for the 2012/13 fishing season

2.7 Eight Members submitted notifications for a total of 19 vessels intending to participate in krill fisheries during the 2012/13 fishing season. Six new vessels are intending to enter the fishery: two vessels from each of Germany and Ukraine and one vessel from each of Chile and Poland. 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 notified catch for 2012/13 was 672 700 tonnes, the highest notified catch in Area 48 so far (WG-EMM-12/05, Figure 6).

2.8 The Working Group noted that Germany has notified, for the first time, its intent to harvest a total of 150 000 tonnes of krill with two vessels, and Poland, which is a long-standing krill fishing nation with recent catches of 3 000–8 000 tonnes, has notified as much as 150 000 tonnes with two vessels.

2.9 Dr Siegel informed the Working Group that a meeting between the fishing companies and relevant scientists is scheduled in Germany for late July 2012 and further information will be available to the Scientific Committee. The Working Group noted that Poland had submitted a notification to fish for krill in 2012/13 but was not represented at the meeting, and reiterated its request for all Members engaged in the fishery to provide scientists to the relevant working group.

2.10 The Working Group noted that the notified catch for Area 48 in 2012/13 is the highest on record and in excess of the trigger level of 620 000 tonnes, but considering the discrepancy between notified and actual catches in the past, the notifications are likely to be more indicative of the total capacity of the vessels rather than their actual expectations to achieve those catches.

2.11 The Working Group reviewed all notifications received and confirmed that all basic information have been provided. However, the Working Group did note the following in respect of the inconsistencies between notifications:

- in many cases, the indications of proposed catches, fishing areas and dates do not necessarily provide the information on their exact plans regarding spatial and temporal fishing patterns

- notifications from four Members were using a previous version of the notification form in CM 21/03, Annex 21-03/A, which was revised by the Commission in 2010 (as provided by the Secretariat in COMM CIRC 12/45).

Green weight

2.12 The Working Group recalled the Scientific Committee's previous advice that all methods for estimating green weight of krill have associated uncertainty, and that the absolute uncertainty in catch estimates increases in proportion to the catch (SC-CAMLR-XXX, paragraph 3.14). It noted that this uncertainty is not accounted for in the current management process which uses an estimate of total catch without any uncertainty associated with that estimate, and that the Scientific Committee requested that the Working Group characterise such variability and uncertainty to investigate their impacts on krill management advice.

2.13 The Working Group agreed that total removals of krill should not exceed the total allowable catch, that reported catches have errors in their estimation and the level of error in reported catches is dependent on the process by which the reported catch is estimated, which may vary between product types, vessels and inherent attributes of krill in a given time of year.

2.14 Given the errors in determination of the reported catch, a fishery may need to be closed when the reported catch is less than the total allowable catch in order that the total removals have no more than an agreed probability of exceeding the total allowable catch. The acceptable level of risk that the total removals exceed the total allowable catch needs to be determined by the Commission.

2.15 Notifications to fish for krill in the 2012/13 fishing season contained descriptions of a range of different methods for estimating green weight (i.e. conversion factors, codend estimate, cubic metre of the holding tank, flow scale, flow meter) (WG-EMM-12/06 to 12/13). However, these notifications did not include sufficient details of the methods to estimate the green weight of krill caught and the exact method of how each of the conversion factors were derived.

2.16 The Working Group recognised that it did not currently have the necessary detailed information and data to estimate the uncertainty associated with green weight reported by vessels or for understanding the underlying variability in the constants used for making these estimations. A more detailed description of this issue and a process by which the required information and data could be acquired is described in Appendix D.

2.17 The Working Group recommended that the information presented in Table 2 of Appendix D provided a clear indication of what should be included in the 'description of the exact detailed method of estimation of the green weight of krill caught' required in the notifications for the krill fishery (CM 21-03, Annex 21-03/A) and that Members submitting notifications should refer to this table as a guide when completing the notification.

2.18 The Co-conveners of WG-EMM agreed to forward Appendix D and the relevant recommendations of the Working Group to all Members who had submitted a notification under CM 21-03 for the 2012/13 season in order to prepare a paper, based on Appendix D, for the Scientific Committee to progress the issue of green weight estimation arising from the discussions held at WG-EMM.

2.19 The Working Group encouraged Members to further explore the relationship between estimates of catch from the same haul as derived at different points along the production line (e.g. flow meter vs. conversion factors or codend estimates vs. conversion factors) as suggested in SC-CAMLR-XXX, Annex 4, paragraph 2.56, in order to understand accurately the different conversion factors for different production lines.

2.20 The Working Group agreed that the catch reporting form C1, used to submit catch data as required in CM 23-06, should be updated to facilitate the submission of the following relevant information:

- indicate the method used for estimating the green weight (i.e. as in Appendix D, Table 2)

- report haul-by-haul the measurement of the haul-specific attribute (i.e. the 'H_h' height of the krill catch in the holding tank) and other constants used.

2.21 The Working Group requested that the multipliers used to convert the measured component of the catch to an estimate of green weight should be estimated at least once every reporting period where those reporting periods are specified in CM 23-06.

2.22 Arising from the analysis of the descriptions of the methods for estimating green weight, the Working Group agreed that a parameter common to all methods and which is likely to vary throughout the fishing season, but is currently not reported in any of the notifications, is the estimation of the volume to weight conversion factor (parameter Rho (ρ) in Appendix D, Table 2). The Working Group agreed that the method for estimating Rho provided in Appendix D could be suitable for providing the necessary information on volume to weight conversion.

2.23 Recognising that the reporting of catch is a Flag State responsibility, the Working Group recognised that this process could be done by, or with the aid of, the scientific observer. Likewise, scientific observers could aid in providing detailed descriptions of the method(s) used on the vessels to estimate each parameter in the relevant equation in Appendix D, Table 2, including an evaluation of the associated uncertainty.

Data from former Soviet krill fishing expeditions

2.24 In 2009, Drs Milinevskyi and L. Pshenichnov (Ukraine) initiated a project to digitise haul-by-haul catch and effort data from 54 former Soviet krill fishing expeditions between 1973 and 1992. These data were uploaded to the CCAMLR database in 2011.

Drs Milinevskyi and Pshenichnov then proposed processing of the biological data from these expeditions, should the funding allow. These data, when available, would be integrated in the CCAMLR database. Drs Milinevskyi and Pshenichnov noted that the funding arrangement for processing the biological data had not eventuated.

2.25 The Working Group asked whether the Scientific Committee is able to consider potential ways for allocating funding for supporting the continuation of the project to digitise the historical biological data (see also SC-CAMLR-XXVIII, paragraphs 13.8 to 13.10).

Krill fishery analysis

2.26 WG-EMM-12/15 examined the distribution of spatial management and Antarctic krill (*Euphausia superba*) catch across pelagic bioregions in the Southern Ocean by developing a GIS. Krill fishing activity in Area 48 from 1995 to 2010 was identified to occur in only 26% of the area open to krill fishing and was concentrated in three of the seven bioregions found in this area (see also paragraphs 3.69 and 3.70).

2.27 WG-EMM-12/35 presented a description of krill distribution in the Indian sector of the Southern Ocean (Divisions 58.4.1 and 58.4.2) based on commercial fishing data from the former Soviet fleet from 1977 to 1984. Fishable krill aggregations occurred off the continental shelf (i.e. depths deeper than 1 000 m). The fishery in the sector ceased due to operational impediments arising from remoteness of the area from the ports as well as the availability of alternative fishing areas.

2.28 WG-EMM-12/30 described krill fishing activities in Subareas 48.1, 48.2 and 48.3 by the Chilean-flagged vessel *Betanzos* during June 2011 and April 2012. It highlighted the distributions of effort, catches, trawl depths and fishing yields and length-frequency distribution of krill. The Working Group noted that if the vessel operates in similar areas and months during 2012/13, this would provide an opportunity to examine potential changes in fishing proficiency of new fishing operators.

2.29 WG-EMM-12/50 analysed the space–time dynamics of the krill fishery in Area 48 and its relation to climate variability using the CCAMLR fishery data and a time series of the Antarctic Oscillation Index (AAO) as an indicator of climate variability between 1986 and 2011. Changes in seasonal distribution of krill catch from 1996 to 2011 compared with previous seasons (1986–1995) were observed; this seasonal shift of the fishing period towards autumn–winter months had been associated with climate variability. The most significant shift of the fishery regime occurred in 2006, when fishery transferred to the state of high CPUE from 2006 to 2011. This period is characterised by the highest values of CPUE index and AAO index reached in Area 48 for the whole 1986–2011 observation period. The significant positive correlation coefficients between CPUE and AAO trends provide evidence that the ongoing climate changes are one of the reasons for the revealed changes in the fishery regime. At the same time, the lack or weakness of correlation between the trends of interannual CPUE dynamics between Subareas 48.1, 48.2 and 48.3, and increasing of the Subarea 48.1 contribution to the total dynamics of fishery in Area 48 in the recent years, were observed.

2.30 The Working Group welcomed the analysis as an important contribution to improve our understanding of the krill fishery dynamics in relation to climate change. With regard to the high CPUE regime from 2006 to 2011, the Working Group postulated that this may have arisen from an increase in the catch rates of vessels using the continuous fishing system. The shift of the fishing season towards autumn–winter may have resulted from changes in the krill fishing operation and market-related considerations and strategies. The Working Group encouraged the authors to consider how much of the changes observed in recent years can be attributed to changes in fishing technology.

Krill escape mortality

2.31 A preliminary observation on krill escape mortality through trawl nets was made using an underwater video camera attached on the trawl net of the Japanese commercial trawler *Fukuei Maru* in 2011 (WG-EMM-12/66). Few krill were observed to escape from the posterior part (mesh size of 70 mm) of the trawl net, but a high proportion of krill was observed to escape from the anterior part (mesh size of 150 mm) of the net. Video footage from the anterior part of the trawl net showed that krill swam actively after they escaped through the net, suggesting that their escape mortality may be low. The Working Group noted that a higher rate of krill passing through the larger mesh may be associated with a lower rate of krill being killed as a result of collision with the net, whereas the opposite has been shown for 60 mm mesh sizes in previous years; e.g. WG-EMM-11/15 reported that the equivalent of 2% to 3% of the retained catch passed through the net, of which 60% to 70% were killed.

2.32 WG-EMM-12/43 described methods for the investigation of krill escape mortality, building on the Russian history of research on interactions of krill with trawls. The paper described the use of small-mesh catchers (chafers) on the outside of trawl nets to collect and retain krill that pass through the mesh during towing. The description of chafer construction and its installation on trawl nets was shown. The survival rate of krill after they passed through the trawl net was determined by monitoring survival rates of those krill in a seawater aquarium for over 24 hours.

2.33 The Working Group noted potential difficulties in defining an objective criterion for krill survival after passing through the trawl net in the aquarium and therefore encouraged authors to submit further information and results obtained from this experiment. The Working Group noted that this study provides useful information for developing a standard methodology to quantify escape mortality in the krill fishery.

2.34 WG-EMM-12/24 described a three-year project (commenced in 2012) to apply a mathematical modelling tool (FISHSELECT), designed to investigate the relationship between morphology of marine organisms and net design in order to predict basic selective characteristics of different trawls. Results will be used to quantify the theoretical catch efficiency and escapement of krill for different net designs, and also to construct design guides to minimise escape mortality. The Working Group looked forward to seeing the results of the project.

Finfish by-catch

2.35 WG-EMM-12/28 analysed variables influencing finfish by-catch in the krill fishery in Area 48 using a delta-lognormal modelling approach based on scientific observer data collected on the *Saga Sea* between 2007 and 2012. There was a wide disparity in the influence of the explanatory variables, i.e. time of day, krill catch, sea-surface temperature (SST), bottom depth and fishing depth and season, on the presence of finfish in by-catch, which varies markedly by taxonomic grouping to the family level (the lowest level of identification that could be achieved) and CCAMLR subarea. There were, however, some trends which persisted across subareas and taxonomic families, the most notable observed trend being the reduced by-catch ratio for all families of finfish investigated in dense krill aggregations, which is consistent with the literature.

2.36 WG-EMM-12/29 used the model as described in WG-EMM-12/28 to estimate total finfish by-catch by the *Saga Sea*. The methodology provided quantitative analysis of the impact of the krill fishery on finfish species at a family level, as well as for individual species. Estimates of total unrealised spawning biomass of the by-catch (i.e. the spawning biomass that the small fish caught in the krill fishery would have contributed to the population) from the *Saga Sea* suggested that finfish by-catch rates of the vessel are unlikely to impact on the finfish stock biomass in Area 48.

2.37 The Working Group noted that these two studies are useful to understand the potential impact of the krill fishery on finfish stocks. The Working Group requested the methodologies and assumptions of these two papers be reviewed by WG-FSA.

Scientific observation

2.38 Analyses of the scientific observer coverage during the 2010 and 2011 fishing seasons were presented in WG-EMM-12/60, 12/64 Rev. 1 and 12/65. In 2010 there were 10 vessels in the fishery and there were observers on nine of these vessels with an overall rate of vessel × month coverage (i.e. the number of months when observer data were collected as a percentage of the months when fishing occurred) of 80%, in 2011 there were 13 vessels of which 12 carried observers with an overall rate of vessel × month coverage of 90%. The Working Group appreciated this level of coverage and noted that scientific data had been collected in all months and subareas where the fishery had operated and had greatly exceeded the minimum requirements in CM 51-06.

2.39 The Working Group agreed that the improvements in coverage and quality of data collected on krill length measurements were evident in the analyses presented in WG-EMM-12/60 and 12/67. Both of these analyses indicated that variability in the length-frequency distribution of krill was predominantly at the scale of subarea and month, suggesting that aggregating krill length data at those scales was appropriate for analysing krill population processes. The analysis of the remaining between-haul variability, having accounted for the spatio–temporal factors, indicated that, while there remained an effect of vessel, there was no effect of fishing method.

2.40 The between-haul variability in krill length-frequency distributions showed a distinct seasonal pattern and was greatest during the period November to February. The Working Group recommended that the sampling frequency should be increased between November and February to collect samples at three-day intervals, while continuing sampling at the current five-day periods between March and October, noting that this sampling frequency would be reviewed in future when more data become available.

2.41 The Working Group thanked the authors of WG-EMM-12/60 and 12/67 and encouraged further collaboration between the Secretariat and Members in developing these types of analyses.

2.42 In contrast to the similarity between vessels in the krill length measurements there were substantial differences in the reported fish by-catch between vessels. The Working Group recognised that conducting a fishery-wide analysis of fish by-catch was confounded by variability in the data quality and quantity between vessels. However, noting also the analysis in WG-EMM-11/39 and WG-EMM-12/28 and 12/29, the Working Group agreed that improving the overall quality of fish by-catch data should be a priority for scientific observers.

2.43 The Working Group discussed a proposal for a three-year study to provide an improved understanding of the magnitude, species and size composition of fish by-catch in the krill fishery. This study would require the collection of fish by-catch data in all months and areas that the fishery operates and would require clarity in the sampling protocols to be used. The Working Group recalled the decision to remove the old K5 fish by-catch form from the observer logbook and stressed the importance of using the most recent version of the e-logbook and the K10 forms in order to avoid any confusion over the reporting protocol of fish by-catch.

2.44 The identification of fish that occur as by-catch in the krill fishery at the level of species (including larval fish) is a specialist task, and the availability of technically qualified observers may mean that it is not possible to collect high-quality data on all vessels throughout the entire period of the fishery. In order to address this, the Working Group agreed that there was a need to improve observer training, possibly through workshops hosted by Members, as well as development of field guides (possibly similar to the CCAMLR VME taxa classification guide – www.ccamlr.org/node/74322) and suitable data collection protocols that allowed data collection at appropriate taxonomic levels.

2.45 Feedback from observers suggested that there are contradictory instructions in the *Scientific Observers Manual* and the logbooks that cause confusion, and the Working Group noted the discussion of sampling requirements for observers in all CCAMLR fisheries by the Scientific Committee (SC-CAMLR-XXX, paragraph 7.15). The Working Group encouraged simplifying the observer logbooks to make them more efficient for observers on krill fishing vessels.

2.46 The Working Group recalled the request from the Scientific Committee to consider the potential conflict between the sampling flexibility allowed in the instructions in the *Scientific Observers Manual* and the precise requirements of paragraph 3(ii) of CM 51-06. The number of hauls per day ranged from 3 to 20 between vessels in the krill fishery in 2010 and 2011, therefore specifying a fixed target coverage rate would result in uneven data collection between vessels.

2.47 The Working Group recommended that the target coverage of at least 20% of hauls or haul units be removed from paragraph 3(ii) of CM 51-06, noting that the sampling rates for the priority items of krill length measurement and fish by-catch are specified as a sampling requirement on a per-fishing-day basis rather than as a haul-based rate.

2.48 In reviewing the potential future requirements for the collection of scientific observer data in the krill fishery, the Working Group agreed that it was desirable to maintain the rate of observer coverage that had been achieved in the 2010 and 2011 fishing seasons (paragraph 2.38) as this had been shown to provide a large improvement in quantity and quality of data required by the Scientific Committee to achieve its objectives. However, noting the potential constraints arising from the availability of suitably qualified observers, the Working Group agreed that in revising CM 51-06 it will be important to specify a rate of vessel coverage that maintains the current level of coverage and allows flexibility in the deployment of observers to ensure that data quality is not compromised.

2.49 The Working Group recommended that those vessels that do not carry observers for all of their fishing operations should have an observer on board during some period of their fishing activity in each year. However, the Working Group suggested that a decision on the required level of observer coverage rate (time period when observer data is collected as a proportion of the time period that the vessel is fishing) that is specified in the conservation measure is a matter for the Commission.

Krill ecology and management

Krill biology

2.50 WG-EMM-12/32 presented preliminary results of the impacts of ocean acidification due to elevated seawater pCO_2 and reduced pH levels on the activity, mortality and moulting of post-larval krill. The experimental system was set up at pCO_2 levels of 380, 1 000 and 2 000 μatm. Krill activity levels were recorded and growth rate was measured using the instantaneous growth rate (IGR) method, and seawater carbonate chemistry was measured in detail:

(i) Results showed that in general, krill mortality was greater in animals exposed to increased levels of pCO_2 compared to controls. At the same time neither the IGR nor the inter-moult period (IMP) were significantly influenced by exposure to the increased pCO_2 levels. Krill activity levels were found to be significantly reduced when exposed to increased pCO_2. Other qualitative observations indicated bacterial growth on poor-conditioned animals, unconsumed phytoplankton, and increasing inability to properly complete the moulting cycles.

(ii) Projection for the year 2100 suggested that pCO_2 maxima could approach close to 1 400 ppm, although its distribution will be highly variable in space and depth. The authors therefore concluded that krill could be negatively affected by elevated CO_2 within the range projected for 2100 in some regions of the Southern Ocean.

(iii) Furthermore, the authors stressed that ocean warming and acidification, together with other environmental change, are likely to occur concurrently. They therefore argued for the establishment of a physiology-based krill growth and a life-history model which must be responsive to climate change scenarios, including ocean acidification.

2.51 The Working Group welcomed these new research activities as being of high relevance, because there is an increased body of evidence showing the impact of climate change on biological and ecological traits in the Southern Ocean which will need to be considered in its advice to the Scientific Committee on managing the krill stocks as soon as possible.

2.52 In this regard the Working Group also noted the very recent publication of the report of the EU/NL-sponsored workshop on climate change impacts on the krill-centric ecosystem in *Marine Ecology Progress Series* in which many CCAMLR scientists were actively involved.

2.53 WG-EMM-12/38 reviewed approaches to assess productivity of krill and what will be needed to account for its regional variation and long-term trends when establishing sustainable catch limits for krill. It reviewed the models available in the literature for growth and reproduction. A growth model is proposed that is based on observed instantaneous growth rates and takes account of the physiological response of krill to the amount of food consumed, the temperature and the investment in reproduction.

2.54 The new model in WG-EMM-12/38 aims to facilitate adaptation of production models to changing environments. The energetic moult-cycle model presented here utilises field observations of growth and can take account of important factors that vary in space and time, notably temperature and food. A great challenge for all models will be to take account of movement of krill during their life cycle between areas under spatially and temporally varying environmental and ecological conditions.

2.55 The Working Group welcomed the growth model presented in WG-EMM-12/38 and noted that the proposed model represents a revision and further development of the model presented to WG-EMM at its 2006 meeting. The Working Group regarded the progress made as an important step forward and realised that results of the model outputs well reflect published data on krill growth. Furthermore, it regarded the flexibility of the model as a great improvement to take account of reproduction, difference between males and females and changes in primary production due to climate change.

2.56 The Working Group recalled that results based on the von Bertalanffy growth function (VBGF) are acceptable for short-term predictions, however, continued use of these models would require a re-estimation of the parameters for different regions and periods.

2.57 The Working Group therefore recommended the proposed new growth model for Antarctic krill based on energetics and knowledge of the moult cycle should be submitted to WG-SAM for review to be incorporated into future assessments of yield for krill and in developing feedback management procedures.

Krill-based food web

2.58 WG-EMM has developed and used ecosystem models to evaluate options for spatially allocating the krill catch in Subareas 48.1 to 48.3. The Working Group is likely to use such models for evaluating feedback management options and other future tasks. WG-EMM-12/20 Rev. 1 proposed a formal and strategic framework for assessing uncertainty in ecosystem models, provided a general sensitivity analysis for the FOOSA model (WG-EMM-06/22), and described an algorithmic calculation of initial steady-state parameters.

2.59 The study considered multiple output variables, which had previously been used by WG-EMM and which differed markedly in their sensitivity to perturbations to input variables. Results indicated that overall FOOSA is stable, but results are sensitive to parameters estimated in the conditioning process.

2.60 The Working Group welcomed the presentation of results as wheel plots. It agreed that sensitivity analyses are important to future applications of models. Such analyses may also be useful for guiding data collection. For example, WG-EMM-12/20 Rev. 1 highlighted the importance of parameters describing penguin winter mortality, and the krill population response to environmental forcing. The Working Group noted that there are trade-offs in terms of the prioritisation of effort between model development, model evaluation and data collection for model validation.

Krill assessment

2.61 WG-EMM-12/31 presented a recalculation of krill biomass for the 2006 BROKE-West summer survey in Division 58.4.2, applying the advice from SG-ASAM. Four data processing updates were applied. Two amendments were related to the calculation of mean volume backscattering strength within elementary distance sampling units and the integration interval. The other changes were related to revised krill target strength estimation and subsequent acoustic target identification.

2.62 The Working Group noted that the analysis could be improved by using the parameterisation of krill orientation distribution in the target strength model derived at SG-ASAM-10 for the reanalysis of the CCAMLR-2000 Survey. Consequently, the assessment of WG-EMM-12/31 was updated during the WG-EMM meeting with that krill orientation distribution.

2.63 The Working Group estimated B_0 in Division 58.4.2 during 2006 to be 24.48 million tonnes (CV 0.20). On the subdivision level, the revised estimates were 14.87 million tonnes (CV 0.22) for the western area, and 8.05 million tonnes (CV 0.33) for the eastern area.

2.64 The Working Group noted that the revision of the assessment resulted in smaller biomass estimates than used for the yield estimates in 2010. However, the Working Group expressed the opinion that it would not recommend a recalculation of the potential yield and a change of the existing CM 51-03 (2008) this year because of work needed to improve parameterisation of recruitment variation in the GYM and the work in progress on this matter (see paragraphs 2.69 to 2.71). The Working Group also noted that there are no pending notifications for the krill fishery in the area for the 2012/13 season, which would allow time for work on the GYM.

2.65 WG-EMM-12/26 presented an analysis of krill sampling data which were supplied to the GYM as the ‘vector of recruitments’ input option to simulate the population dynamics of krill in the Antarctic Peninsula region (Subarea 48.1) under various assumptions. Simulations were run for 21 years with either no fishing, or with fishing at yields representing either the trigger level (gamma = 0.0103), the current precautionary catch limit (gamma = 0.093) or half the precautionary catch limit (gamma = 0.0465). Natural mortalities were set at either the 'base-case' value (M = 0.8), 'variable mortality' (M with a uniform distribution between 2 and 0.8) and 'high mortality' (M = 3). CVs of either 0%, 10%, 20% or 30% were added to the observed recruitment values.

2.66 Past modelling studies on the effects of different harvest levels on the Antarctic krill population using the CCAMLR decision rules have been based on the Beta distribution or 'proportional' option for recruitment. However, when levels of variance in proportional recruitment above 0.176 were assigned, the GYM projections started terminating prematurely, so the effects of higher values of recruitment variability were not able to be consistently assessed (SC-CAMLR-XXIX, Annex 6, paragraphs 2.76 and 2.77). The current study therefore used a data series for recruitment in the GYM based on the observed size frequencies in net samples rather than on a theoretical distribution.

2.67 The base-case study (natural mortality set to 0.8 with no additional CV on the recruitment vector) showed that catch levels up to half the precautionary catch level did not trigger either decision rule. At the highest level of catch, the precautionary catch level (gamma ≈ 0.09), two of the four recruitment vectors triggered the depletion rule. This indicates that populations would not support sustained catches of about 9% of unfished biomass under the depletion rule.

2.68 In general, as the values for natural mortality and additional recruitment variability were increased beyond the base-case values, fewer of the simulation scenarios were able to achieve the CCAMLR 'depletion' decision rule. The results indicated that, as gamma was increased, the distribution of spawning stock biomasses shifted towards having more trials that ended with lower biomass.

2.69 Another important aspect of the current analysis indicated that for most years the size distributions in the AMLR database have either a high proportion or a low proportion of recruits, with fewer years having intermediate proportions of recruits rather than the continuous decline assumed by the Beta distribution. There is also some indication from the integrated model (paragraphs 2.159 to 2.161) that recruitment might be serially correlated over time, with good recruitment periods of a year or two occurring on approximately a five-year cycle.

2.70 The Working Group welcomed the progress made on the recruitment variability and recalled that the high variation in recruitment of the icefish stocks around South Georgia triggered the recruitment criteria even without fishing. As a consequence, the GYM is only used for short-term predictions in the assessment and the decision rules were modified to reflect conditions relative to a no-fishing scenario rather than B_0.

2.71 The Working Group pointed out that the current analysis indicated areal differences in the sensitivity of the gamma level when mortality and recruitment variability was to be increased. In the past the GYM has always been applied to Area 48 as a whole. Areal differences in recruitment had not been considered.

Future assessments, timetable, work plan

2.72 The Working Group agreed that its future work plan shall focus on:

- accommodating krill recruitment better in current assessments
- review the decision rules for the krill fishery in light of climate change.

2.73 The Working Group advised the Scientific Committee that it does not recommend changes to the current conservation measures related to krill catch limits (CM 51-01, 51-02 and 51-03) this year, and reiterated that for Area 48 (CM 51-07) and Division 58.4.2 (CM 51-03) the existing subdivisions of catch limits and trigger levels should remain in force. However, the Working Group also highlighted to the Scientific Committee that the catch limit for Division 58.4.1 is subdivided into two subdivisions (CM 51-02), but that there is no trigger level that can be regarded as a safeguard until new assessment approaches will be developed.

Issues for the future

Feedback management strategy

Introduction

2.74 The Working Group recalled its plan for future work concerning the development of a feedback management strategy for the krill fishery (SC-CAMLR-XXX, Annex 4, paragraphs 2.149 to 2.192), which included:

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.

2.75 The Working Group noted that the Scientific Committee had considered the proposed work schedule (SC-CAMLR-XXX, paragraphs 3.33 to 3.35) and had agreed that WG-EMM should consider elements 1 and 2 of feedback management development in 2012, elements 3 to 4 in 2013 and elements 5 to 6 in 2014.

2.76 The Working Group structured its discussion of feedback management elements 1 and 2 by considering:

(i) general monitoring issues
(ii) land-based predator monitoring issues
(iii) krill-related monitoring issues
(iv) candidate feedback management approaches.

General monitoring issues

2.77 The Working Group recognised that the current precautionary approach for krill management uses the GYM and projections based on the results from the CCAMLR-2000 Survey. The Working Group noted that the current management approach could be extended by utilising more frequent assessments of krill biomass, and that this would thus become a feedback management approach. The Working Group recalled (SC-CAMLR-XXX, Annex 4, paragraphs 2.149 to 2.192) that various other indicators could also be used in feedback management, including indicators of predator status and trends and indicators from the krill fishery.

2.78 The Working Group considered three papers (WG-EMM-12/P04, 12/P05 and 12/P06) that respectively describe: prior development of the precautionary approach to fisheries management; the development of CEMP; and ongoing work to consider how monitoring data, such as that collected by CEMP, could be used to implement a feedback management strategy for the krill fishery in Area 48. Important issues that arise from these papers relate to how a new management strategy would be formed, what indicators would be required for that strategy, how monitoring of the ecosystem would provide those indicators, and how decision rules would be developed to facilitate decision making.

2.79 WG-EMM-12/P04, 12/P05 and 12/P06 suggested that (i) estimates of predator production derived from consumption of a target species, (ii) predator abundance, and (iii) predator recruitment, all provide useful indices for the development of a candidate feedback management approach. The Working Group agreed that such indices, with either proximate or ultimate relationships to variability in krill stocks, may provide important information for CCAMLR to take necessary management actions.

2.80 The Working Group also recognised that CCAMLR may wish to take action in managing the krill fishery, regardless of the causal mechanism involved. For example, if monitoring data were to indicate that predators were decreasing in Area 48, possibly because of ecosystem changes related to climate change, CCAMLR may wish to alter the distribution and intensity of harvesting.

2.81 WG-EMM-12/P06 reviewed CCAMLR's experience in the development of ecosystem-based fisheries management. The paper considered how food-web models and simulation approaches can be used as operating models to evaluate alternative feedback management approaches and how they could be used as assessment models. The Working Group noted that food-web models can be used to examine broad-scale changes in the dynamics of components of the ecosystem, particularly those due to effects of climate change.

The Working Group agreed that a combination of monitoring data and food-web models that use such monitoring data provide useful information on ecosystem status and trends and that both would be useful in the development of a feedback management approach.

2.82 The Working Group next discussed WG-EMM-12/45 and 12/59, which highlighted the potential for international collaborative work with the SCOR Working Group for Identifying Ecosystem Essential Ocean Variables for Measuring Change in the Biological Properties of Marine Ecosystems and the ICED Southern Ocean Sentinel (SOS) program for measuring and monitoring the status and trends of Southern Ocean ecosystems. The programs are currently considering plans for data collation and coordination and plans for large-scale surveys to provide estimates of the biological status of the Southern Ocean on a circumpolar scale.

2.83 The Working Group noted that the SOS included a program of work to estimate the ecological status of the Southern Ocean by 2020. The program of work includes the development of a set of ecosystem indicators by 2016, evaluating designs of the multinational proposal to benchmark Southern Ocean ecosystems by 2017, development of methods for assessing status and change of Southern Ocean ecosystems based on the indicators by 2015, and finalising an implementation plan for benchmarking by 2017. The Working Group noted that the time frames for implementing these two international programs might not align with CCAMLR's plans for the development of feedback management. However, the Working Group recognised that these programs provide valuable opportunities to collaborate with experts outside CCAMLR with regard to issues related to indicators for feedback management, and encouraged Members to develop collaborations with such international programs to the extent possible.

2.84 The Working Group recognised that Members contributing time series of monitoring data for management purposes, such as CEMP data or mesoscale krill surveys, continually face challenges in securing the resources needed for maintaining their programs. The Working Group therefore wished to bring to the attention of the Scientific Committee the value of these programs, and their potential utility in feedback management.

2.85 The Working Group noted that candidate management approaches that depend on monitoring data that are collected on a voluntary basis should include a consideration of the consequences of that monitoring data becoming unavailable in the future.

Land-based predator monitoring issues

2.86 The Working Group considered several papers related to the monitoring of land-based predators and potential indicators arising from such monitoring activity that could be used to inform a candidate feedback management approach. These papers included WG-EMM-12/04, 12/16, 12/17, 12/18, 12/22, 12/39, 12/58 and 12/71. These papers reviewed topics relevant to monitoring the status and trends of krill-dependent predators, including:

(i) expansion of current monitoring methods to new monitoring sites
(ii) development of new monitoring methods
(iii) theoretical models of changes in population abundance

(iv) reviews of CEMP data in terms of interannual variability
(v) measurement of functional responses
(vi) mechanistic relationships between indicator and indicated variables.

The Working Group focused its discussion of these papers on their role in identifying candidate feedback monitoring indicators.

2.87 The Working Group noted that these papers, as well as those discussed in paragraphs 2.118 to 2.120 focused on a restricted set of predator indices that could be used in a candidate feedback management approach. Specifically, the papers included options for the use of predator abundance, offspring fledging mass, reproductive success, diet composition and combined indices as potential indicators for use in a feedback management approach.

2.88 The Working Group agreed that a particular indicator for a feedback management approach need not necessarily constitute a single predator index and that multiple indices could be combined via a statistical procedure to derive a single composite indicator of ecosystem status for use in a candidate feedback monitoring approach. For example, reproductive success and fledging mass could be combined to provide an indicator of per capita reproductive success as an index of predator fitness, or multiple indices could be integrated as a combined standardised index (Boyd and Murray, 2001; de la Mare and Constable, 2000).

2.89 The Working Group noted that multiple indicators, either analysed independently or as a combined index, potentially integrate over different temporal and spatial scales, and thus reflect different ecological properties; it agreed such analyses are useful when developing some types of feedback management approach. However, interpreting multiple indicators simultaneously requires thorough analyses of each dataset to understand probable causes or drivers of variability. Such analyses would be helpful for reducing uncertainty in decision-making processes that utilised integrated indices.

2.90 The Working Group agreed that estimates of functional relationships, such as those presented in WG-EMM-12/17 and 12/22, require sufficient temporal coverage to build plausible relationships. In some instances, identifying such relationships may not be possible with current data. The Working Group agreed that estimation of functional relationships, although desirable, may not be necessary for advancing some feedback management approaches.

New or expanded monitoring programs

2.91 The Working Group noted that a candidate feedback management approach for the krill fishery may require the development of a new or extended monitoring program for krill-dependent species. Such expansion may be warranted especially if the krill fishery is to operate over large spatial scales and in areas where no existing monitoring, including CEMP monitoring, is present. In particular, the Working Group noted that individual areas may differ in their underlying patterns of variability such that predator responses measured in one local area would not represent predator responses at a larger spatial scale (WG-EMM-12/P04 and 12/P05). The Working Group agreed that if monitoring data were available only in one particular region, then there would be higher uncertainty associated with establishing an appropriate feedback management response at a regional level.

2.92 The Working Group recalled that there may be monitoring data analogous to CEMP data collected at sites around Antarctica that have not been reported to CEMP. The Working Group encouraged Members to prepare and submit such data in order to help expand the spatial extent of current CEMP data holdings, recognising that this would help facilitate the development of feedback management approaches.

2.93 The Working Group considered some of the issues associated with the development of a new or expanded monitoring program based on WG-EMM-12/04, noting that the costs of such monitoring must be evaluated relative to the benefit derived from the availability of additional data. WG-EMM-12/14 suggested that one plausible method to increase availability of data on predator abundance throughout Area 48 combines the use of satellite remote-sensing aerial surveys, opportunistic visits to penguin breeding colonies using ships of opportunity, and remote cameras to provide broad-scale information on the size and trends of regional predator populations. Such information could be collected: (i) in areas where CEMP sites already exist, (ii) in areas close to where the krill fishery already operates, but no CEMP monitoring occurs, (iii) in areas where the krill fishery has operated in the past, and/or may operate in the future, and (iv) in areas where no krill fishing will be allowed and which could be used as reference sites to help understand the confounding impacts of climate and harvesting.

2.94 The Working Group noted that any new monitoring method will require a program of work to underpin the technique. WG-EMM-12/71 provided an evaluation of remote-sensing methods documented in recent publications (e.g. Fretwell et al., 2012; Lynch et al., 2012; Mustafa et al., 2012) and recommended that such methods could serve as a starting point for future efforts to monitor penguin population changes at a regional or continental scale.

2.95 The Working Group agreed that ground truthing of remote-sensing or photogrammetry-based methods would be critical for ensuring continuity with ongoing ground-based counts conducted by individual Members in accordance with CEMP protocols.

2.96 The Working Group noted further that remote sensing of predator abundance is not the only option for informing a feedback management approach and encouraged Members to provide alternative proposals for other candidate indices so that WG-EMM can explore the relative capabilities and trade-offs of such alternatives in future work (paragraph 2.74).

2.97 The Working Group further agreed that maintaining existing CEMP monitoring is critically important, particularly in this era of rapid environmental change and expansion of fishing capacity (paragraphs 2.7 to 2.11). However, by itself, the current CEMP may not allow the detection of fishery-induced change in a timely manner, although the ability to eventually detect change may improve as harvesting levels increase.

2.98 The ability to detect fishery-induced change in the ecosystem may benefit from experimentally designed structured fishing. The Working Group agreed that structured fishing, envisioned as large-scale fishing experiments in localised regions, would necessarily require a careful design phase to identify the scale of structured fishing experiments, the likely impacts of such fishing that could be assessed, and clear expectations of outcomes from such a work plan. The Working Group noted that reference areas without fishing would provide a key element of such structured fishing to help differentiate fishery- and climate-based impacts. Such reference areas may arise as part of the Domain 1 MPA planning process.

2.99 The Working Group also discussed the temporal scale over which monitoring might need to occur in order to establish a feedback management approach. The Working Group noted that the feedback response time of potential feedback monitoring candidates differed, and the trade-off between indicators with differing lag times (fast or slow) was an important consideration for a feedback approach. The Working Group agreed that relevant timescales for monitoring and management would depend on the indicators selected for monitoring and the frequency with which adjustments to the fishery were needed.

Krill-related monitoring issues

2.100 The Working Group considered two papers (WG-EMM-12/50 and 12/52) relating to the effect of environmental variation on the distribution and trends in krill availability in Area 48.

2.101 WG-EMM-12/50 suggested a relationship between fishery CPUE and large-scale atmospheric indices, with a transition to relatively high CPUE occurring in 2006. The authors inferred that climate impacts may be influencing krill populations and, indirectly, fishery performance. Such variation in krill populations would have implications for how feedback management strategies are implemented and so forecasts of environmental variability would be useful for understanding future fishery performance (paragraph 2.29).

2.102 The Working Group noted that forecasting environmental regimes, such as variation in the Antarctic oscillation index, remained a major goal of atmospheric and climate scientists. Developing such forecasts for the purpose of feedback management, while desirable, were considered unlikely to be operational in the near term.

2.103 WG-EMM-12/52 recalled that current synoptic data on the status of the krill population in Area 48 is now over 12 years old and in need of updating. WG-EMM-12/52 proposed that consideration be given to planning future synoptic surveys.

2.104 The Working Group agreed that there is a lack of up-to-date information on the spatial distributions and trends in krill biomass, fishable biomass and the magnitude of advective movements of krill throughout Area 48. The Working Group recalled that the last synoptic survey of krill biomass was conducted in 2000 and that all krill from that original survey were now dead.

2.105 The Working Group noted that such a synoptic survey would be useful, but agreed that several new methods for providing management information across Area 48 now exist. Development of such methods may provide timely, cost-effective and adequate data for establishing updated management information on krill biomass and distribution in Area 48. In particular, the Working Group noted that survey data provided by fishing vessels (see paragraphs 2.163 to 2.173) or from autonomous gliders could provide much of the data necessary for assessing the status of the krill population. Assessments of these or other approaches in conjunction with research acoustic surveys would be useful.

2.106 The Working Group also noted that an integrated assessment of krill (paragraphs 2.158 to 2.161) would benefit from a variety of datasets. Data on krill distributions and density derived from dedicated research cruises may be necessary to expand the spatial coverage of data outside the traditionally fished areas. The Working Group recalled earlier discussions (paragraph 2.83) about the SOS program and the proposal to benchmark the Southern Ocean ecosystem via large-scale surveys in 2020. The Working Group agreed that such a coordinated circumpolar research effort may provide an opportunity to collect data on krill biomass and distribution on a large spatial scale.

2.107 The Working Group agreed that a feedback management approach would require assessments of krill biomass, and that an updated assessment of krill biomass in Area 48 was a priority.

Candidate feedback management approaches

2.108 The Working Group identified eight candidate feedback approaches. Tables 1 and 2 compare specific components of each approach. The Working Group noted that the existing management approach, used to set the current long-term precautionary catch limit for krill, is a useful control against which to evaluate candidate feedback management approaches.

2.109 WG-EMM-12/P05 described simulation procedures for evaluating candidate feedback management approaches. It considered the need to develop performance measures to compare how well the different approaches achieve multiple objectives. WG-EMM-12/P06 reviewed progress towards developing feedback management approaches in WG-EMM.

2.110 WG-EMM-12/P05 reviewed five ecosystem-based management approaches for the krill fishery that were proposed before 2002 and identified, for each, the objective, decision rule, indicator, monitoring and assessment method. Three of these approaches use an index of krill biomass or density as the indicator and two use characteristics of predators. One of the approaches reviewed in WG-EMM-12/P05 requires the closure of the fishery when krill density falls below a critical density required to maintain predator fitness. The others set specific harvest strategies based on the state of indicators. These approaches can be modified to achieve different feedback management systems in response to specific objectives.

2.111 WG-EMM-12/P06 reviewed an approach proposed in 2008 based on a statistical ecosystem model. This ecosystem assessment model is equivalent to a single-species stock assessment model in that it can be used to estimate parameters, through fitting to spatially resolved time series of krill and predator data; assess the current state of the ecosystem; and project the state of the system for use with decision rules to select appropriate harvest tactics. This requires regular ecosystem assessments, possibly including an integrated krill stock assessment, and could make use of new data methods as they become available.

2.112 WG-EMM-12/44 proposed a feedback strategy based on CEMP data. It included a candidate adjustment method, candidate indicators and candidate reference points. The adjustment method, described as a hockey stick, changes area-specific catch limits in direct proportion to an indicator metric, provided that metric is within a specified range below which catch is zero and above which it is a precautionary maximum. Candidate indicators include an estimate of krill population status from an integrated stock assessment model, penguin fledging mass and five-year trends in penguin abundance. The approach sets regional catch limits on the basis of krill population status, adjusts regional catch limits on the basis of five-year trends in penguin abundance, and adjusts catch limits within penguin foraging areas on the basis of penguin fledging mass. The proposal distinguishes between ‘trailing’ and ‘leading’ indicators, the first of which provide the primary information for adjusting catch limits prior to a fishing period, and the second of which are based on information collected after this primary adjustment and allow further in-season adjustment. The authors suggested that the spatial scale of management should be linked to the scale of indicators.

2.113 WG-EMM-12/19 described a feedback management approach based on control theory, which aims to identify the requirements of, and trade-offs involved in, feedback management. The proposed feedback approach optimises a sequence of future catch limits based on objectives defining the desirable state of the ecosystem in terms of targets (e.g. 0.75 of B_0 for the target stock) and limits. These limits can be soft, which means that there is an agreed level of risk that the specific objective will not be met (e.g. the krill decision rule concerning the maintenance of spawning stock biomass). The paper demonstrated that this optimisation approach is more likely to meet CCAMLR’s objectives than a fixed catch limit. The paper demonstrated how candidate feedback management approaches can be evaluated in a simulation framework that specifically considers the trade-offs between objectives, and the implications of uncertainty. It identified specific trade-offs between the range of options available to managers versus the implied level of risk; catch limit versus the implied level of risk; and catch variability versus ecosystem variability. The paper identified the following requirements for optimisation-based feedback management: a reliable model of uncertainty about future ecosystem states; an understanding of the autocorrelation structure of indicator time series; a state estimation method to distinguish signal from noise; and clarity about the target and limit states associated with the management objectives. The authors proposed that such reference points should be developed through an iterative process of evaluating candidate reference points.

2.114 The Working Group welcomed the candidate feedback approaches and thanked the authors for their thoughtful contributions. It noted that together they offer a range of candidate approaches, some of which may be feasible to implement in the near term, but which might require increased precaution in local catch limits. Near-term implementation may require precautionary controls on catch limits to account for uncertainties about the relationship between indicators and objectives. The candidate approaches could be developed to allow higher catch limits in the longer term if these uncertainties are reduced. The approaches also provide useful means of identifying trade-offs and data requirements.

2.115 The Working Group recalled its extensive discussion of feedback approaches during 2011 (SC-CAMLR-XXX, Annex 4, paragraphs 2.149 to 2.192) and commended the progress that has been made in the first two elements of the six-step process for developing and evaluating feedback management approaches. In particular, the Working Group recalled that feedback management could be developed as a staged approach where the first stage could include directed fishing designed to increase knowledge about ecosystem responses. Noting that work on all elements of the six-step process would be welcome, the Working Group also recalled that elements 3 and 4 are to be addressed next year. It therefore encouraged the developers of candidate approaches to continue developing their approaches and to prioritise questions of spatial scale, and the relationship between indicators and objectives. The

Working Group also recommended that the developers of different candidate feedback management approaches engage with WG-SAM so that technical and modelling aspects of each approach might be considered.

2.116 Recognising the impending need to evaluate different candidate feedback approaches, the Working Group noted that it has previously developed and used simulation-based approaches for evaluating management procedures. The Working Group has also discussed a number of candidate operating models, and the framework provided in WG-EMM-12/19 might be useful in such evaluations. A framework for evaluating operating models is discussed in paragraphs 2.58 to 2.60.

CEMP and WG-EMM-STAPP

Analyses of CEMP data

2.117 The Working Group considered the following papers under this agenda item: WG-EMM-12/16 and 12/17 both of which used data from over two decades of multi-species monitoring at Bird Island, South Georgia; WG-EMM-12/22 (noting that this is the same as WG-EMM-12/48) that reviewed data on Adélie penguin (*Pygoscelis adeliae*) monitoring in East Antarctica; and WG-EMM-12/62 that presented an analysis of data in the CEMP database held by the Secretariat. All of these papers presented analyses of CEMP data and provided a review of the expectation of responses to krill availability and to the covariance of CEMP parameters within and between sites.

2.118 The analyses presented in WG-EMM-12/16 examined the relationships between CEMP variables for four krill-eating species and derived a combined index using a principal component analysis, which in this implementation is equivalent to the combined standardised index. The approach demonstrates the mechanistic links between the combined index and proximate indicators of krill availability. Consistent with previous analyses, negative anomalies occurred at approximately three-year intervals, however, there was no evidence of ongoing trends in krill availability. The results presented in WG-EMM-12/17 indicated that the euphausiid content of the diet of macaroni penguins (*Eudyptes chrysolophus*) was the strongest predictor of fledging mass. The authors suggested that it is appropriate to describe macaroni penguins at Bird Island as krill-dependent, available evidence strongly suggests that macaroni penguins have a sigmoidal functional response to krill availability and that their diets may usefully indicate krill availability.

2.119 The analysis of macaroni penguin diet showed that the use of energy content of the diet components improved understanding of the impact of diet on fledging mass. The Working Group agreed that extending this approach in the analysis of diet from CEMP may be productive but noted that the availability of energy content data may be limited for many prey species.

2.120 WG-EMM-12/22 examined interannual fluctuations of Adélie penguin breeding success, foraging trip duration, meal mass and fledgling weights at Béchervaise Island. Breeding success was correlated with early breeding season foraging trip durations and fledgling weights with later trip durations. There was a lack of concordance between early and late breeding season response parameters. Because the amount of prey available to predators is a function of the underlying distribution and abundance of prey as well as its accessibility in areas where there is extensive sea-ice during the summer months, a key component of the functional relationship between predator response parameters and prey availability relates to prey accessibility. The paper suggested that significant changes in predator response would only be evident when krill availability falls below a given threshold. Results highlight the need to take into account the changing behaviours of birds in the context of life-history requirements, changes in prey accessibility as well as any temporal variability in the amount of prey present when interpreting predator response parameters.

2.121 WG-EMM-12/62 presented the report from the Secretariat that described the ongoing data-checking and validation process for the data held in the CEMP database. An outcome from this process was to provide an opportunity to examine the temporal patterns in the available time series as well as inter-site and inter-species comparisons. The Working Group agreed that this was a useful process that was designed to improve the understanding of the characteristics of different CEMP parameters and how best these should be presented in future.

2.122 In the presentation of penguin population size (A3) data in WG-EMM-12/62 where CEMP data are submitted as multiple colony counts within a single site, in particular where data from all colonies are not provided each year, the Working Group noted that the use of a combined standardised index of population data from a site (as presented in WG-EMM-12/62) allows the inclusion of more data in the index. However, the Working Group noted that this approach may produce a different time-series response than does a simple sum of all colonies where colonies are very different in size and the same weighting factor is given to changes in all colonies regardless of colony size. The Working Group encouraged continued discussion between the Secretariat and Members submitting CEMP data to improve data interpretation and comparability between sites. The Working Group also encouraged further exploration of ways of presenting the results from the CEMP time series and the use and interpretation of a combined standardised index for single parameters across sites.

2.123 The Working Group agreed that in submitting A3 data from sites where the colonies within a site were in fact convenient counting units, rather than discrete colonies, that it may be more appropriate to submit a single value for the population surveys from that site.

2.124 The Working Group considered the potential impacts of inter-observer difference in the collection of meal mass data (Penguin diet A8) on its comparability both within and between sites as a CEMP parameter. Dr Trathan informed the Working Group that after a review of animal welfare and logistic issues, the UK had stopped the collection of gentoo penguin (*Pygoscelis papua*) diet samples at Bird Island in 2010 and was planning to cease collection of all diet samples (gentoo, Adélie and chinstrap penguins (*P. antarctica*)) from Signy Island in the near future. Dr Southwell indicated that diet sampling at Béchervaise Island had not been undertaken since 2003 for similar reasons. However, the Working Group noted that there are also active programs undertaking diet sampling of penguins as part of CEMP where the data collected also provide important krill population indices from measurement of krill size in the diet.

CEMP Fund

2.125 The Working Group welcomed the establishment of the CEMP Fund in 2011 (SC-CAMLR-XXX, paragraphs 11.1 and 11.2) and recalled that the Scientific Committee Chair, the WG-EMM Co-conveners and the contributors to the fund were engaged in the development of terms of reference for the use of the CEMP Fund.

2.126 The Working Group agreed that operating a program to collect CEMP data was very expensive and well in excess of what could be provided for from the CEMP Fund in its current form, and recognised that considering the use of the CEMP Fund would probably involve a trade-off between investing in new approaches which might be applied over broad scales at relatively low cost and supporting monitoring at new sites using existing methods.

2.127 The Working Group noted that the CEMP Fund could be used to undertake short-term work such as an initial evaluation prior to the initiation of CEMP monitoring at new sites or developing new methods with broad application.

Priority analyses

2.128 The discussion of priority analyses of CEMP data was focused on the examination of relationships between parameters and the spatial and temporal design of future monitoring programs as they relate to the implementation of feedback management in the krill fishery. The Working Group agreed that the candidate procedures for feedback management would guide the priorities for future analyses and design as these approaches are further developed.

2.129 In order to provide advice on candidate management procedures that use CEMP parameters, the Working Group agreed that an analysis of the spatial correlations between indices was important for identifying those parameters that might reflect local- versus regional-scale changes in krill abundance.

Other monitoring data

2.130 A number of papers were submitted on monitoring data not currently submitted to CEMP.

2.131 WG-EMM-12/21 and 12/P01 described work by Ukrainian researchers on aspects of the biology of seals in the Argentine Islands region in the West Antarctic Peninsula. The weight of seven Weddell seal (*Leptonychotes weddellii*) pups was measured at three-day intervals from birth to 21 days of age to determine growth, and the contents of faecal samples of five seal species (Antarctic fur seal (*Arctocephalus gazella*), crabeater seal (*Lobodon carcinophagus*), Weddell seal, leopard seal (*Hydrurga leptonyx*) and southern elephant seal (*Mirounga leonina*)) were examined to determine diet. The Working Group noted that the diet of Weddell seals was in excess of 70% krill whereas the literature suggests that they are predominantly fish predators. Dr Milinevskyi indicated that Ukraine hopes to continue predator monitoring in this area and establish two new monitoring sites at which CEMP data will be collected and submitted to the Secretariat. The Working Group supported Ukraine's intention for further monitoring work, noted that there is currently little monitoring in this area, and urged Ukraine to consider how the new monitoring could best contribute to priority future monitoring programs such as for feedback management.

2.132 WG-EMM-12/36 linked population trends of Antarctic shags (*Phalacrocorax bransfieldensis*) in the South Shetland Islands with changes in the abundance of inshore demersal fish. Data showing declines in the shag population are presented from the early 1990s and compared with data on the fishery from Marschoff et al. (2012). The paper concluded that declines of shag populations is most likely due to the decrease in the abundance of their main two prey items *Notothenia rossii* and *Gobionotothen gibberifrons*, and that this decline was a consequence of intensive industrial fishing in the area in the late 1970s and early 1980s.

2.133 WG-EMM-12/58 presented results of population counts of chinstrap and gentoo penguins at a number of breeding sites on the Danco coast in 2010/11 and compared the data with previous counts in 1997/98. Overall, the counts of chinstrap penguins at seven sites were 43% higher in 2010/11 than in 1997/98. However, population trends varied between sites, with populations at three small colonies disappearing and populations at the larger colonies increasing. Counts of gentoo penguins increased at all of the four breeding sites studied, and overall the counts were 103% higher in 2010/11 than in 1997/98. The increase in chinstrap populations in this area is not consistent with a declining trend found for the wider Antarctic Peninsula region, indicating that local-scale population trends may not always reflect regional-scale trends. Count data were also presented for some sites from the 1970s and 1980s and suggest there may have been a decline in populations at those sites over this time. However, interpretation of historical counts needs to take into account the time in the breeding season at which they were made, which are not reported in the paper. The results emphasise the need to provide a temporal context for population changes.

2.134 WG-EMM-12/18 presented results from population models to evaluate the effect of exogenous (climatic conditions and krill abundance) and endogenous (intra- and inter-specific competition) factors on the population dynamics of Adélie, chinstrap and gentoo penguins in the Antarctic Peninsula region. Results indicate that intra-specific competition and combined effects of krill abundance and sea-ice cover are the relevant factors underlying the penguin population dynamics with different relevant factors for the different species. The modelling approach differed from other penguin population modelling studies in using simple theoretical-based population models and by including endogenous factors such as intra- and inter-specific competition. The paper highlighted the importance of climatic factors (sea-ice coverage and SST) in predicting the dynamic of these species. The Working Group welcomed this new modelling approach to understanding the factors driving penguin populations and encouraged further work on this approach.

Potentials and priorities for expanding CEMP

2.135 The Working Group recognised that CCAMLR's requirement for ecosystem monitoring is likely to increase in support of feedback management of the krill fishery and MPAs. It was noted that this could be achieved by:

(i) considering additional monitoring data that is currently being collected but is not submitted to CCAMLR as part of CEMP

(ii) starting CEMP monitoring programs at locations where no such monitoring is under way

(iii) developing and applying methods, other than current CEMP methods, that allow appropriate monitoring at more sites in a cost-effective way.

2.136 In relation to additional monitoring data, a number of papers considered at the meeting (WG-EMM-12/18, 12/21, 12/36, 12/58 and 12/P01) contained data that are not currently submitted to the CEMP database. The Working Group noted that there may be a substantial amount of data currently being collected that is compatible with the currently agreed species, parameters and methods used by CEMP, and that consideration should be given to whether these data could be used to augment the current CEMP. The Working Group acknowledged that there may have been a false perception that in order to contribute to CEMP it was necessary to submit data on all of the CEMP parameters from a site. The Working Group agreed that this was not the case and encouraged Members to contribute data to CEMP from a site even if they are unable to collect data on all CEMP parameters.

2.137 In relation to new methods, the Working Group recognised the potential for new methods to allow broad-scale monitoring of some parameters. WG-EMM-12/04 and 12/71 outlined some potential methods, including satellite technology, aerial surveys and opportunistic surveys for monitoring abundance, and cameras and audio-recording devices for monitoring breeding success and phenology. While some of these methods are still under development and require validation, they may be ready to apply in 2–3 years when more specific monitoring needs in support of feedback management and MPAs are known.

2.138 While the Working Group supported in principle the inclusion of additional data to augment the current CEMP, it also agreed that there was a need to identify the priority types and locations of such data in order to support priority needs of CCAMLR. These priorities will become clearer in the next few years as the monitoring and analysis requirement for feedback management and MPAs are developed.

2.139 The Working Group emphasised that while new data and methods offer the potential to expand CEMP, additional data would need to be collected using methods that had been endorsed by the Working Group to ensure that data quality and comparability of CEMP data are maintained.

2.140 The Working Group noted the initiatives described in WG-EMM-12/45 and 12/59 to undertake new monitoring and bring together available datasets for Southern Ocean ecosystem status and change, and indicated that any expansion of CEMP should be considered in the context of other international programs to ensure that the greatest synergies are achieved and to avoid duplication of effort.

WG-EMM-STAPP

Progress on estimating overall predator abundance and krill consumption in Area 48

2.141 Work by the UK to estimate abundance of Antarctic fur seals breeding at South Georgia is ongoing. Initial analysis of aerial images obtained in 2002 is almost complete, and a statistical modelling framework is being developed. It is expected that fur seal abundance estimates for South Georgia, combined with results of recent fur seal surveys in the South Shetland Islands, will allow estimates of fur seal abundance and krill consumption for Area 48 to be completed by 2014.

2.142 WG-EMM-12/P02 described a sensitivity analysis to identify those known penguin breeding sites that contribute most to uncertainty in estimates of penguin abundance for Area 48. The analysis utilised the penguin count database developed by WG-EMM-STAPP. The approach ensures that future surveys to reduce uncertainty in estimates of penguin abundance, and subsequently estimates of krill consumption by penguins, are prioritised and targeted towards the sites of greatest need. The paper identified 14 locations where high-quality surveys would reduce uncertainty in population estimates by approximately 72%. For example, if high uncertainty at a site identified by this process is related to the large size of the colony and related difficulty in counting, a reduction in uncertainty may be possible if new methods are available for reliable estimation of abundance in large colonies.

2.143 Penguin survey work in priority locations by a number of national programs and the Oceanites Antarctic Site Inventory is continuing with the aim of achieving up-to-date penguin abundance estimates for Area 48. The researchers undertaking this work are aiming to submit penguin abundance estimates, and a database of count data that these estimates are based on, to CCAMLR as soon as possible. Two recent published papers by researchers attending the meeting potentially provide important contributions to this effort. The authors were encouraged to submit these papers to a relevant WG-EMM agenda item in the future.

2.144 There has been no progress on estimating flying seabird abundance in Area 48. The USA indicated that data on flying seabirds collected during US AMLR at-sea surveys could contribute to this goal. The Working Group recognised that further progress is unlikely without substantial additional resources for data collation and analysis. As krill consumption by flying seabirds is likely to be significant, a lack of abundance estimates for this group would mean that krill consumption for land-based predators will be underestimated.

Progress on estimating overall predator abundance and krill consumption in East Antarctica and the Ross Sea

2.145 Although the priority region for WG-EMM-STAPP's work is Area 48, WG-EMM-STAPP is also developing estimates of predator abundance and krill consumption for East Antarctica and the Ross Sea. Dr Southwell reported on progress of this work in these regions:

(i) Estimates of pack-ice seal abundance for these regions are available from APIS surveys conducted in 1999/2000 (WG-EMM-05/23 for East Antarctica).

Application of the consumption model developed by the UK for crabeater seals (WG-EMM-PSW-08/06) to these abundance estimates will allow estimation of krill consumption.

(ii) Work to estimate Adélie penguin abundance in East Antarctica is continuing. Australia is planning to conduct new surveys in the Windmill Islands in 2012/13. This region has not been surveyed since 1989/90. In combination with recent surveys described and summarised in WG-EMM-11/31 and 11/32, all the major Adélie penguin populations in the Mawson, Davis and Casey regions will have been surveyed recently. Japan and France have agreed to contribute Adélie penguin count data for the Lützow–Holm Bay and Adélie Land regions of East Antarctica. Work is under way to synthesise all these data and derive a current abundance estimate for Adélie penguins across East Antarctica.

(iii) New Zealand is processing aerial photographs of all Adélie penguin populations along the Victoria Land coast of the Ross Sea taken in recent years and plans to derive an Adélie penguin abundance estimate for the Ross Sea.

(iv) Australia and New Zealand are aiming to submit revised estimates of Adélie penguin abundance for East Antarctica and the Ross Sea, and a database of count data that these estimates are based on, to CCAMLR in 2013 or 2014.

(v) Australia has been working to adapt the crabeater seal consumption model developed by the UK for use on Adélie penguins. In combination with abundance estimates, this will allow estimates of krill consumption by Adélie penguins. The adapted consumption model is nearly complete. Australia and New Zealand plan to use the abundance estimates and consumption model for Adélie penguins to derive estimates of krill consumption by Adélie penguins for East Antarctica and the Ross Sea.

Progress on partitioning krill consumption estimates using foraging data

2.146 WG-EMM-12/37 provided a synopsis of US AMLR satellite telemetry data obtained over a 14-year period for three species of penguins and three species of pinnipeds breeding at the South Shetland Islands. The data highlight species and seasonal differences in the patterns of foraging distribution. The Working Group noted that these data are an important contribution to the development of foraging models for understanding krill consumption estimates in Area 48.

2.147 The Working Group recognised that further modelling effort would be required to predict foraging effort and at-sea distribution for colonies where no tracking data were available. Foraging distribution data, modelled in relation to environmental data, will be necessary to partition estimates of overall krill consumption by predator populations in Area 48 into smaller spatial units. An important part of this work will be predictions for colonies where no tracking data exist, or colonies where tracking data are temporally constrained.

2.148 The Working Group recognised that modelling foraging distribution provided a number of challenges and was a substantial body of work, given that tracking instruments have been deployed at a restricted number of breeding sites, some species have small ranges while others travel long distances, and foraging distributions may vary substantially across seasons and between life-history stages.

2.149 At the request of WG-EMM in 2011, Dr Trathan liaised with representatives from BirdLife International and the SCAR Expert Group on Birds and Marine Mammals during the intersessional period to assess areas of common interest and expertise that may expedite this work. BirdLife International and SCAR were both keen to be involved, but BirdLife International indicated that they did not currently have the ability to incorporate dive data into their analysis framework which had been developed for flying seabirds. Both groups indicated that they did not currently have the capacity or resources to focus the work specifically needed for CCAMLR.

2.150 The Working Group recognised that the synthesis of dive data and location data was an important consideration when modelling the spatial and temporal distribution of consumption; however, it agreed that it may be possible to use location data as a proxy for foraging distribution but that the inclusion of diving data would greatly enhance this work.

2.151 The Working Group recognised that collaboration with groups in the wider scientific community had the potential to facilitate work on distribution of krill consumption by predators. However, it agreed that it would be important that any such collaborations were clearly focused on delivering outcomes that addressed priorities identified by WG-EMM.

2.152 The Working Group reiterated the need for WG-EMM-STAPP to maintain its existing focus on work on the overall estimation of predator abundance and krill consumption, and that the work on modelling foraging data should not detract from this task. The work on the abundance of fur seals and penguins and their consumption of krill are expected to be complete by 2014, but the Working Group indicated that WG-EMM-STAPP should consider any feasible means for developing estimates of abundance and krill consumption by flying seabirds.

2.153 The Working Group noted that Dr Southwell had indicated that he would like to step down from leading WG-EMM-STAPP after the work on estimating penguin and fur seal abundance and krill consumption is completed in 2014. The Working Group therefore asked Dr Trathan to liaise with those members of WG-EMM-STAPP with relevant experience in telemetry, to progress work on modelling foraging distribution data, including further liaison with other relevant groups, and to present a paper for consideration by WG-EMM in 2013. The Working Group recommended that WG-EMM-STAPP also consider how other relevant work, including the feasibility of estimating flying seabird abundance, is undertaken in the future.

2.154 In 2011 the Working Group indicated that the work of WG-EMM-STAPP in understanding the interactions between air-breathing predators and krill might be extended to include the role of fish as krill predators. The Working Group recommended that WG-FSA review this issue.

New methods

2.155 The work of WG-EMM-STAPP has led to the consideration and development of a number of new methods for estimating predator abundance.

2.156 WG-EMM-12/04 and 12/71 discussed the potential for remote-sensing methods to contribute to regional-scale estimation and monitoring of predator abundance. Recent studies have demonstrated that satellite technology can be used to estimate circumpolar abundance of emperor penguins, but application to smaller land-breeding species is likely to be more difficult and requires validation work. It will be important to take a coordinated approach to validation work and utilise existing land-based work for ground-truthing. Existing work is based on the use of satellites that record visible light and closely allied frequencies; however, the Working Group recognised that other satellites that use microwave sensors may have utility, especially as these may not be limited by cloud cover.

2.157 WG-EMM-12/14 summarised improvements to a previous version of the ICESCAPE software (WG-EMM-09/20). ICESCAPE is a suite of routines in R that implements a parametric bootstrap model for standardising counts of colonial-breeding animals at sub-optimal times of the breeding season to a common point in the breeding chronology. The Working Group welcomed the improvements and noted the utility of the software for standardising population counts and estimating penguin abundance and its uncertainty.

Integrated assessment models

2.158 The Working Group considered two papers that reported work related to integrated assessment models for Antarctic krill.

2.159 WG-EMM-12/27 presented details of an integrated model for krill that is under development by US AMLR. The model follows individual cohorts of krill as they are sampled through time and can estimate a number of parameters representing krill recruitment, mortality and productivity, as well as parameters representing survey selectivity. The model can be configured to estimate movement but in its current form does not converge when movement is estimated. The authors reported that high estimates of natural mortality produced by the model could be partially due to the model being unable to distinguish between mortality and movement of krill out of the sampling area.

2.160 The Working Group noted that configuration of the model can be varied depending on whether acoustic data or net data are used as model inputs. Modifications are continuing to improve the estimation of selectivity parameters when multiple sources of biomass survey data are available. Additional data sources from krill fisheries, krill predators and other krill surveys in the region will be incorporated into the model in the future as development progresses.

2.161 The Working Group recognised the potential value of the model for estimating krill production and for its use in different candidate feedback management approaches, and encouraged the authors to continue their work, particularly by including data sources from outside the US AMLR study area.

2.162 The Working Group also considered WG-EMM-12/38 as part of its discussions on krill integrated assessment models; this paper presented details of a growth model for krill that is currently under development by Australian scientists (see paragraphs 2.53 to 2.57 for further discussion of this paper). The Working Group noted that errors in the growth model used for stock assessments of Antarctic krill, particularly growth rates higher than occur naturally, could inadvertently lead to over-exploitation of the krill stock with potential impacts on krill-dependent species. The Working Group recognised the potential value of the model for estimating krill growth rates and for use in assessments of the precautionary yield for krill, including through feedback management approaches. The Working Group therefore encouraged the authors to continue their work and provide updates to WG-EMM in the future.

Fishing vessel surveys

Scientific use of acoustic data collected from krill fishing vessels

2.163 Scientific research vessels provide high-quality estimates of biomass with quantified levels of uncertainty associated with the data. However, it is recognised that these research vessel surveys are relatively limited in terms of areal and temporal coverage and are also expensive and resource-intensive to undertake. Therefore, developing the use of alternatives to such intensive research-based surveys should form part of an overall strategy of collecting acoustic data in the future.

2.164 In contrast, there is an increasing number of commercial fishing vessel notifications and given the year-round fishery operation, their importance as potential platforms from which to collect acoustic data is likely to increase.

2.165 Last year the Scientific Committee asked SG-ASAM to consider the use of krill fishing vessel-based acoustic data to provide qualitative and quantifiable information on distribution and abundance of Antarctic krill and other pelagic species such as myctophiids and salps (SC-CAMLR-XXX, paragraph 2.10). In particular, SG-ASAM was requested to provide advice on survey design, acoustic data collection and acoustic data processing.

2.166 SG-ASAM considered that there are two broad research objectives that are likely to be achievable through the collection of acoustic data from fishing vessels:

- (i) abundance of krill at a defined temporal and spatial scale
- (ii) spatial organisation of krill, e.g. horizontal and vertical distribution, swarm density or structure.

2.167 The Working Group noted that SG-ASAM agreed:

- (i) that biomass estimates (research objective 1) would only be achievable when collecting data which followed an agreed survey design (Annex 4, paragraph 2.8). Furthermore, SG-ASAM agreed that collecting acoustic data along existing transects defined as part of national research program krill surveys will add significant value to the interpretation of fisheries acoustic data (Annex 4, paragraphs 2.14 and 2.17)

(ii) that abundance estimates could be generated either from a single fishing vessel undertaking a multi-transect survey or from multiple vessels undertaking single transects to achieve the same level of transect coverage (Annex 4, paragraph 2.18)

(iii) that calibration was a fundamental component of acoustic data collection and that currently a standard sphere calibration should be used if the acoustic equipment is to be used for quantitative krill biomass assessments (Annex 4, paragraph 2.23). However, it was recognised that opportunity to undertake a standard sphere calibration could be limited by a range of factors, including, for example, location, weather conditions and availability of technical expertise. Therefore, it strongly recommended the development of alternative or secondary calibration approaches (Annex 4, paragraph 2.24)

(iv) a set of high-level instrument requirements in terms of acoustic data collection, related to the two main research objectives (Annex 4, paragraph 2.20, Tables 1 and 2). It also provided outline recommendations for data collection protocols (Annex 4, paragraph 2.29 and Table 3). However, it was not possible to provide a detailed, prescriptive set of requirements suitable for a range of vessels that might have quite different acoustic equipment and vessel noise characteristics (Annex 4, paragraph 2.36)

(v) a proof of concept program to work through the issues that will need to be resolved when implementing surveys from fishing vessels using different acoustic equipment (Annex 4, paragraph 2.37).

Working group discussion of SG-ASAM report

2.168 The Working Group agreed that acoustic data collected by commercial fishing vessels could form a very valuable data source for use in the work of WG-EMM, in particular in the context of providing inputs to the developing feedback management strategies. The collection and use of such data would also increase the opportunity of the fishing industry to participate in CCAMLR data collection and to increase the collaboration between scientists and fishers.

2.169 The Working Group recognised that a range of different research questions, other than quantitative regional biomass estimation (research objective 1 in paragraph 2.167i), could be answered with the acoustic data from the fisheries. For instance, information on the temporal variability in the density and spatial organisation (research objective 2 in paragraph 2.167i) of krill aggregations targeted by the commercial vessels could provide key insights into the operation of the fishery.

Proof of concept

2.170 The Working Group agreed that the proof of concept as proposed by SG-ASAM was a valuable first step in developing the scientific use of acoustic data collected from fishing vessels.

2.171 The Working Group recommended that the acoustic sample data requested from fishing vessels should be acquired under different weather conditions and during different vessel activities. In particular, it was emphasised that data should include some periods when the ship was steaming at a constant speed (in the region of 10 knots) and on a steady course that would be representative of acoustic survey conditions.

2.172 The Working Group noted that many vessels have observers on board and recommended that the acoustic data collection should be accompanied by krill length-frequency data collected by the observer.

2.173 The Working Group noted that, while a standard sphere calibration was presently required to derive absolute abundance estimates, in the context of the proof of concept it was impractical to require the vessels to undertake such a calibration prior to submitting proof of concept data. However, any information provided by the vessels on the practicalities of undertaking such standard sphere calibrations would be extremely useful in developing future protocols for calibration of fishing vessels.

Future development beyond the proof of concept stage

2.174 To take the use of acoustic data collected from fishing vessels beyond the proof of concept stage, the Working Group recognised that it would need a longer-term research plan that takes into account the broader development of the work of WG-EMM. The Working Group recognised that in developing this plan, consideration would need to be given to the following broad issues:

(i) What are the sources of data that can be obtained? How might data from many sources be combined if they are not calibrated according to standard methods? Would there be a minimum standard required, with perhaps an accreditation system, to control data quality?

(ii) Where are data going to be collected? The Working Group noted that future consideration should be given to whether it was feasible to request data from areas that are not presently sampled, for instance data from the pelagic areas between the present main fishery areas.

(iii) How will data be analysed? The Working Group noted that one method is that being developed by Norway where there is a direct collaboration between scientists and fishing companies covering design, data collection and analysis. However, other arrangements could be developed where some form of centralised analysis could be coordinated through CCAMLR. Whatever arrangements were developed for analysis of these fishing data, the Working Group noted that these analyses were complex and would be likely to require involvement of the appropriate experts in the CCAMLR community.

2.175 The Working Group recognised that it is at the first stage in the process of implementing acoustic data collection from the commercial krill fishing vessels. The Working Group emphasised that there is still a strong requirement to undertake scientific surveys and recommended that there should be no reduction in the conventional scientific survey activity.

2.176 Given the future potential and importance of this field of work to WG-EMM, the Working Group strongly encouraged Members to develop methods and plans for collection and use of such data to be presented at future meetings.

2.177 WG-EMM-12/63 presented an example of what acoustic and ancillary data can be obtained from a commercial vessel during normal fishing operations. A basic comparison with data collected by the same vessel during a directed scientific survey in the same period showed that the vessel operated consistently in the locations of highest krill concentrations during the period of fishing operations, and that catch rates were correspondingly very high. Krill length data collected by the observer in parallel with the acoustic data collection were highly variable between hauls.

2.178 The Working Group welcomed the approach presented in WG-EMM-12/63 and noted the large haul-to-haul variation in length-frequency distribution but also noted the analysis presented in paragraphs 2.38 to 2.40.

SPATIAL MANAGEMENT

Marine protected areas

ASPAs and ASMAs, and coordination with the ATCM

3.1 Dr Grant introduced a discussion of revised and new management plans for ASPAs or ASMAs which contain marine areas. In accordance with ATCM XXVIII, Decision 9 (2005), the approval of CCAMLR is required for proposals for ASPAs or ASMAs which contain marine areas in which there is actual harvesting, or the potential capability of harvesting, or for which there are provisions specified in a draft management plan which might prevent or restrict CCAMLR-related activities.

3.2 Dr Arata presented three revised ASPA management plans which were submitted to ATCM XXXV by Chile (WG-EMM-12/40, 12/41 and 12/42). All three areas are small, no deeper than 200 m, and were designated due to their value as important areas for benthic research. Dr Arata clarified that the management plans do not allow for harvesting as a permitted activity within the areas and he reported that anchoring is also not allowed.

3.3 The Working Group, noting the importance of these areas for scientific research and that these areas were unlikely to be subject to harvesting, recommended approval of the management plans for ASPA No. 144 (Discovery Bay, Greenwich Island, South Shetlands), ASPA No. 145 (Port Foster, Deception Island) and ASPA No. 146 (South Bay, Doumer Island, Palmer Archipelago) by the Scientific Committee.

3.4 WG-EMM-12/47 proposed a management plan submitted by the USA and Italy to ATCM XXXV for a new ASPA at Cape Washington and Silverfish Bay, Terra Nova Bay, Ross Sea. The main values to be protected include one of the largest emperor penguin colonies known, as well as the associated marine ecosystem which is a nursery area for the Antarctic silverfish (*Pleuragramma antarcticum*). The total area of the proposed ASPA is 282 km^2, 98% of which is marine. The draft management plan has no provision for harvesting within the proposed ASPA, which is located within SSRU 881M which currently has a catch limit of 0 tonnes.

3.5 In response to questions regarding the depth of the area, Prof. Vacchi confirmed that the majority of the marine area was less than 500 m deep, and that it was often ice-covered, and thus there should be little CCAMLR interest in harvesting within the area.

3.6 Dr Grant noted that the proposed ASPA lies within the areas proposed by New Zealand and the USA for a Ross Sea MPA. She recalled that the 2011 MPA Workshop (SC-CAMLR-XXX, Annex 6, paragraph 4.4) noted that a harmonised approach in the Antarctic Treaty System to spatial protection may result in having ASPAs and ASMAs designated by the ATCM within CCAMLR MPAs. This multi-level approach to area management could harmonise decisions made at the ATCM and CCAMLR, and allow for detailed consideration of activities not normally considered by CCAMLR; thus more comprehensive protection might be provided for such areas (SC-CAMLR-XXX, Annex 6, paragraph 6.17).

3.7 The Working Group, noting the importance of Cape Washington and Silverfish Bay for scientific research and that these areas were unlikely to be subject to harvesting, recommended approval of the draft management plan for a new ASPA in this area by the Scientific Committee.

3.8 Dr Penhale, on behalf of Brazil, chair of the Management Group of ASMA No. 1, Admiralty Bay, King George Island, South Shetland Archipelago, outlined the process for the revision of the management plan by Brazil, Poland, Ecuador, Peru and the USA (WG-EMM-12/61). The management plan is currently being revised and will be presented to the ATCM in May 2013. The plan will then be submitted to CCAMLR for approval per ATCM Decision 9 (2005).

3.9 The values to be protected include a diverse marine ecosystem which has been the subject of long-term scientific research going back nearly 40 years. These long-term studies include research on predator–prey dynamics of penguin–krill populations conducted at a CEMP site and detailed studies of the benthic invertebrate communities. During the IPY, there was a focus on marine biodiversity under the Census of Antarctic Marine Life program. The area of the ASMA is 360 km^2, of which 50% is generally ice-covered.

3.10 SC-CAMLR-XXX (paragraphs 3.24 to 3.26) reported that in 2009/10 the krill fishery operated in Admiralty Bay. At its last meeting, the Scientific Committee was unsure whether such fishing activity was compatible with the management plan and noted that at the time when this management plan was established, the effects of fishing in the region were not considered.

3.11 WG-EMM-12/61 explicitly proposed that the Working Group should discuss potential harvesting within the ASMA, and how best to minimise human impacts on the long-term scientific research. The Management Group of ASMA No. 1, noting the high scientific value of the long-term ecosystem studies, would prefer that no harvesting take place within the ASMA in order to achieve the goals of the management plan. Another option would be prior consultation between those planning to harvest within the ASMA and the Management Group in order to minimise impacts to ongoing research.

3.12 Dr Arata, noting that the ASMA area is quite small with regard to the total area available for krill fishing in Area 48, recommended that no harvesting take place within the ASMA.

3.13 Mr T. Kawashima (Japan) stated that, should the ASMA be proposed as a no-take area, then the objectives of the ASMA should be clearly stated, information on how fishing would be detrimental to the objectives should be described, and a description of the monitoring program to study the effects of no harvesting should be provided. It was agreed that the provisions of the ASMA adequately addressed these requirements.

3.14 There was broad support for the idea of no harvesting within the ASMA; however, the Working Group noted that a formal review and recommendation would occur when the draft management plan was submitted to CCAMLR in 2013.

3.15 The Working Group encouraged Dr Penhale to communicate the deliberations of WG-EMM, and subsequently of the Scientific Committee, to the Management Group of ASMA No. 1 for consideration as the revised management plan is produced.

3.16 The Working Group was informed that krill fishing vessels were recently observed within ASPA No. 153, Eastern Dallmann Bay, off the northwest coast of Brabant Island. The management plan of the ASPA, which is approximately 676 km^2, does not allow for harvesting as a permitted activity.

3.17 The Working Group suggested that the recent appearance of krill fishing vessels within ASMA No. 1 and ASPA No. 153 probably occurred due to a lack of awareness of the existence of these designated areas among those responsible for fishing vessels.

3.18 Noting that the Convention (Articles V and VIII) provided for close cooperation between CCAMLR and the Antarctic Treaty, the Working Group observed that there was a lack of informative and timely communication between the ATCM and CCAMLR with regard to the location and management plans of ASPAs and ASMAs containing marine areas.

3.19 A number of suggestions were made to improve communication, such as linking the management plans of relevant ASPAs and ASMAs to CCAMLR conservation measures so that a link to the management plans with maps could be readily accessed. Members were encouraged to be proactive in passing on information to fishing vessels under their jurisdiction. In June 2012, COMM CIRC 12/79–SC CIRC 12/42 was issued to call Members' attention to the issue of harvesting within ASPAs and ASMAs.

3.20 The Working Group noted that information on the locations and provisions of all ASPAs and ASMAs (including maps, management plans and GIS shapefiles) is available on the Antarctic Treaty Secretariat website. Figure 1 was prepared using data from the ATS website, and shows marine and partially marine ASPAs and ASMAs located in Subareas 48.1 and 48.2.

MPA proposals

3.21 WG-EMM-12/25 proposed the establishment of an MPA near Akademik Vernadsky Station, Argentine Island Archipelago, in order to protect the highly diverse benthic community in the area. A video presentation of a diver-conducted benthic survey illustrated this diversity. While the paper presented the location of one MPA, Dr Milinevskyi stated that the intent is to formally propose a network of MPAs within the area along the Antarctic Peninsula from Petermann Island to Bertholot Islands within the next two years.

3.22 The Working Group noted that the area near Akademik Vernadsky Station, Argentine Island Archipelago, had high scientific value due to its benthic diversity and agreed that the area warranted protection.

3.23 Some Members questioned the rationale for seeking protection of the scientific values as an MPA under CCAMLR as compared to an ASPA or ASMA under the ATCM. The Working Group, noting that both the ATCM and CCAMLR have provisions for the establishment of protected and managed areas, agreed that this subject was more appropriately discussed at the Commission on a case-by-case basis. It was also noted that communication within the ATS was important in order for goals for marine spatial protection and management to be achieved.

3.24 The Working Group, noting that this proposed MPA network is within Planning Domain 1, observed that there were already several marine ASPAs and two ASMAs within the domain (paragraph 3.6).

3.25 Several members recalled that a joint meeting of SC-CAMLR and the CEP was held in 2009 (ATCM XXXII WP 55). Progress on topics of mutual interest in areas such as climate change research, spatial marine management and protected areas, as well as ecosystem and environmental monitoring, would provide a solid agenda for discussions aimed at increased cooperation. The Working Group recommended that the Scientific Committee consider another joint meeting to be held in the near future.

3.26 WG-EMM-12/34 is a revised version of WS-MPA-11/17 presented to the 2011 CCAMLR MPA Workshop and subsequently to SC-CAMLR-XXX (SC-CAMLR-XXX/13) on a proposal for establishing precautionary spatial protection to facilitate the scientific study of habitats and communities under ice shelves in the context of recent, rapid, regional climate change. Dr Trathan reported that the current paper incorporates points arising from previous discussions and that two major changes were that the paper now more clearly articulates the scientific rationale for protection and that the boundaries of the proposed areas for protection are changed in order to focus on those areas where rapid regional climate change was occurring. The paper highlighted that rapid climate change has been documented in the Antarctic Peninsula region, indicated by the retreat of 87% of the Peninsula’s glaciers. Ice-sheet collapse leads to the destruction of existing under-ice habitats with the creation of new habitats. The paper proposed that the study of colonisation processes in these habitats is scientifically important and that this is best undertaken in the absence of human impact.

3.27 The Working Group recognised that the proposal in WG-EMM-12/34 to protect areas and habitats under ice shelves was consistent with the protection objectives agreed by the 2005 CCAMLR Workshop on Marine Protected Areas (SC-CAMLR-XXIV, Annex 7, paragraphs 62 and 63). It also recognised that the proposal was consistent with the recommendations of the Antarctic Treaty Meeting of Experts on the Impacts of Climate Change for Management and Governance of the Antarctic Region (ATCM XXXIII – CEP XIII Document WP063) which recommended (Recommendation 26) the precautionary protection of areas under ice shelves (SC-CAMLR-XXIX, paragraphs 8.3 to 8.7).

3.28 The Working Group noted that the recently exposed areas of ocean uncovered by the collapse of the Larsen A and Larsen B ice shelves were not included in the proposal. It recognised that the proposal was designed to be precautionary and forward-looking to future ice-shelf collapse. Further, that should the Commission consider areas already uncovered by collapse of the Larsen ice shelves be worthy of protection, this could be achieved through a separate MPA proposal, or incorporated into the current MPA proposal.

3.29 Mr Kawashima observed that the area of protection was quite large and wondered whether the scientific community had the capacity to conduct the necessary scientific research and monitoring activities. Dr Trathan agreed that the area might appear to be large, but he emphasised that it was extremely unlikely that all ice shelves in the defined area would collapse at a single time and that a more likely scenario was that ice shelves might recede gradually, with only some collapsing catastrophically. He suggested, therefore, that the actual area set aside as a no-take zone might be quite small. Further, it was difficult to exactly predict when and where ice shelves might collapse, so a precautionary approach was necessary. Finally, he noted that the area of protection covered a large latitudinal range, so the defined area had the potential to protect different habitats as they were exposed by ice-shelf retreat or collapse.

3.30 Mr Kawashima also suggested that the area might be protected via means other than designation as an MPA. Dr Trathan noted that the areas under ice shelves could be protected under Article IX.2(g) or in accord with the MPA general measure (CM 91-04) and that the authors had preferred to follow designation in accord with the latter.

3.31 The Working Group considered that the proposal to protect areas and habitats under ice shelves was inherently different in nature from those MPA proposals being developed by those focusing on the various MPA planning domains (SC-CAMLR-XXX, Annex 6, paragraph 6.6), yet it was consistent with the provisions of the MPA general measure (CM 91-04).

3.32 The Working Group noted that draft outline research and monitoring plans for the areas under ice shelves should be developed and presented to the Scientific Committee; however, it recognised that more detailed plans would only need to be developed once an ice shelf had actually collapsed. The Working Group recognised that the review period of 10 years after ice-shelf collapse would enable the Scientific Committee to determine whether the scientific community had begun to implement research and monitoring activities. As the objective of interim protection for areas and habitats under ice shelves was to facilitate scientific research, it was recognised that continuation of such protection might not be warranted if no research had been initiated or was envisaged.

3.33 The Working Group noted that the Scientific Committee (SC-CAMLR-XXX, paragraphs 5.76 and 5.77) and the Commission (CCAMLR-XXX, paragraph 7.32) had previously noted that the ability to acquire the necessary science from under ice shelves was limited because the areas to be protected were currently inaccessible. The Working Group, therefore, agreed that the scientific basis for protection was adequate and that no further scientific justification would be required from the authors.

Research and monitoring plans for the Ross Sea region

3.34 While the requirement and general guidance for research and monitoring plans was established in CM 91-04, an agreed structure and content for such plans does not yet exist.

Two draft research and monitoring plans (WG-EMM-12/46 and 12/57) for potential application in the Ross Sea region were submitted to WG-EMM for its consideration.

3.35 WG-EMM-12/46 presented a draft research and monitoring plan to support an MPA in the Ross Sea region. Priorities for research and monitoring are discussed in terms of three general categories of sampling strategies. These are research from space (e.g. remote sensing, telemetry), from land (e.g. CEMP-style approaches, predators as indicators of ecosystem status, food web analysis) and at sea (e.g. oceanographic surveys, benthic and pelagic surveys, fisheries research). Multiple tools are recommended for analysing data to provide more robust advice. The results of this research and monitoring will be synthesised to provide advice on the degree to which the objectives of the MPA are being achieved and whether specific management actions would improve the performance of the MPA with respect to achieving these objectives.

3.36 WG-EMM-12/57 presented a preliminary research and monitoring plan for the Ross Sea region. The plan was structured by linking research and monitoring activities to eight general conservation objectives, with 27 specific conservation objectives embedded within the general objectives. Research and monitoring activities for each objective were designed to: (i) ensure that the boundaries of the priority feature remain accurate and to determine to what extent those boundaries may be moving; (ii) understand the importance and ecosystem role of the priority feature and to understand processes that affect it (including potential threats from fishing); and (iii) demonstrate the extent to which achievement of the specific objectives is being met. While for some objectives the design of the research and monitoring activities aimed to demonstrate whether identified threats are being effectively mitigated by the MPA, it was noted that when representativeness was the objective, threat mitigation would not apply.

3.37 The Working Group observed that the plans presented in WG-EMM-12/46 and 12/57 were different in structure and focus, yet both were positive contributions to the development of a framework to achieve research and monitoring objectives. The Working Group noted that guidance will ultimately come from the Scientific Committee and the Commission on the detailed structure of research and monitoring plans.

3.38 Some Members felt that certain elements of WG-EMM-12/46, such as the utility of remote sensing as a research tool, should be further detailed in the plan. Finer-scale monitoring may be needed, particularly with regard to take and no-take zones.

3.39 The Working Group, noting the detailed list of research activities by general and specific objectives in WG-EMM-12/57, recommended that appropriate time scales and prioritisation between activities be more clearly identified.

3.40 The Working Group discussed the use of fishing vessels to deliver research as part of the research and monitoring plans. It agreed that such opportunities may be useful if compatible with the objectives of the MPA, and that for some kinds of research questions fishing vessels may constitute the best, or only, appropriate research platform.

3.41 The Working Group discussed the need to define priority elements for research and monitoring plans and the level of detail of activities that should be undertaken. It was recognised that general elements would have to be addressed clearly at the first stage of the process and that more specific elements could be identified at a later stage. One way to determine research and monitoring priorities may be to specify which activities are required to address whether objectives are being met. Some activities may be considered mandatory. Other activities may be desirable but would be considered non-mandatory.

3.42 The Working Group agreed that the research and monitoring plan should identify research activities within various regions or spatial areas within the MPA consistent with the specific objectives of the MPA in that area. The Working Group agreed that the research and monitoring plan should be organised geographically and would ideally identify research that relates to the achievement of multiple objectives simultaneously. The plan should contain research that is achievable in practice. The final research and monitoring plan would identify research and monitoring activities, and mechanisms and timescales for review. It was recognised that the proposed MPA Report (paragraphs 3.72 to 3.75) would facilitate the presentation of these elements in a common format.

Domain 1, Antarctic Peninsula

3.43 Dr Arata presented the results of the CCAMLR Technical Workshop on Planning Domain 1 (Western Antarctic Peninsula–South Scotia Arc) which was held in Valparaiso, Chile, from 28 May to 1 June 2012 at the Chilean Subsecretary for Fisheries (WG-EMM-12/69). Drs Arata and E. Marschoff (Argentina) served as Co-conveners and the workshop was partly supported by the CCAMLR MPA Special Fund. Participants from six countries (Argentina, Chile, Japan, Norway, UK and the USA) and the Secretariat contributed to the work. The planning domain includes parts of Subareas 48.1, 48.2 and 88.3. It was noted that Domain 1 contained one CCAMLR MPA (CM 91-03, South Orkney Islands), five marine (and four partially marine) ASPAs, and three ASMAs.

(i) The goals of the workshop were to identify and review existing data, to establish criteria for the analysis of the selection of MPAs (consistent with CM 91-04), to establish a methodology common to Domain 1, to address problems of monitoring and surveillance of potential MPAs, and to make progress on identifying MPA candidates for Domain 1. Finally, a strategy for future work was to be developed, based on progress made during the workshop.

(ii) The workshop, addressing the issue of data use and access, agreed that all data being used for MPA planning should be made available to the CCAMLR Secretariat to allow access for all Members wishing to participate in the process following the Rules for Access and Use of CCAMLR Data. During the workshop, a compilation of data, including GIS data layers and various datasets, was made. This process resulted in the identification of many sources of data, as well as the identification of important data gaps, either as available data which were not considered during the workshop or as data-poor regions within Domain 1.

(iii) The MPA objectives in CM 91-04 were used as a guideline for identifying 10 conservation objectives for Domain 1. For some conservation objectives, the workshop was able to discuss the target areas and protection targets (i.e. proportion to be protected) to be conferred for each objective. Following the identification of conservation objectives and data layers, the workshop discussed the potential uses and activities that could impact these objectives. These potential uses or activities, identified as 'cost' layers, included spatial distributions to represent the historic krill fishery, the potential of resumption of the finfish fishery and tourist activities. The workshop concluded that the krill fishery was the only cost layer to be incorporated into the present analysis, but noted the utility of obtaining information on tourist activities, perhaps via IAATO or the CEP, in order to understand its potential impact. For the krill fishery layer, it was necessary to analyse the fishing unit, the spatial unit and the timescale. The workshop suggested that separate analyses in relation to summer and winter may be useful due to the seasonal differences in ecosystem dynamics.

(iv) The workshop agreed to use decision-support software in the MPA planning process as an aid to identifying potential areas for protection. During the workshop, the group preferred the use of MARXAN and noted that other suitable software could be applied.

(v) Finally, the workshop prepared a list of future work tasks to move forward the development of MPAs within Domain 1. It was recognised that this will be a step-wise process, to be conducted both within the group interested in Domain 1 and in the broader context of the planning domains.

3.44 The Working Group congratulated the Co-conveners and participants for their hard work in progressing MPA planning activities within Domain 1. The Working Group noted that the workshop had agreed a comprehensive list of MPA objectives consistent with the guidance of CM 91-04. It was recognised that this domain involves a latitudinal gradient as well as on- and off-shore environments and that a number of scientific programs and fishing and tourism entities conduct work within the domain.

3.45 The Working Group noted that a good opportunity exists for comparing reference and fished areas by comparing data collected within the US LTER Program and the US AMLR Program. The Working Group, while noting that these two areas are broadly similar, agreed that both areas were subject to similar climatic impacts. Thus, their relationship should remain relatively constant over time, making comparative studies a worthy endeavour.

3.46 The Working Group offered advice on various aspects of the report in terms of structuring future work. Other activities besides krill fishing, in particular tourism activities, should be evaluated in terms of potential impacts. The consideration of benthic layers to help understand the boundaries of pelagic features was noted as an important avenue for consideration and the participants were directed to the results of SO-GLOBEC conducted in Marguerite Bay.

3.47 The Working Group agreed that the analyses should reflect costs and benefits to both conservation and fisheries objectives, which could be done in a variety of ways. For example, impacts on location of fishing or on historical catch distributions may not be the best indication of cost to the fishery; alternatives may include accessibility, future development and economic impacts. Similarly, impacts on conservation could be examined by inverting the analysis so that the importance of fishing areas is examined and the impacts on conservation are considered as costs.

3.48 Further discussion was focused on the steps to be taken to progress work on the MPA planning activities for Domain 1. The plan outlined by Dr Arata was to first finalise and submit data layers and associated metadata (see paragraph 3.50) to the Secretariat with a goal of having 80% completed by the 2012 Scientific Committee meeting and the remaining completed by the 2013 WG-EMM meeting. The next step would be a discussion of qualitative protection targets (e.g. 'high', 'medium' and 'low' rather than quantitative targets describing how much of an area to protect) at WG-EMM and the Scientific Committee at the 2013 meetings. As protection targets reflect both scientific considerations and value judgments, it was therefore envisaged that Members could present candidate MPAs to the 2014 meeting of WG-EMM. Further planning could proceed via a Domain 1 workshop or via correspondence to come to an agreement on a shared MPA proposal, which would be prepared and submitted for review during 2015.

3.49 The Working Group noted that the step-wise planning process was a logical progression, but advised that the timetable should not be viewed as restrictive, and may require adjustment based on results of the planning process. The Working Group also noted that once the objectives and corresponding data layers were agreed and assembled, the process of MPA boundary design could possibly proceed quite quickly. It was noted that other MPA-related activities within Domain 1, such as the planned review of the South Orkney MPA and the review of the draft MPA proposals for areas under ice shelves, would proceed at their own timetables.

3.50 The Working Group produced Tables 3 and 4 which include the list of the MPA objectives identified in WG-EMM-12/69 along with corresponding data layers and specific parameters required. The Working Group indicated that data layers submitted to the Secretariat must include an accompanying rationale for the data layer, the original data sources, methods applied, spatial and temporal resolutions and the metadata description. Further discussion on the tables led to the identification of potential data sources and contact information to assist in completing the production of the data layers. The Working Group encouraged Members to submit the data layers identified in Table 3 and collaborate on this effort.

3.51 It was agreed that Dr Arata will continue to act as the Coordinator of the Planning Domain 1 initiative until the completion of the first phase of this work, which will include the identification and assembly of agreed data layers for each objective for future planning activities for the MPA planning in the domain.

Domain 5, del Cano–Crozet

3.52 The CCAMLR Technical Workshop on Planning Domain 5 (del Cano–Crozet) (WG-EMM-12/33 Rev. 1) was held in St Pierre, Réunion Island, France, from 15 to 18 May 2012 at the Headquarters of TAAF (French Southern and Antarctic Territories). Prof. Koubbi and Dr R. Crawford (South Africa) served as Co-conveners, and the workshop was partly supported by the CCAMLR MPA Special Fund. Four Members participated in this work (Australia, France, Norway and South Africa).

(i) Planning Domain 5 includes Marion and Prince Edward Islands, the del Cano Rise and Crozet Archipelago in the north region. It also includes the Ob and

Lena seamounts. Protected areas already exist in the 12 n miles around the coastal zone of Prince Edward and Crozet Islands. Studies for designating MPAs are in progress within both the South African and French EEZs.

(ii) To achieve the workshop goals, research and monitoring were discussed under three headings: (i) census of biodiversity, (ii) ecoregionalisation classification and (iii) monitoring, which includes contribution to a CEMP-style approach and the use of continuous plankton recorder.

(iii) The workshop provided benthic and pelagic abiotic classifications of the planning domain. Modelled distributions of plankton (mesozooplankton and euphausiids), mesopelagic fishes and top predators were consistent with the abiotic regionalisation showing latitudinal patterns of communities for the pelagic species. Demersal ichthyofauna and benthos were described as being characteristic of the sub-Antarctic zone with some species being endemic. Marion, Prince Edward and Crozet Islands support substantial colonies of seabirds and seals, which for several species have global importance and moderate to high levels of threats. There is accumulating evidence that decreases of albatrosses and petrels have been substantially influenced by by-catch mortality in fisheries both inside and outside the Convention Area.

(iv) The northern part of the domain was initially trawled for finfish, but now supports only longline fisheries for Patagonian toothfish (*Dissostichus eleginoides*). In the southern part of Domain 5 there was a pelagic trawl krill fishery for Antarctic krill from 1974 to 2001; no recent fishing in the south has been recorded.

3.53 The Working Group congratulated the Co-conveners and participants for their hard work in progressing MPA planning activities within Domain 5. The main objective of the workshop was to study the ecological values and the use of the marine environment in Planning Domain 5. Identification of objectives for systematic conservation planning (SCP) and future research was discussed. Depending on the availability of data, the workshop aimed to map species distributions (either observed data or prediction of species or community presence/abundance based on environmental factors). South African and French data were a major focus because these CCAMLR Members have major scientific programs in this region. Norwegian data from the Bouvetøya region were also discussed.

3.54 The Working Group noted a set of preliminary strategic points essential to SCP for this region. These include accounting for ecological relationships with surrounding CCAMLR planning domains (Bouvet–Maud to the west, Kerguelen Plateau to the east and East Antarctica to the south) and also subtropical areas north of the Convention Area, because of the spatial range covered by top predators and because the northern boundary of the Convention Area cuts across the EEZs of both the Prince Edward and the Crozet Islands, as well as the del Cano Rise.

3.55 The Working Group noted the use in the Domain 5 workshop of spatial modelling methods such as boosted regression trees (BRT) to generate spatially continuous biological distributions from discontinuous biological data. It recalled that methods have been developed to validate the accuracy of modelled distributions and, if necessary, to restrict outputs to environments within the spatial planning domain that are well represented by input biological data. The Working Group further discussed potential difficulties with converting spatial data to a common grid cell size, and noted that by summarising gridded outputs as points it was possible using some tools (e.g. WG-EMM-12/56) to use data layers with different spatial resolutions without the need to convert data to a common cell size. The Working Group discussed the application of the SCP approach in data-poor areas where no biological data exist, and noted that it was possible to apply patterns observed elsewhere to subjectively define target areas for protection based on known habitat affinities or ecological first principles. The Working Group noted that all spatial planning exercises and tools are affected by the quality of the data and the accuracy of the assumptions that underlie their use, and that planning processes should always be undertaken with input from those familiar with the relevant planning domains and data sources.

3.56 It was agreed that Prof. Koubbi will continue to act as Coordinator of the Planning Domain 5 initiative until completion of the first phase of this work, which incorporates the description of the area and the collection of GIS data layers representing protection objectives, and associated metadata to be transmitted to the Secretariat. These data layers will then be available for the use of WG-EMM in undertaking SCP in the second phase. A work plan was established according to the two phases presented. The first phase to complete compilation and submission of data layers should be achieved by mid-2013 with the cooperation of all Members. A synthesis concerning Planning Domain 5 will then be proposed to the Scientific Committee in 2013. It was proposed that the second phase should be held during WG-EMM in 2014 with the opportunity for all Members interested in SCP within this region to participate. It was proposed that WG-EMM consider an SCP process for the high-seas part of Domain 5, whereas the time frame for the EEZs will be different and at a finer spatial scale. These different procedures are important as the resolution of ecological data varies among ecoregions in the Planning Domain 5 and procedures should be applied at appropriate scale for species or environmental features. The technical workshop did not work on the sea-ice zone as it considered that this area has been addressed in planning for Domain 7 at the most appropriate scale.

3.57 The Working Group also recommended that the Commission consider collaboration with other regional initiatives in the southern Indian Ocean concerning the potential designation of MPAs across the northern boundary of the Convention Area. As the northern area of Domain 5 is influenced by different fronts, discussions on how to estimate the consequences of climate change were raised. There are scientific approaches to predict changes in biogeochemical regions according to climatic scenarios. However, this has to be tested with considering also the vertical dimension as it is important for determining frontal zones and how they influence the distribution of pelagic and mesopelagic species which are important also for top predators.

3.58 The Working Group agreed that the success of the Domain 1 and Domain 5 workshops had demonstrated that the 'technical workshop' format is a useful and productive mechanism by which to progress the development of MPAs.

Tools for MPA planning and reporting

3.59 WG-EMM-12/56 described the use of a custom GIS-based marine spatial planning (MSP) tool designed to aid the development and transparent evaluation of MPA scenarios, with reference to spatially explicit protection objectives and cost layers representing rational use, in an SCP framework. The tool, originally developed by New Zealand to aid in Ross Sea MPA planning as described in WS-MPA-11/25, has been customised to allow its use by any Member in any of the nine CCAMLR MPA planning domains and to provide improved functionality. The MSP tool automates the selection, import, transformation, clipping to planning domain boundaries and re-projection of spatial data layers representing MPA protection objectives or 'costs', and provides multiple options for inputting MPA boundaries. Evaluation of MPA scenarios is achieved by calculating the percentage of the value or area of each layer that is inside the MPA, as a proportion of the total value or area for that layer in the planning domain. For any MPA, or system of MPAs, the MSP tool will produce a simple performance summary for each objective or cost layer, as in Table 1 of SC-CAMLR-XXX/10.

3.60 The Working Group noted that because the MSP tool automates the storage of GIS data layers used, its use may facilitate dialog and collaborative MPA planning between Members. For example, when input data layers are agreed for a planning domain (e.g. the finalised spatial outputs of the Domain 1 or Domain 5 workshops; paragraphs 3.43 to 3.57) then the use of the MSP tool will assemble these layers in a compact and standardised storage format and generate a corresponding Arc-GIS project file. By making this package available, all Members would have access to identical data layers by which to develop and evaluate their own MPA scenarios using the MSP tool or other planning tools such as MARXAN. However, data layers representing fishing effort distributions from the Secretariat database may need to be acquired individually by Members via a CCAMLR data request.

3.61 The Working Group noted that the tool has not been validated by the Working Group for providing advice. The Working Group considered, but did not agree, whether the MSP tool involved the type of modelling methodology that required a review by WG-SAM or WG-FSA. The tool does not have an underlying operating model but is a tool to streamline and automate a sequence of GIS layer manipulations and arithmetic calculations that are routinely undertaken individually in GIS, but that would be extremely time-consuming to perform manually. WG-SAM and WG-FSA have previously reviewed quantitative tools used to provide management advice.

3.62 The Working Group noted that the MSP tool could be complementary to other decision-support tools or software which might be used in the design of candidate MPAs and that this tool provides a platform by which to evaluate and compare different options.

3.63 The Working Group agreed that the MSP tool has the potential to contribute to MPA planning, and thanked Dr Sharp for his efforts to further develop this tool and to make it available for use by all CCAMLR Members. The Secretariat agreed to make the tool available on the CCAMLR website with links via the MPA subgroup website. The Working Group agreed it was useful to have additional documentation available to facilitate the use of the tool. Trialling the tool in other domains would also help to build more experience and guidance on best practice and facilitate its validation if appropriate. It was noted that other algorithms for summarising data, rather simple summation or counts, within polygons or proposed MPAs may be useful, particularly with respect of evaluating costs and benefits of different options.

GIS tools

3.64 WG-EMM-12/70 presented a joint UK–Secretariat proposal for the British Antarctic Survey (BAS) to develop a web-based GIS to aid the management of spatial data, including data on proposed and designated MPAs (SC-CAMLR-XXX, paragraph 5.13). The proposal includes the development of the Secretariat's capacity to handle, maintain and deliver geographic information in accessible format to support analysis, decision-making and compliance. The proposed GIS would be implemented in two sections: an open public section containing data layers which are not restricted in access, and a password-protected section providing secure access to restricted datasets related to CCAMLR's administration, science and management.

3.65 The first stage of the implementation would be for BAS to build the GIS and to populate it with primary data layers. The second stage would be to transfer and implement the system at the Secretariat, to train the Secretariat staff to use the system and to maintain it. The second stage would also consider the addition of new datasets.

3.66 The Working Group agreed that this initiative would encourage collaborative approaches among Members, in particular for the development of MPA proposals. The proposed GIS would allow for effective dissemination of a range of spatial information to Members, as well as to other organisations, including the CEP, as appropriate.

3.67 The Working Group recommended that collaboration with the SCAR Biogeographic Atlas initiative would also be useful. The Working Group noted that the development of appropriate metadata is critical. This documentation on input GIS data layers will need to include references to all the source data and the algorithm(s) used to generate data layer, a clear expression of the units of the data layer and the spatial resolution, including capacity for detailed text descriptions of methodologies used to create, summarise, or derive the data layers from the raw data.

3.68 The Working Group recognised that the development and support of a fully operational web-based GIS service will be a long-term project; therefore it was agreed that any data layers available now could be immediately shared on password-protected pages of the CCAMLR website as an interim measure. The Working Group noted that the new CCAMLR website included an outline of this type of webpage. These webpages will be particularly useful for uploading GIS layers for work being undertaken in the MPA planning domains. Coordination and management of software, metadata and data would require focused effort and resources.

3.69 WG-EMM-12/15 presented the distribution of spatial management and Antarctic krill catch across pelagic bioregions in the Southern Ocean (see also paragraph 2.26). This paper described the structure and content of a GIS which has been developed to provide standardised information on the location of spatial fisheries management measures (see also WG-EMM-12/70), and demonstrated a potential application of this tool in examining the relative spatial distribution of fishing activities, existing management and ecological characteristics.

3.70 The Working Group welcomed this analysis, noting its particular relevance in support of systematic conservation planning, and highlighted the importance of making such GIS data layers available through the CCAMLR website.

MPA Reports proposal

3.71 WG-EMM-12/49, in recalling that CM 91-04 provided guidance for the establishment of an MPA, noted that the Scientific Committee may be called upon to provide advice on topics such as the scientific basis for establishing MPAs, research and monitoring plans, and the review and revision of MPAs. It was recommended that a standardised format may be useful to consolidate and maintain scientific information in a readily accessible and current document that could be used as a basis for providing advice.

3.72 Modelled on the Fishery Reports that have been developed by the Scientific Committee in order to provide advice to the Commission in reviewing and revising conservation measures, WG-EMM-12/49 proposed an MPA Report with the following structure:

(i) description of the region, including the physical environment, biogeography and ecology

(ii) objectives to be achieved in MPAs, including objectives for the region, specific objectives of the individual MPAs and the attributes of the MPA relative to the objectives

(iii) historical activities

(iv) assessment of the MPA(s) and the effects of activities

(v) limits on activities permitted in the MPA

(vi) research and monitoring plan.

3.73 The Working Group supported the development of a standardised format and structure for scientific information pertaining to MPAs as contained in MPA Reports and noted that the format outlined in paragraph 3.72 would be useful in collecting and organising detailed information so that the Scientific Committee could readily access the data required to prepare advice to the Commission. The Working Group acknowledged that the Scientific Committee should determine the ideal format and content of an MPA Report. The Working Group considered that in future WG-EMM would be the appropriate working group with primary responsibility for reviewing and updating the content of MPA Reports.

3.74 The Working Group suggested that MPA Reports could be made available through the CCAMLR website, as living documents which could be updated on a regular basis using a similar process to that used for the publication of the Fishery Reports. Over time, as experience is gained in populating MPA Reports and the process becomes more automated, the Secretariat could take over the responsibility of managing data input into MPA Reports. It was recommended that MPA Reports be organised by MPA planning domains.

3.75 The Working Group recognised the practicality of using the format of the MPA Report to organise the documentation related to MPAs, to clearly distinguish legal text relating to MPA designation and binding measures, as distinct from supporting scientific information. The Working Group noted that this topic would be a question for the Commission. The MPA Report, approved by the Scientific Committee, would contain necessary background and supporting scientific information and analyses required to form the basis of advice to the Commission, and the research and monitoring plan. Together, these documents provide much of the information often seen in management plans.

Other issues: planning for a circumpolar technical workshop

3.76 The Working Group supported the aims and key issues to be discussed at the Circumpolar MPA Technical Workshop, prepared by Co-conveners Drs B. Davis and A. Van de Putte (Belgium). The goal of the workshop, to be held in Brussels, Belgium, from 10 to 15 September 2012, is to progress work towards the CCAMLR goal of establishing a representative system of MPAs across all CCAMLR planning domains.

3.77 Following the principles set out in the circumpolar analysis considered at the 2011 MPA Workshop (SC-CAMLR-XXX, Annex 6), the aim of this technical workshop is to examine those planning domains in which conservation planning is not currently taking place, namely Domain 3 (Weddell Sea), Domain 4 (Bouvet/Maud Rise) and Domain 9 (Amundsen/Bellingshausen Sea).

3.78 The key issues to be addressed during the workshop are to identify and review the existing data for Domains 3, 4 and 9, to identify appropriate conservation objectives based on CM 91-04, paragraph 2, to conduct a circumpolar gap analysis to consider whether there are species or features not captured in existing analyses at the individual domain level and to further progress the systematic conservation planning process by outlining a future work program.

3.79 The Working Group was supportive of the effort to address the three remaining domains in which no systematic conservation planning is currently occurring. This workshop will enable SC-CAMLR-XXXI to demonstrate progress towards the consideration of a representative system of MPAs across all planning domains by 2012.

3.80 The Working Group encouraged attendance by experts with knowledge relevant to the work described in paragraph 3.78 and also the development of a process by which those who cannot attend the workshop can submit data which can be used in the workshop's discussions. The Working Group noted that a Scientific Committee Circular had been sent to Members providing information about the workshop and how to contribute data.

VMEs

3.81 WG-EMM-12/51 provided notifications for new VMEs in Subarea 48.1 under CM 22-06 based on the presence of VME indicator taxa in trawl samples from surveys undertaken in 2003 and 2012.

3.82 The Working Group recalled that the use of abundance thresholds was intended primarily as a means of locating potential VMEs from fisheries by-catch (CM 22-07). With respect to identifying VMEs based on fishery-independent research data (CM 22-06), thresholds of this kind are not necessarily required (SC-CAMLR-XXVIII, Annex 5, paragraph 10.34). Nonetheless, in 2009 the Scientific Committee agreed that the VME trawl catch abundance threshold used in WG-EMM-09/32 was useful for identifying potential VMEs in Subarea 48.1 (SC-CAMLR-XXVIII, paragraph 4.249) at depths similar to those surveyed and considered in WG-EMM-12/51.

3.83 The Working Group recommended that the five stations proposed in WG-EMM-12/51 based on VME by-catch in excess of the proposed threshold be added to the VME registry. Latitude and longitude coordinates for these stations are provided in Table 5.

3.84 The Working Group noted the proposal in WG-EMM-12/51 to use diversity of VME indicator taxa in a sample location as a means of identifying VMEs which can include light VME taxa only. The paper proposed eight stations could be identified with respect to a diversity threshold of ≥16 VME taxa, and some Members agreed that the eight stations should also be registered.

3.85 The Working Group noted that the diversity of any biological community is dependent on the level of taxonomic aggregation assumed in the analysis, such that it would be necessary in any comparison of species richness between locations to standardise the use of taxonomic categories across all datasets included in the analysis. The authors of WG-EMM-12/51 clarified that because earlier trawl survey data (from 2003 and 2006) were recorded at a lower level of taxonomic resolution, the evaluation of species richness in WG-EMM-12/51 used only the 2012 trawl survey results (i.e. 64 bottom trawl stations).

3.86 The Working Group noted that thresholds to identify potential VMEs should be developed with consideration of the sampling design, taking care to ensure that the survey or dataset from which a threshold is derived is at a sufficiently large spatial scale, is of sufficient intensity and is well stratified across a sufficiently wide range of environmental variables potentially affecting VME community composition or abundance, to ensure that thresholds to identify potential VMEs are indicative of true high importance and are not merely an artefact of sampling design (SC-CAMLR-XXIX, Annex 6, paragraphs 3.43 to 3.46).

3.87 Dr Sharp recommended that similar considerations should apply to the derivation of diversity-based thresholds as proposed in WG-EMM-12/51 (or other thresholds). Alternately, the authors of WG-EMM-12/51 could propose a particular depth range or environmental envelope within which a diversity threshold should be applied.

3.88 The Working Group agreed that appropriate survey stratification to identify thresholds to aid VME identification are scale-dependent and area-specific, and that thresholds derived in particular subareas or divisions, or within particular depth strata, may not be applicable in other areas. The Working Group noted that a multivariate ordination analysis of community composition as a function of environmental variation may be useful to demonstrate the extent to which surveys of this kind are appropriately stratified across a suitable range of environmental variables (e.g. depth, water temperature, current speed, substrate) likely affecting VME community composition in the area. Analyses of this kind may also be useful to identify habitat associations or environmental drivers that may inform predictive spatial modelling of likely VME occurrence. The Working Group also noted that overlaying potential correlates with VME composition, such as satellite-derived estimates of primary production or modelled krill abundances, may be useful, but recognised that links between the pelagic and benthic environments in this area may be weak or confounded by horizontal advection processes.

3.89 The Working Group noted that different sampling or fishing gears have very different levels of impact, and that bottom trawls, such as those used in the surveys described in WG-EMM-12/51, are likely to have the highest impacts. Some Members felt, therefore, that VMEs should be defined with reference to a particular gear type, because habitats vulnerable to impact by one type of gear may not be vulnerable to other types of gear. Other Members noted that while impacts vary between gears, the inclusion of locations in the VME registry is not specific to particular gear types.

3.90 The Working Group recommended that WG-EMM-12/51, Figure 6, which proposed VME areas, be included in the report to indicate the presence of black coral (Antipatharia), a CITES Appendix II listed taxon deserving consideration. Inclusion of this figure (Figure 2) will also indicate areas of interest for future work to identify potential VMEs, including within extended areas surrounding multiple survey stations at which potential VME indicators have been recorded, for further consideration by the Scientific Committee, including advice on the publication of location data for this taxon.

3.91 WG-EMM-12/51 further identified an additional taxon consistent with some of the criteria for VME indicator taxa set out in SC-CAMLR-XXVIII, Annex 10, paragraph 3.5. The Working Group was unable to complete a full discussion on whether this taxon, Stauromedusae (benthic cnidarians commonly known as stalked jellyfish) should be added to the CCAMLR VME taxa classification guide, and agreed that this issue should be discussed at a future meeting.

3.92 WG-EMM-12/23 provided information regarding the presence of VME taxa in high abundances, in particular the Antarctic scallop (*Adamussium colbecki*), adjacent to Terra Nova Bay, ASPA No. 161. The Working Group noted the provision of data from multiple sources and detailed descriptions and analyses supporting the conclusion that the identified locations were of particular ecological importance. The Working Group further noted that because the analyses included time series of ongoing monitoring efforts conducted from Mario Zucchelli Station in Terra Nova Bay, the sites were also of high scientific importance, potentially providing insights regarding the ecological role of these benthic communities and environmental change. The Working Group noted the value of investigations of this kind and encouraged CCAMLR to make full use of scientific research and monitoring information from shore-based research.

3.93 The Working Group recommended that the identified locations with high abundances of the Antarctic scallop (*A. colbecki*), adjacent to Terra Nova Bay should be added to the VME registry. Latitude and longitude coordinates for these locations are provided in Table 6.

OTHER ECOSYSTEM CONSIDERATIONS, INCLUDING FISH-BASED ECOSYSTEM INTERACTIONS

4.1 WG-EMM-12/53 described a network characterisation of the food web of the Ross Sea. The analysis used the mass-balance trophic ecosystem model described in Pinkerton et al. (2010) to: (i) characterise the trophic structure and function of the Ross Sea shelf and slope ecosystem, and (ii) identify ecosystem sensitivity to perturbations to each functional group. The model characterised average trophic flows (biomass) between 35 functional groups on the Ross Sea shelf and slope, over the course of a typical year. Effects at smaller spatial and temporal scales, or involving only subsets of functional groups, are not resolved within the model and cannot be addressed using the outputs of this analysis. The current fishery for Antarctic toothfish (*D. mawsoni*) is not included as a functional group.

4.2 The Working Group agreed that ecosystem models such as these were valuable for identifying plausible ecosystem risks from foreseeable perturbations such as fishing or climate change, for informing the design of monitoring programs to detect and understand mechanisms of ecosystem change, and for generating testable hypotheses to inform future research.

4.3 The Working Group noted that the analysis suggests that Antarctic toothfish have only a moderate level of structural importance. These analyses do not support the hypothesis that changes in the abundance of toothfish in the Ross Sea will substantially alter the wider food web, but they do suggest that such changes are likely to affect the abundance of the 'medium demersal fish' functional group in WG-EMM-12/53 (e.g. *Macrourus* spp.) due to changes in predation pressure. The Working Group agreed that dedicated monitoring to detect such changes would be useful.

4.4 The Working Group noted that trophic effects on toothfish predators (Weddell seals, killer whales (*Orcinus orca*) and sperm whales (*Physeter catodon*)) are not expected to be strong at the scale of the model; however, localised effects may be possible that cannot be resolved in the analyses presented here, and the model does not distinguish between killer whale variants. Where plausible, risks from localised interactions are identified by other means, these may be amenable to mitigation by spatial management.

4.5 The Working Group noted in particular the high trophic importance of Antarctic silverfish – such that the Ross Sea shelf can be characterised as a silverfish-centric ecosystem, in contrast to krill-centric ecosystems elsewhere in the Southern Ocean – and of small demersal fishes. The Working Group agreed that further research investigating these important species should be a high priority. Prof. Vacchi noted ongoing research from Mario Zucchelli Station in Terra Nova Bay and offered to collaborate with other Members to progress this work. Other functional groups with high trophic importance include phytoplankton, mesozooplankton, *E. superba*, cephalopods and *E. crystallorophias*. The Working Group agreed that research to detect and monitor changes to the Ross Sea shelf ecosystem should perhaps prioritise these functional groups, or sensitive indicators of these groups.

4.6 The Working Group noted that the utility of the model to inform our understanding of particular mechanisms and identify ecosystem risks could be improved by dis-aggregating some of the functional groups, and encouraged the authors to progress this work. In particular: (i) dis-aggregating phytoplankton to distinguish between diatom- vs. haptophyte- (e.g. *Phaeocystis antarctica*) production would enable links with ongoing physical oceanographic research to anticipate likely food-web impacts of alternate climate change scenarios; (ii) dis-aggregating the small demersal fish group may inform ecological understanding, particularly in the coastal zone and under ice; and (iii) distinguishing between the three distinct killer whale variants in the Ross Sea will be important if food-web model outputs are used to evaluate potential trophic ecosystem impacts involving killer whales or risks of trophic overlap with fisheries.

4.7 WG-EMM-12/54, 12/55 and 12/P03 described research in the Ross Sea region characterising the diets of *P. antarcticum*, cephalopods, and *Macrourus* species respectively, using stomach content analysis and stable isotopes. For silverfish, copepods were identified as the main prey item using the Index of Relative Importance (IRI), a standardised diet metric incorporating both prey number and prey weight, but by weight alone the main prey were fishes and krill. Significant diet variation was detected with respect to silverfish size and location. Squid and octopod species were found to feed across a wide range of trophic levels with indications of both pelagic and benthic foraging. For an undifferentiated mixture of two formerly cryptic *Macrourus* species, *M. whitsoni* and *M. caml*, amphipods and copepods were the dominant prey by IRI, but fish were also important prey by mass.

4.8 The Working Group noted the value of diet studies of this kind to inform our understanding of the life cycle and ecology of these species, and to parameterise and/or validate food-web models such as described in Pinkerton et al. (2010) and WG-EMM-12/53, noting that for the latter purpose characterising diets by prey mass rather than IRI may be more appropriate. With respect to silverfish, the Working Group suggested that the term 'larval/post-larval' referring to fish >50 mm and <90 mm may be misleading, as this size range does not usually include larval fish. With respect to *Macrourus* spp., the Working Group noted their importance in the diet of Antarctic toothfish and encouraged the authors to further develop this work, for example to distinguish between the two formerly cryptic *Macrourus* spp. in future analyses.

4.9 WG-EMM-12/17 reported that macaroni penguins at Bird Island consume fish and amphipods when krill are scarce, but fledging weight is generally lower when these taxa are prominent in the diet. WG-EMM-12/16 reported some trends in predator variables at Bird Island which are not attributable to krill availability and may indicate the state of alternative prey. WG-EMM-12/36 attributed declines in the abundance of Antarctic shags at the South Shetland Islands to declines in fish stocks associated with industrial harvesting in the 1970s. These papers indicate the importance of trophic pathways that do not include krill in Area 48.

4.10 Dr Constable noted that it is difficult to provide commentary in this section when WG-FSA is the working group assigned with responsibility for fish and squid biology and ecology and not WG-EMM. As a result, he recommended that these papers and the commentary of WG-EMM be forwarded to WG-FSA for comment in order that the Scientific Committee can have input on these issues from the working groups that are expected to have the expertise on these topics. He also indicated that there should be a greater expectation of WG-EMM to engage with WG-FSA on fish-related issues rather than to work in isolation.

4.11 Dr Sharp recalled that on multiple occasions (WG-EMM-05/18, 06/14, 07/18, 08/42, 08/43 and 09/42) WG-EMM has reviewed and provided comment on scientific papers describing the development and application of the Ross Sea food-web model applied in WG-EMM-12/53. WG-FSA has not in the past reviewed papers describing this model. On previous occasions when CCAMLR has devoted specific agenda items to considering ecosystem effects of finfish fisheries, i.e. the 'Fisheries Ecosystem Models in the Antarctic' (FEMA1 and FEMA2) workshops in 2007 and 2009, these were addressed within WG-EMM. On this basis, Dr Sharp maintained that WG-EMM remains the appropriate body to review ecosystem modelling applications such as described in WG-EMM-12/53, and that transferring that responsibility to WG-FSA was inadvisable. Similarly, WG-EMM-12/55 referred to cephalopods, and 12/16, 12/17 and 12/36 described the ecosystem effects and implications of changing seabird diets; these topics are outside the traditional remit of WG-FSA. With respect to WG-EMM-12/54 and 12/P03, Dr Sharp agreed that these were of interest to WG-FSA and thanked Dr Constable for his suggestion. Dr Sharp also strongly supported Dr Constable's suggestion that WG-FSA be asked to comment on the recommendations of WG-EMM when those recommendations can be expected to directly affect, or be affected by, the work of WG-FSA.

ADVICE TO THE SCIENTIFIC COMMITTEE AND ITS WORKING GROUPS

5.1 The Working Group's advice to the Scientific Committee and its working groups is summarised below; the body of the report leading to these paragraphs should also be considered.

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

(i) Krill fishery –

(a) fishery notifications for 2012/13 (paragraphs 2.7, 2.8, 2.10 and 2.11)

(b) green weight estimation (paragraphs 2.13 to 2.17)

(c) additional requirements for C1 data (paragraphs 2.20 and 2.21)

(d) requirements for scientific observations (paragraphs 2.38, 2.40, 2.43 and 2.47 to 2.49)

(e) historic biological data from the Soviet fleet (paragraph 2.25).

(ii) Krill ecology and management –

(a) review by WG-SAM of a new growth model (paragraph 2.57)

(b) revised biomass estimate for Division 58.4.2 (paragraphs 2.63 and 2.64)

(c) precautionary catch limits (paragraph 2.73).

(iii) Feedback management strategy –

(a) general monitoring considerations (paragraphs 2.77, 2.80 and 2.84).

(iv) Fishing vessel surveys –

(a) proof of concept (paragraphs 2.170 and 2.171).

(v) Marine protected areas –

(a) management plans for ASPAs Nos 144, 145 and 146 (paragraph 3.3)

(b) draft management plan for a new ASPA at Cape Washington and Silverfish Bay (paragraph 3.7)

(c) krill fishing vessels observed in ASPA No. 153 (paragraphs 3.16 and 3.17)

(d) linkages between ASPAs and ASMAs and CCAMLR (paragraphs 3.18 to 3.20)

(e) proposed MPA near Akademik Vernadsky (paragraphs 3.22, 3.23 and 3.25)

(f) proposed MPA under the Larsen ice shelves (paragraphs 3.28, 3.31 to 3.33)

(g) research and monitoring plan for the Ross Sea (paragraph 3.42)

(h) MPA planning activities for Domain 1 (paragraph 3.48)

(i) MPA planning activities for Domain 5 (paragraphs 3.56 and 3.57)

(j) proposed web-based GIS to aid the management of spatial data (paragraph 3.66)

(k) development of a standard format and structure for MPA reports (paragraphs 3.73 to 3.75)

(l) addition of new VMEs in the VME registry (paragraphs 3.83 and 3.93)

(m) observations on black coral (Antipatharia) (paragraph 3.90).

(vi) Other matters –

(a) participation of observers at working group meetings (paragraphs 7.3 to 7.6)

(b) participation of IWC observers at working group meetings (paragraphs 7.7 and 7.9).

FUTURE WORK

6.1 The Working Group agreed the following future work:

(i) Notification –

(a) to further improve estimation of green weight caught by the krill fishery (paragraphs 2.13 to 2.17, 2.20 and 2.21).

(ii) Scientific observer coverage –

(a) to better understand finfish by-catch in the krill fishery, including training observers to identify fishes and simplifying observer logbooks (paragraphs 2.43 to 2.45).

(iii) Krill-based food web and krill assessment –

(a) review its current assessments of precautionary catch limits for krill (paragraph 2.72) in light of:

- recent estimates of variation in krill recruitment
- the need to account for climate change effects in decision rules for krill.

(iv) Candidate feedback management –

(a) continue to progress work on developing candidate feedback management approaches for the krill fishery according to the schedule agreed in 2011 (paragraphs 2.74 and 2.75)

(b) prepare and submit monitoring data that is analogous to CEMP data and might help to expand the spatial extent of current CEMP data holdings (paragraph 2.92 but noting also paragraphs 2.138 to 2.140)

(c) collect up-to-date information on the spatial distribution including movement, and trends in krill biomass including fishable biomass, throughout Area 48 (paragraphs 2.104 to 2.106).

(v) CEMP and WG-EMM-STAPP –

(a) continue current work by WG-EMM-STAPP to complete estimates of abundance and krill consumption for fur seals and penguins in Area 48, to consider any feasible means for developing estimates of abundance and krill consumption by flying seabirds, and to develop similar estimates for predators in East Antarctica and the Ross Sea (paragraphs 2.143 to 2.145)

(b) develop foraging distribution models to partition estimates of overall krill consumption by fur seal and penguin populations in Area 48 into smaller spatial units (paragraphs 2.152 to 2.153)

(c) priority analysis of CEMP and other monitoring data to support the evaluation of candidate procedures for feedback management (paragraphs 2.128 to 2.129).

(vi) Integrated assessment models –

(a) continue to develop an integrated assessment model and new growth model for use in feedback management of the krill fishery (paragraphs 2.106, 2.161 and 2.162).

(vii) Fishing vessel surveys –

(a) support SG-ASAM in pursuing a proof of concept program to develop the scientific use of acoustic data collected from fishing vessels (paragraphs 2.170 to 2.176).

(viii) Marine protected areas –

(a) to communicate deliberations of WG-EMM regarding a revised Management Plan for ASMA No. 1 (Admiralty Bay) (paragraph 3.15)

(b) to progress work on MPA planning activities for the Western Antarctic Peninsula–South Scotia Arc planning domain (Domain 1) (paragraphs 3.48 and 3.49)

(c) to progress work on MPA planning activities for the del Cano–Crozet planning domain (Domain 5) (paragraph 3.56).

(ix) Ship-based activities –

(a) US AMLR Program:

Dr Watters informed the Working Group about an impending change to the operational period of the US AMLR Program's annual ship-based research and monitoring effort. The ship-based work, which has historically been conducted during the austral summer, has been re-scheduled to occur during the austral winter. Although this change will provide new, important and relevant research opportunities, the change will impact the long time series of summer observations collected by the US AMLR Program. Work will therefore be conducted to provide some calibration between summer and winter observations. Dr Watters invited members of WG-EMM to consider future ship-based collaborative research with the US AMLR Program and opportunities to collect observations during the winter period.

The Working Group reiterated the important scientific contributions made by the US AMLR Program to the work of the Scientific Committee, and expressed thanks for efforts to ensure continuity of its research.

(x) Planning for activities in 2014/15 –

(a) the Working Group noted a new collaborative project involving the Institute of Marine Research (Norway) and BAS (UK). This project would involve a joint survey in 2014/15, focusing on processes in the southern Scotia Sea. Planning for this survey had begun and Dr Watkins invited members of WG-EMM to consider collaborative research and coordinated activities

(b) the Working Group noted possible opportunities for such collaboration, as reported by:

- Dr Siegel on proposed German ship-based research in the Bellingshausen Sea in 2014/15

- Dr Watters on opportunities for collaborative research with the US AMLR Program.

(c) the Working Group also noted the proposal for future synoptic surveys of krill in the Scotia Sea which was outlined by Dr S. Kasatkina (Russia) (WG-EMM-12/52, see also paragraph 2.105). This proposal aims to provide new information on the distribution and abundance of krill throughout the Scotia Sea (including pelagic areas) which will lead to the estimation of an updated B_0, and an improved understanding of the flux of krill in this region. The design of the synoptic surveys would be based on the methods established for the CCAMLR-2000 Survey, and a steering committee would be formed to plan and coordinate research effort amongst Members. The Working Group recognised that the implementation of this proposal would make a valuable scientific contribution to the development and implementation of the feedback management strategy for the krill fishery

(d) the Working Group encouraged Members to further explore these opportunities for collaborative research. Such activities may also provide contributions to other regional initiatives such as ICED, Southern Ocean Sentinel, and SOOS if conducted at a similar time to these initiatives.

Participation of observers in working group meetings

7.1 Following the Working Group's advice in 2011 regarding the participation of observers in its meetings (SC-CAMLR-XXX, Annex 4, paragraph 6.5), the Scientific Committee had requested further consideration of the relevant qualifications and expertise of observers who might participate in the meetings, the minimum standards for allowing their participation and mechanisms to ensure confidentiality (SC-CAMLR-XXX, paragraph 11.17).

7.2 In considering this matter further, the Working Group:

- recognised that its work relies on the long-term commitment of participants to undertake relevant science and provide expertise at meetings

- recognised the important contributions made by observers and invited experts at the technical MPA workshops in 2012 and other meetings

- agreed that conditions for participation at meetings should apply equally to all participants.

7.3 The Working Group noted that a mechanism to ensure confidentiality at meetings exists for invited experts and this mechanism may be applied to other experts from outside the CCAMLR membership.

7.4 The Working Group also noted that observers from SCAR and IWC had attended previous meetings where specific items of relevance to these organisations had been considered. In addition, procedures were in place in some national delegations for inclusion of industry and NGO representatives. These existing mechanisms provided opportunities for additional expert contributions as needed.

7.5 The Working Group sought further advice from the Scientific Committee on the procedure to be followed by working groups during the intersessional period in order to invite observers to their meetings. The Working Group also sought clarification on the procedure to follow for invited experts.

7.6 The Working Group agreed that observers may have two different roles: (i) facilitate the exchange of information between CCAMLR and external bodies; (ii) contribute specific expertise to the work of a meeting.

Participation of IWC observers in working group meetings

7.7 The Working Group noted the proposed participation of an observer from IWC at the 2012 meeting of WG-EMM. The Working Group did not reach consensus on the observer's participation at the meeting, and sought further guidance from the Scientific Committee on the participation of observers at working group meetings.

7.8 The Working Group recognised that the development of the feedback management strategy for the krill fishery may be of interest to the IWC Scientific Committee, and that participation in this work by the IWC may contribute additional expertise. In addition, the Working Group expressed interest in participation in the IWC's development of models of baleen whales and prey interactions.

7.9 The Working Group suggested that the Scientific Committee may wish to consider a standing invitation to IWC experts to participate at WG-EMM meetings while the feedback management strategy for the krill fishery is being developed.

Review of the format of working group meetings

7.10 The Working Group discussed a proposal by Dr Constable to revise the format of working group meetings. This proposal aimed to:

- improve the coordination of the Scientific Committee's work between WG-EMM, WG-FSA and WG-SAM

- bring together participants from these working groups to discuss and develop topics of shared interest (e.g. VMEs, fish-based ecosystem interactions, review of fishery notifications, scientific observations, feedback management procedures)

- increase the level of participation in the work of these working groups.

It included a revised meeting format that allowed for:

- WG-EMM, WG-FSA and WG-SAM to meet together, mid-year over a three-week period with sessions interleaved sequentially as much as possible, and with WG-EMM meeting over the first two weeks of the three-week period and

WG-FSA meeting over the last two weeks (with one week overlap to facilitate joint sessions). Topics for WG-SAM could be interleaved as appropriate

- the agendas and timetables for the mid-year meetings would be developed by working group conveners and the Chair of the Scientific Committee, with support from the Secretariat, in order to facilitate interactions and coordination amongst working groups

- WG-FSA would also meet for less than one week immediately prior to the meeting of the Scientific Committee to review stock assessments and develop fishery management advice.

7.11 The Working Group recognised various challenges arising from such a proposal, including a higher level of coordination required amongst working groups and whether the program of work could be managed to achieve participation by small delegations. However, the Working Group noted that concurrent sessions are commonly used during meetings of WG-FSA and WG-EMM, and it recognised the benefits of greater interactions between working groups, increased flexibility in meeting agendas and work, and potential improvement in the level of participation in the work of the Scientific Committee.

Meetings in 2013

7.12 The Working Group noted that:

- the Secretariat was in preliminary discussions with several Members regarding a venue for the 2013 meeting of WG-EMM, but there are no firm offers and any Member who wishes to host WG-EMM should contact the Secretariat

- a World Conference on Stock Assessment Methods for Sustainable Fisheries will be held in Boston, USA, from 16 to 18 July 2013. The conference will mainly consider single stock approaches including data-poor fisheries but will also consider multispecies- and ecosystem-based approaches

- the SCAR International Biology Symposium will be held in Barcelona, Spain, in July 2013.

ADOPTION OF THE REPORT AND CLOSE OF THE MEETING

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

8.2 In closing the meeting, Drs Kawaguchi and Watters thanked all participants for their contributions to the meeting, the subgroup coordinators for leading detailed deliberations, the rapporteurs for preparing the report and the Secretariat for its support. The Co-conveners also thanked the Centro Oceanográfico de Canarias for hosting the meeting, and Mr López Abellán and colleagues for their kind hospitality and assistance during the meeting. The Working Group presented Mr López Abellán with a small gift.

8.3 Dr Watters also thanked Dr Kawaguchi for co-convening the meeting this year and offering to lead the Working Group as Convener after SC-CAMLR-XXXI. WG-EMM has entered an interesting and scientifically challenging period at the cutting edge of science and policy.

8.4 Drs Kawaguchi and Reid, on behalf of the Working Group, thanked Dr Watters for his time as Convener during which he led the formative stages of the development of the feedback management procedure for the krill fishery and made expert contributions to that work. The Working Group looked forward to Dr Watters' continued involvement in the work of WG-EMM, and presented him with a small gift in recognition of his term as Convener.

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Table 1: Main characteristics of potential feedback management approaches reviewed in WG-EMM-12/P05.

	Management approaches previously discussed by CCAMLR				
Approach	Precautionary catch limits for target species*	Target population size for predators	Average fitness of predators	Median predator productivity arising from harvested species should not fall below 80% of the pre-exploitation level	No interference by fisheries near colonies with land-based predators
Objective	The median escapement from the fishery of the krill spawning stock should be 75% (current CCAMLR precautionary approach for krill)	Abundance of predator populations should not fall below 50% of that prior to harvesting of the prey species	Predator fitness remains unaffected by fishing	Median predator productivity attributed to the consumption of harvested species to be maintained at or above 80% of its level prior to harvesting	To eliminate the potential for interference with foraging of land-based predators by fisheries
Indicator	Biomass of krill population	Biomass of krill population	Krill density	Index of predator productivity based on predator population size, foraging success based on krill and predator weight	Foraging activity
Monitoring frequency	Single estimate of krill biomass; krill demography	Single estimate of krill biomass; krill and predator demography and functional feeding relationship between predators and krill	Annual krill density in the foraging grounds of predators; relationship between predator fitness and krill density in foraging grounds prior to harvesting	Parameters necessary for estimating predator productivity attributed to the consumption of harvested species (e.g. predator abundance, weight, diet)	Predator abundance and foraging locations
Spatial domain	Area of survey	Area of survey	Area of foraging ground survey	Area of predator monitoring	Area of predator monitoring
Adjustment frequency	n/a	Annual	Annual	Annual	Annual

* Existing management approach used to set the current long-term precautionary catch limit.

Table 2: Main characteristics of candidate feedback management approaches presented at WG-EMM-12.

Management approaches currently under consideration by CCAMLR			
Approach	WG EMM-12/44*	WG-EMM-12/P06	WG-EMM-12/19
Objective	1) Maintain precautionary management objectives for krill using escapement and depletion decision rules that include consideration of climate effects 2) Provide precautionary protection for krill-dependent predators using a decision rule that adjusts total catch 3) Provide precautionary protection to krill-dependent predators using a decision rule that adjusts the spatial distribution of catch	1) Maintain target stock appropriate to achieving target status and avoiding depletion with a specified risk 2) Maintain predators either specifically or collectively equal to or above a state that can recover within 2–3 decades if fishing was to cease 3) Maintain an agreed spatial harvest strategy	Maintain: (1) the area-specific state of the harvested stock close to target levels and within specified bounds; (2) area-specific predator populations within specified bounds; (3) overall fishery performance as required.
Indicator	1) Krill biomass estimates and size-frequency distributions 2) Trends in regional penguin abundance 3) Quantiles of penguin fledging weight distributions	Time series of krill and predator indices, in fished and unfished areas suitable to the spatial harvest strategy	Area-specific predator and prey abundance estimates.
Monitoring frequency	1) Annual 2) Annual 3) Annual	Annual	Annual
Spatial domain	1) Regional 2) Regional 3) Variable, dependent on winter foraging distributions of fledglings	Within a regional configuration determined by the preferred harvest strategy	Regional, with appropriate spatial resolution.
Adjustment frequency	1) 5 years 2) 5 years 3) Annual	Annual	Annual

* Points 1–3 refer to the three-step implementation process identified in WG-EMM-12/44.

Table 3: Status on the preparation and submission of data layers for each conservation object identified during the first workshop on Domain 1, with Members submitting data indicated in brackets. For a full list of the conservation objects identified, review WG-EMM-12/69.

MPA objectives	Bioregions, ecosystem processes etc.	Data layer(s) and specific parameter(s)	Prepared	Submitted
1. Representative examples of benthic habitats (CM 91-04, 2i)	a) Benthic environment types	Douglass et al. (2011) classification, layer derived from environmental types	Yes	Yes
2. Representative examples of pelagic habitats (CM 91-04, 2i)	a) Pelagic bioregions	Raymond et al. (2011) classification	Yes	Yes
3. Important benthic ecosystem processes (CM 91-04, 2ii and v)	a) Large-scale canyons	Douglass et al. (2011) classification	Yes	Yes
	b) Smaller-scale canyons	Specific location: - Cape Shirreff	Yes	Yes
	c) Benthic areas under ice shelves	Ice shelf locations (Antarctic Digital Database)	Yes	No (UK)
	d) Up/down-welling and mixing areas	Specific locations: - North of Elephant Island	No	No (Coord.)
4. Large-scale pelagic ecosystem processes (CM 91-04, 2ii and v)	a) Predictable highly productive areas – surface	Satellite-derived surface summer chlorophyll-a	Yes	Yes
	b) Predictable highly productive areas – water column	LTER observations Specific locations: - Downstream of Elephant Island - Seymour Island (?)	No	No (Coord.)
	c) Up/down-welling and mixing areas	Specific locations: - North of Elephant Island	No	No (USA)
	d) Frontal features	Mean frontal positions: - area between the mean positions of the southern and northern boundaries of the ACCF. Divide this into three sectors. Plus 30 km buffer on the southern boundary of the ACCF.	Yes	Yes
	e) Marginal ice zone	Ice-edge position in early summer (December)	No	No (Coord.)
	f) Polynyas	Specific locations: - Coastal polynyas (×2) south of Alexander Island	Yes	Yes
	g) Other dynamic/ important areas	Specific locations: - Southern Marguerite Bay; - Tip of Antarctic Peninsula; - Canyon northwest of South Orkney Islands (krill concentration)	No	No (USA)

(continued)

Table 3 (continued)

MPA objectives	Bioregions, ecosystem processes etc.	Data layer(s) and specific parameter(s)	Prepared	Submitted
5. Important (spatially constrained/predictable) areas for mammal and bird life-histories (CM 91-04, 2ii)	a) Foraging distributions of central-place foragers during breeding season	Breeding locations: - Chinstrap, gentoo, Adélie penguin - Antarctic fur seal To be updated with WG-EMM-STAPP data at WG-EMM-12	No	No (UK)
		Foraging range for each species	No (USA; UK)	No (Coord.)
	b) Prey distributions	Density distribution of: Krill Copepods Myctophids *Pleuragramma antarcticum*	No (USA; Germany)	No
		Survey tows: *P. antarcticum* (Kg/conservation unit)		
	c) Winter feeding grounds: Marginal ice zone: Average 10-years marginal ice zone during winter (e.g. Jun–Aug)			
	Winter distribution of top predators	Marginal ice zone	No	No (Coord.)
		Penguins + whales distribution May–June	No (USA; UK)	No (USA; UK)
6. Important (spatially constrained/ predictable) areas for fish life cycles (CM 91-04, 2ii)	a) Spawning/ recruitment areas of: *Notothenia rossii* *Gobionotothen gibberifrons*	Depth 0–100 m from 64°00'S to the north	No	No (Coord.)
7. Important (spatially constrained/ predictable) areas for zooplankton life cycles (CM 91-04, 2ii)	a) Spawning/ recruitment areas (spp?)		No (USA; Germany; Argentina; FIBEX)	No (USA)
8. Rare or unique habitats/features (CM 91-04, 2iv)	a) Geothermal features	Specific locations: - Deception Island; - Shackleton Ridge (='seamount ridges' in geomorph classification)	Yes	Yes
	b) Seamounts	Douglass et al. (2011) classification – seamount categories	Yes	Yes
9. Vulnerable areas (CM 91-04, 2iv)	a) VMEs	VME data layer from scientific surveys	Yes	No (Coord.)

(continued)

Table 3 (continued)

MPA objectives	Bioregions, ecosystem processes etc.	Data layer(s) and specific parameter(s)	Prepared	Submitted
10. Reference areas for scientific study (CM 91-04, 2iii)	a) Existing study locations, e.g. CEMP sites	Study locations subject to the historical finfish fishery and recent krill fishery:		
		- Potter Cove and Potter Peninsula (Stranger Point, King George Island)	No	No (Coord.)
		- Cape Shirreff	No	No (Coord.)
		- Admiralty Bay (Copa)	No	No (Coord.)
		Study locations subject to the historical finfish fishery:		
		-Signy Island (South Orkney Islands)	No	No (Coord.)
		- Laurie Island (South Orkney Islands)	No	No (Coord.)
		Study locations not subject to any fishery:		
		- Esperanza Station (Hope Bay)	No	No (Coord.)
		- Danco Coast (Base Primavera)	No	No (Coord.)
		- Palmer	No	No (Coord.)
	b) Historically un-fished/upstream areas: LTER area, 200 to 600 transects	Polygon line of the LTER area	No	No (USA)
	c) US AMLR area, downstream, fished area	Polygon line	No	No (USA)
	d) ASPAs and ASMAs		Yes	Yes

Table 4: Human activities.

Potential uses or activities	Data layer(s) and specific parameter(s)	Prepared	Submitted
Krill fishery	Fishing effort (No. hauls)	Yes	No (Coord.)
Tourism vessels tracks	Vessels tracks (Contact IAATO)	No (USA)	No (Coord.)
Tourist Site	Frequency of use of different sites	No	No (Coord.)

Table 5: Start and end positions, depth, distance, and seabed area sampled for the proposed South Shetland, Elephant and Joinville Islands VME stations.

Date	Mean depth (m)	Distance (n miles)	Start latitude S	Start longitude W	End latitude S	End longitude W
18/03/12	63	1.89	61°20.00'	54°87.17'	61°20.50'	54°93.63'
16/03/03	169	1.26	60°55.02'	55°43.21'	60°52.95'	55°41.85'
14/03/03	125	1.42	61°14.34'	54°48.66'	61°15.03'	54°35.50'
14/03/03	198	1.09	61°03.61'	54°34.00'	61°04.01'	54°35.15'
20/03/03	86	1.21	61°27.08'	55°51.49'	61°24.31'	55°53.44'

Table 6: Location of proposed VMEs in Terra Nova Bay, Ross Sea.

Site name	Latitude S	Longitude E
Tethys Bay	74°42.140'	164°3.308'
Tethys Bay	74°41.605'	164°5.468'
Road Bay	74°41.790'	164°7.069'
Road Bay	74°41.974'	164°7.296'
Adelie Cove	74°46.234'	163°57.472'
Adelie Cove	74°46.239'	163°56.033'
Adelie Cove	74°46.504'	163°57.370'

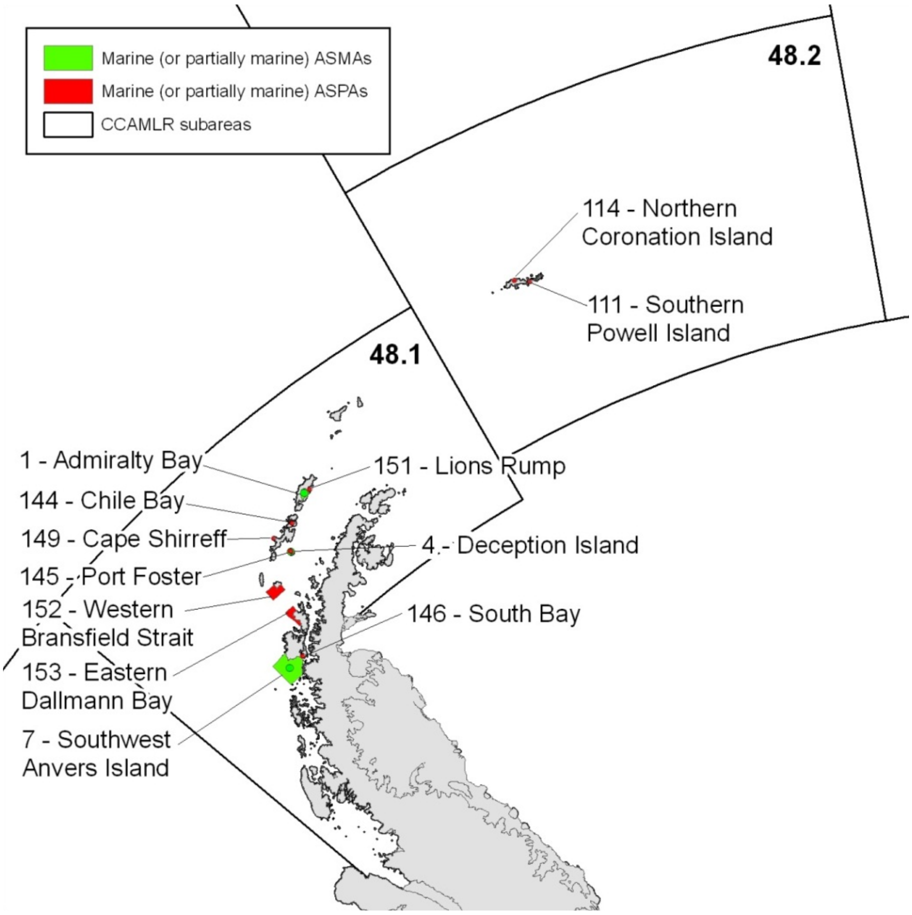

Figure 1: Marine and partially marine ASPAs and ASMAs located in Subareas 48.1 and 48.2. Sites are labelled in accordance with the ASMA and ASPA numbering system adopted by the ATCM (ASMA Nos 1, 4 and 7 and ASPA No. 111, 114, 144, 145, 146, 149, 151, 152 and 153). Map drawn using GIS shapefiles available on the Antarctic Treaty Secretariat website (www.ats.aq/devPH/apa/ep_protected.aspx) Antarctic Protected Areas Data. Source: Environmental Research and Assessment (ERA) (2011).

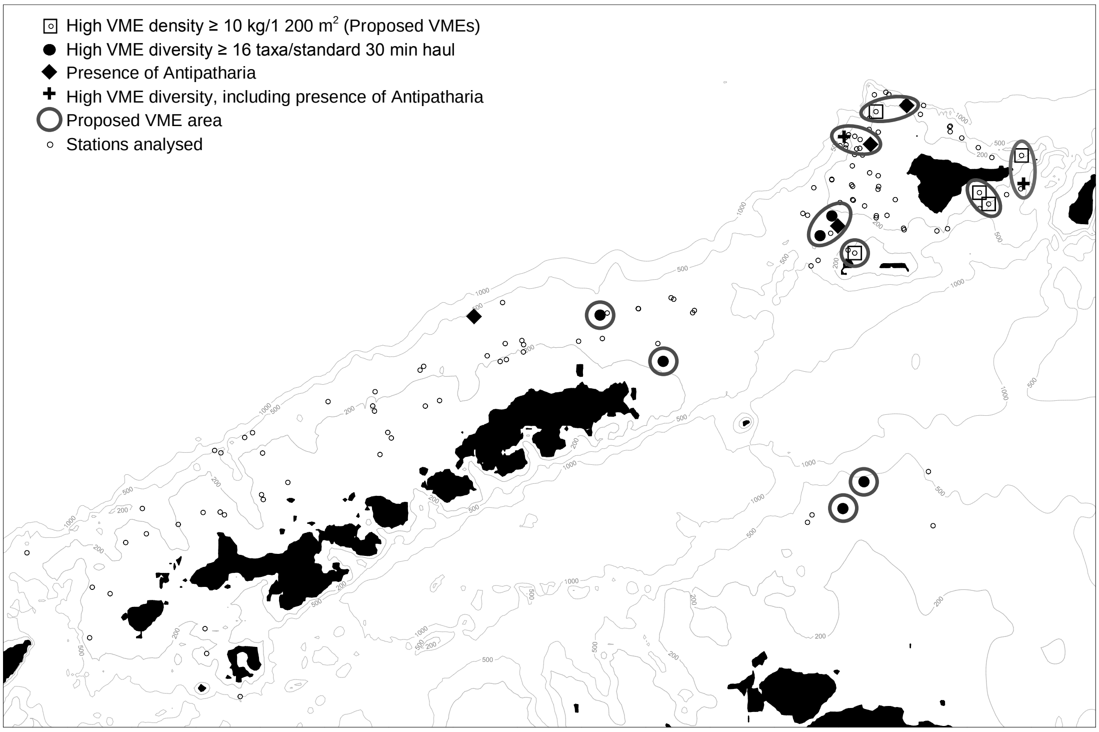

Figure 2: Proposed VMEs, locations of the presence of black coral and areas of interest for future work as identified in WG-EMM-12/51. The five locations characterised by VME by-catch in excess of 10 kg per 1 200 m^2 in 2012 are recommended for inclusion in the VME register. Other locations are identified as areas of interest for future work as in paragraph 3.90.

LIST OF PARTICIPANTS

Working Group on Ecosystem Monitoring and Management
(Santa Cruz de Tenerife, Spain, 2 to 13 July 2012)

ARATA, Javier (Dr)	Jefe Departamento Proyectos INACH Plaza Muñoz Gamero 1055 Punta Arenas Chile jarata@inach.cl
BARBOSA, Andrés (Dr)	Museo Nacional Ciencias Naturales Dpt. Ecologia Evolutiva C/José Gutierrez Abascal. 2 28006 Madrid Spain barbosa@mncn.csic.es
BARREIRO, Santiago (Mr)	Centro Oceanográfico de Canarias Instituto Español de Oceanografía Vía Espaldón, Dársena Pesquera, PCL 8 38180 Santa Cruz de Tenerife Spain santiago.barreiro@ca.ieo.es
CONSTABLE, Andrew (Dr)	Australian Antarctic Division Department of Sustainability, Environment, Water, Population and Communities Antarctic Climate and Ecosystems Cooperative Research Centre 203 Channel Highway Kingston Tasmania 7050 Australia andrew.constable@aad.gov.au
DARBY, Chris (Dr)	Centre for Environment, Fisheries and Aquaculture Science (Cefas) Pakefield Road, Lowestoft Suffolk NR33 0HT United Kingdom chris.darby@cefas.co.uk

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
GRANT, Susie (Dr)	British Antarctic Survey High Cross Madingley Road Cambridge CB3 0ET United Kingdom suan@bas.ac.uk
HILL, Simeon (Dr)	British Antarctic Survey Natural Environment Research Council High Cross, Madingley Road Cambridge CB3 0ET United Kingdom sih@bas.ac.uk
HINKE, Jefferson (Dr)	US AMLR Program Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla, CA 92037 USA jefferson.hinke@noaa.gov
ICHII, Taro (Dr)	National Research Institute of Far Seas Fisheries 2-12-4 Fukuura, Kanazawa-ku, Yokohama-shi Kanagawa 236-8648 Japan ichii@affrc.go.jp
JONES, Christopher (Dr)	US AMLR Program Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla, CA 92037 USA chris.d.jones@noaa.gov

KASATKINA, Svetlana (Dr)	AtlantNIRO 5 Dmitry Donskoy Street Kaliningrad 236000 Russia ks@atlant.baltnet.ru
KAWAGUCHI, So (Dr) (Co-Convener)	Australian Antarctic Division Department of Sustainability, Environment, Water, Population and Communities 203 Channel Highway Kingston Tasmania 7050 Australia so.kawaguchi@aad.gov.au
KAWASHIMA, Tetsuya (Mr)	Assistant Director International Affairs Division Fisheries Agency of Japan 1-2-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8907 Japan tetsuya_kawashima@nm.maff.go.jp
KNUTSEN, Tor (Dr)	Institute of Marine Research Research Group Plankton Nordnesgaten 50 PO Box 1870 Nordnes N-5817 Bergen Norway tor.knutsen@imr.no
KOUBBI, Philippe (Prof.)	Laboratoire d'Océanographie de Villefranche/mer Université Pierre et Marie Curie BP 28 06234 - Villefranche/mer France koubbi@obs-vlfr.fr
LOCKHART, Susanne (Dr)	US AMLR Program Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla, CA 92037 USA susanne.lockhart@noaa.gov

LÓPEZ ABELLÁN, Luis (Mr)	Centro Oceanográfico de Canarias Instituto Español de Oceanografía Vía Espaldón, Dársena Pesquera, PCL 8 38180 Santa Cruz de Tenerife Spain luis.lopez@ca.ieo.es
MILINEVSKYI, Gennadi (Dr)	National Taras Shevchenko University of Kyiv Volodymirska, 64 01601 Kyiv Ukraine genmilinevsky@gmail.com
OKUDA, Takehiro (Dr)	National Research Institute of Far Seas Fisheries 2-12-4, Fukuura, Kanazawa-ku Yokohama-shi Kanagawa 236-8648 Japan okudy@affrc.go.jp
PENHALE, Polly (Dr)	National Science Foundation Office of Polar Programs Arlington, Virginia USA ppenhale@nsf.gov
PETROV, Andrey (Dr)	VNIRO 17a V. Krasnoselskaya Moscow 107140 Russia petrov@vniro.ru
PSHENICHNOV, Leonid (Dr)	YugNIRO Sverdlov Street, 2 Kerch 98300 Crimea Ukraine lkpbikentnet@rambler.ru
SARRALDE, Roberto (Mr)	Centro Oceanográfico de Canarias Instituto Español de Oceanografía de Canarias Via Espaldón. Dársena Pesquera, PCL 8 38180 Santa Cruz de Tenerife Spain roberto.sarralde@ca.ieo.es

SCOTT, Robert (Mr)	Centre for Environment, Fisheries and Aquaculture Science (Cefas) Pakefield Road, Lowestoft Suffolk NR33 0HT United Kingdom robert.scott@cefas.co.uk
SHARP, Ben (Dr)	Ministry for Primary Industries PO Box 1020 Wellington New Zealand ben.sharp@mpi.govt.nz
SIEGEL, Volker (Dr) (representing the EU)	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
SKARET, Georg (Dr)	Institute of Marine Research Nordnesgaten 50 PO Box 1870 Nordnes 5817 Bergen Norway georg.skaret@imr.no
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
TRATHAN, Phil (Dr)	British Antarctic Survey High Cross, Madingley Road Cambridge CB3 0ET United Kingdom pnt@bas.ac.uk
VACCHI, Marino (Prof.)	ISPRA c/o Museo Nazionale Antartide Università degli Studi di Genova Genova Italy m.vacchi@unige.it

VAN FRANEKER, Jan Andries (Dr) (representing the EU)	IMARES PO Box 167 1790 AD Den Burg (Texel) The Netherlands jan.vanfraneker@wur.nl
WATKINS, Jon (Dr)	British Antarctic Survey High Cross Madingley Road Cambridge CB3 0ET United Kingdom jlwa@bas.ac.uk
WATTERS, George (Dr) (Co-convener)	US AMLR Program Southwest Fisheries Science Center National Marine Fisheries Service 3333 North Torrey Pines Court La Jolla, CA 92037 USA george.watters@noaa.gov
YEON, Inja (Dr)	National Fisheries Research and Development Institute 152-1 Gizang-heanro Gijang-eup, Gijang-gun Busan Republic of Korea ijyeon@nfrdi.go.kr
ZUO, Tao (Dr)	Yellow Sea Fisheries Research Institute Chinese Academy of Fishery Sciences 106 Nanjing Road Qingdao 266071 People's Republic of China zuotao@ysfri.ac.cn

Secretariat:

FORCK, Doro (Ms) (Publications Officer) RAMM, David (Dr) (Data Manager) REID, Keith (Dr) (Science Officer) WRIGHT, Andrew (Mr) (Executive Secretary)	CCAMLR PO Box 213 North Hobart 7002 Tasmania Australia ccamlr@ccamlr.org

Appendix B

AGENDA

Working Group on Ecosystem Monitoring and Management (WG-EMM)
(Santa Cruz de Tenerife, Spain, 2 to 13 July 2012)

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
        2.1.1 Fishing activities
        2.1.2 Scientific Observation
        2.1.3 Krill Biology, and Ecology and Management

    2.2 Issues for the future
        2.2.1 Feedback management strategy
        2.2.2 CEMP and STAPP
        2.2.3 Integrated assessment model
        2.2.4 Fishing vessel surveys

3. Spatial management

    3.1 Marine Protected Areas
    3.2 VMEs

4. Other ecosystem considerations, including fish-based ecosystem interactions

5. Advice to the Scientific Committee and its working groups

6. Future work

7. Other business

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

Appendix C

LIST OF DOCUMENTS

Working Group on Ecosystem Monitoring and Management
(Santa Cruz de Tenerife, Spain, 2 to 13 July 2012)

WG-EMM-12/01	Draft Preliminary Agenda for the 2012 Meeting of the Working Group on Ecosystem Monitoring and Management (WG-EMM)
WG-EMM-12/02	List of participants
WG-EMM-12/03	List of documents
WG-EMM-12/04	Extending ecological monitoring to underpin the development of feedback management approaches for the Antarctic krill fishery P.N. Trathan (UK), H.J. Lynch (USA), C. Southwell (Australia), P.T. Fretwell (UK), G. Watters (USA) and N. Ratcliffe (UK)
WG-EMM-12/05	Krill fishery report: 2012 update Secretariat
WG-EMM-12/06	Notification of Chile's intent to conduct krill fishing in 2012/13 Submitted on behalf of Chile
WG-EMM-12/07	Notification of China's intent to conduct krill fishing in 2012/13 Submitted on behalf of China
WG-EMM-12/08	Notification of Germany's intent to conduct krill fishing in 2012/13 Submitted on behalf of Germany
WG-EMM-12/09	Notification of Japan's intent to conduct krill fishing in 2012/13 Submitted on behalf of Japan
WG-EMM-12/10	Notification of Korea's intent to conduct krill fishing in 2012/13 Submitted on behalf of Korea
WG-EMM-12/11	Notification of Norway's intent to conduct krill fishing in 2012/13 Submitted on behalf of Norway
WG-EMM-12/12	Notification of Poland's intent to conduct krill fishing in 2012/13 Submitted on behalf of Poland
WG-EMM-12/13	Notification of Ukraine's intent to conduct krill fishing in 2012/13 Submitted on behalf of Ukraine

WG-EMM-12/14	Update of the ICESCAPE software routines J. McKinlay (Australia)
WG-EMM-12/15	The distribution of spatial management and Antarctic krill catch across pelagic bioregions in the Southern Ocean S.M Grant, S.L. Hill and P. Fretwell (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-12/16	Two decades of variability in krill predators at Bird Island, South Georgia and their potential as ecosystem indicators S.L. Hill, C.M. Waluda, H.J. Peat and S. Fielding (United Kingdom)
WG-EMM-12/17	Diet variability and reproductive performance of macaroni penguins (*Eudyptes chrysolophus*) at Bird Island, South Georgia C.M. Waluda, S.L. Hill, H.J. Peat and P.N. Trathan (United Kingdom)
WG-EMM-12/18	Warming effects in the Western Antarctic Peninsula Ecosystem: the role of population dynamic models for explaining and predicting penguin trends M. Lima and S.A. Estay (Chile)
WG-EMM-12/19	A feedback approach to Ecosystem Based Management: model predictive control of the Antarctic krill fishery S. Hill and M. Cannon (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-12/20 Rev. 1	Towards a strategic framework for assessing uncertainty in ecosystem dynamics models: objectives are sensitive too S. Hill and J. Matthews (United Kingdom) (*CCAMLR Science*, submitted)
WG-EMM-12/21	Features of growth of young Weddell seal A. Salhanskyy (Ukraine)
WG-EMM-12/22	Temporal variability in Adélie penguin CEMP parameters and their response to changes in prey availability L. Emmerson and C. Southwell (Australia)
WG-EMM-12/23	Dense populations of the Antarctic scallop (*Adamussium colbecki*) in Terra Nova Bay (Subarea 88.1J): potential VMEs adjacent to the Terra Nova Bay ASPA (No. 161) M. Chiantore and M. Vacchi (Italy)
WG-EMM-12/24	Net escapement of Antarctic krill in trawls B.A. Krafft (Norway), L.A. Krag, B. Herrmann (Denmark), A. Engås, S. Nordrum and S. Iversen (Norway)

WG-EMM-12/25	The first site of the Marine Protected Area network in the Akademik Vernadsky Station region: Argentine Islands, Skua Creek Delegation of Ukraine
WG-EMM-12/26	Effects of recruitment variability and natural mortality on Generalised Yield Model projections and the CCAMLR Decision Rules for Antarctic krill D. Kinzey, G. Watters and C. Reiss (USA) (*CCAMLR Science*, submitted)
WG-EMM-12/27	An integrated assessment model for Antarctic krill: progress update D. Kinzey, G. Watters and C. Reiss (USA)
WG-EMM-12/28	Analysis of variables influencing finfish by-catch in the krill fishery in Area 48 S.M. Martin, T. Peatman, J. Moir Clark (United Kingdom), O.R. Godø (Norway) and R.C. Wakeford (United Kingdom)
WG-EMM-12/29	A methodology for estimating total finfish by-catch of the Area 48 krill fishery T. Peatman, S.M. Martin (United Kingdom), O.R. Godø (Norway) and R.C. Wakeford (United Kingdom)
WG-EMM-12/30	Operations of Chilean vessel *Betanzos* fishing Antarctic krill (*Euphausia superba*) (June 2011 – April 2012) P.M. Arana (Chile)
WG-EMM-12/31	Recalculation of Antarctic krill (*Euphausia superba*) biomass off East Antarctica (30–80°E) in January–March 2006 M.J. Cox and S. Kawaguchi (Australia)
WG-EMM-12/32	Impacts of ocean acidification on Antarctic krill biology: preliminary results and future research directions S. Kawaguchi, T. Berli, R. King, S. Nicol, P. Virtue and A. Ishimatsu (Japan)

WG-EMM-12/33 Rev. 1	Estimating the biodiversity of Planning Domain 5 (Marion and Prince Edward Islands – Del Cano – Crozet) for ecoregionalisation P. Koubbi (France), R. Crawford (South Africa), N. Alloncle, N. Ameziane, C. Barbraud, D. Besson, C.-A. Bost, K. Delord, G. Duhamel (France), L. Douglass (Australia), C. Guinet (France), G. Hosie (Australia), P.A. Hulley (South Africa), J.-O. Irisson (France), K.M. Kovacs (Norway), R. Leslie, A. Lombard, A. Makhado (South Africa), C. Martinez (France), S. Mormede (New Zealand), F. Penot (France), P. Pistorius (South Africa), P. Pruvost (France), B. Raymond (Australia), E. Reuillard, J. Ringelstein (France), T. Samaai (South Africa), P. Tixier (France), H.M. Verheye (South Africa), S. Vigetta (France), C. von Quillfeldt (Norway) and H. Weimerskirch (France)
WG-EMM-12/34	Precautionary spatial protection to facilitate the scientific study of habitats and communities under ice shelves in the context of recent, rapid, regional climate change P.N Trathan, S.M. Grant (United Kingdom), V. Siegel and K.-H. Kock (Germany) (*CCAMLR Science*, submitted)
WG-EMM-12/35	Some peculiarities of the distribution and fishing of *Euphausia superba* in the Indian sector of the Southern Ocean (by results of USSR fleet operations in 1970–1990) L. Pshenichnov (Ukraine)
WG-EMM-12/36	Linking fish and shags population trends R. Casaux and E. Barrera-Oro (Argentina)
WG-EMM-12/37	Synopsis of data from satellite telemetry of foraging trips and migration routes of penguins and pinnipeds from the South Shetland Islands, 1997/98 to present J. Hinke, G. Watters, W. Trivelpiece and M. Goebel (USA)
WG-EMM-12/38	Modelling growth and reproduction of Antarctic krill: implications of spatial and temporal trends in temperature and food for ecosystem-based management of krill fisheries A.J. Constable and S. Kawaguchi (Australia)
WG-EMM-12/39	Assessing indicators for feedback monitoring and management of the krill fishery: data and methods for assessing predator productivity as an indicator C. Southwell, L. Emmerson and A. Constable (Australia)
WG-EMM-12/40	Management Plan for Antarctic Specially Protected Area No. 144 Delegation of Chile

WG-EMM-12/41	Revised Management Plan for Antarctic Specially Protected Area No. 145: Port Foster, Deception Island, South Shetland Islands Delegation of Chile
WG-EMM-12/42	Revised Management Plan for Antarctic Specially Protected Area No. 146: South Bay, Doumer Island, Palmer Archipelago Delegation of Chile
WG-EMM-12/43	Method for collecting of data on traumatic death of krill passed through the trawl meshes V.V. Akishin, I.G. Istomin, V.A. Tatarnikov, A.F. Petrov and R.O. Lebedev (Russia)
WG-EMM-12/44	Towards developing a feedback management procedure for the Antarctic krill fishery G. Watters and J. Hinke (USA)
WG-EMM-12/45	Proposal for a SCOR Working Group to identify Ecosystem Essential Ocean Variables for measuring change in the biological properties of marine ecosystems A. Constable (Australia)
WG-EMM-12/46	Research and monitoring to support an MPA in the Ross Sea Region G.M. Watters and C.S. Reiss (USA)
WG-EMM-12/47	Proposal for a new Antarctic Specially Protected Area at Cape Washington and Silverfish Bay, Terra Nova Bay, Ross Sea Delegations of the USA and Italy
WG-EMM-12/48	Temporal variability in Adélie penguin CEMP parameters and their response to changes in prey availability L. Emmerson and C. Southwell (Australia)
WG-EMM-12/49	A proposal for compiling information, assessments and science that underpin established CCAMLR Marine Protected Areas and provide the basis for ongoing management, science and review: an MPA Report A. Constable, M. Guest, D. Welsford (Australia), P. Koubbi (France) and L. Weragoda (Australia)
WG-EMM-12/50	Analysis of spatial and temporal structure in long-term krill fishery in the Area 48 and its relation to climate variability P. Gasyukov and S. Kasatkina (Russia)

WG-EMM-12/51	Potential VMEs around Elephant and the South Shetland Islands (Subarea 48.1) S.J. Lockhart (USA), N. Wilson (Australia) and E. Lazo-Wasem (USA)
WG-EMM-12/52	Proposals on providing international synoptic surveys for management application S. Kasatkina (Russia)
WG-EMM-12/53	Network characterisation of the food-web of the Ross Sea, Antarctica M.H. Pinkerton and J.M. Bradford-Grieve (New Zealand)
WG-EMM-12/54	Diet and trophic niche of Antarctic silverfish (*Pleuragramma antarcticum*) in the Ross Sea, Antarctica M.H. Pinkerton, J. Forman, S.J. Bury, J. Brown, P. Horn and R.L. O'Driscoll (New Zealand)
WG-EMM-12/55	The Ross Sea cephalopod community: insights from stable isotope analysis D.R. Thompson, M.H. Pinkerton, D.W. Stevens (New Zealand), Y. Cherel (France), S.J. Bury (New Zealand)
WG-EMM-12/56	A customised Marine Spatial Planning tool in Arc-GIS to facilitate development and evaluation of Marine Protected Area scenarios in the CCAMLR Area B.R. Sharp and K. Ollivier (New Zealand)
WG-EMM-12/57	Preliminary plan for research and monitoring in the Ross Sea region, in association with spatial marine protection M.H. Pinkerton and B. Sharp (New Zealand)
WG-EMM-12/58	Abundance and reproductive distribution of Pygoscelids sp. in the northern area of Danco Coast, Antarctic Peninsula M.M. Santos, E.F. Rombolá, D. González-Zevallos, M.A. Juáres, J. Negrete and N.R. Coria (Argentina)
WG-EMM-12/59	Preliminary report of outcomes of the 2nd international workshop on the ICED Southern Ocean Sentinel, held in Hobart Australia 7–11 May 2012 A. Constable (Australia)
WG-EMM-12/60	An initial analysis of data provided from the deployment of scientific observers in the krill fishery S. Thanassekos (CCAMLR Secretariat), S. Candy (Australia), E. Appleyard (CCAMLR Secretariat), S. Kawaguchi (Australia) and K. Reid (CCAMLR Secretariat)

WG-EMM-12/61	Working Plan for the Review of the Admiralty Bay Antarctic Specially Managed Area Management Plan (ASMA No. 1) Jaqueline Leal Madruga (Submitted by Brazil on behalf of the ASMA No. 1 Management Group – Brazil, Ecuador, Peru, Poland and the United States)
WG-EMM-12/62	A review and analysis of indices from CEMP data Secretariat
WG-EMM-12/63	Krill stock evaluation with data from commercial fishing vessels G. Skaret (Norway), J. Moir Clark (United Kingdom), O.R. Godø, R.J. Korneliussen, T. Knutsen, B.A. Krafft and S.A. Iversen
WG-EMM-12/64 Rev. 1	A summary of scientific observer programs undertaken during the 2011 and 2012 seasons Secretariat
WG-EMM-12/65	Results of scientific observation in Antarctic krill fishery in 2010/11: I. state of observer deployment and data collection M. Kiyota and T. Okuda (Japan)
WG-EMM-12/66	Preliminary observation about the possibility of Antarctic krill escapement from a trawl net K. Fujita and S. Hasegawa (Japan)
WG-EMM-12/67	Results of scientific observation in Antarctic krill fishery in 2010/11: II. analysis of variability of krill size and fish by-catch T. Okuda and M. Kiyota (Japan)
WG-EMM-12/68	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-12/69	Report of the First Workshop on the Identification of Priority Areas for MPA Designation within Domain No. 1 (CCAMLR). Valparaiso 2012
WG-EMM-12/70	Outline proposal for geographic information services for CCAMLR Submitted by the Secretariat on behalf of Adrian Fox, British Antarctic Survey (United Kingdom)
WG-EMM-12/71	Penguin monitoring via remote sensing H. Herata and F. Hertel (Germany)

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WG-EMM-12/P01	The feeding peculiarities of the Antarctic seals in the region of the archipelago of Argentina Islands I. Dykyy (*Ukraininan Antarctic Journal*, 8 (2009))
WG-EMM-12/P02	Sensitivity analysis identifies high influence sites for estimates of penguin krill consumption on the Antarctic Peninsula H.J. Lynch, N. Ratcliffe, J. Passmore, E. Foster and P.N. Trathan (*Ant. Sci*., in press)
WG-EMM-12/P03	Diet and trophic niche of *Macrourus* spp. (Gadiformes, Macrouridae) in the Ross Sea region of the Southern Ocean M.H. Pinkerton, J. Forman, D.W. Stevens, S.J. Bury and J. Brown (In: Orlov, A. (Ed.). *Journal of Ichthyology, Special Issue on Grenadiers* (accepted))
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ESTIMATION OF TOTAL REMOVALS (GREEN WEIGHT)

PURPOSE OF ESTIMATING TOTAL REMOVALS

1. Catch limits in CCAMLR fisheries are set at a level that is considered sustainable and will allow the Commission to satisfy the requirements of Article II of the Convention. In setting such catch limits it is assumed that the reported catch from a fishery reflects the total removals by that fishery from the exploited population. Accurate information on the total removals is essential for:

(i) stock assessment allowing the tracking of the dynamics of the stock and the impact of the fishery

(ii) the real-time monitoring of catches to ensure that area-based catch limits are not exceeded.

2. For the purposes of this report, green weight refers to the total weight of krill landed on the vessel and is assumed to be equivalent to total removals (the potential for escape mortality of krill to introduce a difference between green weight and total removals is not considered in this appendix).

BACKGROUND

3. In 2008 WG-EMM discussed the issue of catch uncertainty associated with the use of conversion factors in the krill fishery (SC-CAMLR-XXVII, Annex 4, paragraphs 4.34 to 4.39) and those Members engaged in the krill fishery were requested to provide information to ad hoc TASO in order to address this issue (SC-CAMLR-XXVII, paragraph 4.13 to 4.18). The issue was further considered by TASO in 2009 (SC-CAMLR-XXVIII, Annex 9, paragraph 3.6) and WG-EMM (SC-CAMLR-XXVIII, Annex 4, paragraph 3.49), including discussion of the conversion of volumetric estimate to mass of catch (SC-CAMLR-XXVIII, paragraph 4.16). In 2010 there was recognition by the Commission that standardisation of methods for estimating the green weight of krill caught was urgently required to achieve more accurate estimates of actual catches (CCAMLR-XXIX, paragraphs 4.13 to 4.15). Accordingly, the Commission adopted the following amendment to CM 21-03 to require submission of information concerning the estimate of green weight:

> 'As of 2011/12, the notification shall include a description of the exact detailed method of estimation of the green weight of krill caught and, if conversion factors are applied, the exact detailed method of how each conversion factor was derived. Members are not required to re-submit such a description in the following seasons, unless changes in the method of green weight estimation occurred.'

4. In 2011 the issue was further discussed in WG-EMM (SC-CAMLR-XXX, Annex 4, paragraphs 2.56 to 2.58), including a description of the process of catch estimation on vessels and advice on the type of analyses required to investigate uncertainty in these estimates. The

Scientific Committee noted that all methods for estimating green weight of krill have associated uncertainty and that this uncertainty is not accounted for in the current management; it requested that WG-EMM characterise such variability and uncertainty to investigate their impacts on krill management advice (SC-CAMLR-XXX, paragraphs 3.14 and 3.15). The Commission noted that the uncertainty in the estimation of green weight of krill was not accounted for in the current management process for krill and looked forward to receiving advice from the Scientific Committee on the potential impacts of this on the management of krill (CCAMLR-XXX, paragraph 4.13).

ESTIMATING TOTAL REMOVALS

5. Removals, *R*, as green weight in a haul can be estimated directly from the measured component of the catch, *W*, according to the following equation

$$R = mW + \varepsilon \tag{1}$$

where *m* is a multiplier that converts the measured component to green weight.

6. Examples of the measured component of the catch and the associated multiplier are:

Example of measured components of the catch	Multiplier
Weight of total krill landed on deck	Approx. 1
Flow meter estimates of total catch	Approx. 1
Estimate of volume of haul in fish pond	Volume-to-weight conversion factor
Weight of product from factory	Product-to-green weight conversion factor.

7. The estimation of total removals will be less sensitive to errors in those multipliers that are close to 1.0 (e.g. using a flow meter or frozen whole estimates of krill weight) than to multipliers for other products that have higher (and more variable) product-to-catch ratios.

8. If the error in the multiplier is random with respect to all of the hauls in a season then the estimate of total removals, $\hat{R}$, used in the approaches described above needs to consider only the multiplier and the measured component of the catch of each haul, *h*, such that

$$\hat{R} = \sum_h m_h W_h \, . \tag{2}$$

9. Typically, total removals are estimated using a function in place of haul-specific measures of m_h, such that

$$m_h = f\left(W_h, \vec{a}_h, \vec{c}\right) \tag{3}$$

where $\vec{c}$ is a vector of constants that can be used to convert a particular attribute of the haul into an estimate of green weight and $\vec{a}_h$ is a vector of those haul-specific attributes (see

Table 2). The inclusion of W_h in the function (2) reflects those situations where the multiplier has non-linear relationships with catch. This part of the function would be 1 for a linear relationship.

10. Understanding of the details of the different methods that are used in order to determine the actual values (and uncertainties) of the attributes and constants used in the estimation of removals has been identified as a priority for CCAMLR (see 'Background' above). In particular, there has been a focus on understanding the implications of using product weight and product-to-green weight conversion factors in a fishery that produces a range of products that have quite different product-specific conversion factors.

11. At present, few data are available to assess whether the values of multipliers, such as product conversion factors, are well estimated or consistent between hauls. This data was summarised in WG-EMM-08/46, which provided a compilation of available information on the conversion factors reported to the Secretariat. Another source for understanding the uncertainty associated with the different multipliers is the values reported in the notifications; for example, an estimate of the variance in conversion factors for different products from notifications is presented in Table 1.

Table 1: Summary product-to-green weight conversion factors indicated in notifications for the 2012/13 fishing season.

Products	Mean	SD	Factor							
Meal (feed)	8.78	1.64	7.7	10.0	9.0	10.0	10.0	6.0		
Meal (human)	10.00	na	10.0							
Krill paste	na	na								
Oil	na	na								
Hydrolisate	na	na								
Lipid complex	na	na								
Frozen whole	1.00	0.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Boiled	1.00	na	1.0							
Peeled	10.25	3.18	12.5	8.0						
Raw (crude)	1.00	na	1.0							

12. Figure 1 indicates how the relative risk that the reported catch might exceed a catch limit may change as a function of reported catch for a particular function. This type of figure might be useful in decision-making. The shape of the curve would depend on the particular set of attributes and constants used in the multiplier. With a more detailed understanding of the uncertainty in the multipliers (in particular in the error distribution) it would be possible to appropriately parameterise this type of risk curve for each method presented in Table 2, with which the Commission could determine management response according to an appropriate level of risk that the removals might exceed the catch limit.

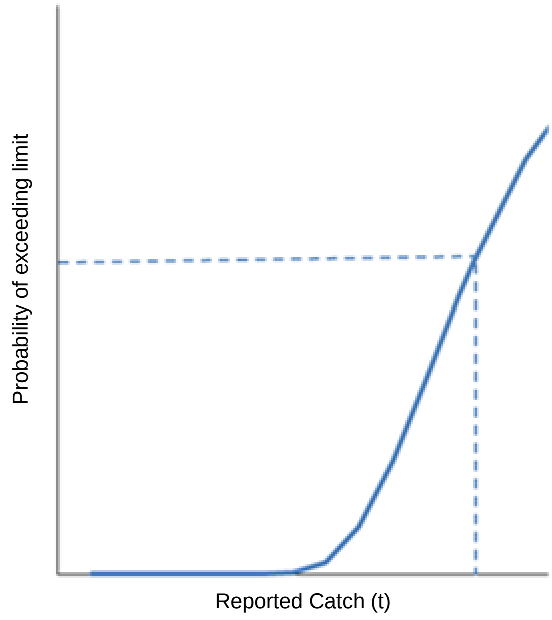

Figure 1: Example relationship between reported catch and the probability of that catch exceeding a specific catch limit. The vertical dashed line indicates the point on the horizontal axis where reported catch equals the catch limit. The horizontal line indicates how the probability that this reported catch is greater than the catch limit can be read off the vertical axis.

DATA REQUIREMENTS

13. The Working Group agreed on the need to acquire more detailed information on the uncertainties associated with each method used by different vessels for estimating green weight. In particular, being able to measure the variability associated with haul-by-haul and vessel-by-vessel estimates of green weight was identified as important. As a way forward, it was proposed to:

(i) review those methods that had been described in notifications

(ii) determine which of those methods included sufficient details to assess uncertainty in the estimate of catch

(iii) provide recommendations on the details that would be required for the Working Group to assess uncertainty in the estimate of catches for each method.

14. The review of notifications revealed a total of five different methods that have been described for the 2011/12 and 2012/13 fishing seasons and of these, most methods used volume as a proxy for krill mass and the multiplier for converting volume-to-weight has not been provided for any method. It was also noticed that although the equation and parameters for estimating the green weight for each haul was known for several methods, the notifications did not provide enough information as for estimating the accuracy for each

parameter and thus, the total uncertainty of the haul-by-haul green weight (Table 2). Accordingly, the Working Group provided recommendations on the details that would be required to assess uncertainty in the estimate of green weight for each method.

15. The recommendations for specific methods are as follows:

Flow meter

This method uses the volume estimates from the flow meters associated to the production line to estimate the green weight (M) of each haul. The formula used is:

$M = V_h \rho$,

where 'V_h' is the volume estimated for each haul; and 'ρ' is the volume-to-mass multiplier.

Specific recommendations for each parameter are as follows:

Volume (V): provide the precision of the flow meters used (i.e. the percentage error associated with the equipment itself and/or undertake experiments to repeatedly pass a known weight of krill through the flow meter and record the resultant meter readings).

Rho (ρ): explain in full the exact method used for estimating the value of the volume-to-weight parameter (i.e. by weighing a 10 litre bucket of krill with a balance accurate to ±0.1 kg).

Flow scale

This method use direct estimates of krill mass as it is transported on the conveyor belt from the holding tank to the factory. Estimates of green weight using this method should measure and report the multiplier accounting for the fraction of krill and water on the belt.

Holding tank volume

This method uses the volume of the catch estimated from the height at which each holding tank is filled with krill for estimating the green weight (M) of each haul. The formula used is:

$M = V_h \rho$, with $V_h = WLH_h$,

where 'W' is the width of the holding tank; 'L' is the length of the holding tank; 'H_h' is the height of the krill catch in the holding tank for haul 'h'.

Specific recommendations for each parameter are as follow:

Describe the formula (depending on tank shape) and total volume of each holding tank and the accuracy of these estimates (i.e. ±0.0001 m^3)

H_h: describe the exact method used for estimating the height of krill in the holding tanks each haul and the accuracy of the measurements (i.e. ±5 cm)

Rho (ρ): explain in full the exact method used for estimating the value of the volume-to-mass parameter (i.e. by weighing a 10 litre bucket of krill with a balance accurate to ±0.1 kg).

Condend volume

This method takes advantage of the regular stylidium shape of the codend to estimate the green weight (M) of each haul. The formula used is: $M = \rho\pi WHL/4$,

where 'M' is the mass of the catch; 'W', 'H' and 'L' are the width (major axis), height (minor axis) and length of the filled codend respectively; and 'ρ' is the density of the catch.

It is noticed that W and H remain constant for all hauls. Vessels shall provide the exact method and accuracy (i.e. ±5 cm) for estimating these measures.

Rho (ρ): explain in full the exact method used for estimating the value of the volume-to-mass parameter (i.e. weighing a 10 litre bucket of krill with a balance accurate to ± 0.1 kg).

Length (L): describe precisely the method used for measuring the length of the codend. According to information provided in CCAMLR-XXX/10, the length of the codend is estimated by counting the number of equidistant rope rings designed to strengthen the codend. This method has large inherent error associated with it (that will depend on the number and spacing of the rope rings) and a more precise method for estimating the codend length on each haul is strongly recommended.

Product conversion factors

This method estimates the green weight (M) of hauls by multiplying the total weight of each product produced in each haul by a known conversion factor: $M = A_{hz}*\beta_z$,

where 'A_{hz}' is the weight of product 'z' for haul 'h'; and 'β_z' is the conversion factor for product 'z'.

16. The Working Group noted that conversion factors are not estimated regularly and often remain constant over multiple seasons. Regular measurements of each will assist in determining how variability in these parameters may affect the estimation of total removals. Accordingly, it is strongly recommended that conversion factors shall be estimated frequently during each fishing season, using, for example, the method outline in WG-EMM-11/29.

17. This method should include an estimation of the value of the volume-to-weight parameter used (see below recommendation for estimating Rho). Furthermore, the Working Group recommended that estimations of green weights should be conducted in the most direct possible way.

18. Arising from the analysis of the descriptions of the methods for estimating green weight, the Working Group agreed that a parameter common to all methods, and which is likely to vary throughout the fishing season, but is currently not reported in any of the notifications, is the estimation of the volume-to-mass conversion factor (parameter Rho (ρ)).

19. The Working Group requested that the multipliers used to convert the measured component of the catch to an estimate of green weight should be estimated at least once every reporting period where those reporting periods are specified in CM 23-06.

20. A method suggested for estimating Rho is as follows:

1. Fill a 25 litre container with krill from the point at which the estimation of volume is made.

2. Drain the sample and weigh the krill to a precision greater than ±0.1 kg.

3. Repeat the process 10 times, provide the values to the Secretariat.

21. Although the reporting of catch is a Flag State responsibility, the Working Group recognised that this process could be done by, or with the aid of, the scientific observer. Likewise, scientific observers could aid in providing detailed descriptions of the method(s) used on the vessels to estimate each parameter in the relevant equation in Table 2, including an evaluation of the associated uncertainty. The Working Group also recommended that for those vessels using product-to-green weight conversion factors, these should also be re-estimated at least once every reporting period.

Table 2: Examples of parameters on which uncertainty estimates are needed. *V* – volume of krill; *W* – width; *L* – length; *H* – height; ρ – volume-to-weight conversion factor; *A* – product weight; β – product-to-green weight conversion factor; sub-index ‘*h*’ indicates haul-by-haul estimation.

Method	Equation	Parameter	Parameter type	Estimation method	Examples of error estimation
Flow meter	V_h* ρ	*V* = volume (litres of krill)	Haul-specific	Difference between flow meter 1 (krill + water) and flow meter 2 (water content extracted before processing)	± 0.01% or ± 0.1 litre every 1 000 litres measured
		ρ = density of the catch	Constant	Not provided	± 0.01 kg/litre
Flow scale	M_h*(1–*F*)	M_h = mass of krill	Haul-specific	Direct estimate	± 0.01% or ± 0.1 kg every 1 tonne measured
		F = fraction of water in the sample	Constant	Not provided	± 0.001
Holding tank volume	*W***L**H_h*ρ	*W* = tank width	Constant		± 5 cm
		L = tank length	Constant		± 5 cm
		ρ = density of the catch	Constant	Not provided	± 0.005 kg/litre
		H = tank height	Haul-specific	Not specified	± 5 cm
Codend volume	*W***H**L_h*ρ*π/4	*W* = codend width	Constant	Measure before fishing starts. Exact method not provided	± 10 cm
		H = codend height	Constant	Measure before fishing starts. Exact method not provided	± 10 cm
		ρ = density of the catch	Constant	Not provided	± 1 kg/m^3
		L = codend length	Haul-specific	Number of equidistant rope-rings designed to strengthen the codend are counted	± 1/4 distance between rope rings
Conversion factors	A_{hz}*β_z	A_{hz} = weight of product ‘*z*’ for haul ‘*h*’	Haul-specific	Weight of product obtained from factory estimate	± 1 kg
		β_z = product ‘*z*’-to-green weight multiplier	Constant	See WG-EMM-11/29	Mean ± SD